

Sept. 21, 1943.

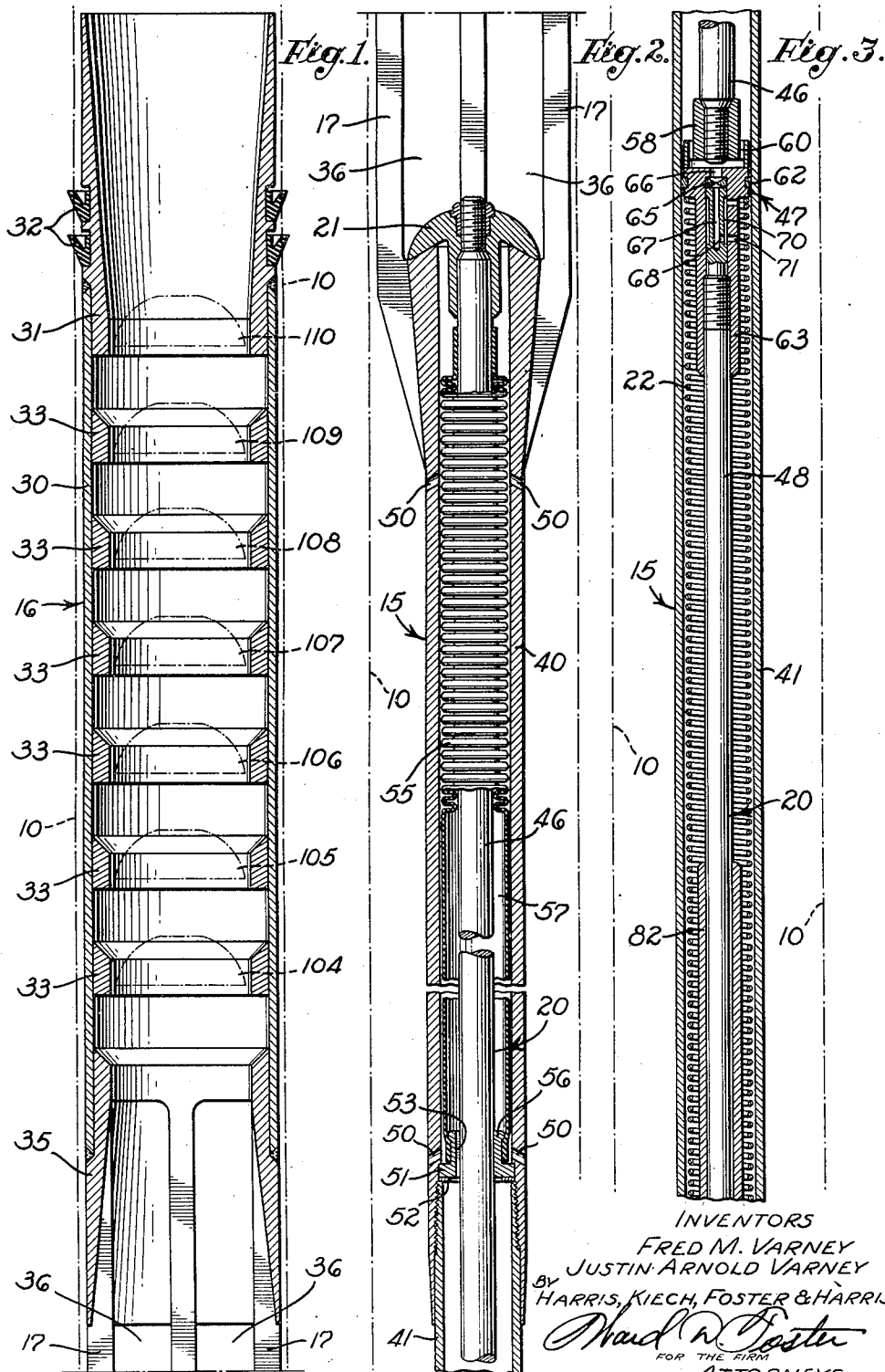
F. M. VARNEY ET AL

2,329,732

SIGNALING DEVIATION DETECTOR

Filed Sept. 8, 1941

2 Sheets-Sheet 1



Sept. 21, 1943.

