Dec. 5, 1961 D. R. HOLBERT ET AL 3,011,547

METHOD OF PREVENTING LOSS OF GASEOUS DRILLING FLUID

Filed Sept. 25, 1957 2 Sheets-Sheet 1

Fig. 5.

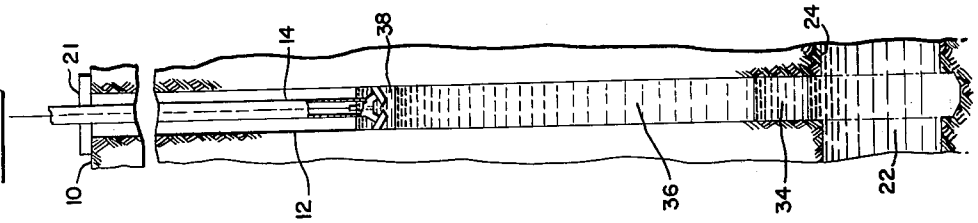


Fig. 4.

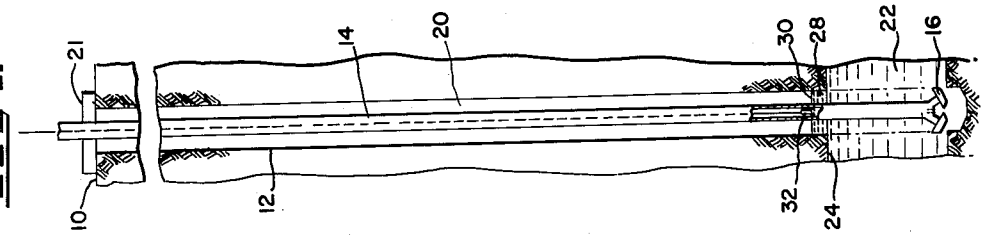


Fig. 3.

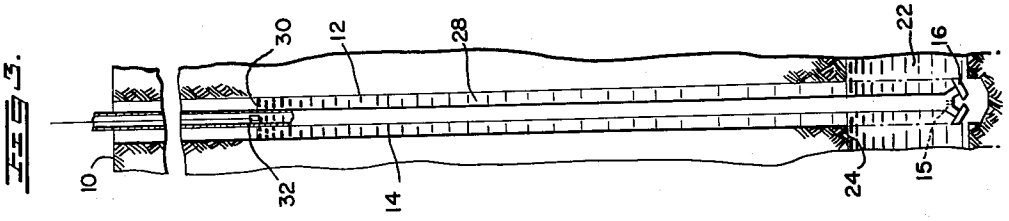


Fig. 2.

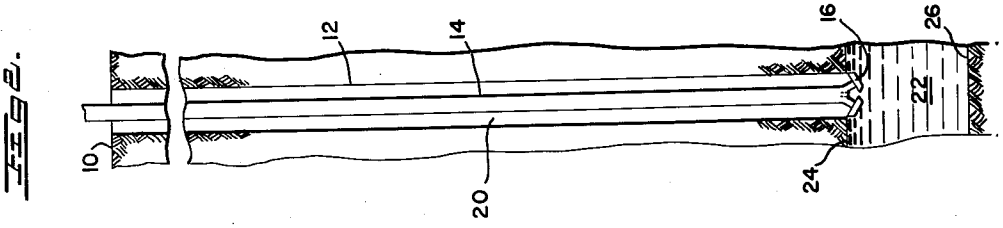
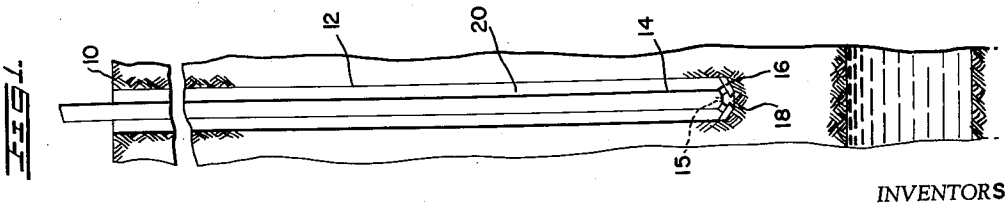


Fig. 1.



