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METHOD OF DETERMINING THE FLUID CONTENT OF WELL CORES

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Fig. 1.

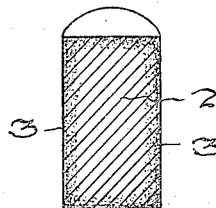


Fig. 2.

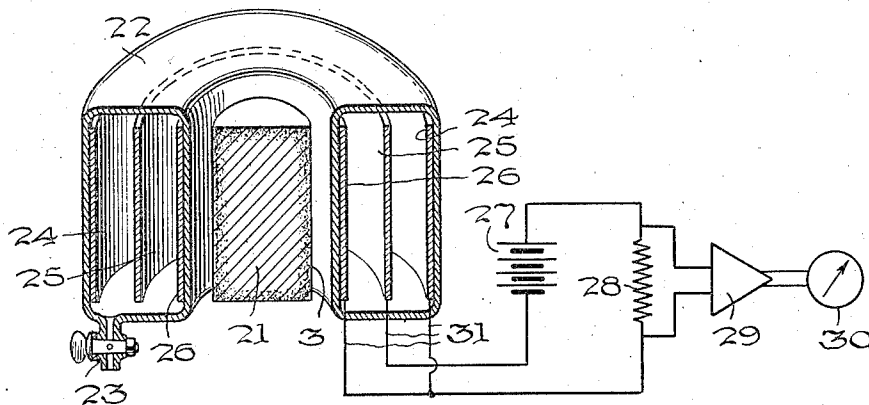
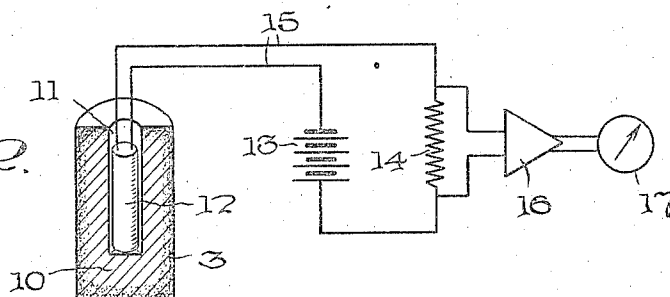


Fig. 3.

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## UNITED STATES PATENT OFFICE

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METHOD OF DETERMINING THE FLUID  
CONTENT OF WELL CORES

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1 Claim. (Cl. 250—83)

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This invention concerns an improved method of determining the amount of fluid in a core obtained from a certain level in a well bore. More particularly, it involves a method of determining by means of a radioactive technique the drilling fluid content of a well core, so that this information may be used as a method of logging or applied as a correction to connate fluid determinations.

In the drilling and producing of oil wells, it is customary to cut cores of the formations penetrated. These cores are useful for identifying formations which might be oil bearing, and they are particularly useful in determining the productivity which might be expected of the various formation horizons encountered in the well.

In the determination of the productivity of an oil bearing horizon, a core sample is subjected to certain well known tests. These tests involve determination of porosity and permeability by known methods. It is also necessary to know the pore content of the producing formation. This is done by taking bottom hole samples under pressure, bringing them to the surface and analyzing them. The samples may contain gas or oil or connate water.

A serious difficulty in the above determinations arises from the fact that wells are drilled with the use of a fluid of some type to cool the drill and remove drill cuttings and carry them to the surface. This drilling fluid is commonly maintained with a bottom hole pressure slightly greater than that of the formation being drilled, in order that the well may at all times be kept under control. Any formation which is porous enough to produce oil will obviously have forced into it a certain amount of the drilling fluid during the drilling process and this fluid contaminates the connate fluid in the formation to such an extent that a subsequent test on a sample brought to the surface may not give reliable results. In case an oil base drilling fluid is used, the oil content analysis may obviously be in error. If an aqueous drilling fluid is used, the connate water analysis may be in error.

A further limitation arises from the fact that the determination of connate fluids is a time consuming and expensive laboratory procedure and is therefore ordinarily not used except for relatively widely spaced samples. A more continuous log of the borehole with respect to the amount of drilling fluid entrained in the core has heretofore not been commercially practicable because of the difficulty and uncertainty heretofore incident to the measurements. The method of our invention when applied to cores would per-

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mit such measurements to be made very simply and quickly so that one may log the cores with respect to the amount of drilling fluid invasion as a basis of correlation and indexing the type of strata which the drill has traversed. Such a log will reflect the variations in permeability and porosity of the strata. An especially advantageous feature of our invention is that quantitative measurements of the drilling fluid invasion may be made before and without the tedious process of extraction, whereas in other methods extraction is necessary.

One of the objects of this invention is the evaluation of a correction in a core fluid determination for the amount of drilling fluid foreign to the core which was forced into the core during the drilling process before or during the cutting of the core.

Another object of this invention is to provide a simple and accurate method of correcting a core fluid determination for the amount of fluid absorbed by the core from the drilling fluid.

A still further object of this invention is to determine the amount of drilling fluid absorbed by the core by means of introducing a radioactive tracer into the fluid.

An ancillary object of this invention is to provide a simple, quick and accurate method of logging the cores of a borehole with respect to drilling fluid invasion.

These and other useful objects of the invention are accomplished in the manner described in the following specification.

A fuller understanding of our invention may be obtained by reference to the drawing, in which:

Figure 1 shows in section a core sample taken from a well bore in the manner of our invention;

Figure 2 shows an arrangement of measuring device for determining the amount of drilling fluid penetrating such a core sample; and

Figure 3 shows another arrangement of measuring device for determining the amount of drilling fluid in such a core sample.

