Jan. 13, 1953 L. J. NEUMAN 2,625,374

METHOD OF CONTROLLING FLUID INFILTRATION

Filed Jan. 22, 1946 2 SHEETS—SHEET 1

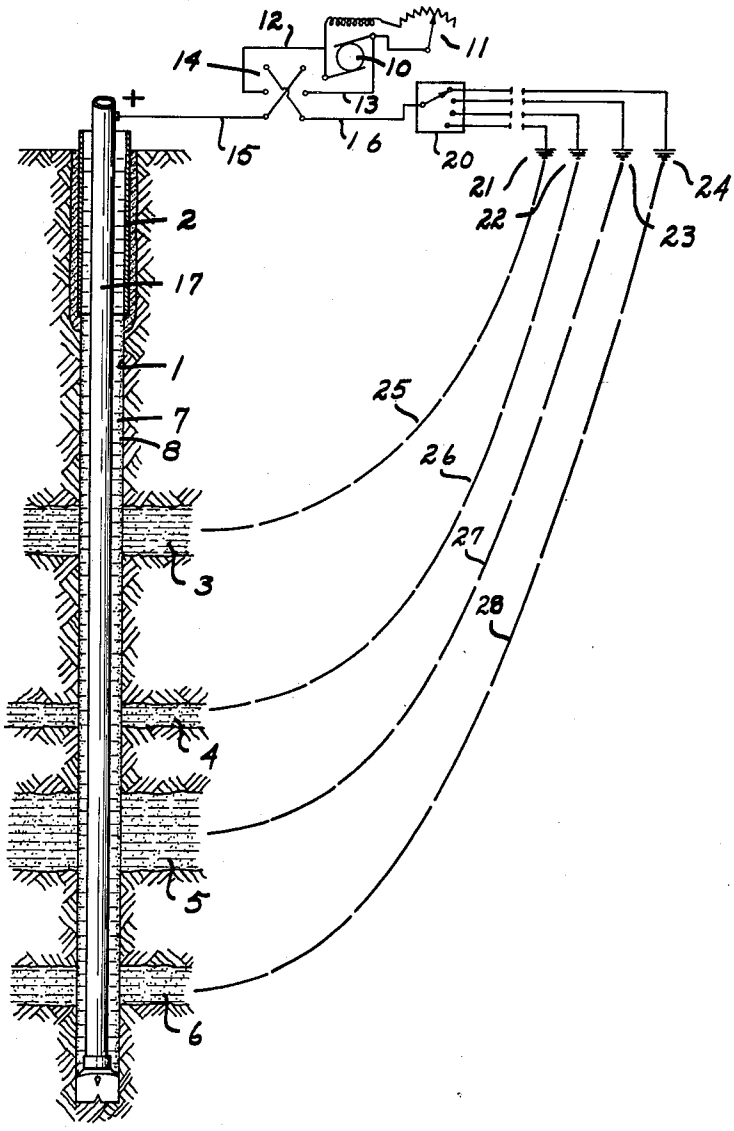


Fig 1

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METHOD OF CONTROLLING FLUID INFILTRATION

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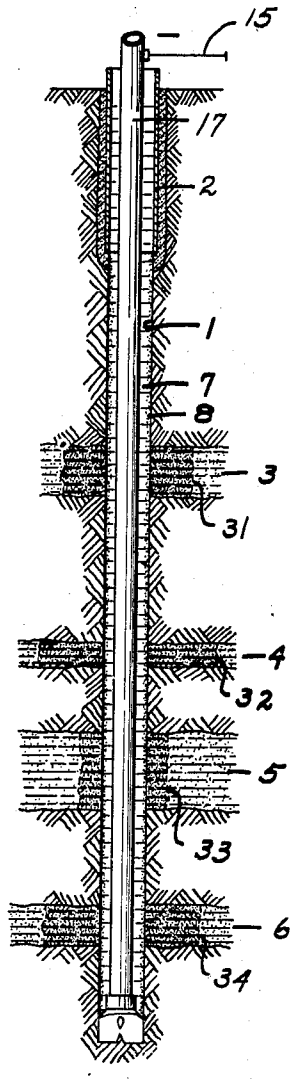


