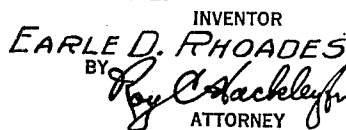


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## UNITED STATES PATENT OFFICE

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SURVEYING OF SUBSURFACE WATER  
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the United States of America as represented  
by the Secretary of the Interior

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5 Claims. (Cl. 73—151)

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amended April 30, 1928; 370 O. G. 757)

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The invention described herein may be manufactured and used by or for the Government of the United States for governmental purposes without the payment to me of any royalty thereon in accordance with the provisions of the act of April 30, 1928 (Ch. 460, 45 Stat. L. 467).

This invention relates to a method of subterranean surveying to determine the liquid levels of a plurality of superimposed fluid bearing strata through a single drill hole. Still more particularly this invention relates to a method of isolating various subterranean fluid bearing strata to permit the measurement of the liquid levels in each of the isolated strata through a single drill hole, and to a new type packer assembly for use in isolating subterranean fluid bearing strata.

Underground water or other fluid tables, sometimes referred to as horizons or strata, are frequently found at various levels at a given location. In choosing a dam or reservoir site, and after the completion of the dam, the structure of the rock and the character of the streams within a range of several hundred feet down and over a considerable area around the proposed site must be explored in order to determine whether or not the rock will support the tremendous weights of big dams, whether subterranean streams will undermine the foundation, and whether such streams will cause the water to leak out of the reservoir. Heretofore in order to survey such subterranean strata it has been necessary to sink a separate drill hole for each horizon to be surveyed at each of the many points to be studied. The sinking of drill holes is a costly and time consuming operation.

Core records taken during drilling operations indicate elevations where the water tables may and should exist from a geological standpoint, but afford no means of accurately determining the actual depth of the subsurface water in such tables, nor do they afford a means for recording changes in the depth of the water in these tables due to the dam construction, grouting operations, irrigation projects, or other activities.

Accordingly, it is an object of this invention to provide an economical method for surveying a plurality of subterranean fluid horizons through a single drill hole.

It is another object of this invention to provide a method for isolating the various subterranean fluid horizons, so that the fluid or liquid level in each of the isolated horizons can be determined through a single drill hole.

Still another object of this invention is to pro-

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vide a new type packer assembly for subterranean drill holes.

Other objects and advantages will be apparent from the following detailed description, taken in connection with the accompanying drawings, in which:

Fig. 1 is a diagrammatic vertical cross section of a drill hole embodying the principles of this invention.

Fig. 2 is a vertical cross section of a packer useful in carrying out this invention such as the packer 12 in Fig. 1.

These objects and advantages are accomplished in accordance with this invention by the method of surveying a plurality of subterranean fluid horizons through a single drill hole which comprises drilling a (substantially straight and vertical) hole in the earth to the maximum depth to be surveyed, inserting in said drill hole a plurality of sounding tubes, one for each horizon, each of said tubes approximately equal in length to the maximum depth of its horizon; isolating each of said horizons from one another; and sounding through said tubes to determine the liquid elevation of the horizons.

In another embodiment of this invention these objects and advantages are accomplished by a drill hole packer assembly which comprises a packing member associated with each of the sounding tubes between the end of this sounding tube and the end of the next shortest sounding tube, each of these packing members above the lowest in the series being provided with means to permit the passage of the longer sounding tubes. The packing members may be of an expansible type and may include, for example, an elastic gas impervious tube slightly less in diameter than the drill hole to be packed, pressure tight closure members for the ends of the elastic tube, and means for introducing and confining a compressed gas within the elastic tube whereby it may be expanded within the drill hole.

Referring now to Fig. 1, there are a plurality of underground water tables 1, 2, 3, and 4 occurring at the same point beneath the earth's surface 5. While such strata are shown as water tables, the invention is not limited thereto since the invention may also be useful in surveying other subterranean liquids and fluids such as brine, liquid hydrocarbons, gaseous hydrocarbons, and the like. A drill hole 6 is shown extending from the earth's surface through each of the water tables. Installed in the drill hole 6 are the sounding tubes 7, 8, 9, and 10, which are shown going to the various water horizons;

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7 to 1, 8 to 2, 9 to 3, and 10 to 4. Drill hole packers 11, 12, and 13 are shown permitting the passage of sounding tubes and isolating the various water tables; 11 isolating table 1 from 2, 12 isolating table 2 from 3, and 13 isolating table 3 from 4. A grout seal is shown by 14, 15, and 16. The use of a grout is optional and can be concrete, cement, or other similar grouting composition.

