March 28, 1944. W. L. HORNER 2,345,535

METHOD OF DETERMINING POROSITY

Original Filed Jan. 3, 1938

Fig. 2.

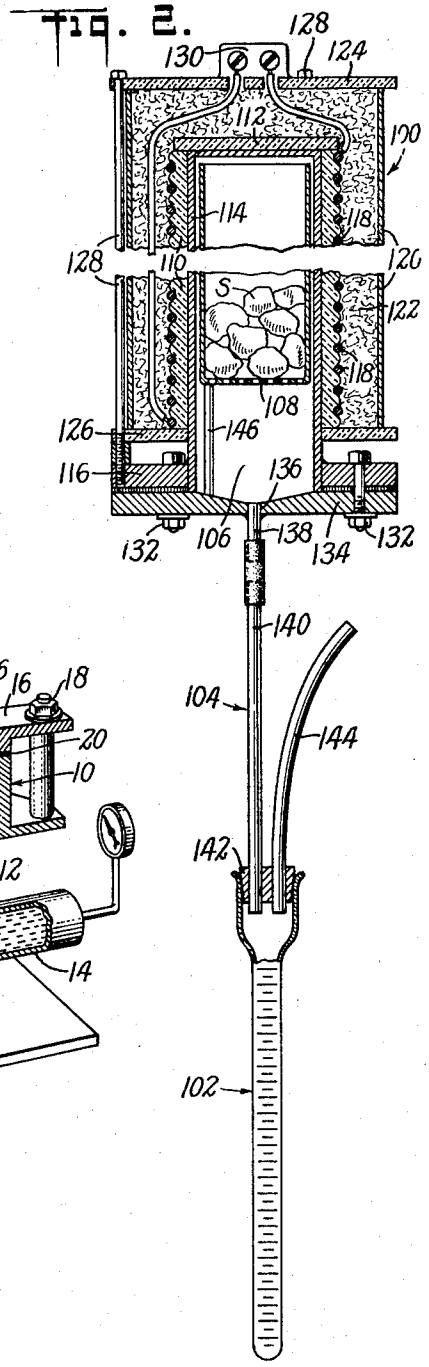
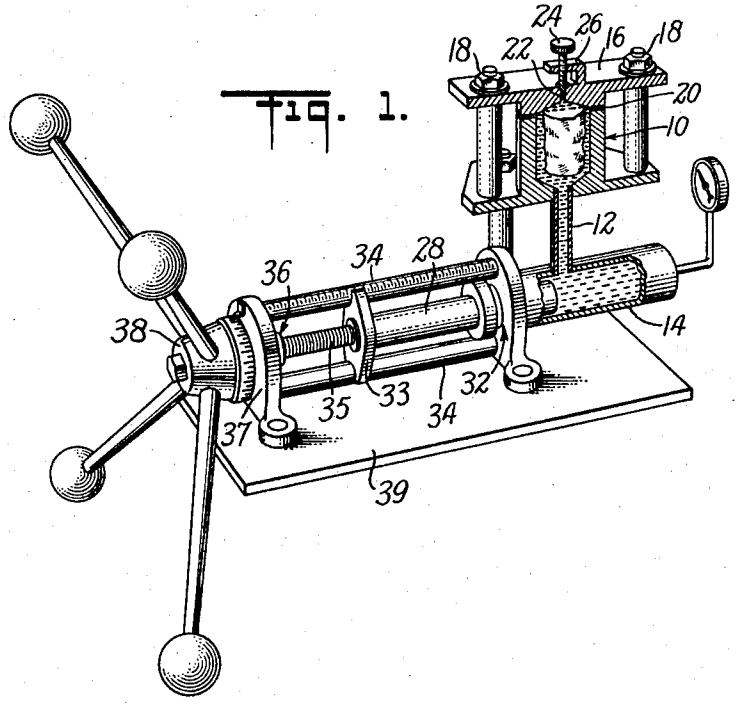


Fig. 1.



INVENTOR

William L. Horner

BY

Blair, Curtis + Hayward

ATTORNEYS

Patented Mar. 28, 1944 2,345,535

UNITED STATES PATENT OFFICE

2,345,535

METHOD OF DETERMINING POROSITY

William L. Horner, Houston, Tex., assignor to Core Laboratories, Inc., Dallas, Tex., a corporation of Delaware

Original application January 3, 1938, Serial No. 183,018. Divided and this application July 6, 1942, Serial No. 449,969

4 Claims. (Cl. 73—51)

This invention relates to the art of determining the porosity of solid, non-compressible, permeable bodies, and more particularly to the determination of the porosity of rock samples taken during the drilling of oil wells.