Fig 2

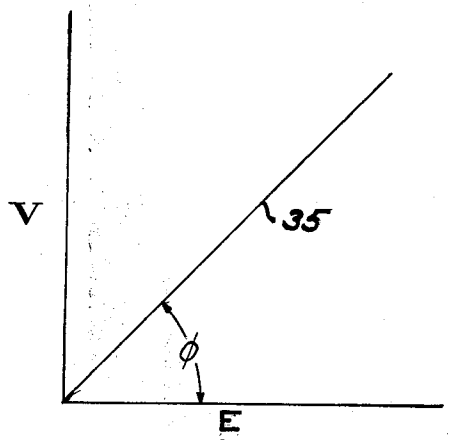


Fig 3

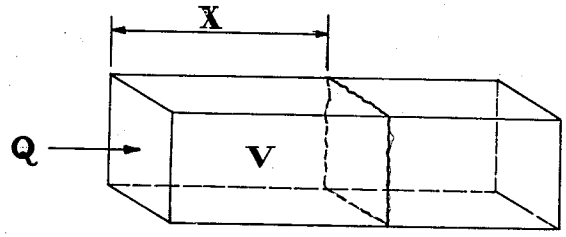


Fig 4

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UNITED STATES PATENT OFFICE

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METHOD OF CONTROLLING FLUID INFILTRATION

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Application January 22, 1946, Serial No. 642,627

6 Claims. (Cl. 255—1.8)

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This invention relates to a method for controlling fluid infiltration, or invasion, into the geological strata penetrated by bore holes and for determining permeability of such strata. The application is a continuation of copending application, Serial Number 329,625 filed April 15, 1940, now abandoned.

A purpose in the use of various components of modern drilling muds in the practice of drilling wells by the rotary method is that of preventing the invasion of permeable formations traversed by the bore hole. Such muds do, for the most part, prevent or minimize invasion from such pressure differentials as may exist across the filter cake formed thereby. They do not, however, prevent invasion by osmosis and differential diffusion through the filter cake and into the formations.

It is now commonly known that, even when muds having the best of cake forming characteristics are used, the formations traversed by the bore hole are seriously invaded by fluid from the muds, often to the extent of thirty or forty feet from the axis of the well bore. This invasion is decidedly detrimental inasmuch as it affects conventional well logging in such a manner that the interpretation of the logs is difficult, and often impossible. For this reason additional laborious operations are frequently necessary to clarify information, and in some cases a potentially productive horizon is entirely overlooked. It is also to be noted that fluid invasion of potentially productive formations often seriously affects production characteristics of the well.

No drilling fluids that are now available completely eliminate invasion by osmosis and differential diffusion, and it has therefore been impossible heretofore to eliminate the difficulties to which reference has just been made.

The terms "differential diffusion" and "osmosis" as used herein include those phenomena which cause infiltration or invasion of liquid components of drilling mud into penetrated formations, and which constitute a component of infiltration other than that which is produced by the mechanical pressure differential across the filter cake. It is well known that "differential diffusion" or "osmosis" is caused by a difference in ion concentration of two fluids separated by an osmotic membrane.

The present invention is concerned with, and it is the primary object of the invention to prevent invasion of formations penetrated by bore holes such as oil and gas wells by fluids introduced as flowing into such bore holes.

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Another object is to control differential diffusion and molecular movement in a well during drilling and during subsequent operations of bringing the well into production whereby the potentially productive horizons may be effectively logged and optimum production characteristics are established.

A further object is to prevent infiltration by osmosis and differential diffusion into shales so that such formations may be effectively drilled by avoiding the heaving of such shales into the well.

Another and more specific object is to apply an electrical potential between the interior of a well and the surrounding formations to overcome the tendency for differential diffusion to take place through the filter cake.

A still further object is to maintain such electrical potential after drilling is completed and prior to the completion of the well so that differential diffusion during such interval is minimized.

The invention also comprehends the application, for a predetermined period of time, of a reversed potential between the drilling fluid and the surrounding formation whereby controlled infiltration or invasion is effected, and correlation of electrical logs prior and subsequent to such infiltration affirmatively indicates permeability of the respective penetrated formations.

The foregoing are primary objects which, together with other objects and advantages of the invention, will be more fully apparent from the following description considered in connection with the accompanying drawings in which:

Fig. 1 is a sectional view through the earth showing an illustrative embodiment of the invention;

Fig. 2 is a sectional view similar to that shown in Fig. 1, but illustrating the extent of controlled invasion of penetrated formations from which permeability of the various formations may be readily determined;

Fig. 3 is a graphical illustration showing the relation for a given formation between the volume invaded and the potential applied;

Fig. 4 shows an elemental unit solid illustrating the manner in which a quantity of fluid Q is caused to flow through an elemental volume V by a potential gradient $\Delta E/\Delta x$.

