

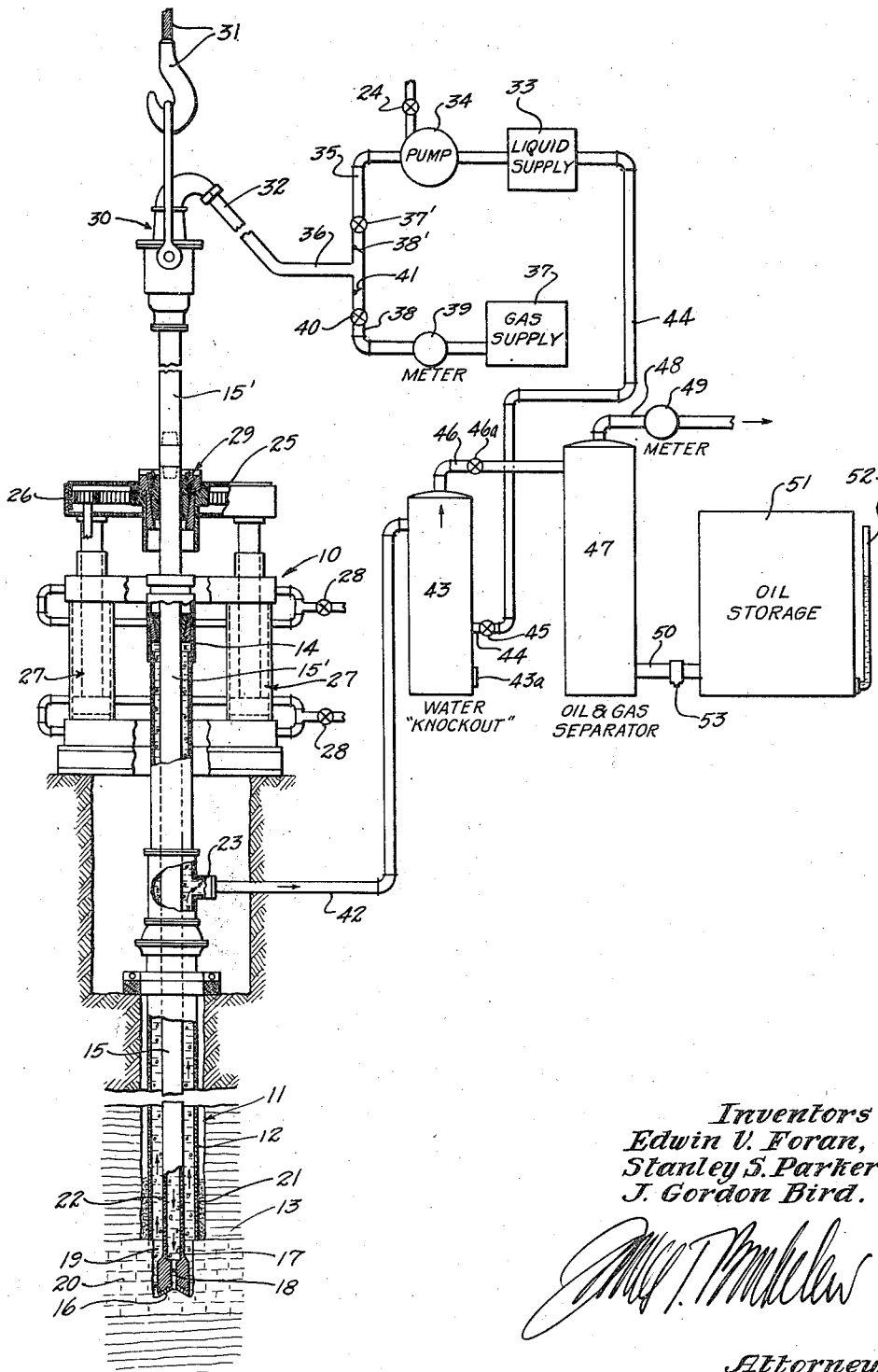
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METHOD OF DRILLING AND SIMULTANEOUSLY EXPLORING OIL WELLS AND THE LIKE

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METHOD OF DRILLING AND SIMULTANEOUSLY EXPLORING OIL WELLS AND THE LIKE

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12 Claims. (Cl. 255—24)

This invention relates generally to methods of drilling and simultaneously exploring oil wells or the like.

