July 19, 1932. F. F. HILL 1,867,832

SUBCIRCULATION FOR OIL WELL DRILLING

Filed May 22, 1928

Fig. 1.

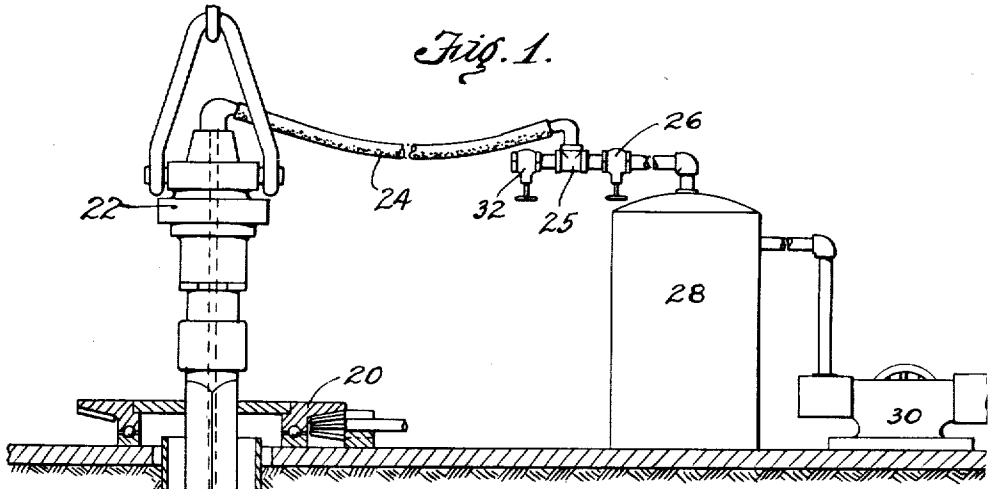


Fig. 2.

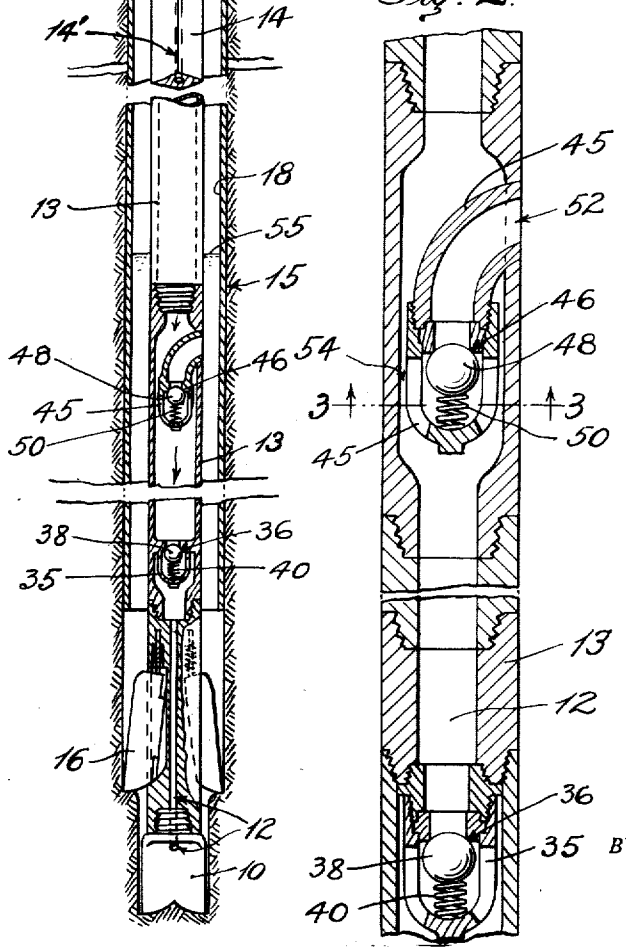
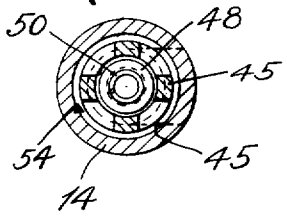


Fig. 3.



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UNITED STATES PATENT OFFICE

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SUBCIRCULATION FOR OIL WELL DRILLING

Application filed May 22, 1928. Serial No. 279,745.

This invention relates to methods and apparatus for the drilling of deep wells, particularly oil wells, and while it is especially adapted to the sinking of wells through low pressure formations and to drilling operations conducted by the rotary method, it is not necessarily limited either to low pressure zones or to rotary procedures.

