March 22, 1932. J. J. JAKOSKY 1,850,399

APPARATUS FOR INDICATING EXCESSIVE DEVIATION OF DRILL HOLES FROM THE VERTICAL

Filed March 11, 1929 5 Sheets-Sheet 1

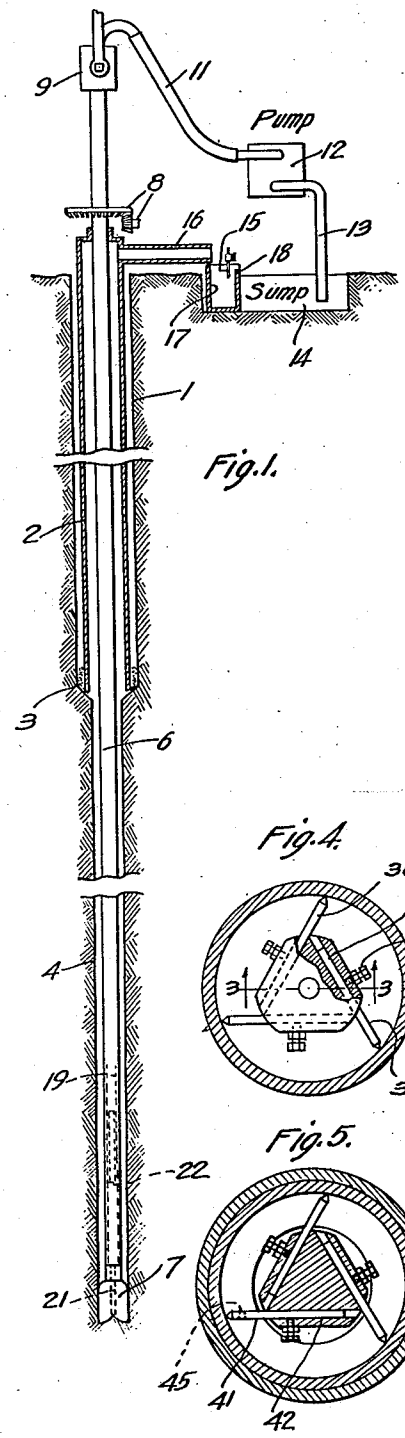


Fig. 1.

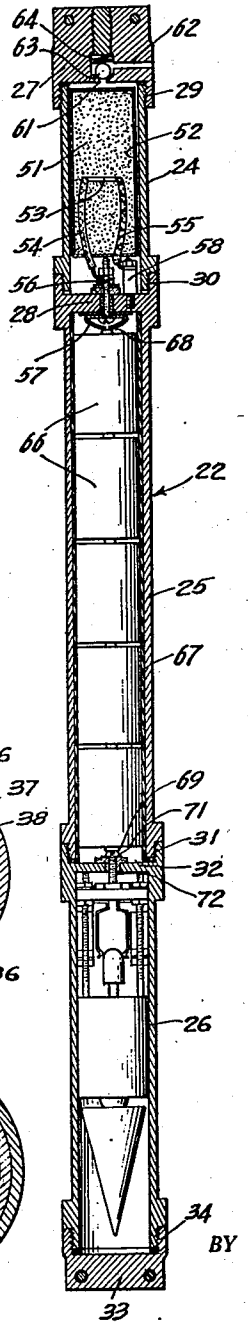


Fig. 3.

Fig. 4.

Fig. 5.

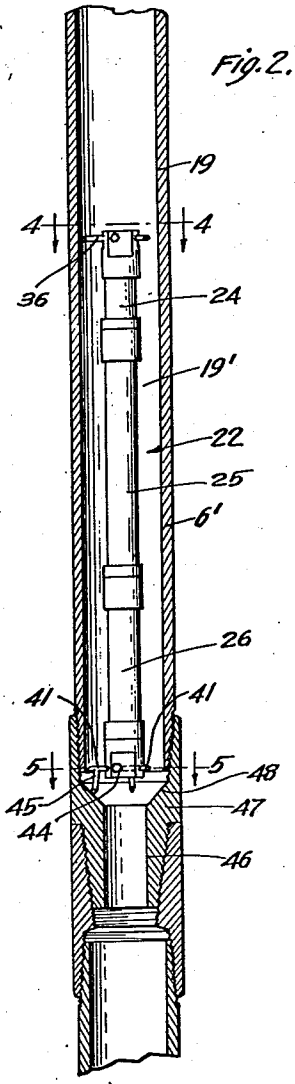


Fig. 2.

INVENTOR.
John J. Jakosky.
BY Arthur P. Knight and Alfred W. Knight
ATTORNEYS

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Fig.6.

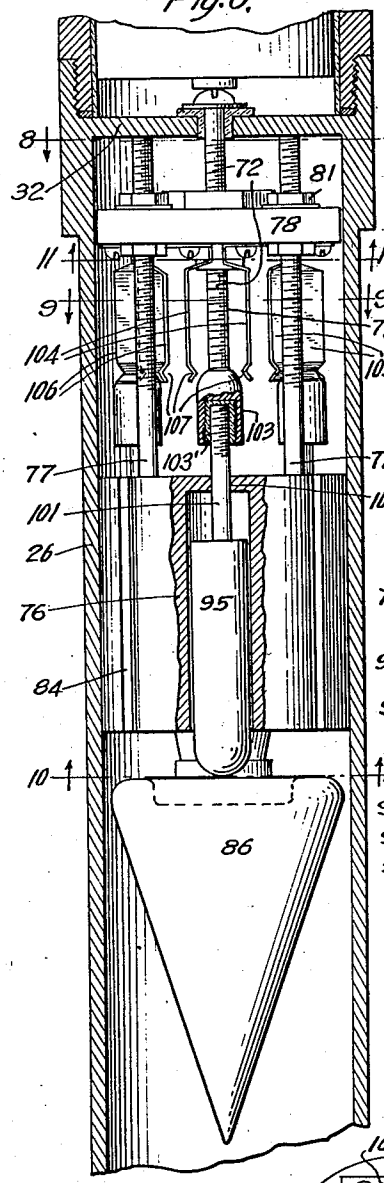


Fig.7.

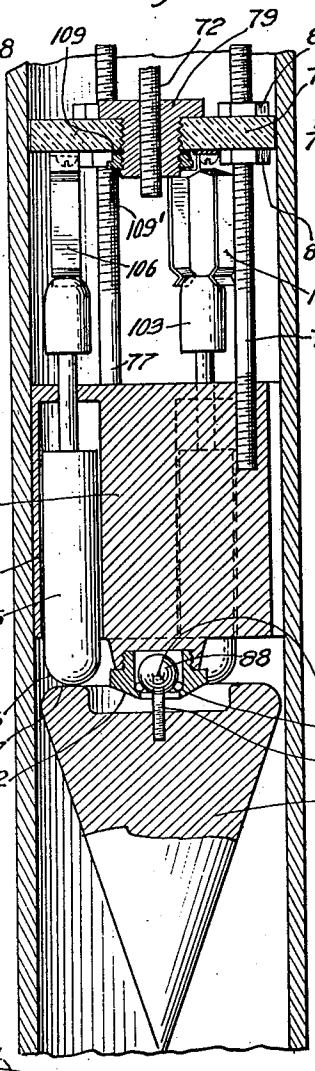


Fig.8.

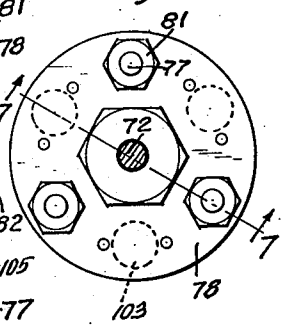


Fig.9.

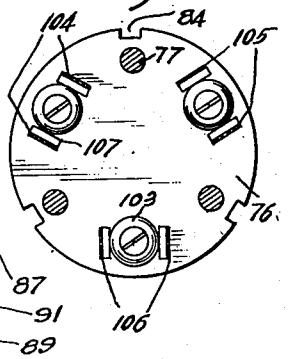


Fig.10.