INVENTORS

ROBERT O. PERRY

DON R. HOLBERT

BY

ATTORNEYS

Dec. 5, 1961 D. R. HOLBERT ET AL 3,011,547

METHOD OF PREVENTING LOSS OF GASEOUS DRILLING FLUID

Filed Sept. 25, 1957 2 Sheets-Sheet 2

Fig. 5.

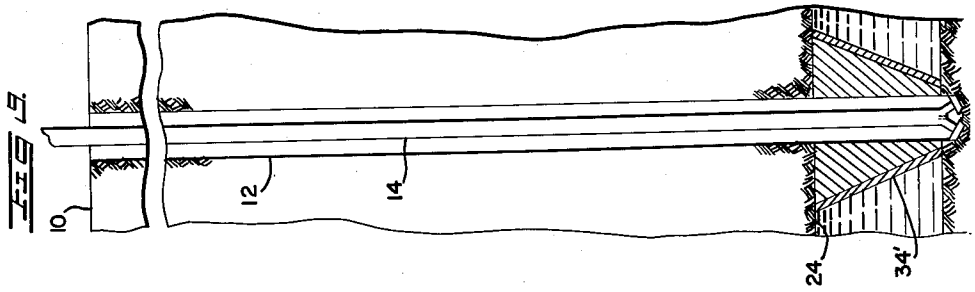


Fig. 8.

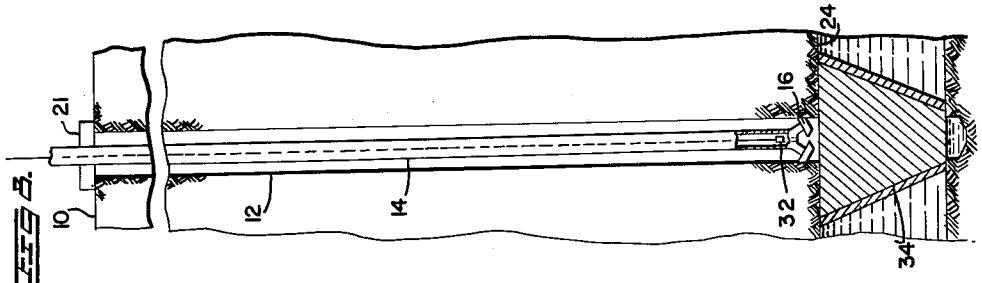


Fig. 7.

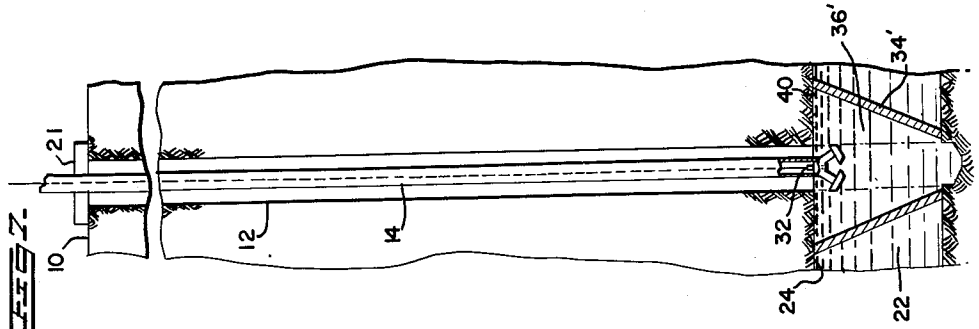
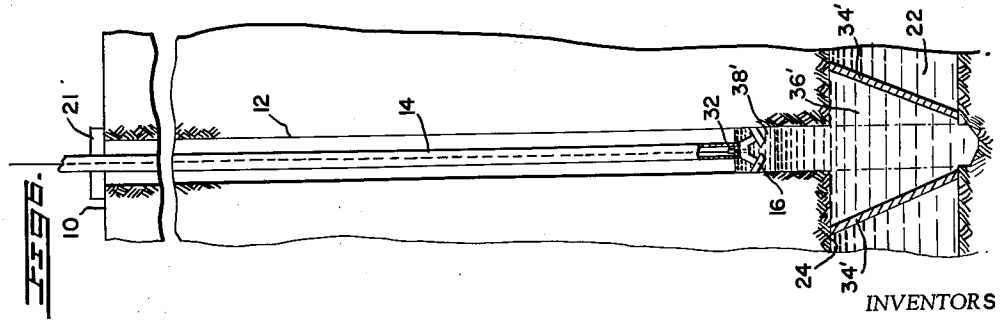


Fig. 6.



