April 9, 1946. B. PONTECORVO 2,398,324

WELL SURVEYING

Filed Aug. 10, 1943

Fig. 1,

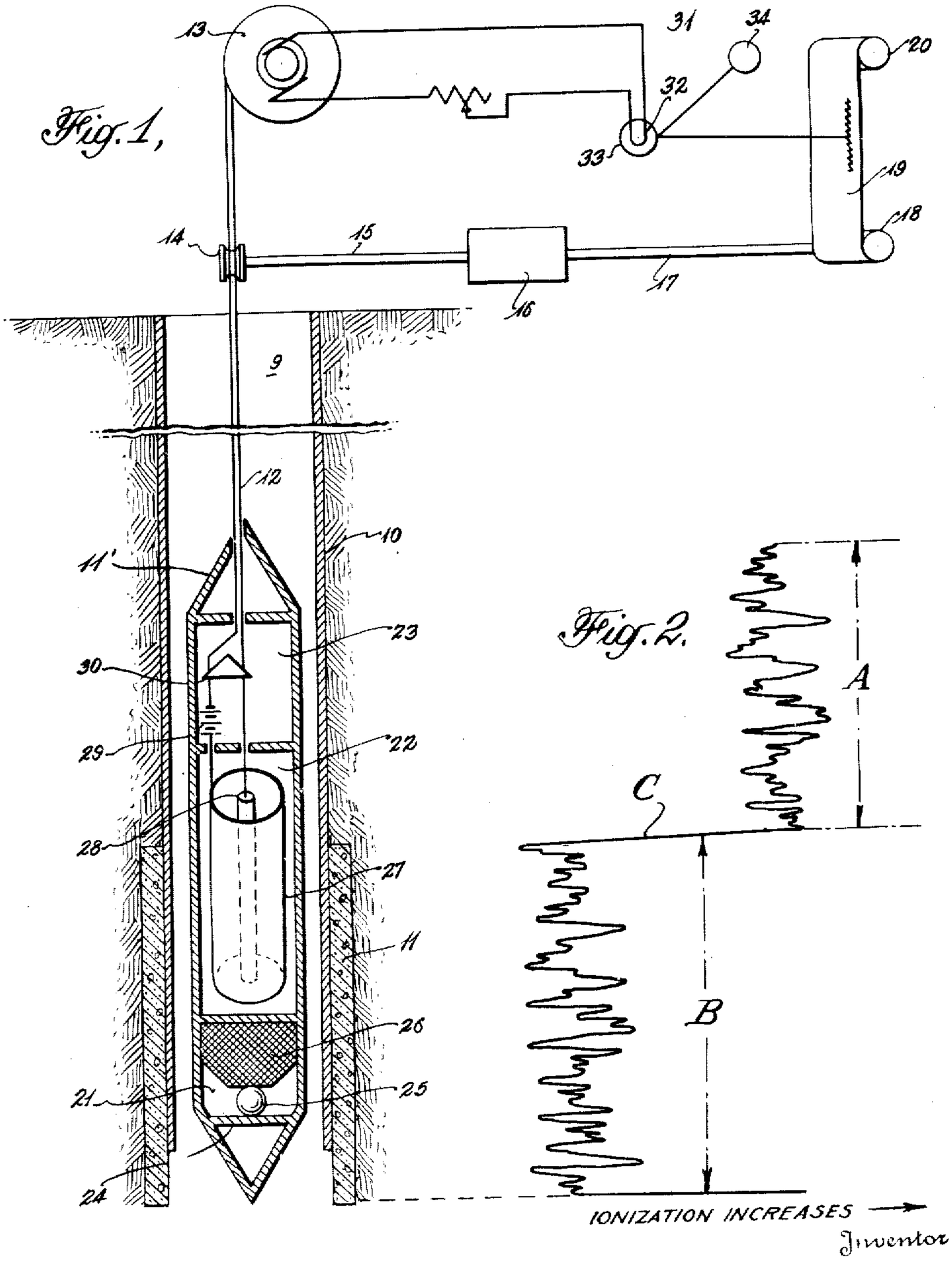

Fig. 2.