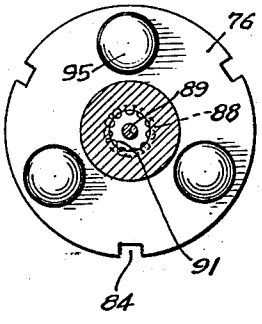
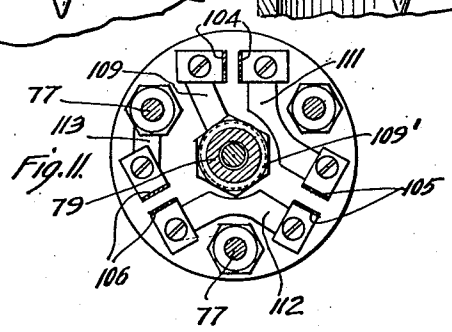


Fig.11.



INVENTOR.
John J. Jakosky,
BY Arthur P. Knight and Alfred W. Knight
ATTORNEYS

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Fig. 12.

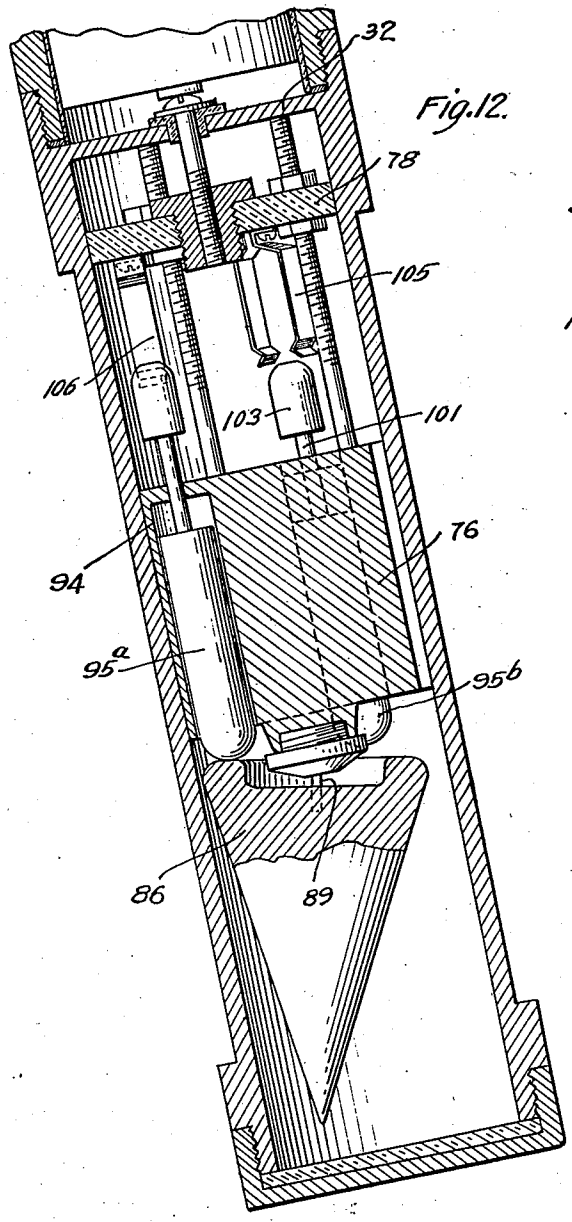
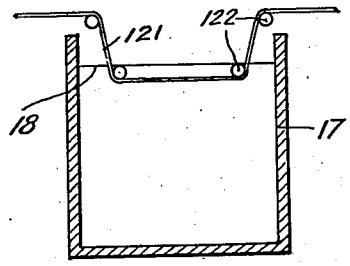


Fig. 13.



INVENTOR.
John J. Jakosky,
BY Arthur P. Knight and
Alfred W. Knight
ATTORNEYS

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APPARATUS FOR INDICATING EXCESSIVE DEVIATION OF DRILL HOLES FROM THE VERTICAL

Filed March 11, 1929 5 Sheets-Sheet 4

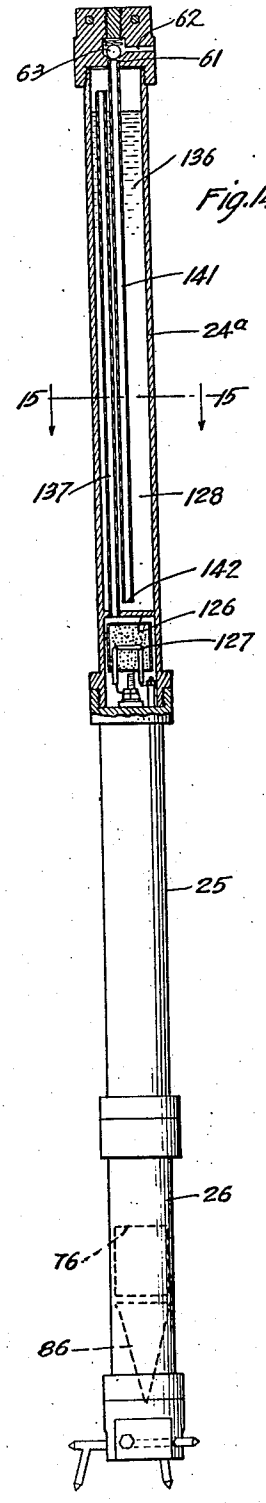
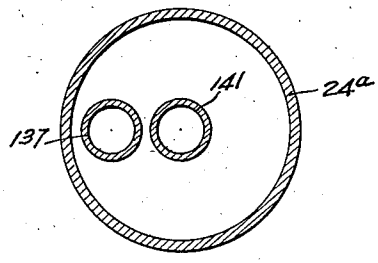


Fig. 14.

Fig. 15.



INVENTOR.
John J. Jakosky,
BY Arthur P. Knight and
Alfred W. Knight
ATTORNEYS

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Fig.16.

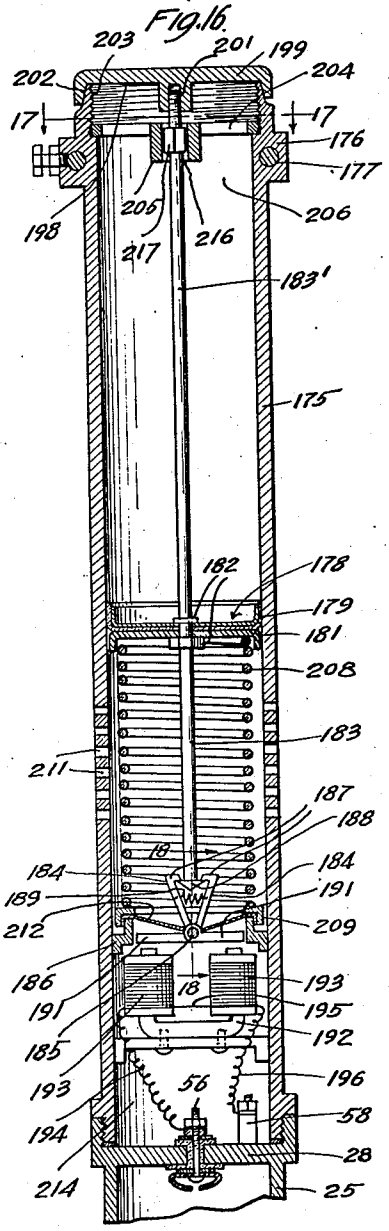


Fig.17.