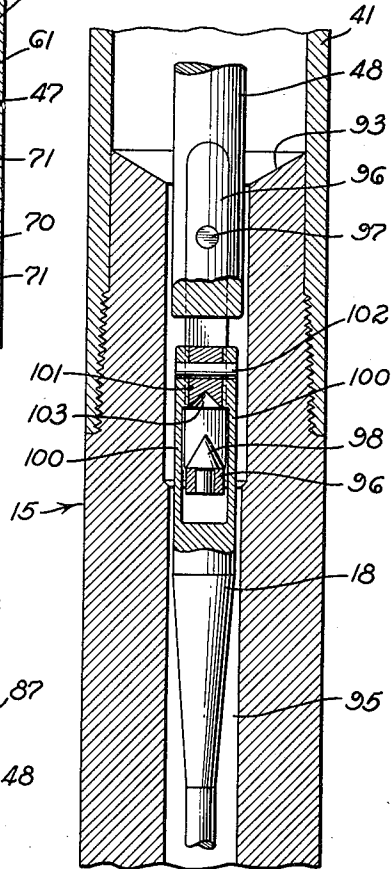
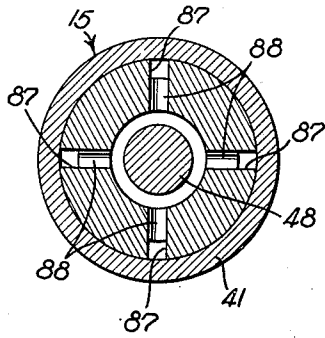
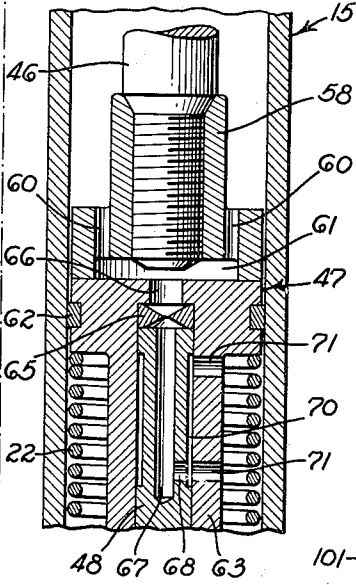
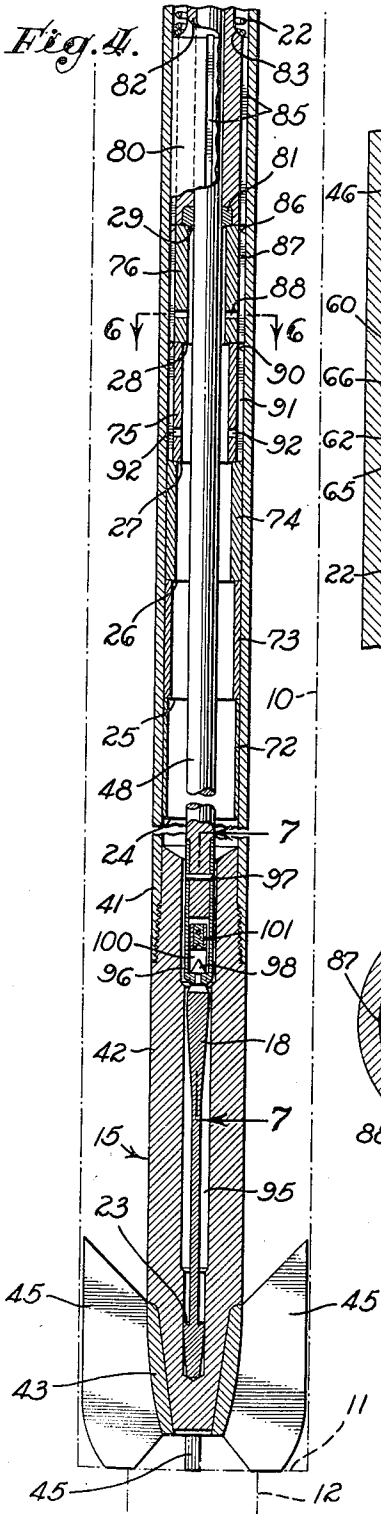
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2 Sheets-Sheet 2



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UNITED STATES PATENT OFFICE

2,329,732

SIGNALING DEVIATION DETECTOR

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Application September 8, 1941, Serial No. 409,989

12 Claims. (Cl. 33—205)

Our invention relates to the art of ascertaining and indicating deviations from vertical of a well bore and is applicable to well surveying devices in general. Since it is contemplated that the present invention will find immediate application in devices that may be incorporated in a string of drill pipe to serve as a deviation-warning means for the convenience of a driller, the present disclosure will be confined to embodiments of such character, but it is to be understood that our invention is not to be restricted to any narrow class of well surveying apparatus.

The present invention is an improvement on the signaling clinograph set forth in our copending application, Serial No. 316,196, entitled "Signaling clinograph," and shares the same objects.

In the prior device an essential portion of the signaling mechanism was in the form of a special channel member separate and apart from the major portion of the device and separately mounted in the drill pipe, the function of the separate portion being to cooperate in repeatedly restricting the stream of drilling fluid for the purpose of generating signal waves therein. One of the objects of the present invention is to provide a self-sufficient signaling apparatus that may be lowered bodily into a string of drill pipe, there being no necessity whatsoever for withdrawing the drill pipe to install special equipment.