In order to point out the advances and advantages represented by our novel method, it will be helpful first to consider briefly standard rotary drilling practices. In these practices the cutters are carried and rotated by a hollow drill stem, through which heavy fluid is pumped (the fluid is usually termed "weighted" or "mud-laden") the fluid emerging from the stem adjacent the cutters to lubricate them in their cutting action and to flush away the cuttings which are then brought to the surface by the return column of fluid surrounding the drill stem. The mud-laden fluid penetrates exposed interstices or crevices of the formation through which the cut is being made, this intrusion serving to hold the formation pressure in check, preventing inflow of gas or oil, and also preventing the wall of the bore from caving or breaking down.

Such "mudding-off" of the bore during drilling operations maintains the well in "dead" condition throughout the drilling operation, the mudded wall plus the circulating pressures preventing the inflow of formation gas or oil. Such practice is still necessary where the formation is lacking in "self-sustaining" or "non-disintegrating" characteristics to an extent that it requires the application of "plugging" material to hold it from caving, but, up to a recent time, the practice was also employed where the formation was relatively self-sustaining and therefore needed no such artificial reinforcement. It is particularly to drilling through such "self-sustaining" formation that our invention is directed.

As a result of the "mudding up" of the bore wall, as brought about by the practice in previous use, as described above, it was impossible to ascertain from inspection of the return-flow stream of circulating fluid, the character of the formation through which the drill was currently cutting or even whether or not productive or "pay" strata were being penetrated. Consequently pay strata were frequently drilled through and passed up entirely. Even where the well was finally brought in, the previous mudding up of the walls had the effect of reducing production below the full potential yield of that zone. The only way knowledge could be gained of the formation, etc., was by taking core samples, a procedure which did not always give accurate information and was, at best, a time consuming, costly operation and therefore done as infrequently as possible, with

consequent lack of detailed information of structure passed through between corings.

Therefore it is the general object of our invention to provide a method of drilling whereby the mudding up or penetration of the walls is avoided and the well is therefore kept "live" throughout the drilling operation. This is accomplished generally by maintaining a differential between the "formation pressure" (the pressure of the gas or oil in the formation being penetrated and tending to flow the gas or oil into the well) and the "bottom hole circulating pressure" (the effective pressure exerted on the exposed formation wall by the circulating fluid at the bottom of the well during periods of circulation, and a factor of which is the hydrostatic head of the return column of circulating fluid). The differential thus maintained, is in favor of the formation pressure, that is, the formation and bottom hole circulating pressures are relatively plus and minus or expressed otherwise, the formation pressure is maintained predominant by regulating the bottom hole circulating pressure so it will be of lower effective value.

As a result of this maintenance of differential pressures, exact and continuous loggings may be made as to the position and productivity of pay zones; the producing sands are kept from damage by the circulating fluid; accurate knowledge as to the nature of producing formations may be had, since the samples of cuttings brought up by the return column of circulating fluid are uncontaminated by foreign matter (and this knowledge is useful both during the actual drilling operations and in determining such matters as the proper placement of packers and the like during subsequent operations on the well); the necessity of taking core samples is avoided; and full "pay production" is assured.

The above advantages can be gained where certain well conditions prevail, by the use of clear water or clear oil as the circulating fluid, this medium having been employed prior to our present invention. For instance, where the formation pressure is such that the well is capable of "self-unloading" (a situation where the natural gas in the formation acts as an aerating medium for the return column, and the formation pressure exceeds the bottom hole circulating pressure so the circulating fluid does not prevent the inflow of gas or oil from the formation) our improved method does not have to be applied, though it still may be used to advantage in that it is never known at what depth a zone of lesser formation pressure may be reached.

