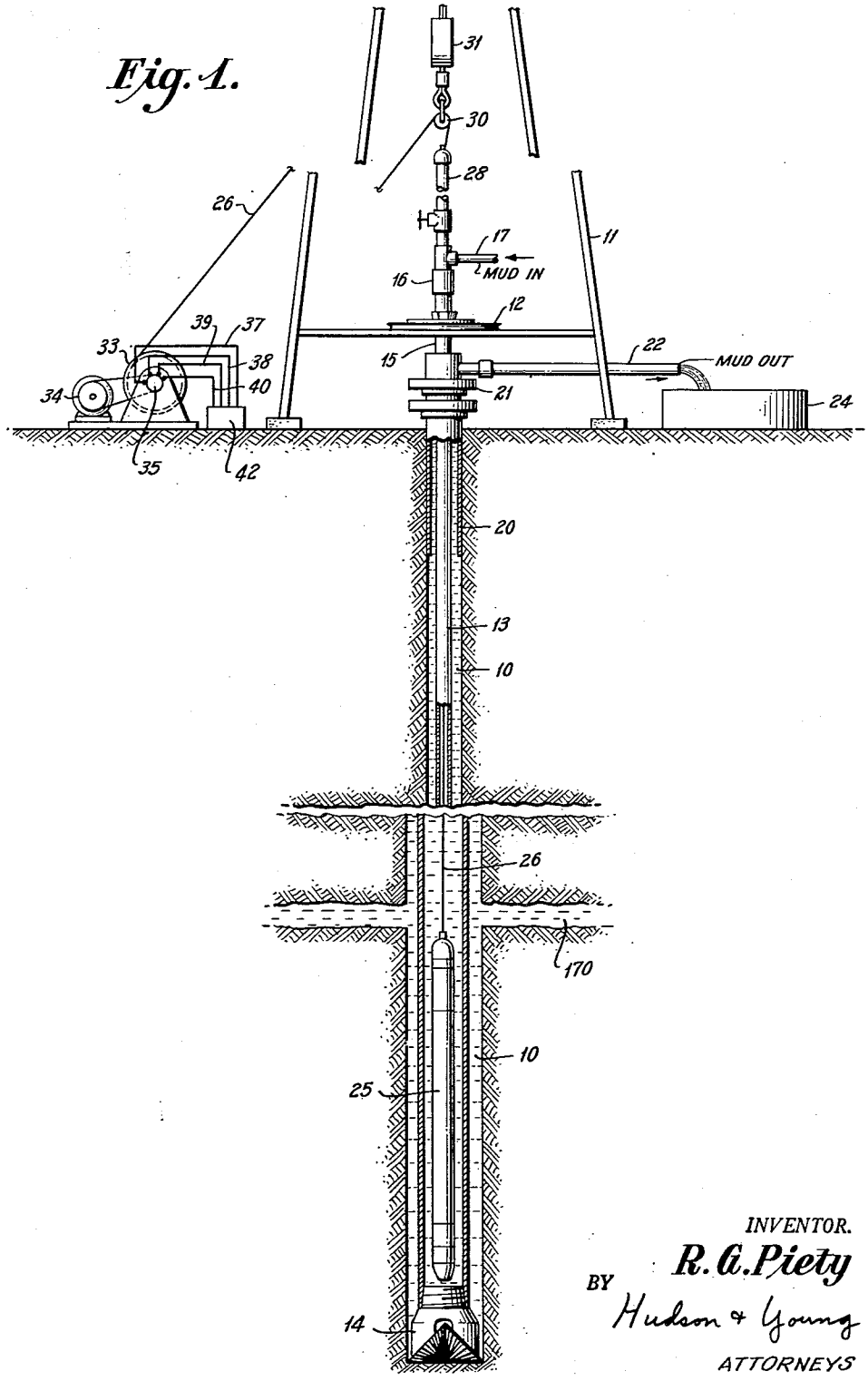
Sept. 3, 1957 R. G. PIETY 2,805,346

METHOD OF AND APPARATUS FOR LOCATING ZONES OF LOST CIRCULATION OF DRILLING FLUIDS

Filed Dec. 22, 1952 4 Sheets-Sheet 1

Fig. 1.



