

Oct. 16, 1962

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3,058,532

DRILL BIT CONDITION INDICATOR AND SIGNALING SYSTEM

Filed July 15, 1953

4 Sheets-Sheet 1

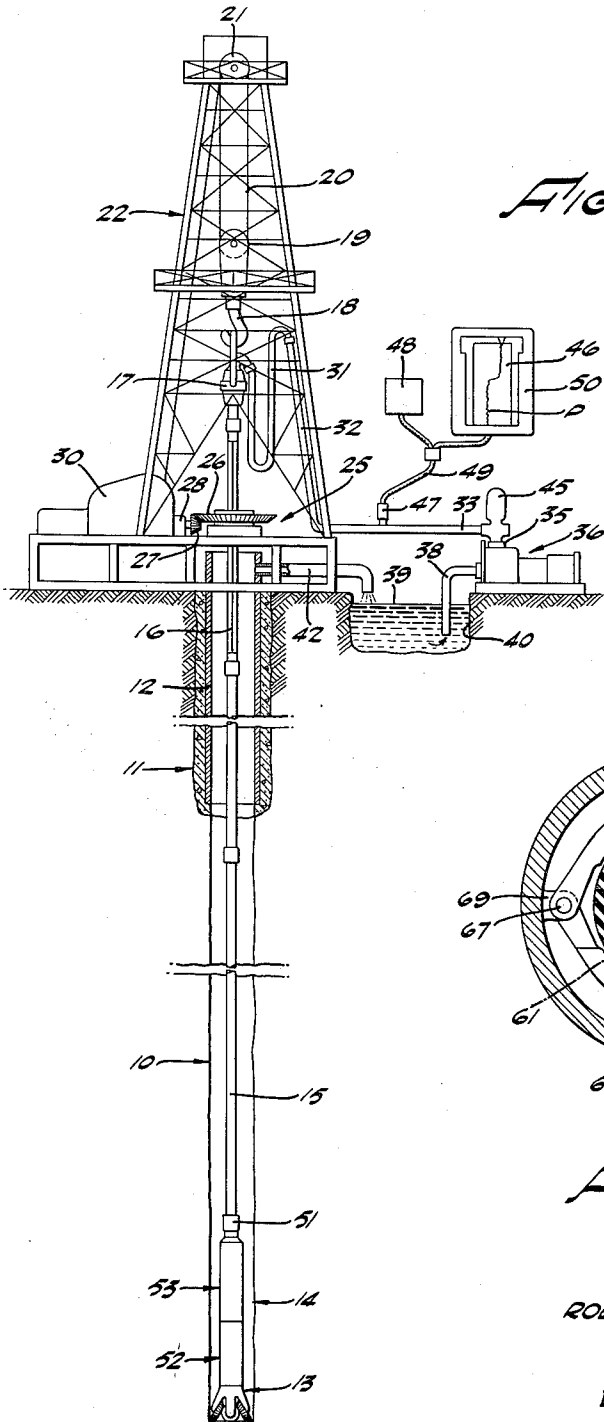


FIG. 1.

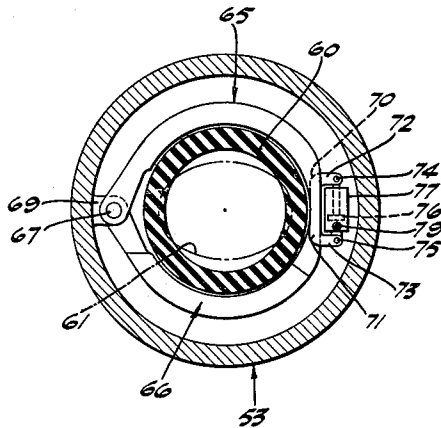


FIG. 3.

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FIG. 2.