However, there are situations where clear water or clear oil will not bring about the desired differential between formation pressure and bottom hole circulating pressure. For instance, there are wells where the formation pressure is of such relatively low value, that, at a given depth, the hydrostatic head of the return column of water or oil would be sufficient to create a differential in favor of the circulating fluid and thus prevent the inflow of gas or oil, and, in effect, "kill" the well during drilling, so none of the yield would rise with the return column for observation, measurement or sampling. Such was the case in a well about 8300 feet deep where the formation pressure was about 1900 lbs. per sq. in., for the return column of water exerted at that depth a back pressure of more than 3600 lbs. per sq. in. on the bottom formation, thus preventing the inflow of gas and oil. In that case, later activities proved that productive "pay" had been passed through entirely without knowledge of its existence.

It is the meeting of such and similar situations to which our invention is directed, that is, situations where the bottom hole circulating pressure of clear water or clear oil would be such that the desired pressure differential in favor of the formation gas or oil would not obtain. Generally, the desired end is reached by using, while drilling ahead, a circulating medium which is less dense than clear water or clear oil, it being noted that this is precisely the opposite of ordinary drilling practice where the circulating fluid is artificially weighted so as to be much heavier than water.

The invention broadly contemplates the use of such a medium, irrespective of its constituents or method of introduction. We have described particular mediums and particular methods of introduction which are preferred, but these are given by way of example and are not to be considered as limitative on our broader claims.

Other objects and features of the invention will be apparent from the following detailed description, reference being had to the accompanying drawing, in which:

Fig. 1 is a schematic representation of apparatus used in carrying out our method.

We have conventionally shown a certain type of drilling equipment which is particularly well adapted for use in the employment of our method, but it will be understood that this is not at all limitative on the invention. So also, for purposes of illustration, we will mention certain relative pressures and amounts of materials, but again these are to be considered merely as illustrative and not as critical or limitative.

The drilling equipment generally indicated at 10 is of the rotary type (though the invention is not limited to rotary drilling operations) and this equipment is disposed over a well bore 11 wherein there is set a casing 12 which extends, in effect, from the bottom of stratum 13 (which, for instance, may be considered a stratum of shale) to combination drilling and casing head 14. Hollow drill stem 15, made up of threadably connected joints 15', carries cutters 16 which may be of any suitable type (for instance, roller-bearing, rock bit cones) the bore 17 of stem 15 opening through a relatively restricted orifice 18 to the bottom of the well bore, here indicated at 19 as being located in stratum 20 through which the drill is currently boring. It will be considered, for the purpose of discussing our method, that stratum 20 is oil-and-gas-bearing, cavernous

lime. It will be assumed that this lime presents a self-sustaining or non-disintegrating formation and that the "formation pressure" thereof is approximately 1900 lbs. per sq. in., it being that pressure which is effective in tending to flow the gas and oil into the well. It is indicated at 21 that casing 12 is "cemented off", it following that circulating fluid passing downwardly through bore 17 and outwardly through orifice 18 will return to the surface between stem 15 and casing 12, this return column being indicated at 22.

Packer head 14 closes off the top of the annular space between stem 15 and casing 12, though it does not prevent the rotation nor axial movement of the stem. The return column is thus forced to flow outwardly through discharge line 23, preferably being controlled in its passage by valve means to be described.

A rotary table is generally indicated at 25, the table being rotated by a driven pinion 26 and being adapted to be reciprocated vertically by the hydraulic piston arrangement generally indicated at 27 and controlled by valves 28. Rotative drive and longitudinal feeding or withdrawal movement is imparted to stem 15 from table 25 through wedge slips 29, these slips preferably being of the type which automatically set in the event the drill stem is driven upwardly by the fluid pressure below.

A circulating swivel 30 is applied to the upper end of stem 15, the swivel being supported by tackle 31 which leads to the hoisting drum of the draw-works (not shown). Hose 32 leads from the source of circulating fluid to drill stem bore 17, and when pressure is applied to this medium it circulates through the path mentioned above. However, it is possible to practice our method and secure our results by a reversal in the direction of circulation by interchanging input and output connections and therefore, where in our claims we specify a certain direction of circulation, it will be understood this specification is merely given to establish a path and is not to be considered as limiting those claims to the traversing of that path in a particular direction.