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Filed Dec. 22, 1952 4 Sheets-Sheet 2

Fig. 2a

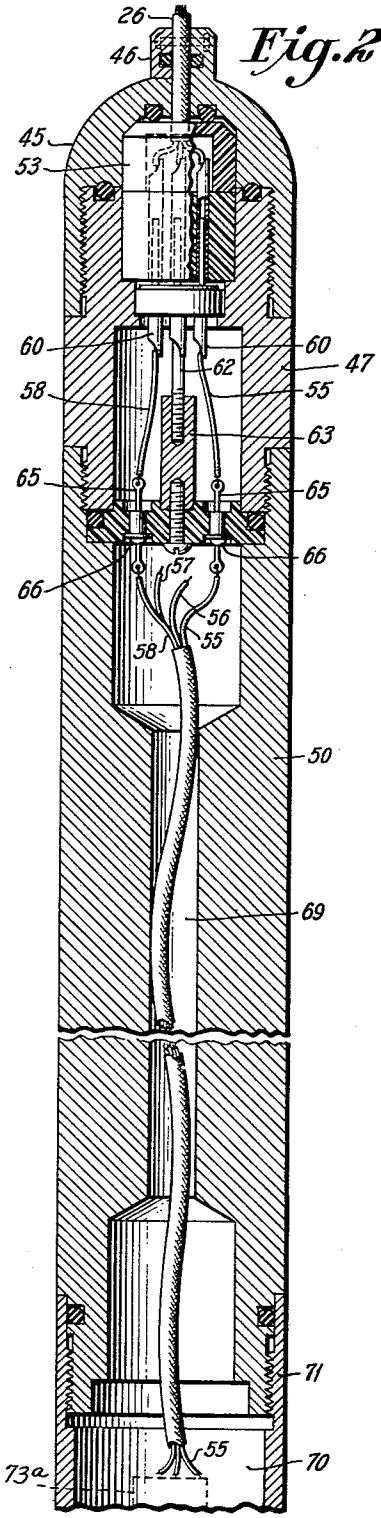
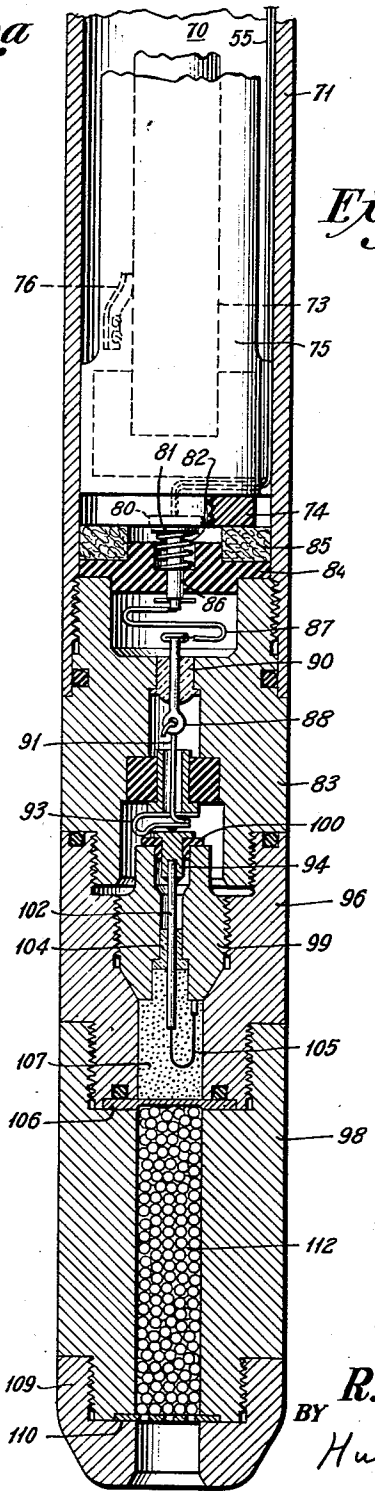