Although well understood in the art to which the invention applies, it may nevertheless be stated here that rotary drilling as usually practiced consists in advancing a drill through earth strata by the rotation of a hollow stem to which the drill is affixed and in circulating a fluid in the form of a comparatively thin mud from the surface down through the drill stem and bit and up through the hole outside the stem for the purpose of removing the cuttings and keeping the drill bit cool. The hydrostatic head thus produced by this mud is necessarily great at the bottom of a deep hole, and in addition to this a pump pressure is employed to produce sufficient mud velocity to carry out the cuttings. In normal drilling the combined pressure exceeds the natural formation pressure. Under these conditions large quantities of mud are injected into porous formations, and clogging thereof by the mud commonly results. In some cases it is of course desirable to thoroughly mud the walls of the hole, for instance, when passing through water strata, or gas zones, or loose formations not productive of oil. Also mudding in high pressure formations is usually not very objectionable because of the fact that the high pressures serve to expel the mud when the well is brought in. But in low pressure formations, such as depleted oil sands, the clogging condition continues to a large extent and thereby seriously retards the flow of oil into the well when production is finally established. This fact is clearly substantiated by results obtained in drilling known formations of low pressure under the old method just described and in then drilling in the same formation and in the same locality according to the present invention, the yield in the latter instance being much greater than in the former and in certain cases being even greater than the maximum production of wells previously drilled by the former method in the same zone.

Thus it is clear that if circulation with mud can be omitted and high head and pump pressures can be eliminated, the formation will not be affected as with the old methods and superior results in the way of increased production will be obtained. There are other objections to the use of a circulating fluid containing mud. One of these is that the mudding of a low pressure sand is frequently so effective as to entirely seal it off during the drilling, and a commercially productive statum may be so effectively mudded as to destroy or materially diminish its productivity. Therefore, the elimination of mud circulation will also make it possible to pass through a low pressure oil bearing stratum without affecting its productivity.

Objects of the present invention therefore are to avoid clogging a formation in order that the subsequent flow of a completed well may not be reduced or hindered, to avoid circulation of a drilling mud and thereby eliminate the consequent clogging and sealing of low pressure formations during drilling; and to avoid the use of any drilling liquid under conditions which create high pressures in the formations being drilled, such as circulation from the surface into and out of the hole under high head and pump pressures conventional with rotary drilling methods. A further object is to permit the drilling of deep wells, particularly through low pressure oil formations, with the use of only small quantities of drilling liquid, and preferably with only such liquid as is produced by such formations.

In attaining these objects, I have found that desirable results can be obtained, especially in rotary drilling, and especially when penetrating low pressure sands, by using only such liquid as the formation produces, by circulating such liquid locally in the vicinity of the bit, and by intermittently removing the cuttings. The local circulation, which I prefer to call "sub-circulation", serves to cool the bit and keep the hole clear around the bit. The head pressure of the liquid used need not be maintained at a value materially

greater than the rock pressure, the term "rock pressure" being that which is usually applied to indicate the natural pressure in the formation acting to supply liquid to the well. By the expression "head pressure not materially greater than rock pressure" is meant the pressure of a liquid head which is not sufficient to disturb the formation either by causing a clogging thereof or by forcing foreign fluids or bodies back into the stratum being penetrated.

According to one embodiment, this method of operation may be carried out so that the head pressure never exceeds the rock pressure, and since an effort is usually made to remove as little liquid as possible when the cuttings are removed, this head pressure remains substantially constant and closely approximates the rock pressure. Pressure equilibrium is thereby maintained and I have elected to apply the term "equilibrium drilling" to drilling operations promoted under these conditions. Such pressure maintenance is highly desirable in that it largely insures the avoidance of caving when working in loose formations where caving is apt to result if the head pressure is allowed to fall materially below rock pressure.

However, there may be occasions when caving is not a material factor or is eliminated by progressive casing as described hereinafter. Under such circumstances the head of liquid is not so material and the only criterion is the maintenance of enough liquid to insure sub-circulation.