The invention comprises in its simplest form adding to the drilling mud in known and controlled proportions a radioactive material which becomes homogeneously mixed in the mud. The core is cut with the use of this radioactive mud, and then later the radioactivity in the core sample is measured. The measured radioactivity will allow a determination of the amount of drilling fluid which actually penetrated into the core. This information may then be plotted in the form of a well log. If the core is extracted to determine connate fluid, the information obtained by our

invention may be used to identify that part of the extracted fluid which is entrained drilling fluid.

Several types of radioactive materials are advantageously added to the drilling fluid. Naturally radioactive material in the form of a salt of uranium, thorium or radium may be used. If the drilling fluid is of the aqueous type, the radioactive salts should be water soluble. In the case of oil base drilling fluids, they should be oil soluble such as, for instance, soaps of radioactive elements. Radium naphthenate or barium-radium-petronate are satisfactory oil soluble tracers. It is also possible to use artificially radioactivated substances. Examples of such artificial radioactive tracer materials are the isotopes of ordinary sodium, namely  $\text{Na}^{22}$  or  $\text{Na}^{24}$  which may be formed by various well known means. Salts of these isotopes are water soluble and emit energetic gamma rays and have suitable decay periods. Sodium naphthenate or sodium petronate are satisfactory as oil soluble artificially radioactive tracers. Artificial radioactive materials may be chosen with lifetime sufficiently long to carry out the methods of this invention and yet short enough so that later radioactivity logs of the well would not be appreciably affected by any mud which might remain attached to the rock strata.

In Figure 1 we have shown in cross section a sample of core 2 cut from a well using mud containing a dissolved radioactive material. The core is somewhat porous and a certain amount of radioactive drilling fluid penetrates the core as indicated in the figures by numeral 3. While the entire core 2 contains connate fluid an extraction would also include the extraneous fluid 3. The amount of fluid 3 is some function of the permeability and porosity of core 2. By means of this invention one may determine the amount of fluid 3. This may then be subtracted from the total amount of extracted fluid in the core to arrive at the correct amount of connate fluid.

After the core has been cut and removed to the surface, its radioactivity may be determined by means of the apparatus shown in Figure 2. Numeral 10 represents a section of core removed from the core barrel, the entrained radioactive drilling fluid being indicated by numeral 3. A small hole 11 may be drilled into the face of the core and into this hole is inserted a detector of radioactivity, such as an ionization chamber or Geiger counter indicated by numeral 12. The counter 12 is supplied high potential by the battery 13 through resistance 14 and leads 15. The potential across resistor 14 may be amplified by amplifier 16 whose output is indicated on meter 17. The meter 17 may be calibrated to read directly the amount of entrained radioactive drilling fluid 3 indicated in the core sample 10.

Another method of determining the radioactivity of the core is by the use of a specially shaped ionization chamber shown in Figure 3. Numeral 21 represents the core being studied having entrained radioactive drilling fluid 3. Numeral 22 represents a vessel which contains an ionization chamber. Stopcock 23 is a connection to the air or to a suitable gas reservoir. The vessel 22 contains three cylindrical conductors, 24 being the outermost, 25 being the intermediate one and 26 the innermost one. All are concentric and inside the annular vessel 22. Leads are brought out as indicated at points 31 and con-

nected as shown to battery 27 and resistor 28. When the core sample is placed inside this annular vessel, the gamma rays emitted from the core pass through the vessel and electrodes and ionize the gas contained in the vessel. As a result of the potential applied by the battery 27, all the ions formed in the region between 24 and 25 and between 25 and 26 are collected. The resulting current traverses resistance 28 and the consequent voltage drop across resistance 28 is a measure of the radioactivity of the core. The potential drop across 28 is amplified by the amplifier 29 and the output fed to meter 30. The indicating meter 30 therefore gives a reading proportional to the ionization current which in turn is a measure of the drilling fluid absorbed by the core. This device is easily calibrated by merely inserting, instead of core 21, a thin walled container filled with a measured sample of drilling fluid. The apparatus of Figure 3 is particularly adapted to logging of long cores in which case the annular vessel 22 may simply be slipped over the core and measurement made along the length of the core.

The concentration of the radioactive material used in the drilling fluid need not be very large because the natural radioactivity of the rocks normally encountered in oil producing formations is very small. The determination may in any case be improved by subtracting from the reading of meters 17 or 30 any indication obtained from a core not drilled with radioactive mud. Such core samples are readily available, so that the reading obtained with a blank core would be known.

In the practice of the invention, the radioactive material is preferably contained in the fluid in a dissolved state, so that it will not be filtered by small pores in the core sample. It should, furthermore, be of such chemical composition that it will not react with or be precipitated by the rocks or the fluids encountered in drilling. We have mentioned several radioactive compounds which may be used in our invention and these are by way of illustration only, many other similar compounds being available for accomplishing the objects of our invention.

What we claim as our invention is:

A method of determining the connate fluid content of a well core sample comprising adding to the drilling fluid a known concentration of artificially radioactivated material soluble in the drilling fluid, cutting and removing the core sample from the well, measuring the radioactivity of a known quantity of core sample to determine the amount of drilling fluid absorbed in the sample, determining the nature and quantity of total fluids in the core sample and subtracting therefrom the said determined amount of drilling fluid absorbed.

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