Fig. 2b



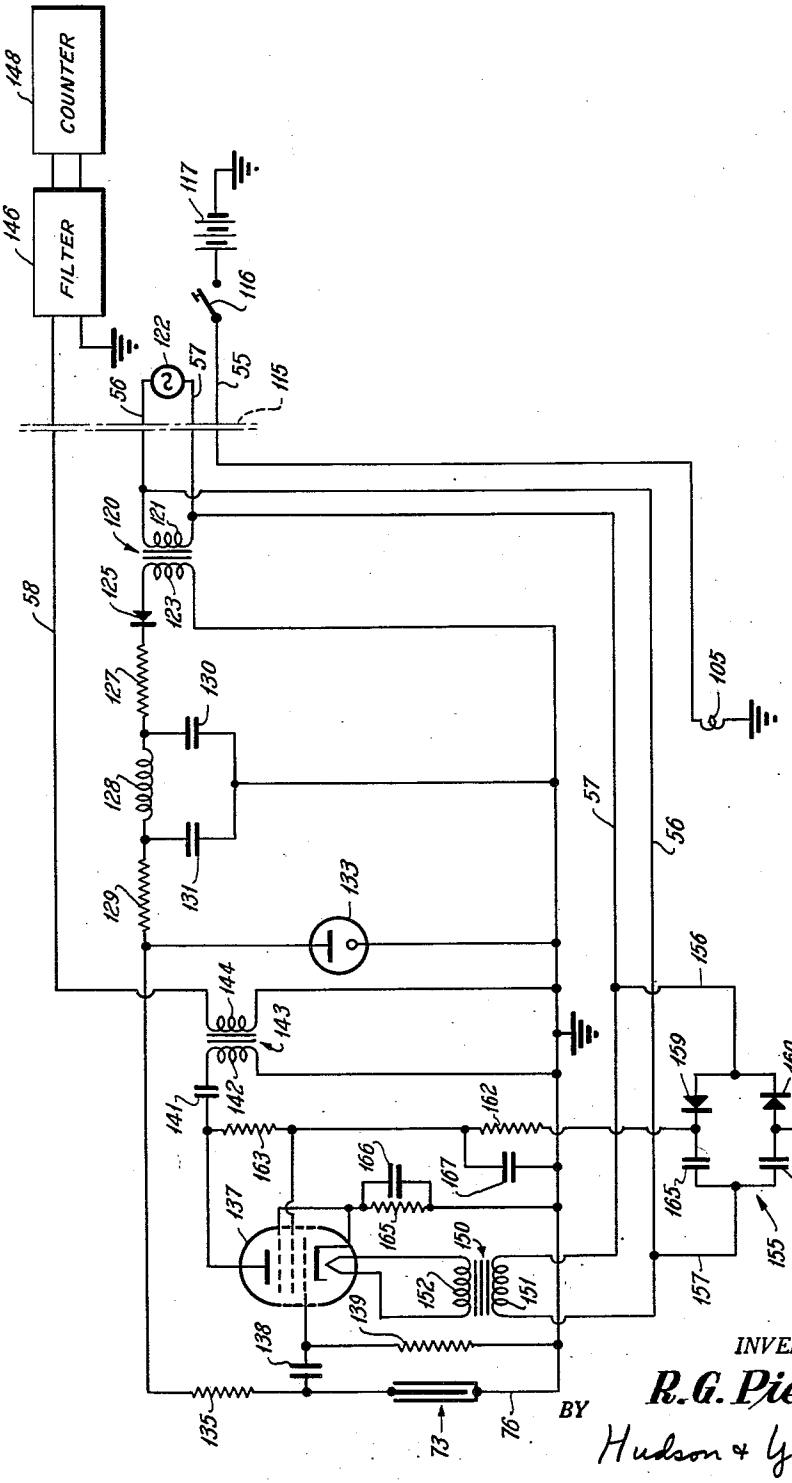
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METHOD OF AND APPARATUS FOR LOCATING ZONES OF LOST CIRCULATION OF DRILLING FLUIDS

Filed Dec. 22, 1952 4 Sheets-Sheet 3

Fig. 3.



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Filed Dec. 22, 1952 4 Sheets-Sheet 4