"Sub-circulation", above defined as local circulation in the vicinity of the bit, may be accomplished in several ways and according to the present improvement is accomplished by pumping with air, or other gaseous medium, e. g., natural gas or steam. Such pumping consists in introducing the air or other gas under pressure into the drill stem upon the surface of liquid standing therein, thereby forcing the liquid down past a check valve, thence down through the bit and thence upward outside the stem to a limited elevation, the gas pressure then being released, thus permitting the check valve at the bottom of the stem to close and allowing the liquid to seek its level in the stem by flowing thereinto from the outside past another check valve. In this fashion circulation of the liquid is accomplished. According to the preferred embodiment of the present disclosure the cuttings are removed intermittently as by means of bailing. Under normal operating conditions drilling may be continued during circulation, and the circulating operation repeated as often as may be necessary to properly cool the bit and to prevent packing of the detritus around the bit; or if conditions require, drilling may cease and the bit be elevated a short distance from the fresh cuttings to start circulation, the bit then being lowered, and the entire operation being repeated as often as necessary. In either case drilling is continued after each circulating operation.

Under normal drilling conditions only a relatively small depth is penetrated before the stem and drill must be withdrawn either for replacement of bit with a sharp one or for landing casing or for testing well or for some other reason recognized by those skilled in the art. When the stem and bit are thus withdrawn, the cuttings are bailed out, and while the extent of penetration varies according to the formation the amount of detritus that accumulates in the hole previous to any one bailing operation will not be sufficient to interfere with the drilling due to the fact that the sub-circulation above described is fully effective to prevent packing and clogging. The intermittent bailing after each removal of the bit allows fairly accurate logging data to be obtained, in much the same manner as in standard tool operations.

The invention may also be stated as residing in advancing the drill through a liquid yielding formation, maintaining a liquid head in the hole not greatly exceeding the natural pressure of the formation, setting up a circulation of said liquid past the drill, and continuing the drilling.

The invention comprises also the substantial maintenance of a limited liquid head, as above defined. The method especially includes the drilling of low pressure oil formations. It also includes the employment of only the liquid furnished by the formation being drilled, the liquid head being maintained approximately constant, thus approximating the rock pressure and maintaining pressure equilibrium.

The method is particularly applicable to rotary drilling but is especially distinguished from previous rotary drilling methods in that no circulating mud is employed as heretofore, and there is no circulation from the surface. The invention therefore also includes the mentioned operations as employed in combination with rotary drilling.

However, the invention is not in all cases limited to rotary drilling since the same conditions can be maintained to good advantage with the so-called standard tools where reciprocation is practiced. Also the invention is not wholly limited to drilling through low pressure formations since high pressure formations may be drilled with beneficial effects. Also non-producing formations may be so drilled, in which case small heads of oil, water or other liquid may be introduced and circulated as specified, particularly where the rotary method of drilling is employed, the advantage here being that there is no application of a high pressure when breaking through to a low pressure formation. If formations produce too little liquid enough

may be added to meet the sub-circulation requirements.

However, it should be understood that, when drilling through zones definitely known to be non-productive, it is usually practicable to advance to within a reasonable distance of productive strata, by means of any of the usual drilling methods, such as under high pressure mud circulation, and then, as the productive horizon is approached (especially if it be a low pressure zone), to change over to the sub-circulation method under low head as herein described, whereby sealing of such low pressure stratum will be avoided upon breaking through to the same. In drilling according to this combined method, that is, using high and low head pressures according to conditions, care must be taken that high pressures are employed only when the structures being drilled are definitely known to be either non-productive or high pressure. Wherever the formations are not definitely known and where productive areas, particularly low pressure zones, are being approached, sub-circulation with low pressure heads according to this invention is the preferred method. Unknown structures should first be cored and tested to determine the pressures in the various formations and therefore one will usually be prepared in subsequent drilling for the existence of low pressure zones.

Broadly stated, the present invention therefore is directed to a method of drilling whereby a fluid is circulated past the bit to cool the same and to prevent the packing of the cuttings, and the pressure of the fluid on the formation is limited in value so as to avoid any material sealing or stopping of the productive formations which may be penetrated.

The invention may be considered also to reside in the steps of drilling a formation to sink an oil well, maintaining a limited liquid head in the hole, that is, a head materially less than that represented by the depth of the hole, setting up a circulation in said liquid (preferably local circulation) in the vicinity of the drilling tool, continuing drilling, and removing the cuttings.