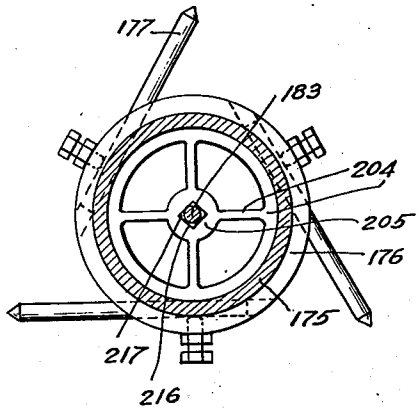
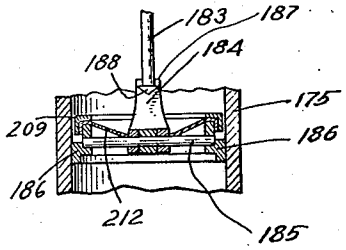


Fig.18.



INVENTOR.
John J. Jakosky.

BY Arthur P. Knight and
Alfred W. Knight
ATTORNEYS

Patented Mar. 22, 1932 1,850,399

UNITED STATES PATENT OFFICE

JOHN J. JAKOSKY, OF LOS ANGELES, CALIFORNIA, ASSIGNOR TO DRILL GUIDE INCORPORATED, OF LOS ANGELES, CALIFORNIA, A CORPORATION OF NEVADA

APPARATUS FOR INDICATING EXCESSIVE DEVIATION OF DRILL HOLES FROM THE VERTICAL

Application filed March 11, 1929. Serial No. 346,223.

This invention relates to the drilling of bore holes, and particularly oil wells, and diamond drill holes, and the principal object thereof is to provide for giving a warning signal or indication, at the surface, whenever the angular deviation of the hole from the vertical, in any direction, exceeds a certain allowable limit.

In the rotary drilling of oil wells, diamond drill holes, or other holes into the earth, inclined structures, or masses of varying hardnesses and physical characteristics, are often encountered, and these or other reasons frequently cause the drill to be deflected from its initial vertically downward direction, thus causing the hole to deviate from the vertical, and in many cases this deviation has been found to continually increase with continued drilling, to a very undesirable extent. In an article in the Oil and Gas Journal, August 23, 1928, page 30, the following are included as some of the more important causes for crooked holes in oil well drilling operations:

"1. Excessive weight on drill bit.
2. Too rapid drilling.
3. Flexure of drill pipe caused by excessive weight.
4. Caving formations allowing excessive flexure of drill pipe.
5. Poor alignment in starting hole.
6. Bent or kinked drill pipe.
7. Unsymmetrical bits.
8. Dip, faulting, and fracturing of strata.
9. Changes in character of formations from soft to hard and hard to soft."

A further condition which has frequently been assigned as a cause of crooked holes is the excessive use of circulating fluid, leading to "hydraulicing", that is, to erosion of the hole by the high velocity of the fluid, so that the hole becomes larger than the bit and allows the bit to "wobble" or the drill pipe to flex.

Many oil well holes, because of such deviation, either enter the productive sands at points far to one side of their original goals, or entirely fail to strike these sands. Furthermore, a well started on one owner's property may deviate to such an extent as to strike the oil sands at a point directly beneath the property of some one else instead of beneath the property on which it was started, thus seriously impairing the production of another well properly belonging to the other property. Another disadvantage of this deviation is that it not only makes further drilling operations more difficult but also interferes to a considerable extent with the subsequent pumping operations.

In the above mentioned article in the Oil and Gas Journal the disadvantages resulting from crooked holes are divided into drilling troubles and production troubles. The list of drilling troubles there enumerated includes the following:

"1. Excessive depreciation of drill pipe caused by crystallization, and permanent bending and kinking of pipe. Some contractors make it a practice to use new drill pipe on every fifth hole.
2. Twisting off of drill pipe.
3. Costly fishing jobs.
4. Difficulties of fishing jobs increased by crooked holes.
5. Loss of drilling time on account of troubles here cited.
6. Sidetracking jobs.
7. Crookedness of holes increased by sidetracking jobs.
8. Difficulties in running casing in crooked holes.
9. Damage to casing caused by flexure.
10. Difficult or impossible to finish some rotary holes with cable tools.
11. In extreme cases, impossible to run cable tools through casing in crooked holes.
12. Loss of circulation through other holes where wells drift close together.
13. Line cutting of casing, especially in combination drilling.
14. Excessive wear upon drilling lines in combination drilling.
15. Collapsing of casing due to line cutting and unequally distributed stresses caused by casing flexures.
16. Excessive consumption of power because of increased friction.
17. Cost of drilling unnecessary footage due to extra length of crooked holes.

18. Time lost in drilling extra footage caused by crooked holes.

19. Damage to neighboring wells, or from neighboring wells, caused by actual intersection or through accidental mudding or cementing of one well by another. The frequently reported migration of mud fluid from one well to another is undoubtedly due to wells drifting close together in many cases.

20. Abandonment of holes caused principally by unsuccessful fishing jobs, holes drifting off structure or becoming too crooked to use and the chance intersection of one hole by another so that one of them must be abandoned.

21. Difficulty of subsurface correlations, especially in determining where to set casing to make proper water shut offs."

The production troubles enumerated by the same writer are as follows:

"1. Inadequate and misleading subsurface information.

2. Well spacing and surface locations lose their significance from a subsurface point of view.

3. Inadequate testing and drainage of productive sands.

4. Excessive wear and failure of sucker rods.

5. Rod cutting of tubing.

6. Excessive wear of pump plungers.

7. Difficulties in getting plunger to enter working barrel except where insert barrels are used.

8. Difficulty in properly counterbalancing the pump equipment in crooked holes.

9. Difficulties in swabbing caused by casing flexures and line cutting.

10. Excessive power consumption caused by friction losses in pumping wells.

11. Difficulty in running tubing catches.

12. Accentuation of fishing troubles, especially in the loss of time in recovering broken rods or parted tubing."

Means have been proposed for determining the course of an oil well or other bore hole after the same has been completed, by lowering suitable deviation indicating or recording instruments therein, but the great disadvantage of all the devices heretofore proposed is that they do not give an indication of the deviation until all the harm is done. If a dangerous or undesirable deviation, or a departure from the proper position at the depth of the oil sands, is found in a well which has been already drilled, it is necessary to re-drill the entire hole from the point at which the excessive deviation begins, this being ordinarily done by cementing the hole at this point, for a sufficient height, so that upon re-drilling through the cement, a new and straighter course will be followed. Needless to say, such operations are not only expensive in themselves, but represent a still greater loss due to the delay in starting the well into regular production.

It has been found, however, that if the deviation can be detected at its inception, or before it exceeds a reasonable allowable angle, the hole may be straightened with comparative ease, by simply raising the drill a little distance and slowly re-drilling the part of the hole at which the excessive deviation began. The object of my invention, therefore, is to provide for ready detection of any excessive deviation, during the drilling operation, so as to permit the operator to take proper steps to eliminate it before the drilling has proceeded very far in the wrong direction. The amount of re-drilling may thus be reduced to a minimum, and the completion of a reasonably straight hole within the shortest possible time is made possible, in addition to insuring that the hole will strike the oil sands approximately at the point intended. The possibility of having to completely re-drill the major portion of the hole is thus eliminated.

My invention is particularly adapted for use in connection with rotary drilling operations, as distinguished from the "cable-tool" or "churn" method. In the rotary method of drilling, a suitable bit is mounted at the bottom of a string of drill-pipe extending to the bottom of the hole, and the pipe and bit are slowly rotated by means of a rotary device connected to the drill pipe above the surface. A continual circulation of fluid, commonly known as "rotary mud", is maintained through the hole, this mud being prepared by mixing a suitable clay with water to the proper consistency. The mud so prepared is pumped down through the central opening of the drill pipe and out through holes in the bit, at sufficient pressure to cause it to flow back up through the hole and around the drill pipe, to the surface, where it is collected and re-utilized. According to my present invention the circulating fluid itself is utilized as a means of communicating to the surface an indication of any excessive deviation of the hole from the vertical, and the fundamental idea of the invention consists in so acting on the circulating fluid at a point adjacent the lower end of the hole, whenever the deviation thereof from the vertical exceeds a certain amount, as to give an indication of such excessive deviation in the circulating fluid at the surface.