Such rock samples are commonly referred to as cores, and the rock strata from which the cores are removed are called "sands." Such sands, and hence their cores, may contain liquids such as water and hydrocarbons, and possibly gas. By the time the core samples are received at the surface of the well, part of the liquid has usually been pushed out of the pores and replaced by gases which, in this specification, will be referred to as free gas. A single core section may be as long as four or five feet and have a diameter of from one and a half to three inches.

For many years such cores have been analyzed for different properties, and in recent years the importance of such analyses has gained increasing recognition. One of the properties that is becoming increasingly important to determine is that known as the porosity of the sand, that is, the amount of pore space of the sand (the space which may be filled with water, extractable liquid, hydrocarbons, or gas, as distinguished from the mineral matter comprising the body of the sand).

It is an object of the present invention to provide an improved method for determining this porosity value, which method is more rapidly carried out and more accurate in its results than those methods previously used. The rapidity with which the porosity determination is made becomes important when the cores are analyzed as they are taken from the well, and the results of the analyses are used to tell at what sand stratum the well is to be completed, that is, the sand horizon from which the well is to produce to the exclusion of other sand horizons through which the well passes. Under such circumstances, long delays, occurring as a result of time taken to make the analyses of the cores, become expensive and unless rapid analysis is possible the results of core analysis cannot be used in deciding upon the best horizon at which to complete the well.

The matter of accuracy is important because, on the basis of the porosity determination, estimates are made as to the amount of hydrocarbons that a sand of given area and depth contains, and since the area may be a matter of square miles and the depth a matter of feet, a small error in the porosity determination may make very considerable error in the total estimate obtained using the porosity determination.

This application is a division of my copending application Serial No. 183,018, filed January 3, 1938.

A core, as it is received at the top of the well, usually contains in its pores a mixture of fluids consisting primarily of free gas, hydrocarbons usually in liquid form, and water. In the present embodiment, the total volume of these fluids is measured in order to obtain the amount of the pore space and the pore space is then figured in terms of, for example, cubic centimeters of pore space per unit volume of core sample. The amount of pore space occupied by free gas is first determined on one part of a divided core sample taken from a section of a core length. On the other part of the same core sample the amount of extractable water and hydrocarbons present is determined. It is assumed that the pore space is filled with gas, water and fluid, or extractable hydrocarbons. The results of these determinations are then added to obtain the total volume of extractable fluids present in the core sample. From this volume is obtained the porosity of the section of the core from which the sample was taken.

Referring to the drawings,

In Figure 1 apparatus is shown for making rapid determinations of (1) the volume of a core sample, which measurement is utilized in determining the density of the sample, and (2) for determining the free gas content of a core sample.

The apparatus shown in Figure 2 is a distillation apparatus for distilling off and collecting the liquid content of the core sample.

The novel subject matter of the apparatus shown in Figure 1 is described and claimed in my copending application Serial Number 351,891, filed August 8, 1940, which is a division of my copending application Serial Number 183,018, filed Jan. 3, 1938, Patent No. 2,296,852. The apparatus shown in Figure 2 is described and claimed in my Patent No. 2,282,654, which issued from application Serial Number 351,892, filed August 8, 1940, which is a division of my said copending application Serial Number 183,018. Therefore, this application is a division of my said copending application Serial Number 183,018, Patent No. 2,296,852.

In practicing the known methods of and in the apparatus for determining the porosity of such core samples it is necessary first to extract from the core sample all extractable material. This is accomplished by means of flowing a sol-

vent through the core sample and in instances where the permeability of the core sample is relatively low, that is, wherein it has a relatively high resistance to passage of the liquid through the sand, this extracting step may involve a considerable period of time, even as much as twenty hours or so, for a single small sample. Further, these known methods require the use of samples of small sizes, that is, from 5 to 20 cubic centimeters, so the possibility of error in a determination is increased. Moreover, because the determinations are made on such small samples of the core taken from a well, it frequently turns out that the small samples selected are not representative of the core itself and that the porosity determinations are inaccurate to the extent that the total liquid content as measured on one portion of a core rock exceeds the total porosity as determined on a small core sample taken from an adjacent section of the core.