In a specific embodiment, the invention resides in accomplishing the circulation by pumping, particularly with air or other gas, to move the liquid past the drill for cooling the same and clearing the hole, the drilling being accomplished with either rotary or standard tools, through low pressure or other formations, and with a limited liquid head as defined, that is, one materially less than that represented by the depth of the hole. The invention resides also in apparatus for practicing the method as herein defined.

The invention resides further in a method combining circulation of a mud or other fluid from the surface, with sub-circulation below the surface as herein disclosed, whereby non-productive formations (and high pressure formations, if desired) may be drilled with the conventional circulation of mud into and out of the hole, and the productive formations, especially low pressure oil strata, are drilled under low liquid head with sub-circulation.

In the accompanying drawing wherein one embodiment of the invention is set out by way of illustration,

Fig. 1 represents the location of a drilling tool equipped with the present invention, in operative position in the bottom of a hole being drilled, the connection of the drill stem through a swivel at the surface with means for supplying a gas, such as air, under pressure, being also illustrated;

Fig. 2 is an enlarged sectional detail showing the two valvular structures in the drill stem which insure the desired circulation; and

Fig. 3 is a cross section taken on line 3—3 of Fig. 2.

As shown, any type of bit 10, provided with a water course 12, is attached to the lower end of a hollow drill stem comprising drill pipe 13 secured to "kelly" bar 14 which is provided with passage 14', said stem being rotated to form the hole 15, and an underreamer 16 being provided if desired in order that casing 18 may be lowered as the hole progresses. Or, instead of the usual bit, a core barrel may be substituted, if coring is to take place. A rotary table 20 serves to rotate drill stem 13, 14 and a swivel connection 22 with a hose 24 provides for the supply of gas under pressure by way of the connection 25 and valve 26 from pressure reservoir 28 supplied by a compressor 30. A shut-off valve 32 provides for exhausting gas pressure on the drill stem, the valve 26 being closed when exhaust is desired, and the valve 32 being closed while the valve 26 is open to supply gas under pressure to the drill stem.

At a point somewhat above the bit 10 a cage 35 having a valve seat 36 is employed to house the ball check valve 38 or the like, such ball check valve being engaged by spring 40 whereby liquid may be forced down past the valve 38 but may not return. Similarly, a liquid entry valve cage 45 having a valve seat 46 to receive a ball check valve 48 urged by a sprng 50 is situated in the drill stem at an elevated point where it communicates with a port 52 in the drill stem for the passage of liquid downward past the valve 48. This valve cage 45 is spaced from the interior of the drill stem as indicated at 54 so that gas may be forced downward around the same, the check valve 48 preventing escape thereof through the port 52. Said valve 48 may be disposed at approximately the liquid level which it is desired to maintain in the hole, or at any desired point therebelow, and under

normal operating conditions this same level exists also in the stem 14.

As the stem is rotated the formation at the bottom of the hole is cut away by bit 10 and the liquid therearound serves to keep the bit cool. However, when the new cuttings accumulate in appreciable quantity so as to cut off the access of fresh liquid to the bit, said gas under pressure is admitted to the stem from the reservoir 28 by way of connection 24, valve 26 and swivel 22 to force down the liquid level in the drill stem, the liquid passing the valve 38 and entering the hole through the passage 12 thereby loosening the cuttings around the bit and elevating them somewhat and mixing them with the liquid. At the same time the liquid level rises above the port 52 controlled by valve 48 to establish an excess head outside the drill stem such as indicated at 55. When sufficient liquid has been moved to accomplish the desired clearing and cooling effects, valve 26 is closed to cut off the gas supply and valve 32 is opened to exhaust the drill stem. The liquid outside the stem then enters around the check valve 48 and again establishes the uniform level. If circulation can be freely accomplished drilling may be continued during circulation. Otherwise, drilling will be stopped and the bit lifted a limited distance until circulation commences, the bit then being gradually lowered to the bottom of the hole to accomplish complete clearing, whereupon drilling will be resumed. These operations may be repeated until such time as the stem and bit are withdrawn, either for replacement of the old bit with a sharp one or for any other reason. Upon such withdrawal the cuttings are bailed out before running in again.

When carrying on the above operations the liquid head in the hole preferably will be that furnished by the formation, and when the cuttings are bailed out, as little liquid usually will be removed as conveniently possible. A lower head sometimes may be maintained by bailing out considerable liquid, it being important, however, that sufficient liquid quantities are retained for sub-circulation. In this event, caving may be avoided by lowering the casing 18 after the underreamer 16 as the hole progresses.