INVENTORS

ROBERT O. PERRY

DON R. HOLBERT

BY

ATTORNEYS

United States Patent Office

3,011,547
Patented Dec. 5, 1961

3,011,547

METHOD OF PREVENTING LOSS OF GASEOUS DRILLING FLUID

Don R. Holbert and Robert O. Perry, Tulsa, Okla., assignors to Sinclair Oil & Gas Company, a corporation of Maine

Filed Sept. 25, 1957, Ser. No. 686,198
4 Claims. (Cl. 166—33)

This invention relates to improvements in a method using air as the circulation medium in the drilling of wells. More specifically, this invention is concerned with a method which combats the effect of reduction or cessation of gas circulation when gas-drilling wells through permeable formations, i.e. those containing gas, liquid or loosely consolidated strata.

In more recent times, "gas- or air-drilling" methods have become prominent in the drilling of wells, particularly oil and gas wells, since they allow a more efficient utilization of the energy employed for drilling purposes as compared to the energy utilized in "conventional" drilling procedures using mud as the circulating medium. The velocity of the mud circulating medium is inherently low during the course of drilling, and accordingly, although small rock particles, e.g. less than 0.10 inch in diameter, are removed from the well bore, the velocity of the mud is insufficient for the purpose of removing large rock particles up to an inch or more in diameter which remain at the site of drilling until they are ground to a size suitable for transportation from the well bore. Thus a large amount of energy is employed for grinding rather than drilling purposes. When drilling a well using the gas-drilling procedure, however, the air or other gas, hereinafter referred to as air for convenience, velocity is sufficient to remove the small as well as the large particles from the well bore and in addition, this procedure utilizes energy for drilling rather than grinding purposes and results in a method more economical and faster than mud circulation drilling procedures. As an example of the speed when drilling with air as the circulation medium, 6.5 feet of a shale formation has been cut through in 40 seconds.

A serious problem, the reduction or cessation of air circulation, has been encountered in the air-drilling procedure when drilling through a gas, liquid or loosely consolidated strata whereby the advantages of this procedure over the conventional procedure, i.e. economy and speed, are reduced significantly. This problem is created for example when either small amounts, e.g. 0.2 gallon per minute, of liquid are admitted into the well bore hole and putty-like material forms to cause a reduction of the air circulation at a given pressure or when large amounts of liquid or loosely consolidated material are encountered, to cause a cessation of the air circulation. Although intermediate amounts of liquid may be tolerated, the drilling rate is substantially decreased. Thus under these conditions the obstruction of air circulation causes a loss of the advantages of this procedure over the mud circulation procedures.

The present invention is directed to a method for combating the effect of a reduction or a cessation of the air circulation in air-drilling methods when drilling through permeable areas from which gas, liquid or loosely consolidated strata enters the well bore being drilled. The desired result is accomplished by selectively and substantially completely sealing formations of this character from the well bore in an expeditious and economical manner so as to maintain the advantages of the air-drilling procedures over the conventional procedures which use mud as the circulating medium.