An advantageous method of detecting or indicating excessive deviations of the hole, according to my invention, comprises providing a charge of indicating agent adjacent the drill bit, or adjacent the lower end of the drill pipe, and causing a quantity or charge of such agent to be delivered to the circulating fluid or mud, at the bottom of the hole, whenever the deviation thereof from the vertical exceeds a certain allowable angle, such

agent having suitable properties by which its presence in the circulating fluid can be readily detected, either visually or by other direct indication, or through the agency of suitable indicating means, upon the return of the fluid to the surface. As only a short period of time is required for the mud to pass from the bottom of the hole to the top, it will be seen that this provides a simple means of giving an indication at the surface of any excessive deviation before such deviation has progressed very far.

The indicating agent may, for example, comprise a dye or coloring agent of high intensity, in which case its presence in the fluid can be detected visually, or by use of suitable indicating means, such as a mordant, immersed in the circulating fluid and adapted to "fix" the dye; or a substance having a characteristic strong odor, or adapted to react with water to form a gas having a strong odor; or it may comprise a salt or electrolyte adapted to influence the electrical conductivity or other property of the mud, and the resulting variation in conductivity or other property may be detected or indicated by any suitable means. Another form of indicating agent comprises a substance having a characteristic chemical reaction with a certain testing agent, by means of which its presence in the circulating fluid can readily be detected. It will be understood that the above are only a few of the many examples which will readily suggest themselves, as suitable agents for use in the above method.

Any suitable deviation-responsive means may be employed for causing the delivery of the indicating agent to the circulating fluid in case of excessive deviation, but my invention also comprises certain novel and advantageous apparatus for this purpose. Such apparatus comprises essentially a container mounted adjacent the bottom of the drill pipe and containing a suitable charge or quantity of indicating agent, a deviation responsive element, and means controlled by said deviation responsive element for releasing or delivering said agent from said container into the circulating fluid whenever the deviation of the hole from the vertical exceeds a certain allowable angle.

In a preferred form of such apparatus, the deviation responsive element comprises a weight or bob supported within a suitable housing, so as to swing freely about its point of support, which is located above its center of gravity, whereby said weight will always maintain a position with its center of gravity directly beneath said point of support. Means are also provided within the housing and surrounding said weight, so as to be operated by the weight whenever the deviation of the hole exceeds a certain predetermined value, said means being adapted to control the release or delivery of the indicating agent. For example, said control means may comprise electric contact means associated with electrically controlled means for effecting the release or delivery of the indicating agent, and means operable by the weight or bob for closing connection between said contact means.

In order to prevent release of the indicating agent from its container upon accidental momentary relative movement of said weight with respect to the housing, as in case of a swinging movement imparted to said weight due to sudden jarring or vibration, I prefer to provide an arrangement, as hereinafter described, whereby relative deflection of said weight from the direction of the axis of the hole must be maintained for a certain period of time, or during one or more complete revolutions of the drill pipe and bit, before delivery of the indicating agent will be effected.

More specifically, the preferred form of my deviation detecting apparatus comprises a weight or bob supported as above described, and a plurality of circuit closing elements, disposed about said weight and normally in open-circuit position, but movable to circuit closing position upon successive operation thereof by said weight during one or more revolutions of said device (due to rotation of the drill pipe when in non-vertical position). The contact means of all the circuit closing elements are connected in series in a control circuit, so that upon movement of all of said elements to circuit closing position said circuit is completed. Completion of this circuit then acts in any suitable manner to cause release or delivery of the indicating agent from its container.

The above described apparatus, including the container for the indicating agent, and the means for effecting delivery thereof to the circulating fluid, in case of excessive deviation, is preferably mounted inside the drill pipe in such manner as to leave room for passage of the circulating fluid around the same. This insures substantial alignment of the apparatus with the drill pipe at all times, protects the apparatus from damage by contact with objects outside the drill pipe, and permits ready discharge of the indicating agent into the stream of circulating fluid.

The accompanying drawings illustrate apparatus embodying the above principles, and the method in which the invention is carried out, using such apparatus, but it is to be understood that the specific forms of apparatus shown are by way of examples only, and that many modifications may be made therein without departing from the spirit and scope of my invention.

Referring to the drawings, Fig. 1 is a vertical section of a bore hole with a rotary drilling apparatus in place therein, and provided with means according to my invention for

indicating excessive deviation of the bore hole from the vertical.

Fig. 2 is a vertical section of a portion of the drill pipe adjacent the lower end thereof, with a deviation detecting apparatus mounted therein.

Fig. 3 is a vertical section of the deviation detecting apparatus shown in Fig. 2, taken on line 3—3 in Fig. 4.

Fig. 4 is a section on line 4—4 in Fig. 2, the deviation detecting apparatus being shown in plan view.

Fig. 5 is a section on line 5—5 in Fig. 2.

Fig. 6 is an enlarged sectional view of the deviation responsive control element of the apparatus shown in Fig. 3.

Fig. 7 is a vertical section thereof on line 7—7 in Fig. 8.

Fig. 8 is a horizontal section on line 8—8 in Fig. 6, with the exterior casing 26 omitted.

Fig. 9 is a horizontal section on line 9—9 in Fig. 6, with the exterior casing 26 omitted.

Fig. 10 is an inverted horizontal section on line 10—10 in Fig. 6, with the exterior casing 26 omitted.

Fig. 11 is a sectional view of the structure shown in Fig. 6 taken along the line 11—11 looking in the direction indicated, with the exterior casing 26 omitted.

Fig. 12 is a view similar to Fig. 7 but showing the device in a tilted position, so as to illustrate the action thereof.

Fig. 13 is a vertical section of the receptacle for receiving the fluid upon its return to the surface, showing an advantageous means for indicating the presence of an indicating agent in the fluid.

Fig. 14 is a partly sectional side elevation of an apparatus having a modified form of means for effecting delivery of the indicating agent.

Fig. 15 is a section on lines 15—15 in Fig. 14.

Fig. 16 is a vertical section of the upper section of a detecting apparatus, showing another means of effecting delivery of the indicating agent.

Fig. 17 is a section on line 17—17 in Fig. 16.

Fig. 18 is a section on line 18—18 in Fig. 16.

Referring to Fig. 1, a bore hole is shown, comprising an upper portion 1 of relatively large diameter provided with a string of casing 2 cemented off at its lower end in the usual manner as shown at 3, and a lower portion 4 of somewhat smaller diameter. The pump is shown as comprising a string of rotary drill pipe 6 having a bit 7 at the lower end thereof and provided at its upper end with bevel gear means 8 for effecting rotation thereof at any usual or suitable speed. The upper end of the drill pipe is connected through the usual swivel 9 and flexible hose 11 to a pump 12 whose inlet pipe 13 leads to a sump or other storage means 14 in which is provided a supply of mud or fluid of proper consistency for circulation through the pump. From the upper end of casing 2, a pipe 16 leads to storage means 14, and in order to facilitate detection of the presence of an indicating agent in the fluid delivered through said pipe, I prefer to provide a separate receptacle 17 in position to receive the fluid discharged from said pipe. From said separate receptacle the fluid may pass in any suitable manner to the main storage means, as by overflowing a weir 18. Means, such as indicated at 15, may be provided in receptacle 17 for indicating the presence of the indicating agent in the fluid. It will be understood, of course, that the drill pipe is provided with an internal passage for downflow of fluid throughout its entire length, the lower portion of said passage being indicated in dotted lines at 19, and the drill bit 7 is provided with one or more passages 21 communicating with the lower end of passage 19 for permitting outflow of fluid adjacent the cutting edges or faces of the bit.