Referring now to Fig. 2, there is shown an elastic gas impervious tube 20; rubber tubing is a satisfactory material, however other similar materials may also be used for this element. The tube is slightly less in diameter than the diameter of the drill hole. Fitted inside the tube ends 21 and 210 are end plates 22 and 23. These end plates are installed sufficiently far inside tube 20 to permit the tube ends 211 and 212 to extend beyond the outer surfaces 222 and 232 of the end plates 22 and 23, respectively. End plate caps 24 and 25 have holes 242 and 252 drilled therein to permit passage of tubes 9 and 10 and have an outside diameter approximately equal to that of tube 20 and which substantially fit over the tube ends 211 and 212. By means of bolts 26 and threaded tap holes 27 in the end plates 22 and 23 the end plate caps are forced or drawn toward the end plates, thereby compressing and confining the tube ends 21 and 210 between the inside of the caps 241 and 251 and the outer surfaces of the end plates 222 and 232, thereby making a pressure tight closure. The upper end plate 22 has a threaded tap 28 extending completely through it which receives the gas filling line connection 29 and permits the introduction of compressed gases into the pressure tight chamber, and the upper end plate cap is drilled 291 to permit passage of filling line connection 29. A check valve 30, such as a Schrader valve, is fitted on the upper end of the filling line connection 29 to confine the compressed gases in the pressure tight chamber. The particular packer shown in Fig. 2 is similar to packer 12 in Fig. 1. However, the device as described up to this point if the end plates 22 and 23 are solid, except for the filling line tap in end plate 22, can be used by itself as a packer. When the packer is to be used as contemplated by this invention, means must be provided to permit the passage of other sounding tubes to levels below the packer. This is shown in Fig. 2 by sounding tube 10 and pass tube 31. Sounding tube 9 goes to the particular level being isolated by this packer and tube 10 is coming up from a lower water table. Sounding tube 9 and pass tube 31 penetrate the end plates and are soldered or brazed to the end plates at the inner junction points 32 and 321. Such joints should be tested for gas tightness.

To install the packer's assembly of this invention, a drill hole is sunk at the selected site by conventional methods. By maintaining a core record during the drilling, it is possible to study the rock strata and accurately locate the elevations at which the various water tables occur. From this information it is possible to determine the proper elevation at which the packers should be placed in order to effectively isolate the water tables. It is presently preferred to place the packers far enough below its table to permit putting a sufficient depth of grout above the packer to insure isolation of the table.

After determining the proper lengths of the sounding tubes and proper elevation for the packer for each of the tables, the installation of the longest of the sounding tubes is com-

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menced. This can be carried out in various ways, but it is presently preferred to construct the tubing string from sections of tubing by welding sufficient additional tubing sections to give a sounding tube of the desired length as the tube string is being lowered in place. If desired the lower portion of the sounding tubes can be perforated as shown in Fig. 1 to insure proper fluid access from the table to the sounding tube.

Referring now to Fig. 1, packer 13 is affixed to a section of tubing. This can be accomplished by drilling holes through the packer end plates and caps through which the sounding tube and filling line connection with pass and which will properly align the tubing string in the diamond drill hole. The end plates are then slipped over the tubing, properly spaced, and welded or soldered in place on tube 10. Thereafter a length of rubber or similar inflatable material corresponding to item 20 of Fig. 2, which has an inside diameter slightly less than the outside diameter of the end plates, is then aligned over the end plates and sounding tube; trimmed so that the rubber tube ends extend slightly beyond the end plates. The end plate caps are then positioned and bolted against the end plates, thereby confining the ends of the inflatable tubing between the caps and end plates, and creating thereby a pressure tight chamber. The filling line connection and check valve are then attached, as shown by 28, 29, and 30 in Fig. 2. A hose or similar means of sufficient length to extend to the bottom of the drill hole is then attached to the filling line connection; this is not shown in either of the figures.

The tube section and completed packer assembly are then lowered into the drill hole to a depth at which a short length of the tube extends above the earth's surface. While holding the assembly in this position another tubing section is then welded or soldered to the portion which has been partially lowered down the drill hole, taking care to assure coaxiality of the tubing and watertightness of the joint. Additional tubing sections are added in a similar manner during the lowering of the assembly until the packer has reached the proper elevation. At this point the packer is inflated by introducing compressed air into the packer through the hose, check valve, and filling line. When a grout is used, it should be poured at this time and the filling line connection, such as that shown by 29 in Fig. 2, should be of sufficient length to extend above the grout so that the hose or filling line can be detached after the grout has set. It is also possible by using a combination of left-hand and right-hand threads to facilitate the detachment of the gas hose without the danger of releasing the gas confined in the packer when unscrewing the filling line connection. By such arrangement it is also possible to detach the hose prior to grouting. Thereafter, tubing string 9 and packer 12 can be installed.