The foregoing method of operation has been found to offer many unexpected advantages. For example, as previously indicated, by thus avoiding the mudding of formations, especially low pressure formations, the subsequent production of the well when completed has been greatly in excess of nearby wells producing from the same formation. Where a new well was drilled according to the present invention, close to and between two old wells drilled by the old method of circulating mud, which old wells had never produced more than 120 barrels per day and had not produced over 90 barrels per day for two years, the new well came in at a production rate of 160 barrels per day and rose to 325 barrels which production has been maintained and is the maximum capacity of the pump. Here the oil formations were drilled with only that liquid head furnished by the formations. While the effects upon high pressure formations are not so marked, the method nevertheless offers advantages here also.

The drilling methods above disclosed may be combined with conventional rotary drilling operations wherein a circulating mud or other liquid is pumped into a hole at the surface, circulated past the bit and then withdrawn from the surface. It is necessary, however, that those formations in which conventional circulation is employed be definitely known to be non-productive, and that sub-circulation drilling according to this invention be substituted as a productive stratum is approached and before the same is penetrated. This is important because of the fact, that, if a productive zone of low pressure be entered with high pressure drilling liquid, said liquid will be forced back into the formation thus contaminating the same and, if mud is employed, said formation will be mudded up thereby failing in the object sought by the present invention. Where drilling formation not definitely known, it is important that high pressure circulation be omitted, if the results sought are to be certainly obtained.

Sub-circulation may also be applied to core drilling with excellent advantage, and is particularly valuable when coring low pressure zones either for the purpose of logging the same originally or for re-logging should the necessity arise.

It is to be understood that the specific disclosures herein made are merely illustrative of the generic invention and are not to be considered as in any way limiting, since many variations beyond those herein indicated may be made within the scope of the claims hereof by those skilled in the art.

I claim:

1. A method for sinking an oil well by means of a hollow drill stem having a drill on its lower end comprising advancing the drill through a formation, accumulating liquid in the hole under a head materially less than that represented by the depth of the hole, applying gas under pressure to one side of the drill stem to circulate the liquid past the drill and up the other side of the drill stem to vary the liquid level on the two sides of the drill stem, and releasing the gas pressure on the applied side to cause the liquid to pass from one side of the drill stem to the other at a point appreciably above the drill when the gas pressure is released and to allow the levels to balance.

2. Well drilling apparatus comprising a

hollow drill stem, a drill on the lower end thereof, a valve in the lower portion of said stem adapted to pass liquid in one direction, a second valve thereabove to pass liquid in the same direction and providing communication between the inner and outer sides of the stem and means for applying gas under pressure to said stem to cause pneumatic circulation of liquid therein.

3. A structure according to claim 2 wherein the lower valve opens to pass liquid from the interior of the stem to the drill.

4. Well drilling apparatus comprising a hollow drill stem, a drill on the lower end thereof, a valve in the lower portion of said stem adapted to pass liquid in one direction, a second valve thereabove adapted to pass liquid in the same direction, said valves opening to pass liquid downward through the stem, said drill stem being provided with means of communication between the inside and outside thereof at a point beyond the second valve and means for applying gas under pressure to said stem to cause pneumatic circulation of liquid therein.

5. A well drilling apparatus comprising a hollow drill stem, a drill mounted on the lower end of said stem, a valve carried at the lower end of said stem adjacent the drill and adapted to pass liquid downwardly past the drill, a second valve positioned in the drill stem at a point elevated materially above the first valve, said second valve having communication with the exterior of the drill stem and adapted to pass liquid from said exterior into the interior of the drill stem and means for applying gas under pressure to said stem to cause pneumatic circulation of liquid therein.

Signed at Los Angeles, in the county of Los Angeles and State of California, this 15th day of May, A. D. 1928.

FRANK F. HILL.

CERTIFICATE OF CORRECTION.

Patent No. 1,867,832. **July 19, 1932.**

FRANK F. HILL.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 1, lines 63 and 64, for "statum" read stratum; page 3, line 3, beginning with the word "However" strike out all to and including "cuttings." in line 49, and insert the same to follow line 88, page 2; page 3, line 118, for the misspelled word "sprng" read spring; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 22nd day of November, A. D. 1932.

M. J. Moore,
Acting Commissioner of Patents.

(Seal)

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