March 29, 1949. H. J. WELGE 2,465,948

CORE POROSITY ANALYSIS AND APPARATUS THEREFOR

Filed Aug. 20, 1946 4 Sheets-Sheet 1

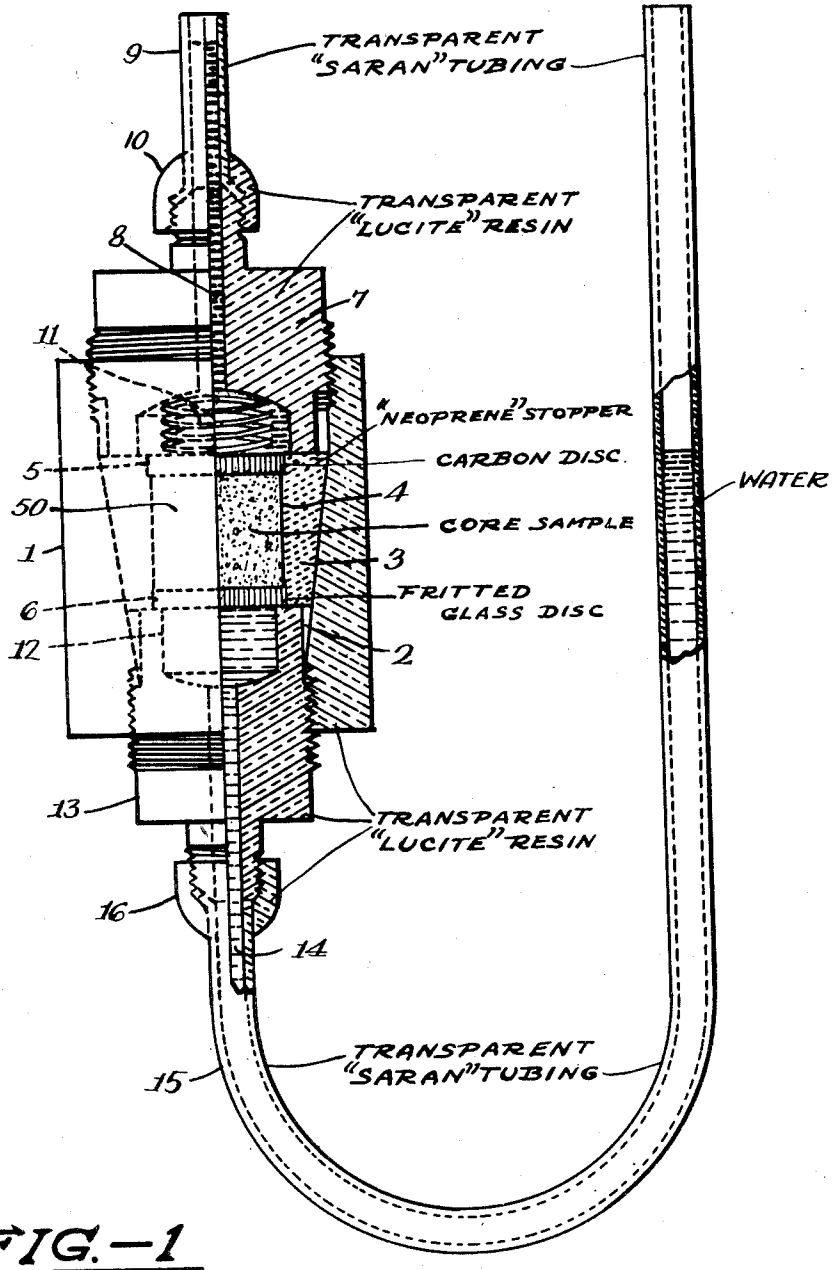


FIG.—1

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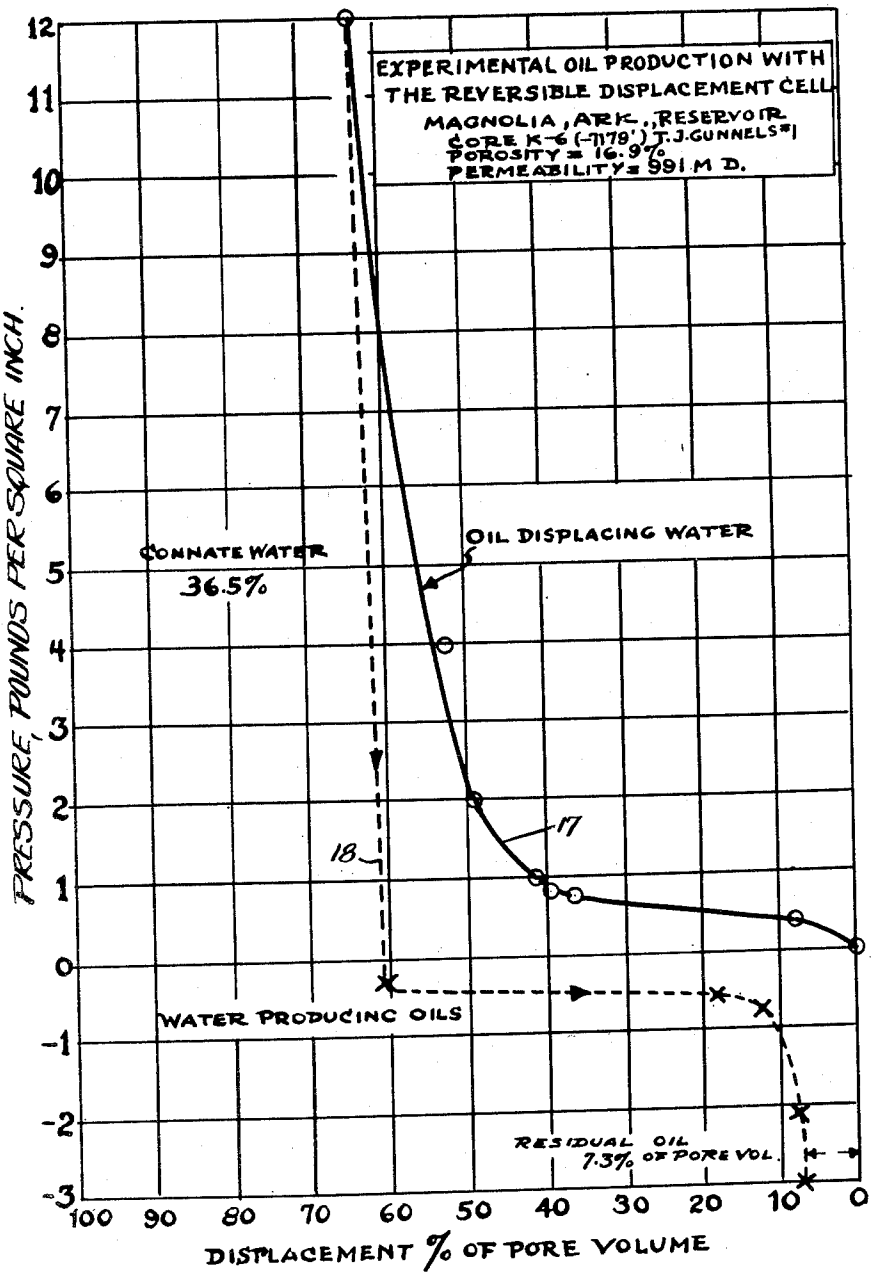