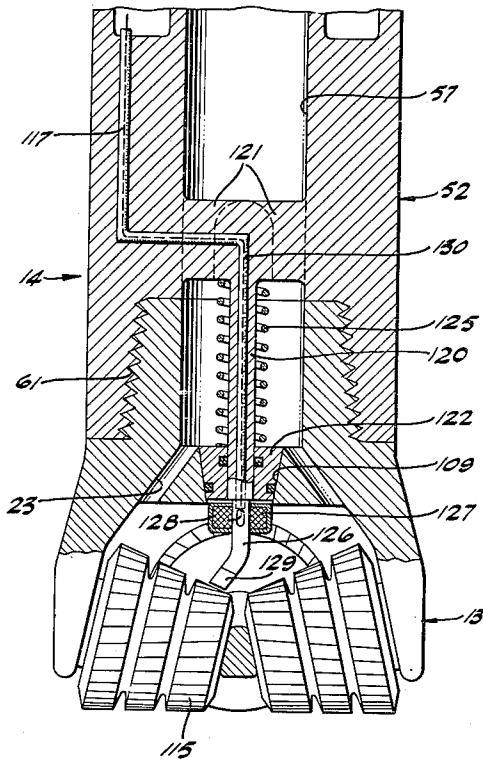
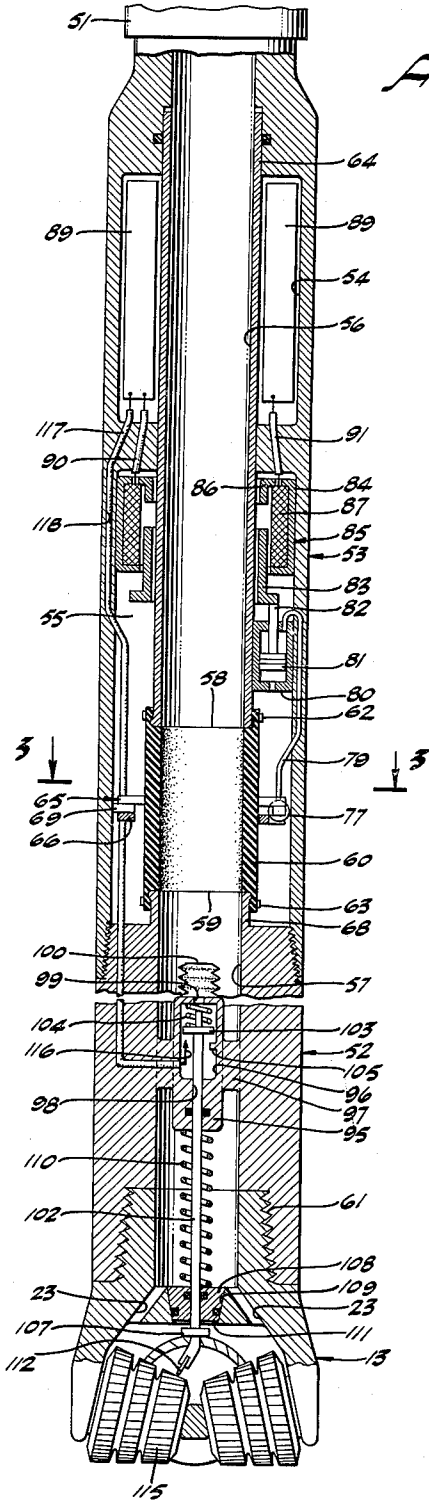


FIG. 4.

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4 Sheets-Sheet 3

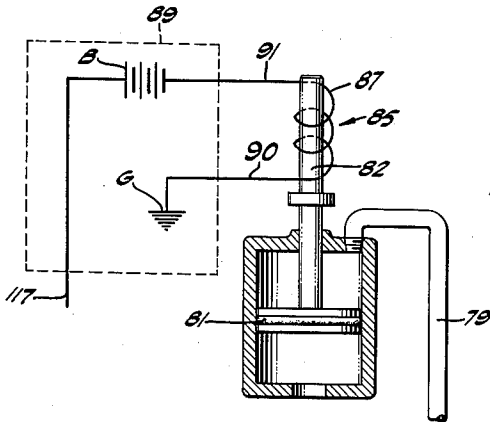


FIG. 10.