Another object of the invention relates to the control of a signal or indicating mechanism by a pendulum member or other gravity-responsive member that stops the mechanism at various points in an operating cycle in accord with various angles of deviation detected by the gravity-responsive member. The problem involved is to provide a time interval for the gravity-responsive member to become stable prior to functioning as a stop. Fluid action may be relied upon to retard or otherwise control the rate of action of the signal or indicating mechanism, but, if so, a second problem arises in that variations of viscosity of the fluid attributable to temperature changes or other factors ordinarily cause corresponding variations in the control effect. In this aspect, an object of our invention is to provide a solution for both of these problems, the solution including the provision of a dash-pot and the provision of a sharp-edged orifice in the dash-pot arrangements to minimize the effects of viscosity variation.

Certain difficulties in designing devices of the present character relate to the manner of mounting or supporting a gravity-responsive

member. To afford sensitivity it is requisite that the bearings freely permit oscillation of the pendulum or other gravity-responsive device, hence friction surfaces should be of minimum area and well lubricated with no tendency whatsoever to stick; yet the bearing must be sturdy and capable of functioning through long operating periods without loss in efficiency and without delays for servicing or inspection. If the invention is to be used in a drill string, it is especially difficult to achieve these ends because the apparatus is continually subject to severe vibration and shock in the course of drilling operation. Ball-and-socket pendulum bearings have been used heretofore, but the relatively extensive friction surfaces required to make such bearings sturdy do not favor sensitive action, especially so because ball-and-socket surfaces are not easily lubricated and tend to become so gummy as to stick. The spherical surfaces of such a bearing, moreover, tend to wear out of round under the continual pounding of drilling operation. To minimize this latter tendency, provision may be made to continuously stress the ball-and-socket bearing whenever the pendulum is out of service thereby to minimize relative movement between cooperating bearing members during drilling operation, but such expedients and refinements have not resulted in satisfactory bearing structures.

One group of objects of our invention relates to these various difficulties in bearing design. These objects include the following: to provide a bearing with minimum areas of friction effective during detection operation; to provide for substantially one-point support of the gravity-responsive member during detection operation; to provide for automatically flushing with lubricant all bearing surfaces prior to detection operation; to provide for shifting all possibilities for wear to non-bearing surfaces during drilling operation; and to completely separate the bearing surfaces during drilling operation.

The above and other objects of our invention will be apparent in our detailed description to follow, taken with the accompanying drawings.

In the drawings, which are to be considered as illustrative only,

Figs. 1 to 4 in sequence represent a longitudinal section through the preferred form of our apparatus, a small portion being shown in side elevation in Fig. 4;

Fig. 5 is an enlarged detail of Fig. 3;

Fig. 6 is a transverse section on an enlarged scale taken as indicated by the line 6—6 of Fig. 4; and

Fig. 7 is a fragmentary longitudinal section on an enlarged scale taken as indicated by the line 7—7 of Fig. 4.

The device shown in the drawings is adapted to be lowered into a drill string to come to rest in the lower portion of the drill string comprising the usual drill collar or sub. In Figs. 1 to 4 dash-dot lines indicate the inner cylindrical wall 10 of the drill string, a transverse face or shoulder 11 (Fig. 4) at the lower end of the drill string, and a passage 12 to conduct the downwardly flowing drilling mud to the rotating bit below.

The principal parts of the preferred form of the invention shown in the drawings are: an instrument case in the form of a cylinder generally designated 15; a fluid-passage means generally designated 16, the fluid-passage means being united with the case 15 by spaced arms 17 to constitute what may be termed a unitary housing assembly; a gravity-responsive deviation detector in the form of a pendulum 18 of non-magnetic material inside the case; and what may be termed a plunger assembly generally designated 20 that extends through the upper end of the case 15 and carries an external plunger head 21. Normally, that is to say during routine drilling operation, the plunger assembly 20 is in a lower or retracted position by virtue of the velocity head of the downwardly flowing drilling mud acting against the plunger head 21.

If the mud pumps at the surface of the well are stopped to interrupt the downward flow of the drilling fluid, a helical spring 22 in the case 15 (Figs. 3 and 4) becomes effective to force the plunger assembly 20 upwardly into progressive extension into the fluid-passage means 16, and the pendulum 18 carried upwardly by the plunger assembly controls the extent of the upward plunger-assembly movement in accord with the deviation of the case 15 from vertical. The desired control is achieved by providing the pendulum 18 with an upwardly presented annular stop shoulder 23 and providing the inner cylindrical wall of the case 15 with a series of downwardly presented stop shoulders 24, 25, 26, 27, 28, and 29 designed for cooperation with the stop shoulder 23 on the pendulum, the stop shoulders 24—28 being arranged in a progressively constricted series with respect to inside diameters to cause the permitted range of movement of the plunger assembly 20 to be varied in a predetermined manner in accord with the degree of deviation from vertical. In the particular arrangement shown, only a relatively short upward movement of the plunger assembly 20 is permitted if the cylinder 15 is tilted beyond a predetermined maximum angle from vertical and a maximum extent of upward movement of the plunger assembly is permitted if the cylinder 15 is vertical within a predetermined tolerance of small magnitude.