According to the method of the present invention, when

an obstruction of air circulation, i.e. a reduction or cessation thereof, is experienced during an air-drilling operation and the obstruction is attributed to the ingress of gas, liquid or loosely consolidated earth particles into the bore from an adjacent stratum, resin-forming material is introduced into the well bore. This material is of the type that will harden at temperatures encountered in the well bore, which in many cases are between about 50 to 80° F. The quantity of resin-forming material used must be adequate to extend horizontally into the formation of ingress for a distance sufficient to securely seal this formation subsequent to the hardening of the resinous material to prevent further ingress of unwanted extraneous materials. This distance usually extends at least about six inches into the formation. Moreover, in our method it is imperative that the resin-forming material occupy the well bore adjacent the formation of ingress when the hardened resin is formed. Accordingly, after the introduction of the resin-forming material into the well bore detection means are employed to track the upper level of the resin-forming material, gas or liquid, e.g. air or water pressure is applied to bring this upper level approximately adjacent the upper level of the strata of ingress, and the resinous material is maintained in this position until it solidifies. Although gas or liquid pressure can be employed in our method, gas is preferable to liquid since (*a*) it permits better control of the plastic material, (*b*) the position of the resin-forming material is determined with facility as a result of the sharp difference in electrode readings (milliamps) between plastic and air and (*c*) the well bore hole is dry following the polymerization of the resin-forming materials. The gas pressure will depend upon the nature of the obstruction encountered but is generally from about 150 to 1000 p.s.i. Following solidification of the resinous material, air-drilling is resumed.

In the practice of the present invention, it may be desirable to place a small volume of liquid or primary buffer before the resin-forming material to prevent contact of the resinous material with the materials in the lower portion of the well bore, e.g. salt water. This primary buffer should have a density in between that of the well bore fluid and the resinous material so that the buffer will have a tendency to float or remain between the well fluid and resinous material. Examples of suitable buffers are mixtures of 60% by volume of kerosene and 40% by volume of carbon tetrachloride with a specific gravity of 1.13 or mixtures of 82% by volume of kerosene and 18% by volume of tetrabromo ethylene.

It may also be desirable to place on the resin-forming material a volume of liquid or secondary buffer possessing a degree of electrical conductivity appreciably different from that of the resin-forming material to facilitate tracking of the resin-forming material; the density of the secondary buffer should be less than that of the resinous material and preferably greater than that of any fluid, liquid or gas, used to pressure the resinous material to its position of hardening. Suitable secondary buffers are 2% by weight of calcium chloride in water with specific gravity of 1.015 and 4% ammonium chloride in water solution with specific gravity of 1.01.

When the resin-forming material is appreciably electrically conductive, the secondary buffer can be essentially non-conductive.

The detection means employed for tracking the position of the resin-forming material in the well bore can vary. In one method, a soluble radio-active tracer may be injected into the polymerizable material and a Geiger-counter attached to a line can be employed to locate the polymerizable material and thus by checking the depth of the Geiger-counter, the position of the polymerizable material is known. In another method, the characteristics

of the material can be such that it is detectable by an electrical conductivity profiling unit when the secondary buffer is placed on the resin-forming material. Thus if the secondary buffer is essentially conductive and the resin-forming material is essential non-conductive the conductivity profiling unit will indicate the degrees of current flow within the resin-forming material and secondary buffer. Accordingly, when the conductivity circuit is essentially good, the instrument is in the secondary buffer and when the conductivity circuit is essentially poor, the instrument is in the resin-forming material. Thus by raising and lowering the instrument the interface in between the resin-forming material and the secondary buffer can be located and by checking the depth of the detection instrument the location of the upper layer of the resin-forming material is known. Conversely, the secondary buffer may be essentially non-conductive and the resin-forming material may be essentially conductive such that an essentially good conductivity circuit indicates the presence of the instrument in the resin-forming material while an essentially poor conductivity circuit indicates presence of the instrument in the secondary buffer.

A device suitable for use in measuring the electrical conductivity of the fluids in the well bore is described in U.S. Patent 2,776,563. This device, known as a magnetic coupler, includes a magnetic core, and two electrically conducting coils essentially composed in two basic combinations. One of the combinations, conveniently referred to as a magnetic coupler sub, is essentially comprised of one of the coils, the first coil, surrounding the magnetic core, and fixedly mounted within a structure. The other combination, conveniently referred to as the stinger, comprises a cable containing an insulated electrical conductor communicating with the other coil which is contained within a structure adapted to removably surround the first coil. Under operational conditions the magnetic coupler sub may be installed in a position just above the drill bit in a rotary type drill string. Accordingly, when the position of a liquid of known electrical conductivity within the well bore is desired, the stinger is lowered into the drill pipe string and joined to the magnetic coupler sub, the drill pipe is maneuvered until the liquid or the interface between liquids is located, and by noting the depth of the stinger, the position of the liquid or the interface between two liquids is known. Additionally, if a two-conductor cable is employed in the stinger arrangement the stinger itself can be used as an integral detection unit.