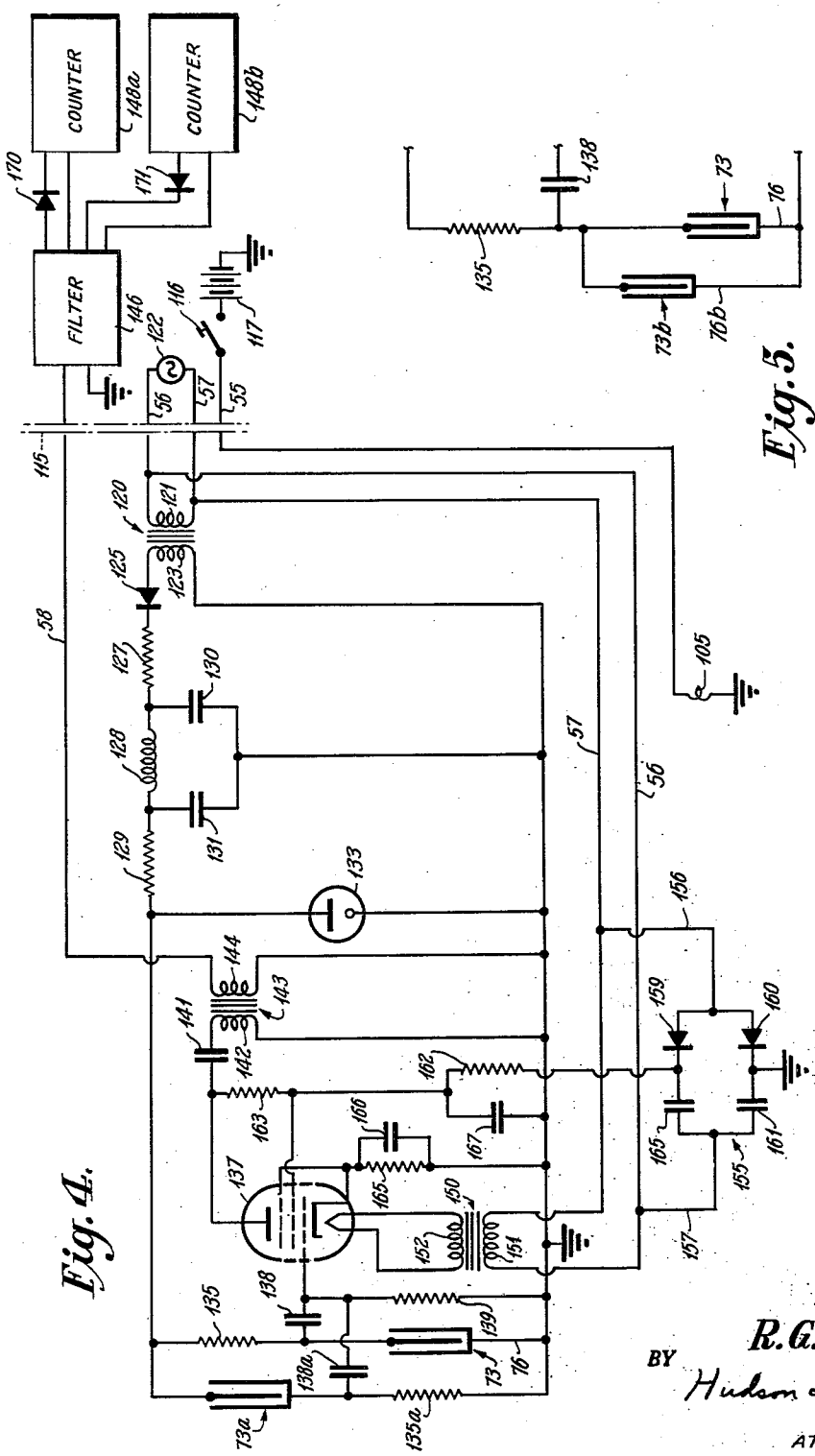


Fig. 5.

Fig. 4.

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United States Patent Office 2,805,346 Patented Sept. 3, 1957

2,805,346

METHOD OF AND APPARATUS FOR LOCATING ZONES OF LOST CIRCULATION OF DRILLING FLUIDS

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Application December 22, 1952, Serial No. 327,283

11 Claims. (Cl. 250—83.6)

This invention relates to a method of and apparatus for locating zones at which liquids escape from well bore holes into surrounding formations. In one specific aspect it relates to the detection of regions of lost circulation of drilling mud employed in the drilling of bore holes.

In the drilling of bore holes in the earth, it is customary to employ a drill bit which is secured to the lower end of a rotatable drill pipe string. Drilling fluid is circulated down through the pipe string, out at the bit, and upwardly to the surface between the drill pipe string and the walls of the hole. This fluid is commonly referred to as "drilling mud" and serves various functions which include: lubricating and cooling of the drill bit, a means of circulating the cuttings to the surface, and a means of preventing "blowout" in the hole. These drilling fluids usually comprise a water suspension of gel-forming materials which impart the desired characteristics to the fluid.

As the bore hole increases in depth, the formation pressure increases such that it becomes necessary to increase the specific gravity of the drilling fluid in order to prevent the flow of fluids from the penetrated formations into the bore hole. Such an increase in specific gravity is effected by adding suitable materials such as barytes to the drilling fluid. However, this increased specific gravity of the drilling fluid may cause the breakdown of earth strata and permit the escape of the drilling fluid from the well bore hole, which condition is noted at the earth surface by a decrease in the rate at which the drilling fluid returns from the hole. This is commonly referred to as "lost circulation." When such a condition is noted it becomes essential to plug the formation into which the drilling mud is escaping in order to prevent further loss of the mud. For the most part such plugging can be accomplished by the addition of suitable materials to the drilling mud which tend to fill and close the openings through which the mud is escaping. These sealing materials are well known in the art and include chopped cellophane, asbestos fibers, feathers, wood pulp, hemp and the like. The choice of materials to be used depends in part on the type of formation in which the leak has occurred. A determination of the depth at which leakage is taking place often assists the operator in determining the type of formations encountered and, accordingly, the preferable type of plugging material to be added to the drilling mud. If extremely large leaks develop in the walls of the bore hole it may become necessary to cement the formation. Such a procedure requires a knowledge of the depth of the leak. Obviously, it is desirable to be able to locate the depth of the leak in as simple and rapid a manner as possible. To this end it is proposed to determine the region of lost circulation without removing the drill pipe from the bore hole.

In accordance with the present invention a quantity of radioactive material is added to a portion of the drilling mud either at the surface or at a region near the drill bit. A suitable radiation detector is lowered into the drill pipe and is slowly raised or lowered to determine the depth at which the radioactive material added to the drilling mud tends to leak out from the bore hole. In order to carry out this testing method in a simple and economical manner, apparatus is provided for releasing a small quantity of radioactive material into the drilling mud at or near the drill bit. The entire operation is carried out by means of suitable indicating and control apparatus positioned at the surface of the bore hole.

Accordingly, it is an object of this invention to provide an improved method of determining the location in a bore hole at which drilling fluids tend to escape.

Another object is to provide leak detecting apparatus which can be lowered into a drill pipe whereby the location of leaks in the walls of a bore hole can be detected without removing the drill pipe from the bore hole.

