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METHOD OF DETERMINING CONNATE WATER CONTENT OF CORES

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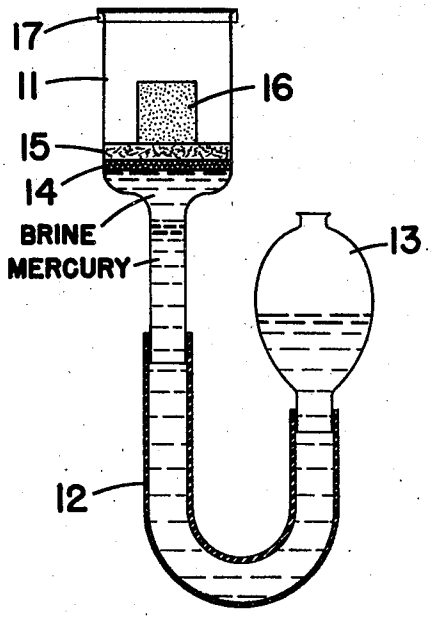


FIG. 1.

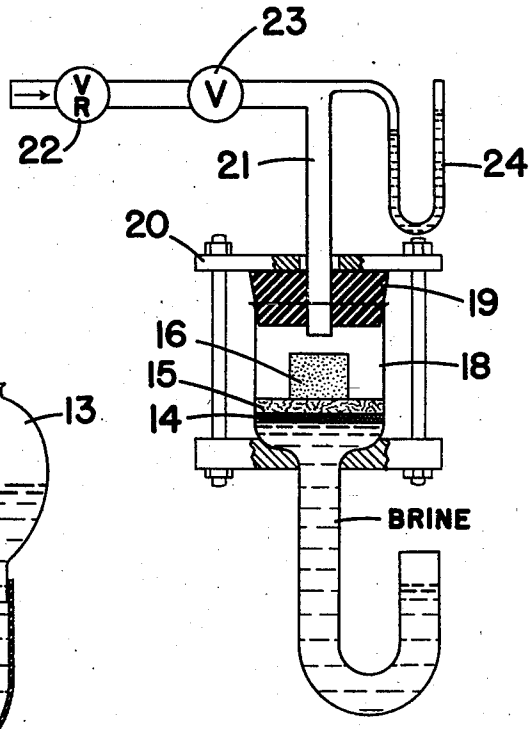


FIG. 2.

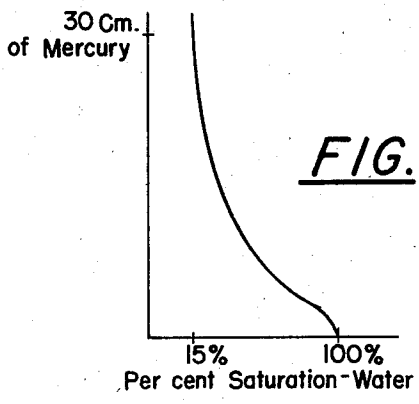


FIG. 3.

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METHOD OF DETERMINING CONNATE WATER CONTENT OF CORES

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6 Claims. (Cl. 73—51)

The present invention is directed to a method of determining the connate water content of cores or samples of subsurface formations.

It is essential to determine the connate water content of producing formations in order to determine the petroleum reserves therein. By "connate water" is meant that water which is found associated with the rock in a petroleum reservoir at the time of first tapping by the drill.

The present methods of determination of connate water content do not adequately take into account the fact that the cores frequently are flushed by water from the drilling fluid. Further, cores taken by any method may lose part of their liquid contents by evaporation prior to laboratory examination. Both these features of conventional core analysis methods are overcome by employing the method of the presvent invention.

Other objects and advantages of the present invention may be seen from a reading of the following description taken in conjunction with the drawing in which—

Figs. 1 and 2 are diagrammatic illustrations of apparatus suitable for use when carrying out the determination of connate water in accordance with the present invention; and

Fig. 3 is a curve indicating the relationship between the capillary pressure and per cent of saturation of a core from a typical producing formation.