Among the resin-forming materials which we can utilize are those affording modified polyester-type resins, and U.S. Patents Nos. 2,255,313, 2,443,735 and 2,443,741 give examples of these materials. The first of these patents describes resin-forming materials containing a resin which is a substantially linear polyhydric alcohol ester of an unsaturated polybasic acid material of the maleic type mixed with a liquid substituted-ethylene body of resin-forming characteristics which is copolymerizable and miscible with the resinous material, for instance a vinyl compound. Thus the resin or plastic obtained from this mixture can be the reaction product of a maleic-type polybasic acid, a polyhydric alcohol and a vinyl compound. This patent lists a number of suitable reactants; for instance, the polybasic acid may be maleic anhydride, maleic acid, fumaric acid, etc. and the preferred acid materials contain a single double bond and up to about 5 carbon atoms. The polyhydric alcohols are preferably dihydric of the type which react with dibasic acids to yield linear molecules or linear polyesters. Various of the dihydric alcohols are listed in the patent, for instance diethylene glycol, ethylene glycol, triethylene glycol, propylene glycol, etc., and the preferred alcohols are the glycol and glycol ethers of up to about 12 carbon atoms. In the resin-forming material the polyester resin formed from the dibasic acid and the glycol is mixed with an ethylenic polymerizable body, preferably a vinyl compound such as vinyl esters, vinyl ethers, styrene, etc. The mixtures containing the polyester resin and ethylenic compound, for instance styrene, are sold commercially and a catalyst and a promoting material can be added to provide a composition which will be satisfactory as the resin-forming material in our invention.

U.S. Patent No. 2,443,735 describes a resin-forming material which includes a resin possessing a plurality of polymerizable reactive alpha, beta enal groups and at least one material containing the $CH_2=C<$ linkage. The resin component of this mixture is produced by the esterification of an alpha, beta unsaturated polycarboxylic acid with a polyhydric alcohol, such as a glycol, while the $CH_2=C<$ body can be, for instance, styrene. Thus, the ingredients of this resin-forming material can be generally the same as those described with reference to U.S. Patent No. 2,255,313. In Patent No. 2,443,741 similar resin-forming materials are disclosed. However, the $CH_2=C<$ body is of the polyallyl type, for instance a polyallyl ester, and a number of these are mentioned in this patent.

As a more specific example a resin-forming material suitable for our use is provided by mixing generally about 8 to 35 percent and preferably about 20 to 35 percent by volume of an unsaturated polyester resin of the type disclosed in these patents as a solution containing about 30 to 60 percent by volume of styrene; about 80 to 65 percent by volume of an esterified, unsaturated polybasic acid; about 0.01 to 4 percent by volume of a promoter; about 0.01 to 3 percent by volume of a polymerization catalyst; and a sufficient amount of a densifier to adjust the specific gravity of the mixture within a suitable range, e.g. less than about 1.18 when the resin is to be placed on salt water in the well. The polyester resin component can be Laminac 4111, a polyethylene glycol maleate resin mixed with styrene. To adjust the specific gravity of the resin-forming mixture within a desirable range, a chemically inert densifier can be added which has a low viscosity, for instance about 1 to 15 centipoises, preferably about 1 to 5, at 60° F.; and a specific gravity of over about 1.5; and which is water-insoluble and non-polymerizable. Among the preferred densifiers are included benzoyl chloride, dichloro-benzene and dinitrodiphenyl. A particularly effective densifier is tetrabromoethane and generally the addition of about 3 to 6 volume percent of this material is advantageous.

In order to facilitate the polymerization reaction the addition of a small amount of a promoter, for example about 0.01 to 4 weight percent of cobalt naphthenate or dimethyl aniline, is preferred. Apparently, the promoter acts as a linking agent and in combination with the catalyst initiates a faster polymerization reaction at the relatively low polymerization temperatures encountered in a well bore. By varying the amount of promoter and catalyst the working life of the resin-forming material can be regulated. Among the promoters which can be employed in this invention are the organic acid salts of metals such as aluminum and calcium, for instance calcium stearate, aluminum stearate, aluminum naphthenate and calcium naphthenate.