FIG.-2

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CORE POROSITY ANALYSIS AND APPARATUS THEREFOR

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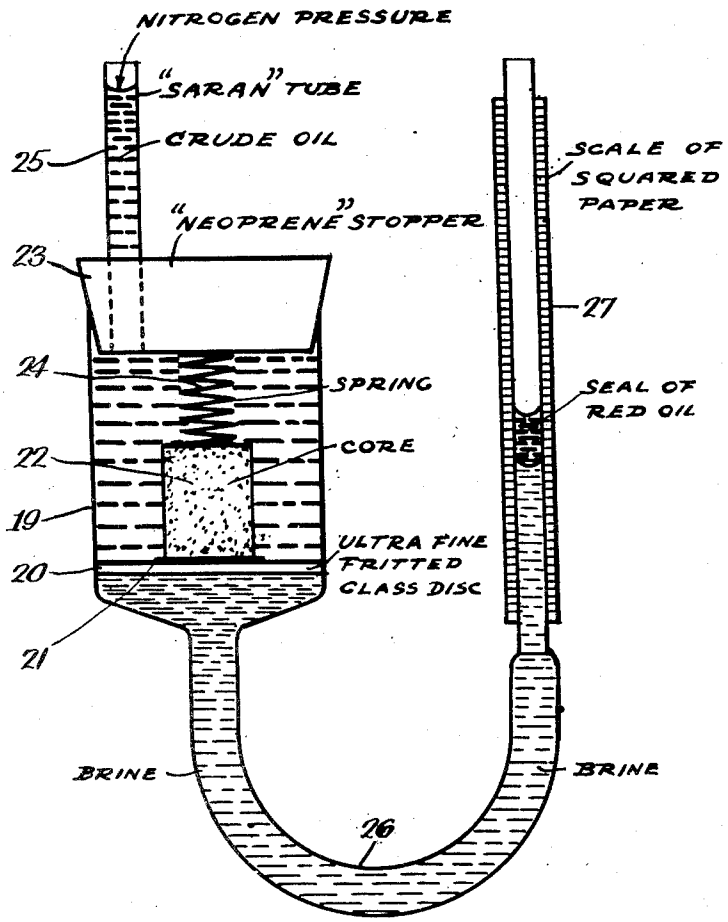