In the practice of the invention as illustrated in Fig. 1 of the drawings, the bore hole 1 is provided with a surface casing 2. Below this casing the bore hole penetrates successive porous, somewhat porous or permeable formations 3, 4, 5 and 6 at succeedingly greater depths. It is to be

understood that the disclosure is illustrative only as fewer or a greater number of permeable formations may be considered.

The bore hole 1 is filled with or usually contains a drilling fluid or mud 7. Such drilling fluid or mud is usually made up of a water base which carries solid or colloidal matter which is compounded for the purpose of accomplishing various functions during the drilling operation and is usually of such nature that a filter cake 8 is formed on the walls of the bore. As already explained such filter cake is usually relatively impermeable and capable of preventing or minimize invasion of the formations by liquids from the mud due to mechanical pressure differential at the face of the well bore 2. It has been found that such a filter cake on the formation face is incapable of preventing invasion of the formation by liquid from the mud due to molecular movement, from osmosis and differential diffusion.

To prevent or minimize invasion from osmosis and differential diffusion the invention comprehends the use of a suitable source of electrical potential such as the generator 10. This generator is provided with a rheostat 11 so that the terminal potential of the generator may be readily controlled within desired limits. Inasmuch as the results obtained in accordance with the invention are primarily dependent upon a potential field at the well bore, and not the current intensity within such area, the terminal voltage of the generator 10 may vary between relatively wide limits. For example, in the Gulf Coast area of the United States where the moisture content of the earth's crust is high, a terminal voltage of fifty volts is adequate. On the other hand, where drilling operations are carried out in more arid areas, such as the uplands of West Texas, a terminal voltage as much as two-hundred and twenty volts may be necessary. These suggested potentials are given by way of illustration and it is not intended that the invention shall be confined to the use of these exact potentials.

The terminals 12 and 13 of the generator 10 are connected to a double pole double throw reversing switch 14 so that the polarity supplied to the circuit conductors 15 and 16 may be readily controlled. When drilling deep wells such as oil and gas wells, the formations traversed contain connate waters that are mineralized, that is containing various salts which carry a negative potential. Under these conditions and in accordance with the invention, it is necessary that the interior of the bore hole be positive with respect to the formation penetrated. To this end the switch 14 is closed so that the conductor 15 is connected to the positive terminal of the generator 10 and to the drill stem within the well bore.

The negative terminal of the generator 10 is connected to a control box 20 through which connections may be selectively made to a plurality of grounds 21, 22, 23 and 24 arranged at selected distances from the well that there is a desired distribution of electrical energy as indicated by the lines 25, 26, 27 and 28 respectively.

Since two to ten weeks of time is usually required to complete a well, the amount of time during which invasion may take place during such operations as changing of bits, logging, running pipe, etc., is relatively small and for this reason during such time, while a potential is not applied in accordance with the foregoing, is negligible.

Following the actual drilling operations in which this invention is utilized in the manner above indicated there is a period during which other operations such as logging, setting of casing, testing for production and cleaning of the well are carried out. During this period it is desirable that potential conditions as above, be maintained insofar as practicable to prevent molecular movement or migration. To this end any suitable electrode may be utilized in the well. For example, a cable may be lowered into the well for temporary use as an electrode or any tubing string lowered into the well will be so used.

After drilling is completed and before the casing is set, the well is logged. One phase of the invention comprises the carrying out of the subsequent step of effecting controlled invasion so that permeability of penetrated formations may be determined. For this purpose the switch 14 is thrown so that a negative potential is applied to an electrode in the well for a predetermined length of time as illustrated in Fig. 2 whereby infiltration into the various formations 3, 4, 5 and 6 is produced as indicated at 31, 32, 33 and 34 respectively. It is to be noted that invasion is a function of permeability and that therefore the extent of invasion varies in the general manner indicated.

At the end of time, t, the well is relogged for the purpose of determining the depth of the controlled invasion of each formation as resulting from the application of a potential, E. These measurements provide values of V, the invaded volume, corresponding to the applied potential E existing during the time, t. These data enable the plotting of the curve 35 shown in Fig. 3. The slope of this curve is:

$$\Delta V/\Delta E=\tan\phi \qquad (A)$$

But, $\Delta V=K\Delta x$ which is a function of the depth of the invasion x. One may therefore write:

$$K(\Delta E/\Delta x)=\cot\phi \qquad (B)$$

The quantity of fluid, Q, entering a unit cube having volume V during time, t, as illustrated in Fig. 4 is related to $\Delta E/\Delta x$ in the following manner:

$$Q/t=K_1x(\Delta E/\Delta x)P \qquad (C)$$

In this equation P is permeability of the formation under consideration. Now from equations (B) and (C):

$$P=Q/t=K_2\tan\phi \qquad (D)$$
$$=K_3V\tan\phi \qquad (E)$$

In equations (D) and (E), V and tan ϕ are determined in the manner just indicated.