The practice of the present invention not only eliminates the extracting step but permits the use of large samples for the determination. Thus the determination of the porosity in accordance with the present invention not only materially reduces the time required for the determination but also gives far more accurate results.

As pointed out, practicing the present invention to determine the porosity of a core taken from a well includes first separating into two parts a sample of the core, one weighing, for example, approximately 40 grams, and the other weighing approximately 180 grams. The first part, which may be called part A, is used for determining the amount of free gas present in the pores of the sample comprising part A; and the second, or part B, of the sample is used for determing the amount of extractable liquid present in the pores of part B. By the term extractable is meant those liquids present in and removable from the pores.

The apparatus shown in Figure 1 may be used on the part A of the sample to determine its free gas content. This apparatus is also used to determine the density of the core sample so that the volume of the part B sample can be calculated from its weight. In this apparatus the core sample is first immersed in a liquid which does not enter the pores of the sample immersed in it. As will be described, the amount of liquid displaced by the immersed sample may be measured and the volume of the sample calculated from such measurement. Then the liquid in which the sample is immersed is subjected to a high pressure to force the liquid into the pores of the core sample to compress and substantially occupy the space previously filled by free gas. The amount of the liquid that thus enters the pores of the core sample is measured and this measurement becomes the total amount of pore space of the core sample occupied by free gas. Now, by dividing the amount of space thus occupied by free gas by the total volume of the sample, the amount of pore space occupied by free gas per unit volume of core sample is obtained.

In using this method of analyzing the free gas content of a porous body it is desirable to use a liquid which does not chemically react with the materials comprising a sample and which has a surface tension such that the liquid does not penetrate the pores without being forced into them. One liquid that I have found which fulfills these requirements is mercury.

Other liquids, however, may be used which have a surface tension such as to wet the sample being analyzed and when using such liquids the sample may first be coated with collodion which may serve to prevent the sample from being wet by the liquid but which does not prevent subsequent penetration of the liquid through the coating.

The apparatus comprises a sampling chamber generally indicated at 10 and this chamber is connected through an inlet 12 with a plunger chamber indicated at 14 of a mercury pump. The chamber 10 is closed at its top by a suitable cover plate 16 which may be bolted in place by bolts 18 after the sample is placed in the chamber. The joint between cover and chamber is made fluid-tight by a suitable gasket 20. The inside of the cover is conically shaped, as shown, and provided with a small vent 22 at the apex of the cone. The small outlet may be closed off by a needle valve 24 which is suitably threaded down through a support 26 to set in the opening 22. As shown in the drawings, the sample chamber is so constructed that it has a suitable air vent at its top and an inlet at its bottom, and is so shaped that as the non-compressible mercury is flowed into the chamber through the bottom all the gas is driven out of the chamber ahead of the liquid as the liquid reaches the vent. Furthermore, the core sample used is preferably suitably shaped and trimmed to eliminate pits and cavities on its surface that might retain air bubbles.

With this construction the sample may be placed in the chamber while the chamber is empty by simply removing the cover 16 and then bolting the cover back on. It is possible to tell when the chamber is full of mercury with no occluded air by filling the chamber with mercury until the mercury appears in the small vent 22.

The inlet 12 of the chamber 10 communicates with the plunger chamber in which a plunger 28 is reciprocally mounted and passes out of the chamber through suitable bearing and stuffing box generally indicated at 32. The outer end of the plunger carries a slider 33 sliding along suitable guide rods 34. Further, the plunger is hollow and threaded to receive a plunger-operating screw 35, one end of which is suitably rotatably mounted in thrust bearings, generally indicated at 36, mounted in a journal 37 secured with respect to the plunger chamber 14 by means of a heavy base 39 and the guide rods. Keyed to the operating screw 35 is a hand-wheel 38 used for operating the screw.

The top guide rod 34 is suitably marked off in units of measurement such, for example, as cubic centimeters, and the hub of the hand-wheel is also suitably marked in cubic centimeters, but in thousandths of cubic centimeters, and in accordance with the pitch of the threads on the operating screw so that the position of the plunger may be read in terms of cubic centimeters and hundredths of cubic centimeters from the scale on the guide rod and in thousandths of cubic centimeters from the scale on the hub 38.

The end of the plunger chamber opposite the end through which the plunger enters is connected to a suitable pressure gauge, as shown.