FIG.-3

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CORE POROSITY ANALYSIS AND APPARATUS THEREFOR

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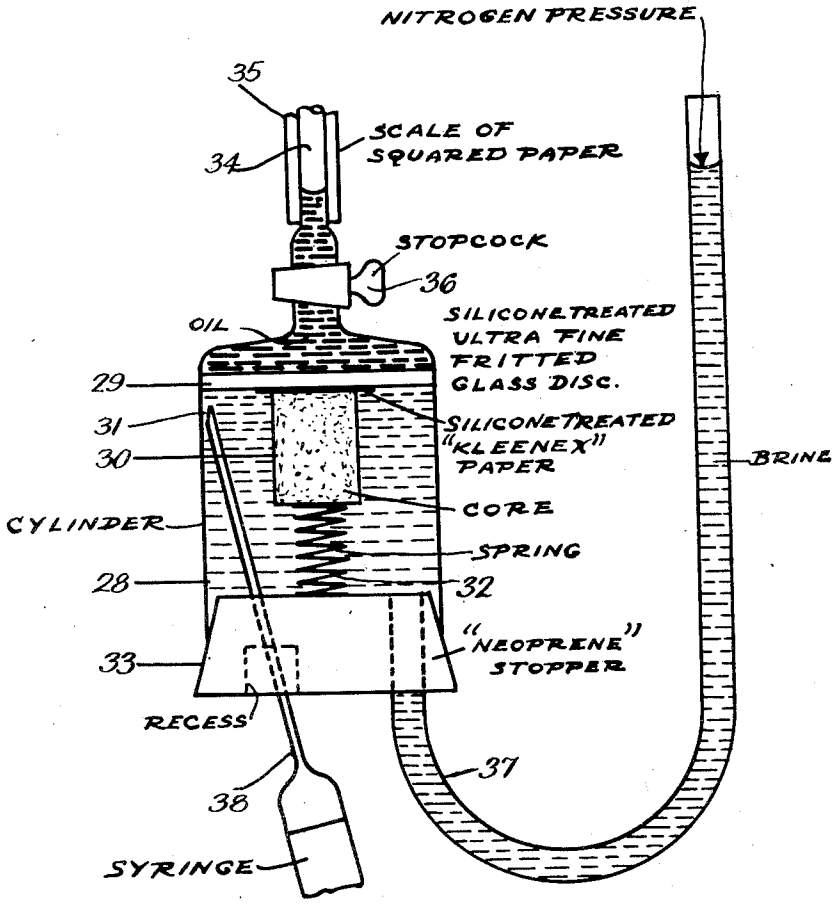


FIG.-4

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UNITED STATES PATENT OFFICE

2,465,948

CORE POROSITY ANALYSIS AND APPARATUS THEREFOR

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Application August 20, 1946, Serial No. 691,840

4 Claims. (Cl. 73—38)

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The present invention is directed to a method and apparatus for studying cores obtained from a subterranean formation.

The principal object of the present invention is the provision of a method and apparatus for the study of porous rock-like materials obtained as cores from subterranean formations or from any other source to ascertain certain of their properties, such as their retentivity for different fluids and productivity of different fluids and the like. In a typical case, a method and apparatus are employed for the study of cores of rock-like materials secured from oil bearing formations to determine, among other things, the productivity of the formation under water drive, the per cent of contained oil retained by the formation as residual oil after production by water drive at a given pressure, and the per cent of water retainable by the formation as connate water when the water was subjected to the displacing action of accumulating oil in a petroleum reservoir.