A further object is to provide a method of locating the depth of drilling fluid leakage from a bore hole during the time drilling mud is circulated within the bore hole.

A further object is to provide apparatus for detecting a region of fluid leakage from a bore hole which can be operated from the earth surface to provide a rapid determination of the location of such leakage.

A further object is to provide a system for determining the rate of circulation of drilling mud in a well.

Various other objects, advantages and features of this invention will become apparent from the following detailed description taken in conjunction with the accompanying drawings in which:

Figure 1 is a schematic representation of apparatus employed to drill a bore hole together with the leak detector of this invention suspended inside the drill pipe, the lower portion of which is shown in enlarged detail;

Figures 2*a* and 2*b* illustrate in detail the leak detecting apparatus which is adapted to be suspended in a bore hole;

Figure 3 is a schematic circuit diagram of the electrical components forming a part of the leak detecting apparatus;

Figure 4 is a modified form of the apparatus of this invention; and

Figure 5 is a second modified form of the apparatus of this invention.

Referring now to the drawing in detail and to Figure 1 in particular there is illustrated a conventional drilling rig employed to drill a bore hole **10**. This equipment comprises a derrick structure **11** upon which is mounted a rotatable table **12** which rotates the drill string **13** having a drill bit **14** attached at the lower end thereof.

The uppermost section **15** of the drill pipe extends upward through table **12** and has a connecting member **16** attached thereto. A conduit **17** communicates with member **16** to circulate drilling mud downward through drill string **13** during the course of drilling operation. A section of casing **20** is fitted in the upper region of bore hole **10** and has a packing gland structure **21** fastened thereto. A conduit **22** is connected to packing gland **21** and extends outward therefrom to discharge the drilling mud returned from the bore hole into a tank or pit **24**. A leak detector assembly **25** is suspended within drill string **13** by means of an armored cable **26**. This assembly, which is illustrated in greater detail in Figures 2*a* and 2*b*, contains a quantity of radioactive material to be released into the drilling mud and a suitable radiation detector. The upper end of cable **26** extends through a lubricator joint **28** attached to member **16** such that assembly **25** can be inserted inside the drill string. Cable **26** extends upward over a pulley **30**, which is supported by a crane **31**, and thence to a rotatable reel **33**. Reel **33** is driven by a motor **34** such that assembly **25** can be raised and lowered into the bore hole to known depths. Armored cable **26** contains four electrical leads which terminate in respective slip rings mounted on the drive shaft **35** of reel

33. Electrical leads 37, 38, 39, and 40 are attached to respective individual brushes which in turn engage the respective individual slip rings on shaft 35. These various leads extend to the surface indicating apparatus shown at 42.

In Figures 2*a* and 2*b* there are illustrated structural details of the assembly 25. Cable 26 is attached to a cap 45 by means of a conventional cable coupling 46. A nipple 47 is threaded to the lower end of cap 45 and a sinker bar 50 is threaded to the lower end of nipple 47. An insulating bushing 53 lines the interior of cap 45 and the upper region of nipple 47. Four electrical leads 55, 56, 57, and 58, contained within cable 26, pass through individual headers 60 which communicate between the interior of bushing 53 and the interior of nipple 47. An insulating disk 51 is interposed between nipple 47 and sinker bar 50. This disk is secured to nipple 47 by a rod 62 and a coupling 63 which extend therebetween. The various leads 55—58 pass between nipple 47 and sinker bar 50 by means of connecting terminals 65 mounted within insulating plugs 66. Electrical leads 55—58 then pass downward through the interior passage 69 of sinker bar 50 and thence into the interior 70 of a casing section 71 which is threaded to the lower end of sinker bar 50.

The upper region of chamber 70 is filled with the various electrical circuit components which are described hereinafter in conjunction with Figure 3. A Geiger tube 73 is mounted in the lower region of chamber 70 by a pair of mounting brackets, one of which is illustrated at 74. A cartridge 75 having a plurality of elongated slots therein encloses Geiger tube 73 and provides a rigid support therefor. A contact spring 76 is attached to cartridge 75 and engages the shell of tube 73 to provide a grounded connection. Electrical lead 55 passes through chamber 70 adjacent Geiger tube 73 and is connected at its lower end to a first contact button 80 which normally is in engagement with a second contact button 81, the latter being retained against the former by a compression spring 82. A hollow plug 83 is threaded to the lower section of casing 71 and a circular plate 84 rests thereon. A ring of cushioning material 85 is interposed between plate 84 and bracket 74. A rod 86 is attached at its upper end to contact button 81 and at its lower end to a flexible connecting cable 87. The lower end of cable 87 is attached to a terminal 88 which passes through an insulating bushing 90 mounted within plug 83. The lower end of terminal 88 is connected to a cable 91 which in turn is attached to a flexible spring contact 93, the latter engaging a contact button 94. A breech block 96 is threaded to the lower end of plug 83 and a barrel 98 is threaded to the lower end of breech block 96. A plug 99 is threaded to the interior of breech block 96 and in turn supports contact button 94 by means of an insulating bushing 100. A terminal 102 is attached to the lower end of contact button 94 and extends downwardly through the interior of plug 99 and through an insulating bushing 104.