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WELL SURVEYING

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Application August 10, 1943, Serial No. 498,035

2 Claims. (Cl. 250—83.6)

This invention relates to the art of well surveying and more particularly to a method and apparatus for locating the top and bottom of the cement that is used in cementing casing when setting them in a bore hole, and further contemplates the achievement of this result while conducting a radiation well survey of the strata penetrated by the cased bore hole.

By the present invention a definite offset can be obtained in the radiation log of the bore hole when traversing the area where cement is used for sealing the casing. This offset is made possible by the incorporation of a substance that will absorb radiations. Thus, when a survey is made of that portion of a bore hole that is free of cement by lowering a capsule into the bore hole which contains a source of radiations and a detecting device, a radiation log is obtained having an average amplitude such that when that portion of the drill hole where the cement is located is traversed, the average amplitude of the log is substantially reduced, thereby producing the definite offset in the log of the bore hole.

Methods for cementing a drill hole are well known in the art and for this reason it is not necessary to dwell at length on the processes for placing the cement. The instant invention relates to the use of a material capable of at least retarding the flow of neutrons to a detectable degree, such, for example, as substances containing boron, lithium, etc., in the cement, which, when radiated by neutrons, will absorb these radiations thereby in part shielding the strata in back of the cement. Boron and lithium are especially suitable for the present purpose, because they not only absorb neutrons, but do not emit gamma rays of capture. These gamma rays of capture, which the heavier elements emit, produce ionization in the ionization chamber and obscure the effect of the cement. Experiments conducted while using boron in suitable concentrations in the cement have shown that even the mechanical properties of the cement are improved.

This invention, however, is directed to lowering a source of neutrons and a detector of gamma rays, which may or may not be in the same capsule, into a bore hole. The strata radiated by the radiations from the source contained in the capsule will give off detectable secondary radiations. Since a material of the above nature has been incorporated with the cement, the location thereof becomes detectable by a change in the intensity of the observed secondary radiation.

Methods and apparatus for making a radioactive log of a bore hole are well known in the art as shown by patents such as those that have issued to Bender, No. 2,133,776, Brons, No. 2,220,509, and Fearon, No. 2,308,364.

Additionally, there are known in the prior art methods and apparatus for locating the cement in cased bore holes. Although some of these methods are practical, one of them achieves the practicability of the instant invention.

At the time the drill hole is made and casing is set by pumping cement thereinto, in order to practice the present invention there is added to the cement a material that will absorb neutrons, such as described above, which by its presence in the cement permits the precise location thereof in the bore hole by the detector, simultaneously with the log of the bore hole and in correlation with depth.

By use of the instant invention a definite and distinguishable point can be detected in the traverse of the drill hole that will indicate to the observer the exact point where the cement starts and where it stops.

Therefore, the principal object of this invention is to provide a method and apparatus whereby the top and bottom of the cement may be determined while making a radiation log of the strata penetrated by the bore hole, both indications being accurately correlated with depth, and recorded.

Other objects and advantages of the instant invention will be apparent from the description which follows when taken with the drawing in which:

Figure 1 illustrates diagrammatically a bore hole which penetrates the strata of the earth and shows the casing, cement, recording apparatus and detecting device; and

Figure 2 illustrates a log such as that made by the instant invention positioned adjacent Figure 1 to show the manner in which the depth of the top and bottom of the cement can be distinguished on the log.

Referring to the drawing in detail, particularly Figure 1, a drill hole 9 is shown penetrating the formation to be explored. The drill hole is provided with a tubular metallic casing such as designated at 10. The bottom portion of the casing 10 is shown as sealed in position in the bore hole by cement 11 which contains a neutron-absorbing substance.