When the mud pumps at the surface of the well are subsequently placed in operation to restore downward flow of the drilling stream through the drill string, the impingement of the stream against the upper surface of the plunger head 21 causes the plunger assembly 20 to retract downwardly and the retracting plunger head cooperates with the surrounding fluid-passage means 16 to intermittently restrict the stream of drilling fluid thereby to engender successive surges or pressure waves to traverse the column of drilling fluid to the surface of the well. For the purpose of causing the intermittent restriction of the downwardly flowing stream,

either the plunger head 21 or the passage means 16 is formed with an alternately expanded and contracted configuration. In the present construction the fluid-passage means 16 is alternately enlarged and reduced in internal diameter so that the plunger head 21 in moving downwardly therethrough intermittently chokes the fluid flow. Since the extent of the upward movement of the plunger assembly 20 is determined by the inclination of the case 15 relative to the pendulum 18, the number of times the plunger head 21 cooperates with the fluid-passage means 16 to restrict the stream of drilling fluid will vary with the instant degree of deviation of the case 15 from vertical and the pressure waves sent to the surface of the well will, in effect, signal the degree of such deviation.

If the restricting action on the mud stream created by the plunger head 21 in cooperation with the fluid-passage means 16 is relatively sharp or severe, no special provision will be required at the surface of the well to make the signals perceptible. The waves may be clearly audible, or may be visually perceptible in movement of parts at the surface of the well, or may be recognized by simply touching the kelly or rotary hose. In any event, the pressure waves may be readily revealed at the surface by an ordinary pressure-responsive device such as a conventional pressure gauge. Any suitable type of automatic pressure recorder may be used if desired.

In the construction of a preferred form of the invention shown in detail in the drawings, the fluid-passage means 16 includes a thin-walled cylinder 30 of nearly the same outside diameter as the internal diameter of the surrounding drilling string. Welded to the upper end of the cylinder 30 is a tapered sleeve 31 that carries a pair of external sealing rings 32, the sealing rings having the dual function of centering the housing assembly in the drill string and preventing downward flow of the drilling stream around the periphery of the fluid-passage means 16. Fixedly mounted inside the cylinder 30 is a series of uniformly spaced flow-restricting rings 33 that give the interior of the fluid-passage means 16 the alternately expanded and contracted configuration required for the desired cooperation with the plunger head 21.

The lower end of the cylinder 30 is welded to a tubular member 35 that is united with the upper end of the case 15, the tubular member having longitudinal slots 36 that form the previously mentioned arms 17 and permit fluid flowing downwardly through the fluid-passage means 16 to pass outwardly around the case 15. The case 15 is substantially smaller in outside diameter than the interior of the surrounding drill string.

The case 15 is filled with a suitable instrument fluid such as light oil and may be made in three sections threaded together: an upper section 40 (Fig. 2), a middle section 41, and a lower section 42 (Fig. 4). The lower section 42 of the case 15 is seated in and secured to a support member 43 that has four radially disposed wings 45, the wings having the dual function of centering the lower end of the case 15 and supporting the lower end of the case above the entrance to the fluid passage 12 to avoid blocking fluid flow into the passage.

The plunger assembly 20 includes an upper plunger rod 46 carrying the plunger head 21, an intermediate piston 47, and a lower plunger rod

48 that is constructed to pivotally carry the pendulum 18.

The upper section 40 of the case 15 is provided with suitable vent ports 50 and cooperates with the middle section 41 to retain a guide bushing 51 for the upper plunger rod 46 and a sealing ring 52. The sealing ring 52 serves to prevent flow around the outside of the guide bushing 51 into the case 15 below the guide bushing, but an inner longitudinal groove 53 permits the instrument fluid to flow through the guide bushing along the plunger rod 46. A diaphragm or sleeve 55, which may have the general configuration of a bellows, embraces the plunger rod 46 at its upper end in a fluid-tight manner and likewise at its lower end embraces in a fluid-tight manner a neck 56 formed by the guide bushing 51. The diaphragm 55, which is made of rubber or material of similar character, may be regarded as a flexible wall of the case 15 or may be considered as forming a chamber 57 of variable volume that is in communication with the case proper through the passage 53 in the guide bushing 51 to permit liquid displacement through the guide bushing occasioned by longitudinal movement of the plunger assembly 20.

One object of the particular form of the invention shown in the drawings is to avoid any possibility of the pendulum 18 being placed under excessive tension attributable to reverse or upward flow of the drilling stream against the under surface of the plunger head 21. This object is attained by breaking the plunger assembly 20 into two sections that simply separate if any anomalous reverse flow of the drilling fluid occurs. The point of separation may have various locations, but in the present arrangement is placed at the juncture of the upper plunger rod 46 and the piston 47. The lower end of the plunger rod 46 is threaded into a cylindrical guide 58 that normally rests against the upper face of the piston 47, fluid access to the upper face of the piston being provided by a series of longitudinal bores 60 through the cylindrical guide and by a central recess 61 on the under side of the cylindrical guide.