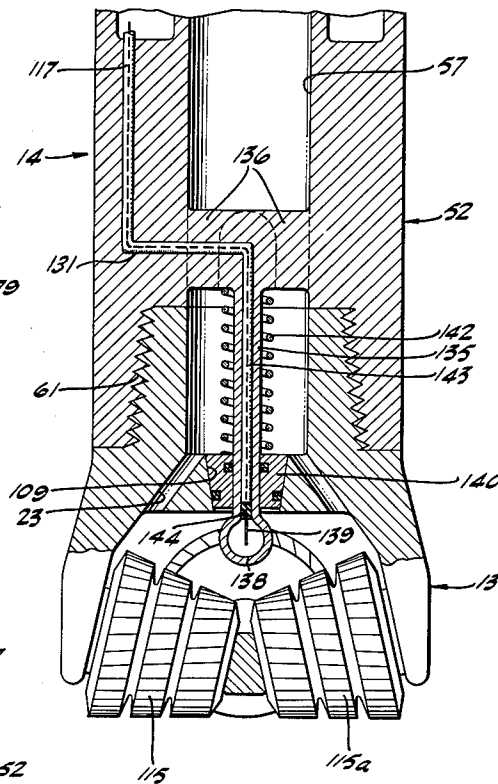


FIG. 5.

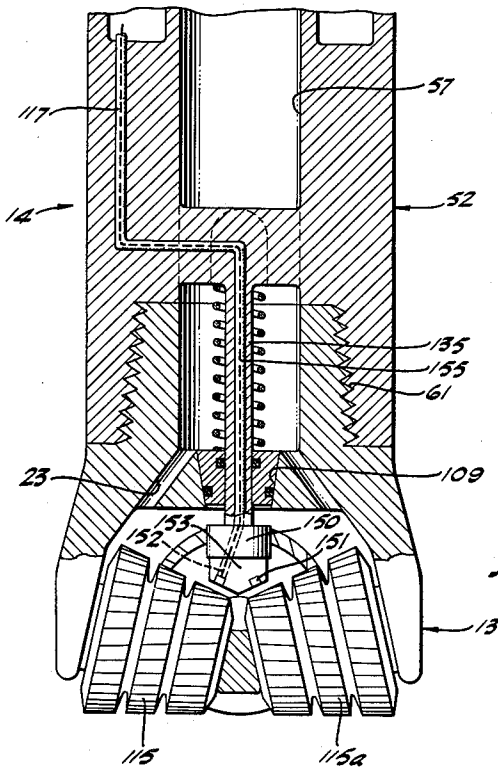


FIG. 6.

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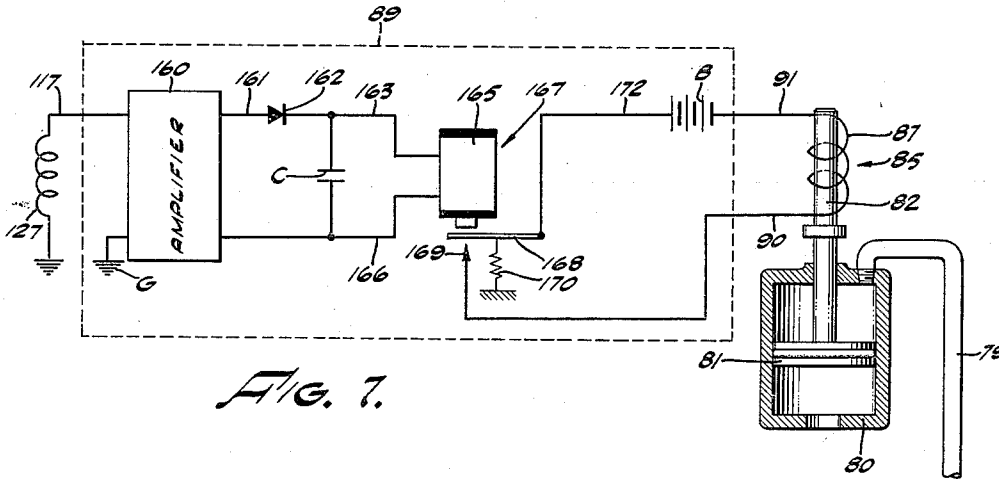


FIG. 7.