A coil of firing wire 105 is connected between the lower end of terminal 102 and plug 99, the latter constituting a ground connection. A diaphragm 106 is interposed between breech block 96 and barrel 98 so as to form a fluid tight chamber which is filled with gun powder 107. A muzzle 109 is threaded to the lower end of barrel 98 and a retainer plate 110 is interposed therebetween. This forms a second chamber which is filled with a quantity of radioactive material 112 to be released into the drilling mud. The radioactive material disposed from chamber 112 preferably is in the form of silica gel pellets having radioactive cobalt impregnated thereon. Retainer plate 110 is provided with several openings to allow pressure equalization between pellets 112 and the well fluid.

The electrical circuit components employed in conjunction with the leak detector of this invention are illustrated schematically in Figure 3. These components to the right of line 115 are positioned at the surface while those components to the left of line 115 are positioned within chamber 70. Lead 55 is connected at its upper end through a switch 116 to one terminal of a voltage source 117, the second terminal of which is grounded. The lower end of lead 55 is connected through the various connecting terminals illustrated in Figure 2*b* to one end of firing wire 105, the second end of which is grounded at plug 99. Closure of switch 116 thus results in the passage of current through wire 105 which ignites gun powder 107 to expell radioactive pellets 112 out through muzzle 109 by rupturing retainer plate 110.

A source of direct potential to operate Geiger tube 73 is supplied by a power supply circuit including a transformer 120 having its primary winding 121 connected by leads 56 and 57 to a source of alternating potential 122 positioned at the surface. One terminal of the secondary winding 123 of transformer 120 is connected to the first terminal of a rectifier 125 and the other terminal of winding 123 is connected to ground. The second terminal of rectifier 125 is connected to a resistor 127, which in turn is connected to an inductor 128, the latter being connected to a resistor 129. A first capacitor 130 is connected between ground and the junction between resistor 127 and inductor 128, and a second capacitor 131 is connected between ground and the junction between inductor 128 and resistor 129. These last five mentioned elements thus form a conventional filter in the output circuit of rectifier 125. The direct voltage appearing across the output terminals of this filter is maintained at a constant value by a voltage regulating tube 133 which is connected between the output terminal of resistor 129 and ground. The voltage appearing across tube 133 is applied across Geiger tube 73 and a resistor 135 connected in series with the center electrode thereof. The outer shell of Geiger tube 73 is grounded by spring contact 76 and the center electrode is connected to the control grid of a pentode vacuum tube 137 through a coupling capacitor 138. A resistor 139 is connected between the grid of tube 137 and ground. The cathode of tube 137 is grounded through a bias resistor 165 which is shunted by a capacitor 166. The anode of tube 137 is connected through a capacitor 141 to a first end terminal of the primary winding 142 of a transformer 143, the second terminal thereof being grounded. The first terminal of the secondary winding 144 of transformer 143 is connected by lead 58 to a filter 146 located at the surface and the second terminal of winding 144 is grounded. Filter 146 is tuned to block signals of the same frequency as generator 122 such as to eliminate stray signals which may be introduced in the system. The output terminals of filter 146 are connected to a suitable counter circuit 148 which measures the number of pulses generated by Geiger tube 73. Counter circuit 148 can include a series of Eccles-Jordan trigger circuits to provide division of the pulses for convenient counting.

Heater current for the cathode of tube 137 is supplied by a transformer 150, the primary winding 151 of which is connected directly across leads 56 and 57. The secondary winding 152 of transformer 150 is connected across the heater of tube 137. A bridge rectifier circuit 155 is employed to supply positive operating potential for the anode of tube 137. Leads 156 and 157 are connected to respective leads 57 and 56 and to opposite terminals of bridge circuit 155. Opposite first terminals of rectifiers 159 and 160 are connected to lead 156. The second terminal of rectifier 160 is connected to ground and to one terminal of a capacitor 161, the second terminal of which is connected to lead 157. The second terminal of rectifier 159 is connected through series resistors 162 and 163 to the anode of tube 137 and is connected directly to a first terminal of a capacitor 165, the second terminal of which is connected to lead 157. The screen grid of pentode 137 is connected to the junction between resistors 162 and 163 and a capacitor 167 is connected between this junction and ground.