The piston 47, which is embraced by a packing ring 62, has a downward tubular extension 63 into which is threaded the end of the lower plunger rod 48, the lower plunger rod cooperating with the piston to retain therein a sharp-edged orifice member 65 of relatively small inner diameter. As best shown in Fig. 5 a dash-pot passage through the piston 47 may be traced as follows: an axial bore 66 through the piston, the previously mentioned sharp-edged orifice member 65, an axial bore 67 in the upper end of the plunger rod 48, a radial bore 68 in the plunger rod, a peripheral recess 70 in the plunger rod, and a pair of radial passages 71 in the tubular extension 63 of the piston.

Suitably fixed inside the instrument case 15 well below the range of reciprocation of the piston 47 is a thin-walled sleeve 72 having its lower edge beveled to form the previously mentioned lowermost stop shoulder 24. Arranged in succession above the sleeve 72 are additional sleeves 73, 74, 75, and 76 that likewise have lower beveled edges to form the corresponding stop shoulders 25-28. Resting on top of the described series of sleeves is a tubular member 80 equipped with a hardened guide bushing 81 for the plunger rod 48, the lower beveled edge of which bushing serves also as the uppermost stop shoulder 29. The tubular member 80 has an upwardly extend-

ing portion 82 of reduced diameter and is formed with an outer annular shoulder 83. The previously mentioned spring 22 that continuously urges the plunger assembly 20 upwardly rests on the annular shoulder 83 and acts against the under side of the piston 47.

As shown in Fig. 4 a fluid passage for flow between the space above the tubular member 80 and the interior of the series of sleeves 72-76 may include the following: four longitudinal grooves 85 in the periphery of the tubular member 80, an annular groove 86 cut in the upper end of the sleeve 76, four longitudinal grooves 87 cut in the periphery of the sleeve 76, and four radial bores 88 in the sleeve 76 extending inwardly from the corresponding longitudinal grooves 87. For increased flow capacity and to divide the inward fluid flow into several jets, the sleeve 75 immediately below the sleeve 76 may be formed with an annular groove 90 at its upper end, four longitudinal peripheral grooves 91 and four corresponding radial bores 92. The division of the inflowing fluid into numerous jets minimizes any flow effect that might tend to force the pendulum 18 out of vertical.

The lower section 42 of the instrument case provides a tapered entrance 93 to a deep cylindrical recess 95 in which the pendulum 18 is normally seated and held immobilized by pressure from the plunger assembly 20. A feature of the present embodiment of the invention is that the bearing that pivotally supports the pendulum on the plunger assembly during a detecting operation provides for relative movement between the pendulum and plunger assembly whereby the bearing surfaces are completely separated when the pendulum is pressed into the recess 95 during normal drilling operations. Such an arrangement avoids any wear whatsoever of the bearing surfaces attributable to the vibration and shock of drilling.

To provide such a bearing a U-shaped stirrup 96 may be mounted on the lower end of the plunger rod 48 by means of a suitable cross pin 97, as shown in Fig. 4, to carry a bearing member in the form of an upwardly extending projection 98. The pendulum 18 is arranged in some suitable manner to link loosely with the stirrup 96 and to present a bearing socket to receive the projection 98. For example, as best shown in Fig. 7, the upper end of the pendulum may be formed with a pair of arms 100 to receive the stirrup 96 and to carry a bearing member in the form of a small block 101 mounted between the arms by a suitable pin 102, the block having a downwardly presented socket 103. Preferably, the socket 103 is of conical configuration and the complementary projection 98 is of sharper conical configuration so that supporting contact is limited to the extreme tip of the projection and the deep center of the socket.

When the device is in a drill string during drilling operation with the plunger assembly 20 in a normal retracted position determined by the seating of the plunger head 21, the plunger assembly confines the pendulum 18 in the well 95. At such time the plunger assembly provides a small clearance for vertical movement on the part of the pendulum, say a vertical clearance of $\frac{1}{8}$ inch, but the pendulum does not reciprocate vertically to any damaging extent under the pounding and vibration of drilling because the lower end of the pendulum forming the annular stop shoulder 23 is dimensioned for a sufficiently snug

fit into the surrounding well 95 to provide a damping dash-pot action.