Our invention contemplates the pressural introduction of a circulating medium having such characteristics that, while drilling ahead through rotation of the drill stem by table 25 and imposing a proper weight on the cutting tool by suitable longitudinal adjustment of that table, (or, more broadly, while actuating the cutters while they are in cutting or operative association with the formation) the bottom hole circulating pressure (as defined above) will be less than the formation pressure, or, in the illustration given, shall be less than 1900 lbs. per sq. in. Assuming that the well were 8300 ft. in depth, it will be seen that were clear water to be used as a circulating medium this condition would not prevail, for the hydrostatic head of the return column would be in the neighborhood of 3600 lbs. Therefore, the circulating medium must be less dense than clear water, and is preferably less than clear oil. The relative density for a given operation may be determined from measurement of the formation pressure, which measurement may previously have been made from earlier drilling operations in the same area, and then calculating the required properties of the circulating medium. In untested formation, circulating fluid of lowest practical density is used. It has been found that a pressure differential of about 600 to 800 lbs. per sq. in. gives satisfac-

tory results. That is, a circulating fluid is chosen which, at given well-depth, will give a bottom hole circulating pressure, in the illustration given above, of about 1300 lbs. per sq. in.

It lies within the scope of our invention to employ any medium having proper characteristics for lubricating the cutters as they encounter the formation and which will make possible the securing of the above specified differential. It may be either a natural product in itself or may be made up of a liquid aerated with a gas. It may, for instance, be a natural product having less density than clear water or clear oil, or it may be oil or water aerated by gas from any source, the gas and water or oil either being premixed, or mixed after individual introduction to the circulation course. Hereinafter we will refer particularly to a circulation fluid made up of water aerated by gas introduced thereto just prior to its admission to the drill stem bore, but it is understood this is done merely for illustrative purposes and is not to be considered as limitative on our broader claims. Likewise, we have shown a particular manner of mixing the water and gas and a particular manner of treating the discharge of the return column, together with certain metering devices, but it will be understood these are not to be considered as limitative on our broader claims.

Water from a supply source 33 is delivered by pump 34 (the delivery of which may be regulated by controlling its speed through valve 24) and line 35 to manifold 36, a control valve 37' and check valve 38' preferably being interposed in this line. Gas under pressure is supplied to line 36 from source 37, the line 38 leading from source 37 to manifold 36 preferably containing an orifice meter 39 of the recording type, a control valve 40, and a check valve 41.

Leading from discharge 23 is line 42 which opens to a high pressure separator or "water knock-out" 43. The water outlet of separator 43 is indicated at 44, this outlet preferably being controlled by valve 45 and leading to the slush pit or, if desired, to water supply 33. A drain 43a provides means for extracting or sampling the cuttings. The oil and gas outlet 46 from separator 43 leads to the oil and gas separator 47, choke valve 46a being interposed in this line. The gas passes off through outlet 48 in which is preferably interposed an orifice meter 49 of the recording type, and the oil discharges through line 50 to storage tank 51 which may have any suitable gauge such as that indicated conventionally at 52.

Valve 40 and regulation of pump delivery provide means for controlling or varying the ratio of gas and water which are mixed when they reach manifold 36. By way of example, on one well having the characteristics given above, that is, 8300 feet deep and having about 1900 pounds formation pressure in cavernous lime, a proportion of about 125 barrels of water per hour with from 700 to 800 cubic feet of gas per barrel introduced to that water, gave a resultant bottom hole circulating pressure which brought about the desired differential, that is, the bottom hole circulating pressure was about six to eight hundred pounds less than the formation pressure and the gas and oil from the formation was capable of entering the return column and being brought thereby to the surface where it was observed, sampled and measured. Also, this input gave sufficient velocity to the circulating stream to elevate the cuttings in spite of the low density

of the circulating fluid, this increase in the velocity of the circulating fluid to a degree which is high with relation to the velocity had by circulating fluids of the "weighted" type in normal drilling, being an important feature of our invention for it makes it possible to elevate relatively heavy cuttings with a fluid of relatively low density.