An additional object of the present invention is the provision of a method and apparatus of the type described characterized by simplicity and ease of construction and operation. An additional object is the provision of an apparatus of the character described which is easily portable so that it can be used at the well site, if desired.

Further objects and advantages of the present invention will appear from the following detailed description of the accompanying drawing in which,

Fig. 1 is a plan view, partly in section, of one type of apparatus according to the present invention;

Fig. 2 is a pair of curves which represent results obtainable by the practice of the method of the present invention;

Fig. 3 is a vertical section of another form of apparatus according to the present invention; and

Fig. 4 is a vertical section of still another modification of the apparatus of the present invention.

Referring to the drawing in detail, numeral 1 designates a block, preferably of transparent material, such as "Lucite" or similar transparent resin, having an interior recess 2 which is generally frustro-conical in configuration. Seated in the recess is a stopper 3 of "Neoprene" or other oil-resistant material having a central cylindrical passage 4. Arranged in the passage 4 is a cylinder 50 of the porous rock-like material to be examined, held in place at its upper end by a disc 5 of carbon or other preferentially oil-wettable material and at its lower end by a disc 6 of fritted

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glass or other preferentially water-wettable material.

The stopper 3 is held on its seat by a threaded plug 7 of "Lucite" or similar transparent resin which is screwed into the upper end of the recess 2. This plug has a central passage 8 which is connected to transparent tubing 9 by a coupling member 10 which may also be a transparent resinous material. Between the inner end of the plug and the disc 5 is a spring 11 which serves to hold the parts firmly in place.

The lower end of the stopper and the disc 6 rest on an annular seat provided by a sleeve 12 which constitutes an extension of lower plug 13, which is likewise of transparent resinous material and is screwed into the lower part of the recess 2. Lower plug 13 has a central passage 14 which is connected to a U-shaped tube 15 by a suitable coupling 16, both of which are likewise preferably made of transparent material. It is desirable that both tubes 9 and 15 be calibrated for volume, so that changes of liquid level in them may be translated into the volume of liquid displaced.

In using the device for determination of connate water, the rock-like material 50 and the disc 6 are first soaked with water as by being boiled in water so as to insure the complete filling of their pores with water. The disc 5 may in similar manner be saturated with oil. The rock sample 50 is then arranged in place in the manner shown. With the U-tube and the space beneath the disc 6 completely filled with water, then oil, such as crude oil, is forced through tube 9. The oil will pass through the disc 5 but will not pass through the disc 6. As pressure is applied to the oil, water leaves the sample 50 and enters the space below the disc 6, causing the water to rise in the leg of the U-tube. In this way the maximum replacement of water by oil at any given pressure may be readily noted by observing the rise of water level in the open leg of the U-tube at the selected oil pressure. The pore space of the sample having previously been determined by other conventional methods, the quantity of water contained therein when saturated can be ascertained. Therefore, by difference, the quantity of water remaining in the core sample under oil drive at a given pressure may be calculated.

It is in general found that all the water cannot be replaced by the above means. By the term "connate water" is denoted the water that is not replaceable from the core by pressure alone. It is thought that the connate water is "trapped" in "blind" or alternate capillaries, and its replacement by oil thus prevented. However, it is not

desired to make the claims for the present invention contingent on the correctness of this explanation for the phenomenon.

In the operation of this device, care should be taken to select a disc 6 which will not pass oil under the operating pressure. The minimum pressure that must be applied to cause the oil to pass through the capillaries in the water-wetted disc is called the entry pressure, P, of the disc medium. It is generally related to the effective pore radius, r, of the medium by the relation,

$$Pr=2c$$

where c represents the interfacial tension between the water and the oil. P and r are therefore inversely proportional to each other; the smaller the capillaries, the higher the pressure required for the oil to enter or pass through them. Construction of the apparatus of transparent plastic resin readily permits observing when this occurs.