The instrument is thus calibrated so that the amount of mercury, measured in cubic centimeters, put into or taken out of the chamber may be read from the indices associated with the plunger 28 and its operating mechanism.

In making a determination of a sample the cover is first bolted on, with no sample in the

chamber, and the needle valve 24 is left open while the plunger is moved inwardly by the hand-wheel until mercury appears at the outlet 22. The position of the plunger at this moment is noted from the scale. The plunger is then retracted to lower the mercury level in the chamber, the lid is taken off and the part A of the sample, suitably prepared and accurately weighed, is put into the chamber and the lid bolted back on. With the needle valve still open the plunger is again moved inwardly by the hand-wheel until the mercury again appears at the outlet 22, at which time the position of the plunger is again noted. From the difference of the two readings the volume of the sample is obtained. The needle valve is now closed so that no mercury can escape and the hand-wheel is operated to move the plunger inwardly to maintain a pressure on the gauge equivalent to 50 atmospheres, the hand-wheel being moved as fast and for such length of time as is required to maintain this pressure. After it is no longer necessary to move the hand-wheel to keep the pressure at 50 atmospheres, the readings on the two scales are again noted and the difference between this reading and the last succeeding reading gives correctly the volume of mercury necessary to compress the gas in the sample and to fill the pore space occupied by the gas. This latter reading, as above pointed out, is increased by two percent in order to take care of the volume of space occupied by the gas now under 50 atmospheres of pressure. By dividing the gas space volume thus obtained by the volume of the sample the cubic centimeters of pore space occupied by free gas per unit volume is obtained.

Further, by dividing the weight of this part A by its total volume the density of the sample is obtained.

The second part of the determination to determine the pore space occupied by liquid may be conveniently carried out in a still such as shown in Figure 2, in which still the weighed part B of the sample is heated to cause the liquid contents therein to distill off, which contents are condensed and collected in a measuring tube. By dividing the weight of this part B by the previously determined density the total volume of the part B is obtained, and then by dividing the volume of the liquid condensed from the part B by the total volume of the sample the amount of liquid present in the pores per unit volume of the sample is obtained.

The still shown is adapted to distill oil and water from core samples S and to collect the products of distillation in a graduated tube generally indicated at 102 supported below the still by a connecting tube generally indicated at 104.

The still comprises an insulated heater having an inner chamber 106 adapted to receive a sample container 108. Around chamber 106 is a ceramic shell, such as porcelain, and indicated at 110. The shell is spirally grooved on its outside, as shown, and is open at its bottom and is closed at its top with a porcelain top 112. Closely fitted inside the porcelain shell is located a polished steel shell 114 having sides and a top and supported at its open bottom by a flange ring 116. Wound around the outside of the grooved porcelain shell is a resistance heating wire 118 and packed around this wire and held in by a suitable metal cover 120 is suitable packing 122, such as magnesium silicate. The top and bottom walls holding the magnesium silicate packing are respectively an asbestos disc 124 and an annular ring 126, held together by three tie rods 128. The ends of the resistance wire come out through the top 124 and are secured to suitable insulated terminals 130 from which extends a cord adapted to connect the resistance wire with a supply of electricity. As shown in the drawings, the heating mechanism does not extend to the lower part of the steel shell 114 and consequently the lower portion of the shell and the bottom 134 are not heated to the temperatures to which the upper parts of the apparatus are heated.

The annular supporting flange 116 is provided with downwardly extending bolts 132 for clamping a base plate 134 to the supporting flange. The inside of the base plate is conically dished at its center, as shown, and at the apex of the conical formation is provided an outlet 136 into which is brazed a short bronze tube 138. The outlet tube is connected by suitable rubber connections to a relatively long copper tube 140 serving as a condenser and terminating in a rubber stopper 142 in the top of the graduated glass tube 102. A suitable vent 144 also extends upwardly from the stopper.

The sample container 108 is preferably made of some corrosion-resisting material, such as Monel metal, or is plated with some corrosion-resisting plating. It is open at its top and has a perforated bottom. A spacing rod 146 extends downwardly from the container.

In operation the sample container is filled with pieces of core samples that have previously been weighed. While the base cover 134 is removed the container is inserted in the heating chamber 106 and is pushed to the top of the chamber by the spacing rod 146 as the base 134 is moved into its closing position. After the container and sample have been placed in the heating chamber 106 and the base plate 134 bolted in place, the heat is turned on and the sample is eventually heated to a dull red temperature which insures all oil, gas and water being driven off. The oil, which is driven off in the form of vapors, is always caused to move to cooler regions, and as it passes down through the tube 140 is sufficiently cooled so that it condenses and drips into the graduated tube 102.