According to my invention a deviation detecting apparatus 22 is mounted adjacent the bit or the lower portion of the drill pipe, and said apparatus is preferably mounted within the interior passage 19 of the drill pipe and as near the lower end thereof as is convenient, for example in the position indicated in dotted lines in Fig. 1.

The deviation detecting apparatus 22 is shown as comprising a housing formed of three sections of tubing 24, 25 and 26. The upper section 24 serves as a container for the indicating agent and is provided with suitable electrically controlled means for causing delivery of said indicating agent therefrom upon completion of the control circuit. The intermediate section 25 contains the source of electric power for said control circuit, while the lowermost section 26 contains the deviation responsive means for causing completion of said control circuit whenever the axis of the detecting apparatus, during rotation of the drill pipe, deviates from the vertical beyond a certain angle, due to deviation of the bore hole. The upper housing section 24 is provided with a cap member 27 threadedly mounted or otherwise tightly secured thereon as at 29, and is threadedly connected or otherwise tightly secured at its lower end to the upper end of the intermediate section 25, as at 30. An end wall 28 is preferably provided at the upper end of section 25, so as to serve as a partition between the interiors of the upper and intermediate sections. The intermediate casing section 25 is in turn threadedly connected or otherwise tightly secured at its lower end to the upper end of the lower section 26, as shown at 31, and an end wall 32 is also preferably provided at the upper end of the lower section, so as to serve as a partition between the lower and intermediate sections.

A closure member 33 is threadedly mounted or otherwise tightly secured to the lower end of the lower section 26, as shown at 34.

The detecting apparatus may be mounted within the drill pipe in any suitable manner so as to maintain the same in substantially rigid position therein and with its axis in substantial alignment with the axis of the drill pipe. The external diameter of the housing of the detecting apparatus is somewhat smaller than the internal diameter of the drill pipe, so that it may be mounted in the passage 19 of the drill pipe without completely filling the same, thus leaving an annular space around the apparatus, as indicated at 19′ in Fig. 2, for passage of the rotary mud past the apparatus. An advantageous form of means for rigidly mounting the detecting apparatus in proper position in the drill pipe is illustrated in Figs. 2, 4 and 5. Such means may comprise a plurality of centering arms or members 36 preferably pointed at their outer ends and slidably mounted in recesses 37 in cap member 27 so as to be adjustable inwardly or outwardly, and provided with means such as set screws 38 for holding the same in any position of adjustment, and a plurality of centering and supporting arms or members 41 preferably pointed at their outer ends and similarly mounted in recesses 42 in the lower closure member 33 and provided with means such as set screws 44 for holding them in adjusted position, said arms 41 also having downwardly extending portions or branches 45 preferably pointed at their lower ends. In mounting the apparatus in the drill pipe, the centering arms 36 at the upper end thereof may be first adjusted so as to make a tight sliding fit with the inside of the drill pipe, and the apparatus may then be inserted upwardly into the lower end of a "joint" or section of drill pipe such as indicated at 6′. The supporting arms 41 are also adjusted so that their outer extremities also make a tight sliding fit inside the pipe and so that their downwardly projections 45 will rest upon a suitable part of the tool joint which is to be secured to the lower end of this joint of drill pipe, in case the arms 36 and 41 should not engage the side walls tightly enough to prevent the apparatus from slipping downwardly in the pipe. For example, in Fig. 2 the "pin" member 47 of the usual tool joint is shown as secured to the lower end of pipe 6′, and the supporting arms 41 are shown as resting upon the bevelled internal face portion 48 thereof. The purpose of the downward projections 45 on arms 41 is to make certain that, in case the apparatus should slip downwardly in the pipe, it will be arrested upon engagement of said projections with the bevelled portion 48 or other portion of the tool joint and while the lower end of the apparatus is still sufficiently above the opening 46 through the tool joint to permit free flow of fluid beneath the bottom of the apparatus and into said opening. Clogging of this opening is thus prevented, as it will be seen that, whether the arms 36 and 41 engage the inside of the pipe tightly enough to hold the apparatus in the position in which it is first placed in the pipe, or whether it is initially placed, or subsequently falls to, the position shown in Fig. 2, said arms will cause the axis of the apparatus to be at all times in alignment with the axis of the drill pipe and will also exert sufficient frictional force to cause the detecting apparatus to rotate with the drill pipe.

For use in the form of apparatus shown in Fig. 3, the indicating agent, such as iodine or a dye, in dry finely divided form, may be placed in the interior of the upper casing section 24 of the detecting apparatus. Such indicating agent is preferably volatile and may be intimately admixed with a suitable combustible material, such as a slow burning powder, the mixture of slow burning powder and indicating agent, shown at 51, being advantageously contained in a container 52 formed of paper, cardboard, or other suitable material, removably inserted within the upper section 24. An igniting fuse 53 is embedded within the mixture 51 and is provided with conducting leads 54 and 55 extending out through the lower end of container 52. One of said leads, such as 54 may be connected to binding post 56 extending centrally through and insulated from the end wall 28 of the intermediate casing section 25 and provided at its lower end with spring contact means 57, while the other lead 55 may be connected to a binding post 58 mounted upon end wall 28 and making an electrical connection therewith. The wall of container 52 is preferably sufficiently thin to permit rupture thereof by the pressure generated upon ignition of the contents of said container. The cap member 27 is provided with passages 61 and 62 leading from the interior thereof to the outside, and a check valve 63 is provided between said passages for preventing entrance of mud or other material from the outside into the interior thereof. A light coil spring 64 may be provided if desired for normally holding the check valve in closed position when the apparatus is not in use, it being understood that when in position in the bore hole during the drilling operation. The pressure prevailing within the drill pipe will be sufficient to tightly hold said valve closed.

The source of electric current, located in the intermediate casing section 25, may advantageously comprise, as shown, a suitable number of small dry cells 66 such as are commonly used in pocket flash lights, placed end to end therein with their terminals in contact. The number of said dry cells should be sufficient to produce sufficient current through

the igniting fuse 53 to cause said fuse to function. A sleeve 67 of insulating material may be provided between said dry cells and the walls of casing section 25. The upper terminal 68 of the series of dry cells makes contact with the spring contact means 57 while the lowermost terminal 69 thereof makes contact with the head 71 of a binding post screw 72 extending centrally through and insulated from the top wall 32 of the lowermost section 36.

The deviation responsive circuit-controlling means mounted in the lowermost section 26 of the apparatus is shown as comprising a cylindrical body member 76 supported by threaded rods 77 from an insulating support 78 consisting, for example, of a disc or plate of bakelite or other suitable material, said insulating support being in turn supported by the binding post screw 72 aforesaid, which may be threaded into a metal bushing 79 secured centrally of said insulating support. The threaded rods 77 extend through the insulating support 78 and are provided with adjustable clamping nuts 81 and 82 above and below said insulating support, whereby the vertical position of said insulating support relative to rods 77 and body portion 76 may be adjusted. It will be seen that when the binding post screw 72 is screwed tightly into bushing 79, the upper ends of rods 77 are caused to bear against the top wall 32 so as to hold the parts above mentioned in rigid position and to also establish electrical connection of rods 77 to said wall 32 and hence to the entire metallic casing. The body member 76 preferably makes a snug fit with the inside of the casing section 26 so as to further assist in holding the parts firmly in position. Said body member, however, may be provided with vertical grooves 84, so as to permit free displacement of liquid from one side of said member to the other when inserting the same into the casing section or when vertically adjusting the same.

A weight or bob 86 is supported beneath the body member 76 in such manner as to permit free movement thereof in any direction about a point of support indicated at 87, said point of support being located above the center of gravity of said weight, so as to cause said weight to always assume a position with its center of gravity directly below said point of support. Said weight may be supported, for example, by means of a ball 88 connected thereto by pin 89, said ball resting in turn upon ball bearings indicated at 91 mounted in a retaining member 92 secured to the bottom of body member 76. An important function of the ball bearings 91 is to minimize the tendency for the weight 86 to be rotated with the rest of the apparatus, upon rotation of the drill pipe, and thus prevent a gyroscopic action or a swinging of the weight about its point of support such as might occur if the weight were caused to whirl rapidly upon rapid rotation of the drill pipe. By supporting the ball 88 upon the ball bearings 91, the frictional force exerted upon ball 88 is so reduced that the inertia of weight 86 will be sufficient to cause the same to remain substantially stationary regardless of rotation of the rest of the apparatus.