The exploratory apparatus proper consists of a housing 11' which is lowered into the bore hole by means of a cable 12, containing insulated conductors. The cable has a length somewhat in

excess of the length of the hole to be explored and is normally wound on a drum 13 positioned adjacent to the top of the drill hole. The cable may be unwound from the drum 13 to lower the exploring apparatus into the hole and may be rewound upon the drum to raise the exploring apparatus. Between the drum 13 and the hole there is a measuring reel 14 which is adjusted to roll on the cable in such a manner that the number of revolutions of the reel corresponds to the amount of cable which has passed up or down in the drill hole. The reel is mounted on a shaft 15, and the motion of the shaft is transmitted through a gear box 16 to another shaft 17 which turns a spool 18 to wind a photographic film 19, the film being supplied from a feed spool 20.

The housing 11' of the exploratory apparatus comprises three parts respectively designated by the numerals 21, 22 and 23. In the partition 21 there is provided upon a solid support 24 an appropriate quantity of radioactive material such, as for instance, mesothorium 2 or polonium mixed with beryllium metal, which is designated by the numeral 25 and a shield 26 formed of layers of lead and paraffin or other material relatively opaque to the penetrating radiations produced by the mesothorium 2 and polonium mixed with beryllium metal which is placed above the source of radiations so as to shield it from a direct communication with the upper partition 22. Mesothorium 2 and polonium are selected merely as examples and it is understood that there may be used any other suitable radioactive material, such as, for instance, a mixture of radium and beryllium, the said mixture being characterized by an intense emission of neutrons.

The partition 22 contains an ionization chamber having a cylindrical outer electrode 27 and a central wire electrode 28. The ionization chamber is filled with inert gas such as argon, preferably under high pressure. The above ionization chamber is illustrated merely as an example. Instead of argon, any other gas having similar characteristics or mixture of such gases may be used.

The partition 23 contains a battery 29 to apply a voltage to the ionization chamber and an amplifier 30 to amplify the current passing through the ionization chamber. The battery 29 has one of its terminals connected to the cylindrical electrode 27 and the other terminal connected to the input terminal of the amplifier. The central electrode 28 is directly connected to the other input terminal of the amplifier.

The output terminals of the D. C. amplifier 30 are connected to the cable 12 which conveys the current from the amplifier to a recording galvanometer 31 located at the surface of the earth. The recording galvanometer includes a moving coil 32 connected to the cable and a mirror 33 attached to the moving coil. The mirror is adapted to reflect a beam of light from a lamp 34 onto the sensitive film 19 to produce, after the film has been developed, a record of the well log.

The operation of the invention may be explained as follows:

The mass 25 is subject to a continuous and progressive disintegration which is well known in the art as radioactive process and transforms itself from mesothorium 2 into an element known as radiothorium. Various radioactive materials may be used to emit neutron radiations.

The radiations transmitted from 25 tend to propagate themselves in all directions. There is provided, however, an absorbing shield 26 which is relatively opaque to penetrating radiations and therefore, prevents a direct path between 25 and the ionization chamber. Consequently, the radiations emitted from 25 are directed substantially laterally into the adjacent formations and the amount of radiations going upwards through the absorbing shield is negligible.

It is well known by those skilled in the art that when a formation constituting the wall of the bore hole is exposed to the radiations which may impinge from a definite direction it becomes itself a source of radiations and these radiations proceed outwards in all directions. These radiations are called scattered or secondary radiations and gamma rays of capture. The radiations coming directly from the mass 25 are called primary radiations to distinguish them from the secondary radiations. It is then apparent that the secondary radiations from the walls of the bore hole enter into the partition 22 wherein they are detected by the ionization chamber.

The operation of the ionization chamber is well known in the art. Under normal operating conditions the battery 29 maintains between the central electrode 28 and the cylindrical electrode 27 a voltage of such a magnitude that a discharge will just not pass between them. When, however, a quantum of energy emitted from the adjacent earth stratum enters the ionization chamber and is absorbed in the gas it creates a large number of ions in the gas which permit a current delivered by the battery 29 to pass between the electrodes 27 and 28. This current becomes amplified in 30 and is transmitted through the cable 12 to the recording apparatus at the top of the drill hole.