The return column thus delivers to separator 43 the aerated circulating fluid, gas and oil or other products from the formation, and the cuttings from the well bottom.

Knowing the input of pump 34, if more water is delivered through pipe 44 than was put in by the pump, the driller knows that there is a water content in the flow from the formation. The oil and gas from separator 43 are separated one from the other in separator 47 and a comparison of the readings of meters 39 and 49 will advise the operator whether or not gas is being delivered from the formation. The gauge 52 on tank 51 will give a direct reading as to any oil which may have been brought up from the formation by the return column. If desired, a test outlet 53 may be provided in line 50 so the nature of the delivered oil may be currently observed.

When new stands or joints are to be added to the drill stem, it becomes necessary to uncouple the upper stem-sections, opening the top of the stem bore to the atmosphere, which invites a "self-unloading" of the aerated fluid from said bore. To prevent this, it is preferable to introduce a quantity of unaerated fluid to the stem bore a few minutes prior to breaking the joint, this heavier fluid overbalancing the lifting effect of the aerated fluid below. Of course, this introduction is taken into account when interpreting the readings made subsequently, that is, after the new joint has been added and the introduction of aerated fluid is renewed. For instance, when the unaerated portion of fluid reaches the output meter, said meter will indicate a substantial decrease in output gas, a reading which would be deceptive if it were not recognized as arising from the wilful introduction of unaerated fluid.

With the capacity for measuring relative input and delivery, the operator is kept continuously advised as to whether or not gas or oil is being produced, and by studying the characteristics of the delivered material, including the cuttings, he is able to ascertain continuously the nature of both the yield and the formation. Since he knows the depth of the well by the length of the drill stem in the hole, knows the rate of drilling (which is under his direct control) and knows the length of time elapsing between the input of circulating fluid and the discharge thereof, his observation will tell him the precise conditions of formation and yield at every depth. It has been found possible to log a well of the depth noted in as little as two inch increments, a feature of particularly great importance when drilling at critical points where the operator must know the exact situation, else he may ruin the entire well by proceeding too rapidly or in a manner improper to the particular situation.

It will be seen that by proceeding under this method, all the advantages mentioned in the foregoing part of this specification are obtained, it therefore being unnecessary to repeat them here.

In drilling through certain structures the formation pressure may increase to a point where the desired differential would be maintained even though clear circulation water or oil were used, but even in that event it is advantageous to con-

tinue the use of the aerated circulating fluid and by regulation thereof control the flow from the formation.

Furthermore it is advantageous to continue the input of gas throughout the entire drilling operation since the continued drain on the formation reduces the formation pressure quite rapidly so it is apt to drop below that degree necessary to maintain the differential requisite to continued inflow of the formation gas and oil. On the other hand, if the formation pressures are so low that even the aerated liquid will not establish the desired differential, the use of the aerated liquid is decidedly advantageous, as such fluid will penetrate the formation to a much less extent than would unaerated liquid, reducing the harmful effect of intrusion a corresponding degree.

In a proven pool where pay depths are known, the use of the aerated liquid is started when the drill closely approaches but before it reaches, the pay depth. On the other hand, in unproven territory, the use is started well before there is any likelihood of reaching a pay depth, as far as it can be judged from experience.

Choke valve 46a, which may be introduced in the discharge at any point between outlet 23 and separator 47, provides means for varying the back pressure on the return column and thereby varying the circulating pressure independently of pump delivery and valve 40. This application of back pressure may be exerted on the return column for purposes of reducing the rate of flow of the products from the formation in the event the flow is so rapid that the available tankage (51) is not sufficiently great to accommodate it, or to prevent damage to the formation by an excessively rapid evacuation of the formation gas and oil.