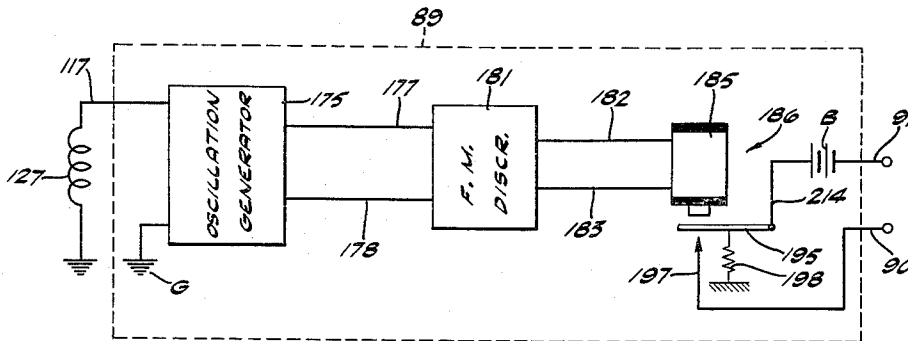


FIG. 8.

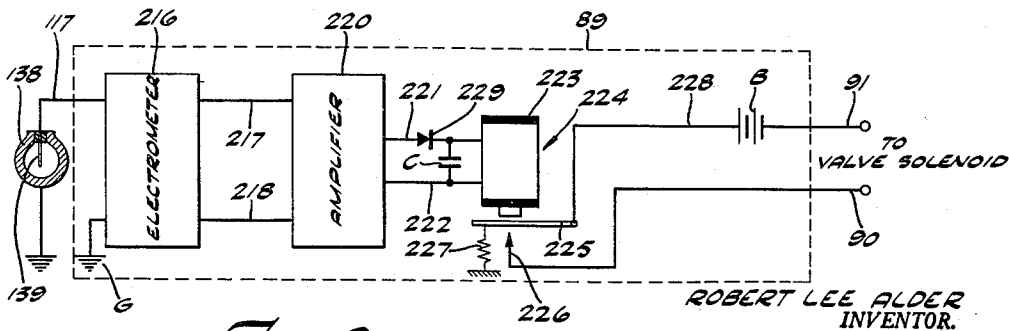


FIG. 9.

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3,058,532

## DRILL BIT CONDITION INDICATOR AND SIGNALING SYSTEM

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Filed July 15, 1953, Ser. No. 368,042

4 Claims. (Cl. 175-39)

This invention relates in general to improvements in borehole drilling control, and more particularly to an improved system for providing signals at the surface exterior to the borehole during drilling indicative of certain conditions within the borehole, such as the malfunctioning of the drill bit due to wear.

During drilling operation as conventionally practiced, numerous instruments have been employed in conjunction with the drilling equipment at the surface exterior to the borehole to provide the driller with information regarding the progress of drilling and whether or not proper drilling conditions are being maintained. Such instruments are the weight indicator, drilling fluid pumping rate and pressure meters, drilling rate meters, rotary table revolution indicators and the like. These instruments, however, have not provided the driller with sufficient information to determine positively whether or not the drilling tools, such as the drill bit within the borehole, are in proper condition. As a result of this, many failures to maintain proper drilling conditions occur within the depths of the well borehole, particularly at the drill bit.

For example, heretofore, when drilling progress has become slow, the driller has been unable to determine, during drilling, whether such slowing down of the drilling rate was caused by the encountering of formations which are difficult to drill or whether the bit had become worn or damaged to such an extent as to render it unsuited for further drilling. This consequently often resulted either in premature withdrawals of the drill string from the borehole for visual inspection of the drill bit, or the attempt to continue drilling with a drill bit which was no longer in proper drilling condition. Either of these procedures resulted in waste of time and unnecessary expense.

In some cases, the lack of ability to determine the condition of the drill bit has resulted in continued drilling efforts after the cutting cones of the roller bit have frozen to their shaft bearings and thus have stopped rotating. This procedure has resulted in sufficient wear on the exposed side of the cutting cones to eventually entirely cut away one side of the cones and a portion of the bearing shaft, permitting the release of the cutting cones into the well borehole and in some cases the breakage of the cutting cone shaft itself, resulting in turn in expensive fishing jobs to recover and remove the cutters and other broken pieces of the drill bit from the drill hole.

It is accordingly an object of this invention to eliminate the hereinbefore described difficulties by providing the driller with means for obtaining more positive information regarding the condition of subsurface drilling equipment while performing drilling operations.