The strata penetrated by the drill hole will vary considerably in their powers of slowing down and absorbing neutrons, and in the gamma rays of capture emitted on their absorption. The significant features of the neutron logs are produced chiefly by gamma rays of capture. Opposite the cement containing the neutron-absorbing substance there will be a marked minimum of ionization, because the cement absorbs many of the neutrons before they get near enough the ionization chamber to exert an effect on it, and because those which do get close to it and are absorbed by the neutron-absorbing substance give off no gamma rays of capture.

In the operation of the device as described above, the record produced thereby is that of a conventional neutron well log. Such a log is illustrated in the portion A of Figure 2 of the drawing. The entire record of Figure 2, however, additionally illustrates a novel feature of the instant invention, namely, that of locating cement in a bore hole.

Considering the record shown in Figure 2, with the cased drill hole, shown in Figure 1, in which a part of the casing is surrounded by cement, it can be seen that the portion of the record marked A is of relatively large average amplitude and corresponds to that portion of the cased drill hole above the cement 11, and that portion of the record marked B of less average amplitude was recorded while the capsule was traversing that portion of the hole in which the casing 10 is surrounded by the cement 11. The offset C in the record corresponds to a sharp reduction of intensity of detected secondary radiations and results from the fact that neutrons emitted from the mass 25, while being radiated substantially

laterally therefrom were, in part, or entirely, absorbed by the cement 11 which contains a neutron-absorbing substance such as described above.

Although the bottom end of the cement is not shown in the drawing, it is obvious that when the bottom end of the cement is passed by the capsule, there will be a second offset in the curve to the right that will be as sharply defined as the offset C described above, differing, however, from C in that the offset is in a direction representing greater average amplitude or greater intensity of detected radiations.

Therefore, from the above description of the apparatus and the method of operation thereof, it can be seen that the instant invention is a marked advancement of the well surveying art in that it provides a method and apparatus for simultaneously producing a radiation well log of a bore hole and locating the extremities of the cement surrounding the casing therein.

Although a particular method of well logging has been described, it is obvious to those skilled in the art that many modifications of the method of conveying the intelligence to the surface can be utilized. Among these many methods may well be included the null systems for determining the intensity of detected radiations. It is to be understood that the present invention is not to be limited to the specific disclosure of any particular method for conducting the desired intelligence to the surface where it is recorded on a moving sensitized paper or photographic film in correlation with depth.

I claim:

1. In a radiation method of logging a cased drill hole that penetrates the substrata of the earth, the improvement of simultaneously locating a cement that contains a neutron absorbing substance disposed behind the casing in the drill hole that comprises the steps of radiating neutrons towards the walls of the drill hole from a neutron emitting source as said source traverses the drill hole and detecting secondary gamma radiations of a certain intensity from that portion of the strata surrounding the casing that is free of cement and detecting gamma radiations of different intensity from the strata adjacent the cement, thereby producing by the differences in intensity of the detected gamma radiations an indication of the location of the cement in the bore hole on a log which when recorded in correlation with the depth will be in the form of an offset.

2. The method of locating the upper level of the cement placed in the annular space between the walls of the bore hole and a string of casing, which comprises mixing with the cement before it is placed in the hole a quantity of a substance capable of reacting with the neutrons and producing a gamma radiation as a result of such reaction, placing the treated cement in the hole so that it will fill part of the space between the casing and the surrounding formations, placing a source of neutrons in the hole, detecting the intensity of the gamma radiations in the surrounding formations and returning to the hole near the said source, and moving the source and detecting means through the hole and observing the variations in the intensity of the detected gamma radiations as the source and the detecting means arrive at or leave the point where the top of the cement is located.

BRUNO PONTECORVO.

Certificate of Correction

Patent No. 2,398,324. April 9, 1946.

BRUNO PONTECORVO

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 1, second column, line 8, for the word "one" read *none*; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 16th day of July, A. D. 1946.

[SEAL]

LESLIE FRAZER,
First Assistant Commissioner of Patents.

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