It is postulated that in a petroleum containing reservoir superimposed over a water stratum, the connate water of the petroliferous parts of the reservoir is in equilibrium with the water in the underlying water stratum. It can be shown that, in order for this to be true, the connate water within the petroliferous parts of the reservoir must exist under a pressure which is less than that of the water in the water table; that is, the water immediately underlying the petroleum bearing sections. It now has been found that the amount of water retained by a core sample at equilibrium depends on this pressure deficiency or capillary pressure.

It is therefore proposed that any core sample which has not in some way been irreversibly altered since removal from the reservoir, can be returned to the water content which it bore in the reservoir by bringing it again into equilibrium with the water at a capillary pressure equivalent to that under which it existed in the reservoir. This capillary pressure can be evaluated from the fact that it is equal to the product:

$$G \cdot \Delta\rho \cdot H$$

where G is gravitational constant, delta rho is the difference in density between the water and the non-aqueous fluid in the reservoir, and H is the difference in elevation of the core in its original position in the reservoir and that of the water table.

One form of apparatus which has been found suitable for practicing the present invention is that shown in Fig. 1. It will be understood that this is merely a diagrammatic illustration, and that the actual apparatus employed in the laboratory will have conventional refinements. In the drawing, numeral 11 is a wide-mouthed thistle tube, to the lower end of which has been attached a flexible tube 12 and leveling bulb 13. Mercury is placed in the apparatus so that it will fill a portion of the leveling bulb, the amount of mercury employed being such that a difference in pressure of approximately 30 centimeters may be obtained in the enlarged portion of the thistle tube, as will be explained hereafter.

In the enlarged portion of the thistle tube there is a porous membrane of a fine granular solid, such as barium sulfate, saturated with a solution having approximately the same salinity as the water in the well from which the core was taken. This membrane is preferably formed by arranging a fritted glass plate 14 in the thistle tube, placing saline solution therein, and then depositing a layer 15 of the granular barium sulfate on the fritted glass plate.

To test a core, the level of the saline solution is pulled to the level of the top of the porous membrane 15 by lowering the leveling bulb, care being taken that the suction applied does not exceed the amount which the porous membrane 15 is capable of sustaining. The sample 16 is then placed in the thistle tube with its lower surface resting on the upper surface of the membrane 15. Either before or after the sample has been placed, the leveling bulb 13 is positioned so that the difference in pressure above and below the porous membrane is equivalent to the capillary pressure under which the core existed in the reservoir. Preferably, the water used should have the same surface tension as the interfacial tension of the water and petroleum in the reservoir, but this I have found to be not absolutely essential in many cases. When the leveling bulb has been so arranged, a loose cover 17 is placed on top of the thistle tube to prevent the undue loss of water by evaporation, and the apparatus is allowed to stand in this position for a suitable period, such as several days, in order to allow the moisture content of the sample to come to equilibrium with the saline solution. The sample is then removed from the apparatus, weighed, dried, and reweighed. The loss in weight is the water content of the core. The volume occupied by this water within the core can be computed from the known salinity of the water.

Another apparatus suitable for practicing the present invention is that illustrated in Fig. 2. In this embodiment numeral 18 indicates a thistle tube having a U-shaped stem. Within this thistle tube is arranged a fritted glass plate 14 and porous membrane of fine granular solid 15

corresponding with like elements described in Fig. 1. In setting up the apparatus, a saline solution is placed in thistle tube 18 and the membrane 15 is laid down in this solution. Excess pressure is then employed to force the solution down to the upper surface of membrane 15. A suitable means of applying the excess pressure is by the use of a stopper 19, clamp 20 and tube 21 connected to a reducing valve 22, through which compressed air is supplied. The amount of pressure used may be determined from mercury filled U-tube 24. The excess pressure is then relieved, as by closing a valve 23 and removing the stopper 19, and sample 16 is placed in position on bed 15. The stopper 19 is again put in position and the pressure above membrane 15 adjusted to the desired value by using regulation valve 22. The sample is allowed to remain in this apparatus until the moisture content of the sample has reached an equilibrium and the sample is then removed and treated as described in connection with Fig. 1.