The above method of distilling the water and oil from the sample has the advantage of being rapid and accurate. The heavy vapors of the distillate flow by gravity to the colder regions and the condensing tube. A further advantage of this method is that the heating of the sample is carried out uniformly so that the sample of water obtained is free from water or crystallization (which is not extractable) and the sample of oil obtained represents practically 98% recovery.

The distillation operation takes approximately forty-five minutes and may be started before the free gas determination and so may be running during the time the free gas determination is being made in the apparatus shown in Figure 1.

For convenience, a chart of the above operations is shown as comprising eleven steps. Whereas other apparatus than that shown in Figures 1 and 2 may be used for carrying out the method of the invention, the apparatus shown has the particular advantages above pointed out.

Chart of operation

1. Divide a core sample (taken from a core) into two parts, A and B, making part A approximately 40 grams and part B approximately 160 grams

2. Weigh part A_____=grams

3. Measure total volume of part A by immersing in mercury_____=cc.

4. Measure total free gas of part A by subjecting it while immersed in mercury to elevated pressure to compress free gas and fill its pores_____=cc.

5. Divide cubic centimeters of free gas (4) by total volume (3) to obtain cubic centimeters of pore space occupied by free gas per unit volume of core sample__=cc./unit volume

6. Calculate density of sample by dividing its weight (2) by its volume (3)_____=cc./gram

7. Weigh part B_____=grams

8. Distill off extractable liquids from part B and collect and measure to obtain total volume of liquid in pore space_____=cc.

9. Calculate volume of part B by dividing its weight (7) by its density (6)_____=cc.

10. Divide cubic centimeters of liquid (8) by total volume (9) to obtain cubic centimeters of pore space occupied by liquid per unit volume of core sample_____=cc./unit volume

11. Add cubic centimeters of pore space occupied by free gas per unit volume of core sample (5) to cubic centimeters of pore space occupied by liquid per unit volume of core sample (10) to obtain cubic centimeters of pore space per unit volume of core sample_____=cc. pore space/unit volume

As various embodiments might be made of this invention, and as various changes might be made in the construction herein described, all without departing from the scope of the invention, it is to be understood that all matter herein set forth or shown in the accompanying drawings is to be interpreted as illustrative and not in a limiting sense.

I claim:

1. The method of analyzing a core taken from an oil sand comprising measuring the volume of free gas in the pores by compressing the gas in the pores with a liquid to such a small volume that the pores are substantially filled with the liquid, measuring the amount of liquid required, measuring the oil and water saturation by distillation and obtaining the porosity by adding together the results obtained from the above analysis.

2. The method of determining the porosity of a core sample comprising the steps of dividing the sample into two parts, weighing each of the parts, immersing one of the parts in a liquid to determine its volume, subjecting the immersing liquid to pressure to cause the liquid to flow into the pores and compress the gas therein to such a small volume that the pore space is substantially filled with the liquid and measuring the liquid that thus enters the pores, combining the volume measurement and the measurement of the amount of liquid that enters the pores to obtain the amount of pore space per unit volume of core sample occupied by gas, distilling off, collecting and measuring the extractable liquid from the pores of the other part, obtaining the density of the sample from the volume and weight of the first part and the volume of the second part from its weight and density, combining the volume of the collected liquid and the volume of the second part to obtain the amount of pore space per unit volume of core sample occupied by liquid and adding the latter determination to the free gas obtained to obtain the pore space per unit volume of core sample.

3. The method of determining the porosity of a core sample comprising the steps of dividing the sample into two parts, weighing each of the parts, measuring the free gas content of the pores of one of said parts without extracting the liquid content therefrom, measuring the volume of said part to obtain the pore space occupied by free gas per unit volume of core sample, distilling off the extractable liquid from said second part, condensing and measuring the same, determining the volume of said second part by dividing its weight by its density obtained from the volume and weight measurements on the first part to obtain the pore space occupied by liquid per unit volume of core sample, and adding the free gas and extractable liquid measurements to obtain the pore space per unit volume of core sample.

4. The method as in claim 3 wherein the weight of the first part is made approximately 40 grams and the weight of the second part is made approximately 180 grams.

WILLIAM L. HORNER.