To ascertain the instant deviation of the bore hole, if any, the operator ceases drilling rotation of the drill string and stops the mud pumps to terminate downward flow of the drilling mud through the drill string, whereupon the plunger assembly 20 is urged upwardly by the spring 22 and the projection 98 enters the socket 103 to lift the pendulum 18 out of the recess 95, the bearing surfaces being well flushed by the instrument fluid. The incorporation of the diaphragm sleeve 55 in the combination permits the device to maintain a constant over-all volume as the plunger assembly rises and falls. As the plunger assembly rises, the instrument fluid flows out of the chamber 57 defined by the diaphragm 55 into the space below the guide bushing 51 by way of the passage 53 and simultaneously instrument fluid flows from the upper side of the piston 47 to the lower side of the piston through the dash-pot passage that includes the sharp-edged orifice member 65.

The dash-pot arrangement serves several purposes: it retards the plunger rise enough to let the pendulum become stabilized at vertical alignment before the annular stop shoulder 23 on the lower end of the pendulum comes within the range of the lowermost stop shoulder 24 on the wall of the instrument case; it retards the plunger rise sufficiently to avoid any appreciable deflection of the pendulum by the drag of the instrument fluid; it retards the retraction movement of the plunger assembly under pressure from the mud stream until the mud stream accelerates to a velocity adequate for generating a strong signal wave; it retards the retraction movement of the plunger assembly to provide adequate time intervals between the signal waves; it prolongs the duration of a pressure rise to insure detection by the operator at the surface of the well; and, by virtue of the sharp-edged orifice, it minimizes any variation in the rate of movement of the plunger assembly that may be attributable to variation in viscosity of the instrument fluid with changing temperature and pressure.

If the stop shoulder on the pendulum engages one of the stop shoulders 24-29, the plunger head 21 will terminate its upward movement at a corresponding one of the six positions 104-110 shown in dotted lines in Fig. 1, and if the instrument case is so nearly vertical that the pendulum escapes all of the stop shoulders 24-29 the plunger head 21 will be carried to the upper limit position 110 in Fig. 1. If the mud pumps are started after the plunger head 21 stops its upward movement at one of the dotted line positions, the velocity head of the mud stream will cause downward movement of the plunger assembly and a sharp pressure wave will be created in the mud stream as the plunger head 21 passes into each of the flow restricting rings 33 and again when the plunger head enters the restriction provided by the tubular member 35.

The degrees of deviation represented by the various stop shoulders 24-29 may be spaced according to the closeness of control desired. For example, seven signals made possible by maximum upward movement of the plunger assembly may indicate a deviation from vertical of less than one-half degree; six signals resulting from the pendulum engaging the stop shoulder 29 may indicate a deviation of between one-half and one degree; five signals re-

sulting from the pendulum engaging the stop shoulder 28 may indicate a deviation of between one and one and one-half degrees; four signals resulting from the pendulum engaging the stop shoulder 27 may indicate a deviation of between one and one-half and two degrees; three signals resulting from engagement of the pendulum with the stop shoulder 26 may indicate a deviation of between two and three degrees; two signals resulting from engagement of the pendulum with the stop shoulder 25 may indicate a deviation of between three and four degrees, and one signal resulting from engagement of the pendulum with the stop shoulder 24 may indicate a deviation in excess of four degrees. It will be noted that in any event the device will send at least one signal to the top of the well to indicate that it is functioning.

The plunger head 21 may be stopped by the various stop shoulders of the plunger at positions of maximum flow between the various flow restricting rings 33. In practice, however, we prefer to arrange for stopping the plunger head at the dotted positions 104-110 inside flow restricting rings, each position being in the restricting ring above the restricting ring that is to engender the first signal when the plunger subsequently moves downwardly. The purpose of stopping the plunger head inside a restricting ring instead of in the larger space below is to provide for a substantial extent of movement of the plunger prior to the first signal engendered by flow restriction. An appreciable interval of time may be required for acceleration of the fluid stream when the mud pumps are started and the described arrangement provides for the required interval of time before the first signaling pressure wave is created in the mud stream. A further reason for delaying the first pressure signal is that mud pumps commonly labor when first started with consequent pounding that might be confused with signals of the deviation detector in the well.

The preferred form of our improvement described herein in specific detail for the purpose of disclosure will suggest various modifications and substitutions under our concept, and we reserve the right to all such departures that properly come within the scope of our appended claims.

We claim as our invention:

1. A well-drilling deviation detector for service in a drilling fluid stream in a drill pipe, said detector including: a housing adapted for insertion into said drill pipe, said housing having a portion forming a channel for said fluid stream; a mechanism movably mounted in said housing for reciprocation, said mechanism being movable in one of its directions of reciprocation in response to said fluid stream, said mechanism having a portion cooperative with said channel portion of the housing to vary the effective cross section of the channel at successive stages in the movement of the mechanism, thereby to produce successive pressure variations in the fluid stream for detection at the surface of the well; and gravity-responsive means to limit the reciprocative movement of said mechanism at various points according to the degree of deviation of the housing from vertical, thereby to vary the number of successive pressure variations to reveal said degree of deviation.