In the following table are given typical values calculated with the aid of the above equation, when $c=15$ dynes per centimeter, a representative value for a crude oil-water interface:

r, microns	P, pounds per square inch
5	.87
2	2.15
1	4.3
0.5	8.7

The result of a typical experiment is shown in Fig. 2. The full curve 17 represents the replacement of water by oil; it is particularly to be noted that, after the initial large replacement without much change in pressure, a great increase in pressure causes only slight additional replacement. At the maximum pressure reached, about 12 lbs./sq. in., the fluid content of the core is considered comparable with its fluid content in the underground petroleum reservoir before the reservoir was trapped by drilling.

Up to this point the use of the apparatus described in the present invention bears some similarity to the method of operation described in United States Patent No. 2,330,721, entitled, "Method of determining connate water content of cores." One point of difference, however, is that the present invention proposes crude oil as the displacing phase instead of compressed air. The displacement by crude oil simulates underground conditions more precisely. The use of oil is also necessary by the processes disclosed hereinafter, which are altogether outside the scope of United States Patent No. 2,330,721, and which constitute further points of difference between it and the present invention.

After any desired quantity of water has been expelled from the core, the direction of fluid flow may be reversed by removing the pressure from the oil and applying pressure to the water phase. The dashed curve 18 shown in Fig. 2 represents typical behavior when this is done, in a manner analogous to the production of crude oil by rise of the underlying water table. The displacement of oil by water may again be followed readily by observation of the change in level of the oil or of the water, since the water, in turn, cannot penetrate the upper oil-wetted carbon disc.

In practice it is usually found that fluid replacement is aided by insertion of a somewhat compressible contacting medium between either retaining disc and the core. For the lower, or water-wetted disc, sheets of soft tissue paper

moistened with water may be inserted, or a layer of a paste of clay or of barium sulfate in water. For the upper carbon disc, sheets of paper have been treated with water-repellent materials, such as silicones. They are inserted after moistening with oil. Alternatively, a layer of carbon black, moistened with oil, may be used as the contacting medium between the disc and the core.

A gas also may be used to displace either water or oil from porous media, using suitable arrangements of discs and contacting media obvious to one skilled in the art. It is, in general, found advantageous to so arrange the apparatus that the denser fluid, i. e., the water or the oil, occupies the lower part of the apparatus, the gas occupying the upper part.

In carrying out this portion of the present invention, it is desirable to use a gas possessing only limited solubility in the oil or aqueous phases, such as nitrogen or argon. Otherwise the volume of the liquid phases displaced may be increased by the dissolved gas, and hence volumetric readings of displacement may be in error.

The processes described above may be used to ascertain the fraction of crude oil in an underground deposit that may be recovered through displacement by either an aqueous phase or by a selected gas. Knowledge of this fraction is of great practical importance in petroleum production technology, inasmuch as it complements knowledge of the total amount of oil lying in a deposit, as obtained from information on the total void space and the proportion of the latter occupied by the connate water.

In Fig. 3 is shown a somewhat simplified form of apparatus which is not of the reversible type as illustrated in Fig. 1. In this figure, numeral 19 designates a transparent glass cylinder having fused in its bottom a fritted glass disc 20 on which rests a sheet 21 of compressible filter medium upon which is placed a sample core 22 of the rock-like material to be studied. The upper part of the cylinder is provided with a "Neoprene" stopper 23 between which and the sample is a spring 24 for holding the sample firmly upon its bed. The stopper 23 is provided with an inlet tube 25 for the introduction of the driving medium.

The cylinder 19 constitutes the upper part of one leg of a U-tube 26, the open leg of which is arranged in front of a scale 27 such as a paper scale marked off in squares, in order that the change in liquid level may be ascertained, and hence the volume of liquid displaced.

In using this arrangement for the determination of replaceable water and connate water, the compressible medium 21 is a soft absorbent tissue such as "Kleenex" paper. The sample is prepared as in the case of Fig. 1, and with the parts in the position shown, oil is forced in through tube 25 under nitrogen pressure. The amount of water displaced is determined by reading the level in the open leg of the U-tube. As indicated in the drawing brine may be used in place of water in this study. A seal of red oil or similar petroleum oil may be used in the U-tube to minimize volumetric changes caused by vaporization of the water from the U-tube.