It seems apparent that the method gives the average permeability of a large sample of formation in situ and is therefore extremely advantageous over the ordinary method of determining permeability from small contaminated samples obtained by coring and the like.

The practice of the invention as above set forth pertains to operations carried out where connate waters are mineralized. The invention is also applicable where drilling operations are carried out for the purpose of producing fresh water. In such case, however, technique is modified to the extent that potentials, as above set forth, are reversed in polarity. This is necessary because under these conditions the drilling mud is made more highly mineralized than are the fresh waters of the formations through which drilling is carried out.

Broadly the invention comprehends a method for controlling fluid infiltration or invasion into geological strata penetrated by bore holes and

also for determining permeability of such strata.

The invention claimed is:

1. The method of preventing infiltration, by differential diffusion, of fluids from drilling mud into the formations containing mineralized water penetrated by a well bore and determining permeability of the penetrated formations comprising, applying a positive electrical potential between the drill string and the earth surrounding the well bore, maintaining said potential during drilling, electrically logging the bore, applying a reversed potential between the mud and the surrounding formation whereby controlled infiltration is effected, and thereafter re-logging the well, whereby the rate of infiltration and hence permeability of the penetrated formations are determinable.

2. In the drilling of wells by the rotary method wherein drilling fluid is pumped downwardly through a drill string during drilling, the method of preventing infiltration by osmosis of the drilling fluid into penetrated formations containing mineralized water during drilling, and determining permeability of the formations comprising, applying a positive electrical potential between the drilling fluid and the earth surrounding the well bore and maintaining said potential, during drilling, at a sufficiently high potential with respect to the surrounding formation to overcome the tendency for infiltration by osmosis, electrically logging the bore so formed, applying a reversed potential between the drilling fluid and the surrounding formations for a predetermined time, and thereafter re-logging the well to determine the amount of infiltration during such time.

3. The method of preventing infiltration, by differential diffusion, of fluids from drilling mud into the formations, containing fresh water, penetrated by a well bore and determining permeability of the penetrated formations comprising, applying a negative electrical potential between the drill string and the earth surrounding the well bore, maintaining said potential during drilling, electrically logging the bore, applying a reversed potential between the mud and the surrounding formation whereby controlled infiltration is effected, and thereafter re-logging the well, whereby the rate of infiltration and hence permeability of the penetrated formations are determinable.

4. In the drilling of wells by the rotary method wherein drilling fluid is pumped downwardly through a drill string during drilling, the method of preventing infiltration by differential diffusion of the drilling fluid into penetrated formations containing fresh water during drilling, and determining permeability of the formations comprising, applying a negative electrical potential between the drilling fluid and the earth surrounding the well bore and maintaining said potential, during drilling, at a sufficiently high potential with respect to the surrounding formation to overcome the tendency for infiltration by differential diffusion, electrically logging the bore so formed, applying a reversed potential between the drilling fluid and the surrounding formations for a predetermined time, and thereafter relogging the well to determine the amount of infiltration during such time.

5. The method of determining the permeability of a porous earth formation penetrated by drilling a well bore while a drilling mud cake is covering said earth formation comprising, forming a drilling mud cake on a porous earth formation strata, said cake minimizing invasion of well fluids from said well bore into said porous earth formation strata by pressure differentials but permitting an invasion of said well fluids by osmosis, thereafter applying a first potential difference between the well fluids and the earth surrounding the well bore for a predetermined period of time to control said invasion by said osmosis, thereafter electrically logging the bore to record the extent of invasion of said well fluid, applying a second potential difference different from said first potential difference for the same period of time as said first potential difference was applied, and thereafter electrically logging the extent of invasion of said well fluid during application of said second potential difference, the two loggings enabling a mathematical computation of the permeability of said porous earth formation in situ.

6. The method of determining the permeability of a porous earth formation penetrated by drilling a well bore in situ comprising, forming a drilling mud cake on said porous earth formation, while said cake remains thereon applying a first electrical potential difference between the well fluids and the earth surrounding the well bore to control osmotic invasion of said porous earth formation through said mud cake, electrically logging the bore to record the extent of said invasion, thereafter applying additional electrical potential differences between said well fluid and said earth surrounding the well bore, said additional potential differences being of different voltage than said first potential difference and each of the other of said additional potential differences, and electrically logging the well liquid invasion caused by each potential difference to thereby obtain data for determining the permeability of said porous earth formation in situ.

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