The polymerization catalysts utilized to effect the copolymerization or condensation reactions between styrene and the modified polyester resin-styrene solution can be the organic peroxide catalysts such as benzoyl peroxide, methylethyl ketone peroxide, tetrabutyl hydroperoxide or cyclohexanone peroxide. Particularly effective catalysts are a 60% solution of methylethyl ketone peroxide in dimethyl phthalate or benzoyl peroxide in a 50% mixture with tricresyl phosphate. As mentioned the working life of the resin-forming material is dependent upon the amounts of polymerization catalyst and promoter present as well as the temperature in the well bore, and generally polymerization starts immediately after the catalyst and promoter have been added. Consequently, at ambient temperatures within a well bore, for instance about 70 to 75° F., the amount of catalyst

employed preferably is in the range of about 0.4 to 0.7 percent by volume of the resin-forming material which affords a working life of about 30 to 60 minutes. The amount of catalyst required to sustain the working life of the resin-forming material will increase as the temperature is decreased and thus at lower temperatures of about 50 to 60° F. the amount of catalyst employed may be as high as 3 percent.

Another resin-forming material which can be utilized in this invention is in an aqueous medium and has an initial viscosity approximating that of water. This material can be formed by dissolving a mixture of acrylamide and N,N'-methylene-bis-acrylamide in fresh water. Generally, this mixture contains about 1 to 25 weight percent of N,N'-methylene-bis-acrylamide and about 99 to 75 weight percent of acrylamide. The aqueous solution will usually include from about 5 weight percent of this mixture to its limit of solubility and preferably this amount is about 5 to 25 percent. Although the acrylamide as such is ordinarily used, its nitrogen atom could be substituted as with a hydroxy methyl or a hydroxy ethyl group. Ammonium persulfate is an acceptable catalyst to polymerize the aqueous mixture and it can be employed with a promoter such as sodium thiosulfate or nitrilo-tris-propionamide. The amounts of each of the catalyst and promoter usually are about 0.1 to 2 weight percent based on the aqueous solution of resin-forming material, and these amounts can be varied to give the desired working life. For instance, a weight ratio of catalyst to promoter of 1 to 2 in an aqueous solution containing 20 weight percent of the acrylamide and N,N'-methylene-bis-acrylamide (95% acrylamide and 5% N,N'-methylene-bis-acrylamide) will give a working life at 70° F. of about 60 to 120 minutes when the catalyst plus promoter is about 0.5 to 1.5% of the aqueous solution. A specific resin-forming material found useful is an aqueous solution which contains 20 weight percent of resin-forming material (95 weight percent of acrylamide, 5 weight percent of N,N'-methylene-bis-acrylamide), 0.6 weight percent of nitrilo-tris-propionamide, 0.3 weight percent of ammonium persulfate, and the balance being water. The mixture is not particularly catalyzed by contact with iron, brass or copper and has an initial viscosity (1.3 centipoises) approximating that of water (which is about 0.5 to 1.5 centipoises under the conditions in many well bores) and is not greater than about 2.0 centipoises over a working life of at least about 90 minutes to facilitate its placement in the desired well area. The specific gravity of the mixture is about 1.12. The aqueous solution of amides can advantageously be used as the resin-forming material as it has a lesser tendency to emulsify in the well than do the modified polyester-type compositions.

The method of this invention can best be described with reference to a specific example and the drawing, FIGURES 1 through 9, in which several distinct phases of the method are illustrated.

Referring to the drawing, FIGURE 1, the numeral **10** represents the earth's surface through which a well bore **12** is being drilled to an oil producing formation with rotary drilling pipe **14** containing a rotary bit **16** at the lower end. Pressurized air is introduced into drill pipe **14** at the surface of the earth, is conducted downwardly therein, exits through opening **15** of rotary drill bit **16** at the site or formation of drilling **18**, and passes upwardly through annulus **20**, surrounding drill pipe **14**, carrying relatively small as well as larger rock particles from the site of drilling to the earth's surface.