The body member 76 is provided with a plurality of cylindrical chambers 94 open at their lower ends, in which are slidably mounted plungers 95 which are preferably rounded at their lower ends as shown at 96 and which rest on the upper face 97 of weight 86. Suitable means are provided for permitting flow of fluid into or out of cylinders 94 above the plungers 95. For this purpose the plungers 95 may be made to fit loosely in said cylinders so as to permit flow of fluid between the plungers and the walls of the cylinders. In the particular construction shown I have provided three cylinders and plungers, but it will be understood that any desired number thereof may be provided. Each of the plungers 95 is provided with a rod or stem 101 extending upwardly through a reduced opening 102 in the body member 76 and provided at its upper end with a knob or head 103 threadedly mounted or otherwise secured thereon. Each plunger 95 with its knob 103 constitutes a circuit closing member. The circuit closing knobs 103 are electrically insulated from one another in any suitable manner, as for example, by means of insulating sleeves 103′ between said knobs and the respective rods 101, as shown in Fig. 6.

On the lower side of the insulating support 78 are mounted a plurality of pairs of contact members, the number of said pairs of contact members corresponding to the number of circuit closing members. In this case I have shown three such pairs of contact members indicated at 104, 105 and 106 respectively. Each of said contact members is formed as a resilient downwardly extending arm, and the arms of each pair are provided at their lower ends with portions such as indicated at 107 disposed at opposite sides of one of the circuit closing knobs 103 and somewhat above the same when the device is in vertical position, but adapted to be engaged by said circuit closing member upon raising of the corresponding plunger due to deviation of the device from the vertical. All of the pairs of contact members above described are connected in series in the electric control circuit. For this purpose the metal bushing 79 of binding post 72 is shown as connected by a conducting member such as a thin metal strip 109, secured thereto by nut 109′, to one of the contact members 104, while conducting members such as metal strips 111 and 112 establish connection between the other contact member 104 and one of the contact members 105 and between the other contact member

105 and one of the contact members 106 respectively. The other contact member 106 is connected by conducting strip 113 to one of the rods 77. As above stated, said rod is in electrical contact with the top wall 32 of the section of the casing, so that an electrical connection to the wall of the casing is thus provided.

The interior of casing section 26 is preferably entirely filled with a liquid, such as a substantially non-conducting oil, which serves not only to lubricate all of the parts and insure free movement thereof, as well as to prevent sparking at the contact points, but also interposes a certain resistance to displacement from the cylinders 94 upon application of a lifting force to the plungers by relative movement of weight 86, in case of deviation of the device from the vertical.

The manner in which the above described apparatus operates to give an indication of excessive deviation of the bore hole from the vertical is as follows: With the device in position in the drill pipe, the drilling operation proceeds in the usual manner, accompanied by a continual circulation of rotary mud or fluid from sump 14, through pipe 13, pump 12, flexible hose 11, swivel 9, thence downwardly in the internal passage 19 of the drill pipe and around the detecting device 22, out through the passage means 21 in the bit, then upwardly through the bore hole 4 and casing 2 and finally through pipe 16 to the receptacle 17, whence it overflows into the main body of mud in the sump. So long as the bore hole remains substantially vertical, or does not deviate from the vertical beyond a certain allowable angle, the electric control circuit remains broken between the contact members above described.

However, in case of deviation of the bore hole from the vertical, the drill pipe, and hence the detecting device located therein, will also deviate from the vertical, as indicated, for example, in Fig. 12, and as the weight 86 tends to always maintain a vertical position, that is to say, with its center of gravity directly beneath its point of support 87, a lifting force will be exerted by said weight upon each of the plungers 95 when it reaches a position, such as indicated at 95*a* in Fig. 12, during rotation of the device, and as the device is continually rotated with the drill pipe, such lifting force will be exerted in turn upon each of said plungers. Upward movement of said plungers, however, is resisted by the liquid contained in the cylinders 94 above the plungers, and the rate of such upward movement is determined by the rate at which liquid can escape from said cylinders around the plungers. The clearance provided around said plungers is preferably so designed, in relation to the upward force exerted thereon, that an appreciable time will be required to move any one of the plungers upwardly far enough to close the circuit between the corresponding contact members, so that a single or momentary upward force or impulse delivered to said plungers, as in case of accidental swinging or vibration of the weight, will be insufficient to effect such lifting of the plungers. However, in case of actual deviation of the drill pipe and the detecting device from the vertical, during the drilling operation, each plunger is subjected to a lifting action at each rotation of the drill pipe, and as the mass of weight 86 is relatively large in proportion to the mass of each individual plunger 95, each plunger will be unable to return by its own weight to its original position during a rotation of the drill pipe and between successive upward impulses, but will remain in raised position, as shown, for example, at 95*b*, so that eventually all of the plungers will be raised to such position that the circuit closing knobs 103 thereof engage the portions 107 of the corresponding contact members, thus closing all of the normally open breaks in the control circuit.

When the control circuit is completed as above described, electric current will pass through the ignition fuse 53, through the following circuit: from the bottom terminal 69 of the dry cells 66, through binding post 72, bushing 79, conductor 109, contact members 104 and the circuit controlling member 103 therebetween, conductor 111, contact members 105 and the circuit closing member therebetween, conductor 112, contact members 106 and the circuit closing member therebetween, conductor 113, rod 77, and wall 32, thence upwardly through the wall of the casing sections 26 and 25 to binding post 58 and through lead 55, fuse 53, lead 54, binding post 56 and contact means 57, back to the upper terminal 68 of the dry cells. Fuse 53 will thereupon ignite the combustible constituent of the mixture 51 which will burn, heating the indicating agent contained in said mixture sufficiently to volatilize the same. The pressure generated by the gas resulting from combustion of the powder, and by vaporization of the indicating agent, will be sufficient to rupture the container 52 and open check valve 63 against the hydrostatic pressure in the well, so as to permit the indicating agent to pass through passages 61 and 62 into the stream of rotary mud.

The indicating agent need not necessarily be volatile at the pressure existing in the drill pipe and at the temperature produced by combustion of the combustible material. If an indicating agent is employed which is non-volatile under these conditions, it will simply be carried out in finely divided form with the outflowing combustion gases, into the circulating fluid, and will become dissolved therein.

The fluid, laden with iodine or other indi-

cating agent, then passes out into the hole and upwardly therein, and hence into receptacle 17, where its presence may be indicated or detected in any suitable manner. For example, when iodine is used as an indicating agent, the indicating means 15 may comprise a rod containing insoluble starch. When the iodine-laden portion of the mud passes said rod it will take on the characteristic deep blue or black color produced by solution of the iodine in the starch. If a dye is used as indicating agent, the indicating means 15 may be made of or contain a mordant, such as aluminum hydroxide, which will remove such dye from solution in the circulating fluid, forming a "lake", and the presence of even a small concentration of dye in the fluid will cause a cumulative coloring of the indicating means. A readily perceptible indication is thus given, at the surface, that the hole is beginning to deviate excessively from the vertical, and steps may immediately be taken to correct such deviation, before it has progressed to such a point as to make such correction difficult or expensive.

The amount of indicating agent delivered to the fluid at any one operation of the device is preferably sufficient to affect only a portion of the entire quantity of fluid in the system, so that while its concentration in this portion, upon its first passage through receptacle 17, is sufficient to be readily detectable, for example by the means above described, yet when distributed throughout the entire quantity of fluid its concentration becomes insufficient to be so detected. Therefore, the same fluid may continue to be used, and after it has once circulated and become thoroughly re-mixed, there will be no visible or appreciable evidence of the presence of the indicating agent therein, until the device, having been re-loaded meanwhile with a fresn charge of indicating agent, again operates to deliver the same to the circulating fluid.