This operation can be more readily followed by referring to Fig. 2. Holes are drilled in the end plates 22 and 23 which will receive pass tube 31, said holes being coaxially aligned with the axis of tubing string 10. Holes are also drilled in the end plates through which the sounding tube 9 will pass and which will properly align the sounding tube 9 within the diamond drill hole. The upper end plate 22 is drilled and tapped 28 to receive the filling line connection 29. Pass tube 31 is then fitted in the end plates 22 and 23 and brazed or soldered in place 32. The lowest section of tubing string 9 is then passed through

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the holes in the end plates adapted to receive it and after adjustment to the proper position thereon, it is brazed or soldered 321 to affix it to the tubing string 9. The rubber or other inflatable sleeve 20 of a length slightly longer than the distance between the end plates is then slipped over the tubing and end plate assembly. Caps 24 and 25 are drilled to permit passage of sounding tubes 9 and 10 and are then slipped over the tubing strings and bolted to the end plates, thereby compressing the rubber tubing ends 211 and 212 against the end plates. The filling line connection 29 is then fitted in its tap and a filling hose of suitable length attached thereto. This entire assembly is then installed in the drill hole by passing tube string 10 through tube 31 of the packer. This assembly is then lowered to the proper position in the drill hole adding coaxially aligned additional lengths of tubing during the lowering operation as aforesaid to complete the sounding tube 9.

Referring now to Fig. 1, when packer 12 is at the proper elevation, compressed air or other fluid is introduced in the packer through the gas filling hose or line which is attached to 29 (but not shown in the drawing) and the packer inflated with compressed air or other fluid. The filling hose is then detached and the packer will remain inflated because of the check valve 30. If desired, grout can then be poured in to complete the isolation of water table 3.

Packer 11 and sounding tube 8 are installed in a similar fashion to isolate table 2, and a sounding tube 7 is run to table 1. The sounding tubes can be braced and aligned at the surface in any suitable manner. This assembly is now completed and can be used to sound the water levels of the various tables. Water collected in the isolated sections during installation of the sounding tubes and packers will soon assume the same level as the water in the respective table.

A convenient way to ascertain the elevation of the water in the various water tables thereby isolated is to lower a calibrated sounding line down the sounding tubes until contact is made with the water and measuring the length of sounding line required to reach to the water level. These procedures are well known to persons skilled in this art. A presently preferred sounding line is one which will indicate contact with the water level by closing an electrical circuit which is coupled through the sounding line to suitable means at the surface which will indicate the completion of the circuit.

From the foregoing description and drawings it is apparent that an economical method of surveying a plurality of fluid bearing strata through a single drill hole has been provided together with a new type of drill hole packer assembly.

Since many widely differing embodiments of this invention will occur to one skilled in the art, the invention is not limited to the specific details illustrated and described and various changes can be made therein without departing from the spirit and scope thereof.

What is claimed is:

1. The method of surveying a plurality of subterranean fluid horizons through a single drill hole which comprises drilling a hole in the earth to the maximum depth to be surveyed; inserting

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in said drill hole a plurality of sounding tubes, one for each horizon, each of said tubes approximately equal in length to the maximum depth of its horizon; isolating each of said horizons from one another; and sounding through said tubes to determine the liquid elevation of the horizons.

2. The method of surveying a plurality of subterranean fluid horizons through a single drill hole which comprises drilling a bore hole to the maximum depth desired to be surveyed; establishing the levels at which the fluid strata occur; installing packers and sounding tubes between each of said strata which isolate the lower stratum from the strata above and which provide an open access from the surface to the isolated stratum without allowing a comingling of the fluids of the various strata; and sounding each of said isolated strata through said open accesses.

3. A drill hole assembly for isolating and surveying a plurality of subterranean fluid horizons through a single drill hole comprising a plurality of parallel sounding tubes of different lengths adapted to occupy a portion of said drill hole, each of said sounding tubes corresponding in length to the maximum depth of a horizon to be surveyed, a packing member for each sounding tube, each packing member being affixed to its respective sounding tube between the lower end thereof and the end of the next shortest sounding tube, each of said packing members above the lowest in the series being provided with means to permit the passage of the longer sounding tubes for surveying the lower horizons.

4. The drill hole assembly of claim-3 wherein each packer member comprises end plates joined to its respective sounding tube by a gas tight connection, and an elastic tube of gas impervious material joining said end plates around the sounding tube.

5. A drill hole assembly for isolating and surveying a plurality of subterranean fluid horizons through a single drill hole comprising a plurality of parallel sounding tubes of different lengths adapted to occupy a portion of said drill hole, each of said sounding tubes corresponding in length to the maximum depth of a horizon to be surveyed, and a drill hole packer for each sounding tube including an elastic gas impervious tube and end closure members therefor, the end closure members of each packer being affixed to its respective sounding tube between the lower end thereof and the end of the next shortest sounding tube, each of said packing members being provided with at least one tube between the end closure members for permitting passage of other of the sounding tubes, and each of said packers being provided with means for introducing and confining a compressed gas for expanding said elastic tube.

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