In FIGURE 2 rotary drill bit **16** penetrates a salt water formation **22** at its upper level **24** as indicated by a reduction in air circulation as well as the muddy nature of the particles recovered from the site of drilling. The depth of the drill bit is noted and thus the position of upper level **24** of salt water formation **22** is known. In FIGURE 3 drilling is continued through the salt water-bearing formation, air circulation eventually ceases due to the back pressure of the salt water, a column of salt water **28** rises in the well bore to level **30**, a detecting device **32** consisting essentially of a stinger employing a two-conductor cable is inserted to locate the upper level **30** of the column of salt water. The lower level **26** of the salt water formation **22** is penetrated by rotary drill bit **16** and drilling is discontinued.

In FIGURE 4 annulus **20** is sealed at the surface with casing head **21**, and a bogey run (not shown) is conducted to determine the position of lower level **26** and includes pumping 20 gallons of a sugar-water solution weighted to float on the salt water column and thus create an interface with the salt water column. Pressure is applied to the sugar-water-salt water column to move the column downwardly in the well bore and the stinger is used to simultaneously track the interface. As the column moves downwardly, the salt water is continuously forced into the permeable formation except for the lowermost portion of the salt water column which extends from the lowermost extremity of the well bore upwardly to lower level **26**. This lowermost portion is substantially immobile and exerts back pressure at level **26**. As a result of this back pressure, the interface will stop moving downwardly at lower level **26** and thus, by noting the depth of the tracking stinger at this point, the position of lower level **26** is known. When other than salt water permeable formations are encountered, it may be necessary to provide salt water to form a column when utilizing this procedure to determine the lower level of the permeable formation.

Pressurized air is introduced at the surface into drill pipe **14** to bring the upper level **30** of water column **28** approximately even with upper level **24** of salt water formation **22**. The position of upper level **30** of the water column is located and tracked during this operation with detecting device **32**.

In FIGURE 5 the drill pipe and bit are lifted to a position just above the upper level **24** of salt water formation **22**, 10 gallons of primary buffer which is a nonconductor fluid and intermediate in density between the salt water well bore fluid and the plastic comprising a mixture of 82% by volume of kerosene and 18% by volume of tetra bromo ethylene is injected into drill pipe **14** and is shown at position **34**. Fifty gallons of resinous material consisting essentially of 20 weight percent of a mixture of 5% N,N'-methylene-bis-acrylamide and 95% acrylamide in water along with 0.3 weight percent of ammonium persulfate and 0.6 weight percent of nitrilo-tris-propionamide is injected down drill pipe **14** at a rate of 2 gallons per minute and positioned in area **36** located above buffer containing area **34**. Four gallons of secondary buffer, which is a conducting solution comprising 2% by weight calcium chloride in water with specific gravity of 1.01 and of a density less than that of the resin-forming material, is injected down drill pipe **14** and is positioned in area **38** located above resin-containing area **36**. Following each of the steps of introducing the primary buffer, the resinous material, and secondary buffer, it is necessary to lift the drill pipe above the level of the material present in the well bore to insure placement of the incoming material on top of the previously introduced material.

In FIGURE 6 detecting device **32** is lowered into secondary buffer **38'**, pressurized air (250 p.s.i.) is introduced downwardly in drill pipe **14** and commences to force a displacement of resinous material **36'** thus causing the resinous material to extend into the formation behind primary buffer **34'**. In FIGURE 7 the displacement of resinous material by the air is discontinued when the upper level **40** of the resinous material **36'** is approximately even with the upper level **24** of the salt water-bearing formation **22** as measured by raising and lowering cell **32** through the resin upper buffer interface. The

resinous material is maintained in this position by regulating the air pressure at the surface, until it polymerizes and solidifies. To track the secondary buffer, thus the upper level of the resinous material, it may be necessary to lower the drill pipe into the solution of resinous material as illustrated in the drawing. However, the drill pipe should be raised above the resinous material before polymerization time as shown in FIGURE 8. The resinous material is co-polymerized to a semi-solid gel in about 90 minutes although copolymerization time can be controlled by changing the concentration of the catalyst or by adding small amounts of potassium ferricyanide to delay polymerization. The mixture of the resinous ingredients employed in this example are particularly desirable since they will not prepolymerize upon contact with iron, brass or copper. Following the solidification of the resinous material, air pressure is discontinued, detection device **32** is removed, air circulation down drill pipe **14** to rotary drill bit as well as drilling are resumed, the solidified resinous material is drilled-through, and the drilling continues downwardly into the earth's surface as exemplified in FIGURE 9 while removing cuttings from the well bore by air circulation down the drill pipe and up the well annulus.