Packing head 14 not only serves as a closure member for diverting the return flow through outlet 23, so the entire yield may be available for analysis and storage, but also prevents appreciable escape of gases to the atmosphere, thus eliminating a hazardous condition which would otherwise prevail.

Merely to illustrate a typical operation, the following examples are given. While drilling ahead and preserving the requisite pressure differential by the use of the aerated water, if no "open spot" or productive zones of oil or gas are encountered, meter 49 will indicate that the volume of gas delivered is the same as that shown by meter 39 as having been put in at the beginning of a given time cycle. It might be supposed that the gas and water of the circulating medium would tend to segregate locally while in transit from meter to meter and thus emerge with a ratio quite different from that prevailing at the time of input, particularly since the medium frequently has to travel downward through 8500 feet of drill pipe and then upward through 8500 feet of casing, requiring about one hour and twenty minutes to make the circuit. Tests have shown, however, that the gas and water remain in substantially the same relative condition throughout the round trip.

If an "open spot" or productive zone in Pennsylvania lime is encountered, that fact becomes known as soon as the new production reaches the surface by way of the return column. If the increase is in the form of water-white oil the gas meters shows the change most clearly in the form of a volumetric increase in the gas, since the meters show the change most clearly in the structure is rather high, it being understood that

reference is made to a particular formation merely for illustrative purposes.

If the increase is in the form of dark oil, the color change from that of clear drilling water to that of a dark oil-water mixture is very positive and a separation of the oil and water at "water knock-out" 43 permits an approximate gauge of the oil while drilling ahead, and of course, gauge 52 gives a complete measure of the oil delivery.

Since the samples of cuttings which are brought to the surface by the return column are entirely uncontaminated with weighting material, such as clay used in normal rotary drilling, accurate knowledge is had of the formation being penetrated.

With all the knowledge as to formation and yield characteristics made possible by the employment of this method as well as the fact that the formation walls are in no way clogged by foreign material, it will be seen that the method makes it possible to secure production results which have heretofore been considered impossible. While we have shown and described a preferred embodiment of our invention, it will be understood that this description is to be considered as illustrative of and not limitative on the broader claims appended hereto.

We claim:

1. The method of drilling a well through given formation that comprises actuating a cutter on a hollow drill stem having an outlet near its lower end, the cutter being adapted to operatively engage the formation, aerating a liquid at the top of the well and independently of formation gases and, simultaneously with said actuation, circulating said aerated liquid downwardly through the stem bore, through said outlet to the well bore and thence upwardly about the drill stem to the top of the well, said liquid in its downward course, being substantially free of solids.

2. The method of drilling a well through given formation, that comprises actuating a cutter on a hollow drill stem having an outlet near its lower end, the cutter being adapted to operatively engage the formation, aerating a liquid at the top of the well and independently of formation gases and, simultaneously with said actuation, circulating said aerated liquid downwardly through the stem bore, through said outlet to the well bore and thence upwardly about the drill stem to the top of the well, and holding the bottom hole circulating pressure to a value lower than that of the formation pressure.

3. The method of drilling a well through given formation, that comprises actuating a cutter on a hollow drill stem having an outlet near its lower end, the cutter being adapted to operatively engage the formation, aerating a liquid at the top of the well and independently of formation gases and, simultaneously with said actuation, circulating said aerated liquid downwardly through the stem bore, through said outlet to the well bore and thence upwardly as a return column, about the drill stem to the top of the well, and holding the bottom hole circulating pressure to a value lower than that of the formation pressure, and creating back pressure on the return column at the top of the well.

4. The method of drilling a well through given formation and exploring the formation while drilling ahead, that comprises actuating a cutter on a hollow drill stem having an outlet near its lower end, the cutter being adapted to operative-

ly engage the formation, aerating a liquid at the top of the well and independently of formation gases and, simultaneously with said actuation, circulating said aerated liquid downwardly through the stem bore, through said outlet to the well bore and thence upwardly about the drill stem to the top of the well, holding the bottom hole circulating pressure to a value lower than that of the formation pressure, and measuring the input and output of circulating fluid.