If desired, however, after an indication has been received, the indicating agent may be rendered ineffective by destroying or neutralizing the same by addition of a suitable reagent to the fluid. For example, if iodine is used, it may be removed by addition of a suitable reducing agent, such as sodium thiosulphate, or, if a basic dye is used, it may be neutralized with acid. In any case, the reagent may be added in sufficient amount to substantially destroy the effectiveness of the indicating agent for further indicating purposes.

A particularly advantageous form of means for indicating, and in fact recording, the presence of an indicating agent such as iodine or dye in the circulating fluid, is shown in Fig. 13. Such means comprises a tape or ribbon 121, formed of paper, fabric, or other flexible material, impregnated with starch in the case of iodine, or with a mordant in the case of a dye, and passed in any suitable manner over rollers 122, so disposed that a portion thereof is always immersed in the fluid in receptacle 17. Said tape or ribbon may be passed at a regular rate through the fluid, and may if desired be marked to indicate the time of passage of each portion thereof through said fluid, so that a lasting record is produced, showing the exact time at which deviation of the hole from the vertical occurred, as indicated by coloration of the tape by iodine or dye delivered to the mud.

A modified form of detecting apparatus is shown in Figs. 14 and 15. In this case the lowermost section 26 and the deviation responsive control means located therein, and the intermediate section 25 with the source of electric current therein, may be substantially the same as above described. The upper section 24*a*, however, is in this case provided with a horizontal partition 126 serving to divide the interior thereof into a lower compartment 127 and an upper compartment 128. The compartment 127 contains a charge of combustible material, such as slow burning powder, indicated at 129, which may be included in the thin walled container 130 and provided with an igniting fuse 131 connected by leads 132 and 133 to the binding posts 56 and 58. The upper compartment 128 contains a quantity of liquid 136 comprising or containing the indicating agent. Said liquid, for example, may consist of a concentrated solution of iodine or of a dye. A pipe 137 is provided opening at its lower end into compartment 127 and extending upwardly to above the liquid level in compartment 128 and opening at its upper end into said compartment above said liquid level. The removable cap 27*a* of this section of the casing is provided as before with passages 61*a* and 62*a* and with a check valve 63*a*, and a pipe 141 is provided leading downwardly from passage 61*a* to near the bottom of compartment 128 and being open at its lower end as at 142.

In the operation of this form of detecting device, the deviation responsive means functions as before to complete the electric control circuit and cause ignition of the combustible material in compartment 127. The gases under pressure resulting from the combustion of this material, pass upwardly through pipe 137 and cause the liquid 136 to be displaced from the upper compartment and to pass through pipe 141 and passages 61*a* and 62*a*, the pressure being sufficient to open check valve 63*a*. The indicating agent is thus delivered as before into the rotary fluid adjacent the lower end of the drill pipe and its presence therein may be detected in any suitable manner, for example as above described, when the portion of the fluid con-

taining such indicating agent reaches the surface.

In addition to the indicating agents above mentioned, many others may also be used. For example, the indicating agent may consist of potassium ferro-cyanide which may be used in dry form in the apparatus shown in Fig. 3, or in solution in the apparatus shown in Fig. 14, and its presence in the circulating fluid may be detected by reaction with a ferric salt, producing the dark blue precipitate known as Prussian blue. For this purpose, the indicating means 15 may consist of, or contain, ferric hydroxide, which, upon contact of fluid therewith containing potassium ferro-cyanide, will take on a deep blue color.

The deviation responsive means above described may be so adjusted as to cause completion of the electric current and hence cause delivery of the indicating agent into the circulating fluid, whenever the deviation from the vertical exceeds any desired predetermined angle. Such adjustment is effected, before the deviation responsive circuit control device is inserted in the casing section 26, by loosening the nuts 81 and 82 on the several rods 77, bringing the insulating support 78 to the desired position relative to said rods, and then tightening said nuts, so as to hold said insulating support in this position. It is evident that the relative positions of these parts determines the angular deviation necessary to effect completion of the electric circuit, for lowering of said insulating support on said rod lowers the contact making portion 107 of the several contact members relative to the respective circuit closing knobs 103, and hence decreases the angular deviation required to effect movement of said circuit closing knobs into engagement with said contact members, while raising of said insulating support produces a reverse effect and increases the angular deviation required to effect closing of the circuit between the several contact members.

Another modified form of means for causing delivery of the indicating agent from the detecting apparatus is illustrated in Figs. 16 and 17. In this case the delivery of the indicating agent is effected by mechanical displacing means whose operation is controlled by the electrical control circuit of the detecting apparatus. The upper casing section 175 of the detecting apparatus is provided adjacent its upper end with a flange or collar 176 in which are mounted the adjustable centering arms 177 which may, for example, be similar to the centering arms 36 of the other form of the invention above described. A plunger 178 is slidably mounted in the casing 175, said plunger being shown as comprising a leather cup 179 making a tight sliding fit with the wall of the casing and a metal disc 181 backing up said leather cup. Said leather cup and disc may be secured, as by clamping members 182, to a vertical rod 183 extending centrally of the casing.

Beneath the lower end of rod 183, a pair of holding arms 184 are pivotally mounted on a shaft 185, said shaft being in turn mounted at its ends on an annular ring or collar 186 secured to casing 175. Said arms are provided at their upper end with inwardly extending lips 187 adapted to engage over the top of an enlarged head 188 on the bottom of rod 183, so as to hold said rod from upward movement. Means such as spring 189 are provided tending to hold arms 184 inwardly in holding position. The respective arms 184 are provided with armature members 191 formed integrally therewith or rigidly secured thereto, said arms extending outwardly over the upper ends of a U-shaped magnetic core member 192, on the arms of which are mounted electromagnetic coils 193. The upper casing section is shown as secured to the upper end of an intermediate casing section 25 as before, in which is provided a battery 66 or other source of current, and electromagnets 193 are connected in series between the binding posts 56 and 58 by wires 194, 195 and 196.

The upper end of the casing section 175 is open as shown at 198 and a removable cap member 199 is mounted upon the open upper end thereof, said cap member fitting thereon in such manner as to be readily removed upon upward movement of plunger 179. Said cap member preferably has a bevelled face 202 engaging a bevelled seat 203 on the casing. The rod 183 may advantageously be continued upwardly above the plunger 178, as shown at 183′, and cap member 199 may be threadedly mounted on the upper end thereof as at 201.

A spider 204 is threadedly mounted in the upper end of casing section 175, the center or hub portion 205 of said spider being provided with an opening 216 of square or other polygonal cross section, adapted to engage a correspondingly shaped portion 217 on shaft 183 when the plunger is in its lowermost position, so as to hold said rod from turning when the cap member 199 is screwed thereon. Said hub portion also serves as a stop for the plunger in its upward movement, and as a guide for rod 183 during such upward movement.

The indicating agent, such as a solution of a dye or other suitable material is placed in the interior of casing section 175 above the plunger 178, as indicated at 206, in sufficient amount to substantially fill said casing to the upper end thereof and leave no gas space therein for compression by the pressure of the surrounding circulating fluid when in position in the well. For effecting upward movement of plunger 178, a compression spring 208 of suitable strength is mounted between the plunger 178 and an annular collar or ring

209. In order to equalize the pressure above and below the plunger, and diminish the force required to move said plunger upwardly and force the indicating agent out of the device, the casing 175 is preferably provided with a plurality of perforations or openings 211 at a level beneath the plunger 178 so as to admit fluid or mud through these openings. The pressure beneath the plunger is, therefore, at all times equal to the pressure outside the device, so that spring 208 need be only of sufficient strength to overcome the force of gravity and lift the plunger 178 and the indicating agent above the same upwardly out of the casing.