The above example illustrates a method designed to remove gas circulation obstructions in a rotary drilling method employing a gas as the circulating medium. The advantages inherent in using our method are readily apparent to those skilled in the art and include, for instance economy and speed. Both of these advantages result in the manner in which our method is conducted, for example since (*a*) removal of the drill pipe and bit from the well bore is not mandatory, (*b*) a resinous material is used that will co-polymerize at ambient conditions in the well bore, (*c*) the polymerization time of the resinous material is controllable, and (*d*) detection means are employed in a manner to place the resinous material properly in the well bore to permit excellent air circulation when drilling is resumed. Although our invention is illustrated with a most expedient and economical method, it will be obvious to those versed in the art to use various modifications incorporating the essential features of our method such as the removal of the drill pipe and bit from the well bore completely and using packers to block fluid flow up annulus **20** during the displacement of the resin from the well bore.

Occasionally, the ingress of gas, liquid or loosely consolidated strata occurs in an area spaced upwardly from the bottom of the well bore during the air drilling operation and obstructs air circulation. Under these circumstances, it is convenient to introduce salt water into the bottom of the well bore such that the upper level of the salt water column formed in the well bore is approximately adjacent to the lower level of the strata of ingress and thus the upper level of the salt water column provides a platform upon which the resin-forming material, which will be lighter in density than the salt water, can be placed and introduced into the formation of ingress employing a method substantially as described in the above example.

It is claimed:

1. A method for combatting the obstruction of gas circulation in drilling wells employing gas as the circulation medium through a drill pipe with a lower opening, wherein the obstruction results from the ingress of extraneous materials into the well bore from a subterranean formation, the steps comprising positioning the lower opening of the drill pipe above the ingress of the extraneous material, introducing resin-forming material above the extraneous material in quantities sufficient to prevent further ingress of extraneous materials into the well bore, tracking the upper level of the resin-forming material in the well bore with detection means, applying pressure to the upper level of the resin-forming material until said level is at the approximate depth of the top level of the formation of ingress as determined by said tracking, maintaining the resin-forming material in this position until it substantially solidifies, drilling through the solidified resin, and continuing drilling with gas circulation to remove cuttings from the well.

2. A method for combatting the obstruction of the circulation in drilling wells employing gas as the circulation medium through a drill pipe with a lower end opening, wherein the obstruction results from the ingress of extraneous materials into the well bore from a subterranean formation, the steps comprising adjusting pressure on the upper level of the extraneous material until said level is at least at the approximate depth of the top level of the formation of ingress, positioning the lower end opening of the drill pipe above the upper level of the extraneous material present in the well bore, introducing resin-forming material in quantities sufficient to prevent further ingress of extraneous materials said introduction being into the well bore through the drill pipe to position the resin-forming material above the extraneous material, tracking the upper level of the resin-forming material in the well bore with detection means, applying pressure to the upper level of resin-forming material until said level is at the approximate depth of the top level of the formation of ingress as determined by said tracking, maintaining the resin-forming material in this position until it substantially solidifies, drilling through the solidified resin, and continuing drilling with gas circulation to remove cuttings from the well.

3. The method of claim 2 wherein the detection means is an electrical conductivity detection means.

4. A method of claim 3 wherein the resin-forming material is a mixture of acrylamide and N,N'-methylene-bis-acrylamide.

References Cited in the file of this patent

UNITED STATES PATENTS

2,345,611	Lerch et al.	Apr. 4, 1944
2,700,734	Egan et al.	May 24, 1954
2,801,985	Roth	Aug. 6, 1957
2,867,278	Mallory	Jan. 6, 1959