The operation of the detector system of this invention

to locate regions of last circulation should now become apparent. Whenever the rate of flow of drilling mud returned from the well suddenly decreases it is known that a leak has been encountered in the walls of the bore hole, such as illustrated by numeral 170 in Figure 1. Assembly 25 then is lowered into the bore hole through the interior of drill string 13 until it is positioned at approximately the bottom of the hole. At this time switch 116 is closed to fire the radioactive pellets 112 into the drilling mud. The circulation of drilling mud is continued such that the pellets become entrained in the mud and are carried downward through drill 14 and upward through the region between drill string 13 and the walls of bore hole 10. As pellets 112 are carried upward by the flow of drilling mud, assembly 25 is raised by rotation of reel 33 at a rate such that Geiger tube 73 remains adjacent the radioactive pellets as indicated by the output signal of counter 148. Once the pellets reach region 170 the signal obtained by counter 148 diminishes in amplitude or discontinues entirely as assembly 25 is raised above leak 170. Accordingly, it is known that the leak occurs at the depth to which assembly 25 is suspended when this decrease signal is observed. Following this, appropriate steps can be taken to seal leak 170 by one of the procedures previously mentioned. If desired the radioactive material can be added directly to the mud as it enters the drill system through conduit 17. Normally such a procedure is not as desirable as one wherein the pellets are released in concentrated form near the bottom of the drill hole, although a second run can readily be made by this procedure without raising assembly 25 to the surface for reloading purposes.

One particular mode of operation that is particularly desirable comprises forming the radioactive pellets of a material slightly more dense than the drilling mud. These pellets normally are thus carried upward by the flow of mud but tend to fall backward when the point of lost circulation is reached because the upward flow of mud beyond such point is at a slower velocity which is not sufficient to carry the pellets upward.

In Figure 4 there is illustrated a second embodiment of the radiation detector assembly. This assembly includes a pair of Geiger tubes 73 and 73*a* mounted inside casing 71 in spaced vertical relation. This spacing can be of the order of three feet, for example. Tube 73*a* and a resistor 135*a* are connected in series across the voltage taken across tube 133, and are connected in parallel with series connected resistor 135 and tube 73. The junction between tube 73*a* and resistor 135*a* is connected to the control grid of tube 137 through a capacitor 139*a*. The remainder of the down-hole circuitry is identcial to that illustrated in Figure 3 and corresponding parts are identified by like reference numerals. At the surface, the output signal from filter 146 is applied to a first counter 148*a* through a rectifier 170 and to a second counter 148*b* through a rectifier 171, rectifiers 170 and 171 being poled in reverse order. In operation, the bias on tube 137 is adjusted whereby the tube operates at a region near the center of its characteristic curve so that either positive or negative pulse applied to the control grid result in an output signal. Assembly 25 is raised or lowered in the well to maintain the slug of radioactive material added to the mud between tubes 73 and 73*a*. If either tube is moved closer to the radiation than the other, the signal received on one of the counters increases and the other decreases. This results from the separate counters 148*a* and 148*b* and the reverse connection of the two Geiger tubes 73 and 73*a* and their associated series resistors 135, 135*a* which provides positive pulses when tube 73*a* is fired and negative pulses when tube 73 is fired. If desired, appropirate servo-mechanism can be connected to counters 148*a* and 148*b* to operate motor 34 to raise assembly 25 to keep tubes 73 and 73*a* on opposite sides of the added slug of radioactive material as the radioactive material rises in well 10.

In Figure 5 there is shown apparatus which can be used to measure the rate of flow of drilling mud at a selected region in the bore hole. This apparatus is identical to that shown in Figure 3 except that a second Geiger tube 73*b* is connected in parallel with tubes 73. Tube 73*b* also is mounted in casing 71 in vertical spaced relation with tube 73. As the radioactive material added to the mud flows upward past tube 73 a first signal is observed on counter 148 and a second signal is observed at a later time as the material passes tube 73*b*. By measuring the time interval between signals the mud velocity can be determined knowing the distance tubes 73 and 73*b* are spaced apart.

From the foregoing description it should be apparent that there is provided in accordance with this invention a simple compact structure for lowering inside the drill string to detect leaks in the well walls. The particular radioactive material employed as a tracer element is in no way limited to the cobalt impregnated silica gel pellets. Other materials which can be used for this purpose include conate sand, radon or any convenient radium salt. These materials preferably are carried by an absorbing material such as powdered charcoal or silica gel. Thus it is not intended that this invention be limited to the precise embodiments illustrated since various changes as to the detailed structure of the illustrated apparatus obviously can be made by those skilled in the art without departing from the scope of this invention. It is further within the scope of this invention to make measurements by lowering the detector assembly of Figure 3 to find the point of lost circulation as well as raising the detector. Either procedure will detect the region at which the radioactive material tends to escape.

What is claimed is:

1. A method of locating a region in a bore hole at which fluid is lost to adjacent formations which comprises positioning a string of drill pipe within the bore hole, circulating drilling fluid downward through said pipe and upward toward the surface of the bore hole outside said pipe, adding a predetermined quantity of radioactive material to the drilling fluid, and measuring the rise of said radioactive material upward in the bore hole from the bottom of said pipe.