2. A well-drilling deviation detector for service in a drilling fluid stream in a drill pipe, said detector including: an instrument case adapted

for insertion into said drill pipe, said case being substantially smaller in cross-sectional area than the interior of said drill pipe to permit said stream to flow past the case; means connected with said case to form a channel for the drilling fluid stream beyond one end of the case; a mechanism movably mounted in said case for reciprocation, said mechanism being movable in one of its directions of reciprocation in response to said fluid stream, said mechanism having a portion cooperative with said channel-forming means to vary the effective cross section of the channel at successive stages in the movement of the mechanism, thereby to produce successive pressure variations in the fluid stream for detection at the surface of the well; and gravity-responsive means to limit the reciprocative movement of said mechanism at various points according to the degree of deviation of the case from vertical, thereby to vary the number of successive pressure variations to reveal said degree of deviation.

3. A well-drilling deviation detector for service in a drilling fluid stream in a drill pipe, said detector including: an instrument case enclosing instrument fluid and adapted for insertion into said drill pipe, said case being smaller in cross-sectional area than the interior of said drill pipe to permit said stream to flow past the case; means carried by said case for contact with the surrounding drill pipe to align the case in the same longitudinal direction as the drill pipe; a reciprocative plunger member extending through one end of said case; spring means to move said plunger member in a first reciprocative direction, said plunger member being movable in the opposite or second reciprocative direction in response to said drilling stream, said case having a movable wall to permit displacement of said instrument fluid in response to movement of said plunger member, whereby the combined volume of the case and of the exposed portion of the plunger member is constant during plunger reciprocation; a passage member carried by said case for cooperation with said plunger member to temporarily restrict the flow of said stream at successive spaced points in the movement of the plunger member in said second direction, thereby to produce successive pressure rises in said stream at the surface of the well corresponding in number to the extent of movement of the plunger; and a gravity-responsive means to limit the reciprocative movement of said plunger member in said first direction at various points according to the degree of deviation of said container from vertical, whereby the number of successive pressure rises reveals said degree of deviation at the surface of the well.

4. A combination as set forth in claim 3 in which one of the two recited cooperating members moves longitudinally past the other and in which one of said members is alternately expanded and contracted in profile to produce said successive restrictions of said stream.

5. A well-drilling deviation detector for service in a drilling fluid stream in a drill pipe, said detector including: a case enclosing instrument fluid and adapted for insertion into said drill pipe, said case being smaller in cross-sectional area than the interior of said drill pipe to permit said stream to flow past the case; a reciprocative plunger member extending through one end of said case; spring means to move said plunger member in a first reciprocative direction, said plunger member being movable in the oppo-

site or second reciprocative direction in response to said drilling stream, said case having a movable wall to permit displacement of said instrument fluid in response to movement of said plunger member, whereby the combined volume of the case and of the exposed portion of the plunger member is constant during plunger reciprocation; means forming a channel in said case for displacement flow of said instrument fluid, said channel-forming means including a sharp-edged orifice to minimize variation in the rate of displacement flow of the instrument fluid attributable to variation of viscosity of the instrument fluid; a passage member carried by said case for cooperation with said plunger member to temporarily restrict the flow of said stream at successive spaced points in the movement of the plunger member in said second direction, thereby to produce successive pressure rises in said stream at the surface of the well corresponding in number to the extent of movement of the plunger; and a gravity-responsive deviation detector to limit the reciprocative movement of said plunger member in said first direction at various points according to the degree of deviation of said case from vertical, thereby to vary the number of successive pressure rises to reveal said degree of deviation at the surface of the well.

6. A well-drilling deviation detector for service in a drilling fluid stream in a drill pipe, said detector including: a case enclosing instrument fluid and adapted for insertion into said drill pipe, said case being smaller in diameter than the interior of the drill pipe to permit said stream to flow past the case; a reciprocative plunger extending through one end of said case, said plunger being effective to temporarily restrict the flow of said stream at successive spaced points in the movement of the plunger in one direction, thereby to produce successive pressure rises in said stream at the surface of the well corresponding in number to the extent of movement of the plunger; a piston in said case connected with said plunger to move therewith, there being a passage for flow of said instrument fluid from one side of the piston to the other, there being a sharp-edged restriction in said passage; yielding means to move said plunger and piston in a first reciprocating direction, said plunger and piston being movable in the opposite or second reciprocating direction in response to said stream of drilling fluid; and a gravity-responsive deviation detector to limit the reciprocative movement of said plunger and piston in said first direction at various points according to the degree of deviation of the cylinder from vertical, thereby to vary the number of successive pressure rises in said stream to reveal said degree of deviation.

7. A combination as set forth in claim 6 including a chamber having a flexible wall, said chamber being in communication with said cylinder and enclosing a portion of said instrument fluid, said portion varying in volume with movement of said plunger.