If it is desired to use this apparatus to determine replaceable oil under gas drive, the disc 20 and the medium 21 are preferably both treated to render them preferentially wetted by oil as by being coated with a silicone or a material such as lead oleate. In this case the core may be a natural oil-containing core or a core which has been artificially saturated with oil to the

point of saturation existing in the formation being investigated. The U-tube in this case is filled with oil and, with the parts in the position shown, nitrogen is forced in through the tube 25 to any desired pressure and the increase in level of the oil in the open leg of the U-tube is observed.

In Fig. 4 is illustrated a particular modification of apparatus used for determining the oil produceable under water drive. In this case the cylinder designated by numeral 28 is inverted with the fritted glass disc 29, suitably coated with a silicone or other substance to render it preferentially oil-wettable, arranged near the upper end. The sample 30 to be studied is held against the compressible filter medium 31 arranged on the lower surface of the disc by a spring 32 which is held under compression by a "Neoprene" stopper 33 sealing the lower end of the cylinder.

The upper end of the cylinder terminates in an upright tube 34 arranged in front of a scale 35 and provided with a stop cock 36. The scale 35 may suitably be a scale made of paper ruled off in squares. The stopper 33 is provided with a passage to accommodate a tube 37 through which water is forced to provide the water drive. The stopper is also provided with a depression to facilitate the introduction of a syringe 38 or similar suction device so disposed that its suction end is adjacent the juncture of the lower face of the disc and the cylinder. The purpose of this syringe is to suck out of the system any gas which may be trapped therein when water is introduced into the system so as to insure that the system below the disc is completely full of water.

In the use of this device the sample is arranged as shown, having been saturated with oil as described above and illustrated in Fig. 3, a space above the disc up to a point in the measuring tube is filled with oil, and the system below the disc is filled with water, the syringe being employed during the filling with water to insure elimination of air. Then pressure is applied to the water tube and the increase in level of the oil in tube 34 is measured. By adjusting the pressure in the water tube the amount of oil recoverable at any given pressure may be ascertained. As indicated in Figure 4, brine may be used in the system in place of water.

In all cases above, it may be found advantageous to check the amount of any given liquid displaced by physical or chemical analysis of the rock-like sample at the end of a displacement. Analysis for the water or the oil is, in general, carried out by methods familiar to one skilled in the art of chemical practice.

The nature and objects of the present invention having thus been set forth and a specific illustrative embodiment of the same given, what is claimed and desired to be secured by Letters Patent is:

1. A method for determining the retentivity of a porous rock-like material for a fluid which comprises confining a sample of said material saturated with said fluid in a closed space with said sample resting on one side of a porous disc capable of preferentially passing said fluid, maintaining a column of said fluid in contact with the other side of said disc and feeding to said confined space a second fluid immiscible with said first fluid and not passable by said disc until a predetermined pressure is built up in said confined space and measuring the amount of said first named fluid displaced from said sample.

2. A method for determining the retentivity of a porous rock-like material for water and its productivity of oil under water drive, which comprises confining a sample of said material saturated with water in a closed space between and in contact with a pair of porous discs, one of said discs being capable of preferentially passing oil and the other said disc being capable of preferentially passing water, maintaining a column of water in contact with said latter disc on the side thereof opposite the sample and maintaining a column of oil in contact with said former disc on the side thereof opposite the sample, applying pressure to said oil column to a predetermined value, observing the increase in level in said water column as a measure of the amount of water displaced from said sample, thereafter applying a pressure to said water column, and observing the increase in level of said oil column as a measure of the oil displaced from said sample.

3. An apparatus for the study of cores comprising a transparent block, having a central passage, a pair of porous discs maintained in said passage, in position to receive a core sample between their inner faces, one of said discs being preferentially permeable to water and the other said disc being preferentially permeable to oil, a stopper for each end of said passage, a tube adapted to hold water communicating through one of said stoppers with the outer face of said disc which is preferentially permeable to water and a tube adapted to hold oil communicating through the other of said stoppers with the outer face of said disc which is adapted preferentially to pass oil.

4. An apparatus for determining the productivity of an oil-containing formation under water drive, which comprises a chamber, a porous disc forming a partition in said chamber, said porous disc being preferentially permeable to oil, means for pressing a sample of the formation containing the oil in place against one side of said disc, means for applying a pressure head of water to that portion of said chamber on the sample side of the disc and means for maintaining a column of oil in fluid communication with the other side of said disc.

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REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
2,327,642	Horner	Aug. 24, 1943
2,330,721	Leverett	Sept. 28, 1943