I also prefer to provide means for protecting the electromagnets 193 and their armatures 191 from access of circulating fluid. For this purpose a flexible membrane 212 of leather or the like may be secured between collars 209 and 186, said membrane making a snug fit at its center about the hinge portions of arms 184. The space 214 beneath said flexible membrane is also preferably substantially filled with a suitable liquid, such as oil, so as to eliminate air or gas from said space, since if any gas were left in this space it would be compressed by the pressure of the fluid above said membrane, causing undue strain upon said membrane.

In preparing the device for use, the plunger 178, with the cap member 199 removed from the upper end of rod 183, is pressed downwardly, compressing spring 208, until the head 188 at the lower end of said rod passes between lips 187 and is caught beneath the same. The indicating agent is then placed in the space above said plunger, substantially filling the same, and cap member 199 is then secured in place on the upper end of rod 183.

In the operation of this form of delivery means, completion of the electric control circuit will energize electromagnetic coils 193, attracting armatures 191, downwardly against the upper ends of core 192, against the action of spring 189. The lips 187 on arms 184 will thus be moved out of engagement with the enlarged head 188 on rod 183. Said rod is thus released, whereupon spring 208 forces plunger 178 and the charge of indicating agent above the same upwardly out of the upper end of the casing, at the same time raising cap member 199 off of its seat. The charge of indicating agent is thus quickly delivered into the circulating fluid and its presence therein may be detected or observed in the same manner as before.

If the space between the plunger and cap 199 is completely filled with liquid indicating agent, there will be substantially no compression of the contents of said space and consequently no tendency to leakage of fluid into said space. If, however, this space is not completely filled with liquid, due for example to trapping of air beneath the cap member when securing the same in place, the air or other gaseous material contained therein will be compressible, and in order to prevent damage to the plunger or other parts, due to a high difference in pressure between the fluid beneath the plunger and the contents of said space, I prefer to provide bleeder means for permitting inflow of fluid into said space under these conditions. Such bleeder means are, in the construction shown, provided by the leather cup 179, which is sufficiently flexible to yield, under pressure from below, and permit upward passage of fluid past the same into the space above.

I claim:

1. An apparatus for indicating excessive deviation of a rotary drill hole from the vertical during drilling thereof, comprising, in combination with a rotary drill including a drill pipe, means adjacent the lower end of the drill pipe containing a quantity of indicating agent, and means at the lower portion of the drill pipe and responsive to deviation of such portion of the drill pipe from the vertical and operable only upon continued rotation of the drill pipe while such deviation exceeds a certain angle to cause delivery of said indicating agent to the circulating fluid adjacent said portion of the drill pipe.

2. An apparatus for indicating excessive deviation of a rotary drill hole from the vertical during drilling thereof, comprising, in combination with a rotary drill including a drill pipe, a deviation detecting device mounted adjacent the lower end of the drill pipe and containing a quantity of indicating agent and operable only upon continued rotation of the drill pipe while the deviation of the drill pipe from the vertical exceeds a certain angle to cause delivery of said indicating agent to the circulating fluid, and indicating means disposed in the path of the circulating fluid upon its return to the surface and adapted to give an indication of the presence of said indicating agent in the circulating fluid.

3. An apparatus for indicating excessive deviation of a rotary drill hole from the vertical during drilling thereof, comprising, in combination with a rotary drill including a drill pipe, means adjacent the lower end of the drill pipe containing a quantity of indicating agent, electrically controlled means operable upon passage of an electric current therethrough for causing delivery of said indicating agent to the circulating fluid, an electrical control circuit for said electrically controlled means, including a source of electric current mounted adjacent the lower end of the drill pipe, and means also mounted adjacent the lower end of the drill pipe and operable to complete said control circuit only upon continued rotation of the drill pipe while such deviation of the drill pipe from the vertical exceeds a certain angle.

4. An apparatus as set forth in claim 3, said

circuit completing means comprising a plurality of circuit closing members disposed at different angular positions about a common center and operable to position to close corresponding normally open breaks included in series in said control circuit, and means operable upon deviation of said drill pipe from the vertical, during rotation thereof, to successively engage said circuit closing members and to cause movement of said circuit closing members to circuit closing position when said deviation exceeds a certain angle.

5. An apparatus for indicating excessive deviation of a rotary drill hole from the vertical during drilling thereof, comprising, in combination with a rotary drill including a drill pipe having an internal passage for circulating fluid, enclosed casing means mounted within said internal passage and spaced from the walls thereof, so as to permit passage of said circulating fluid around the same, a quantity of indicating agent contained within said casing means, and deviation responsive means also contained within said casing means and operable only upon continued rotation of the drill pipe when the deviation of the drill pipe from the vertical exceeds a certain angle to cause delivery of said indicating agent from said casing means into said circulating fluid.

6. In combination with a rotary drill pipe having an internal passage, an apparatus for indicating excessive deviation of said drill pipe from the vertical during drilling operations, comprising an elongated tubular casing mounted within said internal passage and spaced from the walls thereof, a quantity of indicating agent contained within said casing, means within said casing and operable only upon continued rotation of the drill pipe to cause delivery of said indicating agent from said casing into the circulating fluid in said internal passage of the drill pipe when the deviation of the drill pipe from the vertical exceeds a certain angle, and adjustable centering means for mounting said tubular casing within said internal passage and adapted to maintain the axis of said casing substantially parallel to the axis of the drill pipe.

7. In combination with a rotary drill pipe having an internal passage for circulating fluid, an enclosed tubular casing whose external diameter is less than the diameter of said internal passage, means for supporting said tubular casing within said internal passage, so as to hold the same in substantially fixed position with respect to said drill pipe and with its axis substantially parallel to the axis of the drill pipe, a quantity of indicating agent contained within said casing and means mounted within said casing and operable only upon continued rotation of the drill pipe to cause delivery of said indicating agent from said casing into the circulating fluid when the deviation of said casing from the vertical exceeds a certain angle.

8. In an electrically controlled apparatus for detecting excessive deviation of a rotary drill pipe from the vertical, an electric circuit having contact means defining a plurality of normally open breaks in series therein, a casing mounted with its axis substantially parallel to the axis of the drill pipe, a weight disposed within said casing and supported in such manner as to permit free pivotal movement thereof in all directions about its point of support, and a plurality of circuit closing members disposed at different positions about the center of said weight and movable into and out of circuit closing position with respect to the contact means defining the respective breaks in said circuit, said circuit closing members being in position to be successively engaged by said weight upon deviation of said casing from the vertical, during rotation thereof about a longitudinal axis, and being movable to circuit closing position by such engagement of said weight therewith, when said deviation exceeds a certain angle.

9. In combination with the electric control circuit of an electrically controlled apparatus for detecting deviation of a rotary drill pipe from the vertical, a plurality of circuit closing members operable to position to close corresponding normally open breaks connected in series in said circuit, and a weight mounted to swing freely in all directions about a point of support and adapted to always maintain a vertical position, said weight being adapted to successively engage said circuit closing members upon deviation of said drill pipe from the vertical during rotation thereof, and to move said circuit closing members to circuit closing position when said deviation exceeds a certain angle.

10. An apparatus for detecting excessive deviation of a rotary drill pipe from the vertical, during drilling operations, comprising means adjacent the lower end of the drill pipe, containing a quantity of indicating agent, a weight freely supported adjacent the lower end of the drill pipe for pivotal movement in all directions, so as to be gravitally maintained in vertical position at all times, and means operable upon a certain prolonged deviation of said drill pipe relative to the vertical axis of said weight, during continued rotation of the drill pipe, to cause discharge of said indicating agent into the circulating fluid adjacent said containing means.

In testimony whereof I have hereunto subscribed my name this 5th day of March, 1929.

JOHN J. JAKOSKY.