8. A signaling clinograph for service in a well, the well having a channel for a stream of drilling fluid, said clinograph including: a mechanism for subterranean operation in said well, said mechanism being movable in opposite directions and being adapted to move in one of the opposite directions in response to said fluid stream; means cooperative with said mechanism to send a series of signals to the surface of

the well when said mechanism moves; a gravity-responsive deviation-detector to limit the movement of said mechanism in accord with the degree of the deviation of the well from vertical, thereby to vary the number of signals in said series to indicate such deviation at the surface of the well; a first bearing member to support said gravity-responsive deviation detector for oscillation; and a second bearing member unitary with the gravity-responsive deviation-detector, one of said bearing members being formed with a seat and the other of said bearing members being formed with a pointed projection extending into said seat.

9. A well-drilling deviation detector for service in a drilling fluid stream in a drill pipe, said detector including: a housing adapted for insertion into said drill pipe; a mechanism in said housing, said mechanism being movable in opposite directions and being adapted to move in one of the opposite directions in response to said fluid stream, said mechanism having a normal position at one limit of its range of movement; a pendulum in said housing positioned in the path of movement of said mechanism to be held immobile by said mechanism at said normal position of the mechanism; a first bearing means unitary with said pendulum; a second bearing means carried by said mechanism for cooperation with said first bearing means to pivotally support the pendulum, said two bearing means being positioned for separation at said normal position of the mechanism and for mutual cooperative contact upon movement of the mechanism away from said normal position; signal means responsive to movement of said mechanism in one direction; and means cooperative with said pendulum to limit the movement of said mechanism and thereby limit operation of said signal means in accord with deviation of said housing from vertical.

10. In a deviation detector for service in a well bore, the combination of: an indicating mechanism for reciprocative operation in said bore; a gravity-responsive deviation detector to limit the movement of said indicating mechanism at selected positions in accord with deviation of the well bore; and dash-pot means for retarding movement of said indicating means to permit stabilization of said deviation detector prior to limiting action by the deviation detector, said dash-pot means including a body of liquid and a sharp-edged orifice to minimize variation in rates of dash-pot flow caused by variations in viscosity of the fluid.

11. A signaling deviation detector for service in a well having a channel for a stream of drilling fluid, said deviation detector including: a mechanism movable in opposite directions; a pendulum movable longitudinally relative to said mechanism between a retracted position and an extended position; bearing means to support the pendulum from said mechanism in a freely piv-

otal manner when the pendulum is at its relative extended position, the cooperating surfaces of said bearing means being separated when the pendulum is at its relative retracted position; means to urge said mechanism in one of its directions whenever flow of said drilling fluid substantially ceases; means cooperative with the pendulum to limit the movement of said mechanism in said one direction in accord with deviation of the well bore from vertical; signal means responsive to movement of said mechanism in said direction to indicate the magnitude of such movement, thereby to indicate the magnitude of deviation from vertical; means actuated by dynamic pressure from the flowing drilling fluid to move said mechanism in its opposite direction, thereby moving said pendulum longitudinally in said opposite direction; and stop means in the path of said pendulum to cause said movement in the opposite direction to result initially in retraction of the pendulum and subsequently in fluid-derived pressure on the part of said pendulum longitudinally thereof to hold the pendulum normally immobilized during drilling operations.

12. A signaling deviation detector for service in a well having a channel for a stream of drilling fluid, said deviation detector including: a mechanism movable in opposite directions; a pendulum movable longitudinally relative to said mechanism between a retracted position and an extended position; bearing means to support the pendulum from said mechanism in a freely pivotal manner when the pendulum is at its relative extended position, the cooperating surfaces of said bearing means being separated when the pendulum is at its relative retracted position; means to urge said mechanism in one of its directions whenever flow of said drilling fluid substantially ceases; means cooperative with the pendulum to limit the movement of said mechanism in said one direction in accord with deviation of the well bore from vertical; signal means responsive to movement of said mechanism in said direction to indicate the magnitude of such movement, thereby to indicate the magnitude of deviation from vertical; means actuated by dynamic pressure from the flowing drilling fluid to move said mechanism in its opposite direction, thereby moving said pendulum longitudinally in said opposite direction; stop means in the path of said pendulum to cause said movement in the opposite direction to result initially in retraction of the pendulum and subsequently in fluid-derived pressure on the part of said pendulum longitudinally thereof to hold the pendulum normally immobilized during drilling operations; and retaining walls positioned to surround said pendulum at its normal position to prevent lateral movement of the pendulum as additional means to immobilize the pendulum.

FRED M. VARNEY.

JUSTIN ARNOLD VARNEY.

CERTIFICATE OF CORRECTION.

Patent No. 2,329,732.

September 21, 1943.

FRED M. VARNEY, ET AL.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 6, first column, line 55, claim 10, for "fluid" read --liquid--; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 30th day of November, A. D. 1943.

(Seal)

Henry Van Arsdale,
Acting Commissioner of Patents.