2. The method in accordance with claim 1 wherein said radioactive material is added to the drilling fluid at a region within the bore hole near the bottom of said pipe.

3. The method in accordance with claim 1 wherein said radioactive material is added to the drilling fluid at the surface of the bore hole.

4. A method of locating a region in a bore hole at which drilling fluid is lost to adjacent formations during drilling operations in which drilling fluid is circulated downward through a string of drill pipe and upward outside the drill pipe toward the surface of the bore hole which comprises adding a predetermined quantity of radioactive material to the drilling fluid, lowering a radiation detector in the bore hole, and following the movement of the radioactive material added to the drilling mud with said detector as said material moves upward in the bore hole outside the drill pipe.

5. The method in accordance with claim 4 wherein said detector is lowered into the bore hole within the drill pipe.

6. A method of locating a region in a bore hole at which drilling fluid is lost to adjacent formations during drilling operations in which drilling fluid is circulated downward through the drill pipe and upward outside the drill pipe toward the surface of the bore hole which comprises adding a predetermined quantity of radioactive material to the drilling fluid at a region near the lower end of the drill pipe, lowering a radiation detector into the bore hole inside the drill pipe, and raising said detector upward inside the drill pipe to follow the upward movement outside the drill pipe of that portion of the drilling fluid containing the radioactive material.

7. Apparatus for detecting a region in a bore hole at

which fluid is lost to adjacent formations comprising an elongated casing, a motivated reel positioned at the surface of a bore hole, a cable containing a plurality of electrical leads extending between said reel and said casing to suspend said casing in the bore hole, first and second Geiger tubes mounted within said casing in spaced relation whereby said tubes are in vertical spaced relation when said casing is lowered into a bore hole, a vacuum tube biased to operate at the center portion of its characteristic curve whereby either positive or negative input pulses provide corresponding output pulses, first and second resistors connected in series relation with said first and second tubes, respectively, means connecting the output signals across said first and second tubes to the input of said vacuum tube whereby radiation impinging upon the first of said tubes results in a positive pulse being applied to said vacuum tube and radiation impinging upon the second of said tubes results in a negative pulse being applied to said vacuum tube, said vacuum tube and said resistors being positioned within said casing, means to supply operating potentials to said first and second tubes and said vacuum tube by means of leads in said cable, first and second counter circuits positioned at the surface of the bore hole and connected to the output of said vacuum tube by means of leads in said cable, said counters registering positive and negative pulses, respectively, a chamber formed in said casing to receive a quantity of radioactive material, means to open said chamber to release the radioactive material into the bore hole, and circuit means connecting said last mentioned means to the surface of the bore hole by at least one of the leads in said cable whereby the radioactive material can be released by means positioned at the surface of the bore hole.

8. Apparatus for detecting a region in a bore hole at which fluid is lost to adjacent formations comprising, in combination, an elongated casing, means to raise and lower said casing within a bore hole to known depths, a chamber formed in one end of said casing to receive a quantity of radioactive material, means to open said chamber to permit the radioactive material to be released into the bore hole, a first Geiger tube mounted within said casing at a region spaced from said one end, a second Geiger tube mounted within said casing at a region spaced further from said one end than is said first Geiger tube, and circuit means to indicate radiation detected by said Geiger tubes.

9. Detecting apparatus comprising a support; first and second Geiger tubes mounted on said support in spaced relation with one another; a vacuum tube having at least an anode, a cathode and a control grid; means applying operating potentials to said vacuum tube to bias said vacuum tube to operate at approximately the center portion of its characteristic curve so that input pulses applied thereto which are either positive or negative with respect to a reference potential provide corresponding output pulses; a source of direct voltage; a first resistance element connected in series relation with said first Geiger tube; a second resistance element connected in series relation with said second Geiger tube; means connecting said course of voltage directly across said first resistance element and said first Geiger tube so that said first resistance element is connected to the positive terminal of said source of voltage; means connecting said source of voltage directly across said second Geiger tube and said second resistance element so that said second resistance element is connected to the negative terminal of said source of voltage; means connecting the junction between said first resistance element and said first Geiger tube to said control grid; means connecting the junction between said second Geiger tube and said second resistance element to said control grid; and circuit means to measure the output pulses of said vacuum tube.

10. A method of locating a region in a bore hole at which fluid is lost to adjacent formations during drilling operations which comprises positioning a string of drill pipe within the bore hole, circulating drilling fluid downwardly through said pipe and upwardly toward the surface of the bore hole outside said pipe, adding a predetermined quantity of radioactive material to the drilling fluid, positioning a radiation detector in the bore hole, and following the movement of the radioactive material added to the drilling mud when said material moves upwardly in the bore hole outside the drill pipe.

11. The combination in accordance with claim 9 wherein said circuit means comprises first and second counters connected to the output of said vacuum tube through respective unidirectional current flow circuits whereby one of said counters measures said positive pulses and the second of said counters measures said negative pulses.

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