As stated above, it is preferable to adjust the difference in pressure to correspond with the difference in pressure between the sample in position in the earth and the height of the water table. It has been found, however, that when this difference is equivalent to or exceeds approximately 30 centimeters of mercury, the employment of a pressure differential of 30 centimeters of mercury in analyzing the sample gives substantially the same results as the pressure difference actually present in the undisturbed reservoir. This is illustrated by Fig. 3. Fig. 3 is a curve showing the manner in which the percentage of water saturation of the pore space in a typical core sample from a petroleum producing formation varies with the pressure differential used in the analytical procedure. As previously stated, it is observed from this curve that when the applied pressure differential exceeds approximately 30 centimeters of mercury, application of additional pressure differential causes a negligible change in the water saturation. Since, in many cases, cores are taken from positions in the reservoir for which the equivalent pressure differential is more than 30 cm. mercury, these cores can be run by the present technique without precise knowledge of the elevation of the water table in the reservoir. This fact increases the utility of the present method.

From the facts set forth in the foregoing paragraph, coupled with conventional thermodynamic reasoning, it can be shown that for cores taken from well above the water table it is also unnecessary that the surface tension of the water equal the interfacial tension of the water and petroleum in the reservoir. This fact further increases the utility of the method. The phrase "well above the water table" usually implies a distance of more than 15 to 40 feet vertically. The exact distance is variable and depends on the texture of the reservoir rock.

From the foregoing description, it can be seen that the present invention comprises essentially bringing the core sample into communication with water having a surface tension approximately equal to the interfacial tension of the water and petroleum in the reservoir, which water in the test exists under a pressure less than that of the surroundings of the core in the test by an amount which is computable from the position of the core within the reservoir and the density of the reservoir fluids. The water content, after the core has been allowed to come to equilibrium in this situation, is substantially equal in amount to the connate water content in the reservoir.

Having fully described and illustrated methods of practicing the present invention, what I desire to claim is:

1. A method of determining connate water content of a sample taken from an underground petroleum reservoir, comprising the steps of physically contacting the sample with water, inducing a difference in pressure between the sample and the water comparable to the pressure difference between the water table and the connate water in the sample in its original terrestrial position, allowing the moisture content of the sample to come to equilibrium, and removing and determining the water content of the sample.

2. A method of determining connate water content of a sample taken from an underground petroleum reservoir comprising the steps of saturating a membrane with water and retaining it thereafter in at least capillary contact with a body of water, placing the sample in physical contact with said membrane, exerting a differential pressure between said sample and said body of water through said membrane comparable to the pressure differential between the connate water of the sample and the water table in the undisturbed reservoir, and maintaining this pressure differential until the moisture content of the sample becomes substantially constant, and subsequently determining this moisture content.

3. A method in accordance with claim 2 in which the pressure differential between the connate water and the water table in the undisturbed reservoir is determined as less than 30 cm. of mercury, and the pressure differential between the sample and the body of water is maintained at substantially this determined value.

4. A method in accordance with claim 2 in which the pressure differential between the connate water and the water table in the undisturbed reservoir is greater than 30 cm. of mercury, and the pressure differential between the sample and the body of water is maintained at 30 cm. of mercury.

5. A method of determining connate water content of a sample taken from an underground petroleum reservoir comprising the steps of saturating a membrane with a saline solution of the same salinity of the water of the well from which the sample was taken, maintaining capillary contact between a body of the saline solution and said membrane, placing said sample in contact with the membrane on the opposite side of said membrane from the body of solution, adjusting the pressure across the membrane to a constant value so that when equilibrium is established between the sample and the saline solution the moisture content of the sample will correspond to that of the sample when the sample was in the undisturbed reservoir, and determining said moisture content.

6. The method in accordance with claim 2 in which the surface tension of the water comprising said body is substantially equal to the interfacial tension between the water and petroleum within the reservoir.

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