5. The method of drilling a well through given formation, that comprises actuating a cutter on a hollow drill stem having an outlet near its lower end, the cutter being adapted to operatively engage the formation, and, simultaneously with said actuation, introducing measured quantities of a liquid and of a gas into the stem bore, said measured quantities being mixed at the top of the well and being independent of formation gas and circulating the mixture of gas and liquid downwardly through said bore, through said outlet to the well bore and thence upwardly about the drill stem as a return column to the top of the well.

6. The method of drilling a well through given formation, that comprises actuating a cutter on a hollow drill stem having an outlet near its lower end, the cutter being adapted to operatively engage the formation, and, simultaneously with said actuation, introducing measured quantities of a liquid and of a gas into the stem bore, said measured quantities being mixed at the top of the well and being independent of formation gas and circulating the mixture of gas and liquid downwardly through said bore, through said outlet to the well bore and thence upwardly about the drill stem as a return column to the top of the well, separating the gas from the top of the return column, and measuring the gas so separated.

7. The method of drilling a well through given formation, that comprises actuating a cutter on a drill stem, the cutter being adapted to operatively engage the formation, and simultaneously with said actuation, supplying aerated fluid, which is substantially free of solids, to the well bore near its bottom and adjacent the cutter, and allowing said aerated fluid to rise to the ground surface.

8. The method of drilling a well through given formation, that comprises actuating a cutter on a hollow drill stem having an outlet near its lower end, the cutter being adapted to operatively engage the formation, aerating a liquid at the top of the well and independently of formation gases and, simultaneously with said actuation, circulating said aerated liquid downwardly through the stem bore, through said outlet to the well bore and thence upwardly about the drill stem to the top of the well, and introducing un-

aerated liquid to the top of the drill stem bore at intervals.

9. The method of drilling a well through given formation, that comprises actuating a cutter on a jointed, hollow drill stem having an outlet near its lower end, the cutter being adapted to operatively engage the formation, and, simultaneously with said actuation, circulating aerated liquid downwardly through the stem bore, through said outlet to the well bore and thence upwardly about the drill stem to the top of the well, and, when the bore of the uppermost stem-joint is to be opened to the atmosphere, introducing unaerated liquid to the bore of that joint prior to the opening thereof.

10. The method of drilling a well through given formation, that comprises actuating a cutter on a hollow drill stem having an outlet near its lower end, the cutter being adapted to operatively engage the formation, and, simultaneously with said actuation, circulating aerated liquid downwardly through the stem bore, through said outlet to the well bore and thence upwardly about the drill stem to the top of the well, and, when the top of the stem bore is to be opened to the atmosphere, introducing unaerated liquid to the top of said bore prior to the opening thereof.

11. The method of drilling a well through given formation, that comprises actuating a cutter on a hollow drill stem having an outlet near its lower end, the cutter being adapted to operatively engage the formation, aerating a liquid at the top of the well and independently of formation gases and, simultaneously with said actuation, circulating, at relatively high velocity, said aerated liquid downwardly through the stem bore, through said outlet to the well bore and thence upwardly about the drill stem to the top of the well, and holding the bottom hole circulating pressure to a value lower than that of the formation pressure.

12. The method of drilling a well through given formation, and exploring the formation while drilling ahead, that comprises actuating a cutter on a hollow drill stem having an outlet near its lower end, the cutter being adapted to operatively engage the formation, aerating a liquid at the top of the well and independently of formation gases and, simultaneously with said actuation, circulating, at relatively high velocity, said aerated liquid downwardly through the stem bore, through said outlet to the well bore and thence upwardly about the drill stem to the top of the well, holding the bottom hole circulating pressure to a value lower than that of the formation pressure, and measuring the input and output of circulating fluid.

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CERTIFICATE OF CORRECTION.

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It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 4, first column, line 74, strike out the words "meters show the change most clearly in the" and insert instead gas-oil ratio of the water-white products in this; 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 27th day of July, A. D. 1937.

(Seal)

Henry Van Arsdale
Acting Commissioner of Patents.