It is a further object of this invention to provide means to determine the degree of wear of the drill bit while drilling.

It is another object of this invention to provide a system for giving a warning signal at the surface exterior to the borehole whenever the bit or other subsurface equipment becomes worn to the extent that replacement is necessary.

It is a still further object of this invention to provide an improved system for determining a physical condition within the depths of an earth borehole while carrying on

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drilling operations and for transmitting signals indicative of such condition therefrom to the earth's surface.

It is still another object of this invention to provide an improved system and means for impressing signal pressure pulsations upon the circulating drilling fluid stream within the subsurface drilling tools indicative of existent subsurface conditions.

It is a still further object of this invention to provide improved means to detect abnormal wear conditions in the drill bit while drilling, and for the transmission of a fluid pressure signal to the top of the borehole being drilled indicative of occurrence of such abnormal wear conditions.

The hereinbefore mentioned objects of this invention are in general accomplished by providing means for detecting the occurrence or existence of a predetermined condition within the depths of the borehole, such as, for example, a certain degree of wear on the cutting surfaces of the drill bit, and the actuation of drilling fluid flow constricting means to produce a pressure increase signal in the drilling fluid circulating system when such predetermined condition has been reached.

Other objects, advantages, and features of novelty will be evident hereinafter in the more detailed description of the invention.

In the drawings, which illustrate preferred embodiments and modes of operation of the invention, and in which like reference characters designate the same or similar parts throughout the several views:

FIGURE 1 is an elevational view, partly schematic and partly in longitudinal section, illustrating the general arrangement of the apparatus of the invention employed in connection with a typical drilling well;

FIGURE 2 is an enlarged longitudinal sectional view, partially schematic, of a portion of the apparatus of FIGURE 1 located in the drill stem adjacent the drill bit, including the drill collar and drill bit;

FIGURE 3 is a transverse sectional view taken on the line 3-3 of FIGURE 2;

FIGURES 4, 5, and 6 are fragmentary longitudinal sectional views, in enlarged detail, of alternative constructions of the lower portion of the apparatus shown in FIGURE 2;

FIGURE 7 is a schematic wiring diagram of the electromechanical portion of the actuating mechanism employed in connection with the apparatus of FIGURE 4;

FIGURE 8 is a schematic wiring diagram of an alternative electromechanical portion of the actuating mechanism employed in connection with the apparatus of FIGURE 4;

FIGURE 8 is a schematic wiring diagram of an alternative electromechanical portion of the actuating mechanism employed in connection with the apparatus of FIGURE 4;

FIGURE 9 is a schematic wiring diagram of the electromechanical portion of the actuating mechanism employed in connection with the apparatus of FIGURE 5 or FIGURE 6; and

FIGURE 10 is a schematic wiring diagram of the electromechanical portion of the actuating mechanism in connection with the apparatus of FIGURE 1.

Referring first primarily to FIGURE 1, in which the general disposition of the apparatus of the invention is shown in relation to a conventional drilling rig and drilling well, the lower uncased portion of a borehole being drilled is shown at 10, and at 11 the upper portion of the borehole is shown in which the usual surface string or conductor string of casing 12 has been set and cemented.

Within the borehole and at the surface above the borehole is shown a substantially conventional rotary drilling rig including a drill string comprising a drill bit 13, a drill

collar 14 and a drill stem composed of drill pipe 15 connected at its upper end through a kelly bar 16 to a swivel 17, which in turn is suspended from a traveling block hook 18, traveling block 19, drilling lines 20, and crown block 21 located in the top of a derrick 22. The kelly bar 16 passes through conventional gripping means in a rotary table 25 supported in the usual or suitable manner upon the derrick floor or foundations. The rotary table is adapted to be rotated by means of the usual bevel gear and pinion rotary table drive illustrated at 26 and 27, respectively. The pinion 27 is coupled to be driven in accordance with usual practice through a conventional chain drive or through a suitable shaft drive, as illustrated at 28, by the power unit of a drawworks 30.

The drilling fluid circulation passage, as shown in FIGURE 2, extending from the discharge or wash ducts 23 of the drill bit 13, through the drill collar 14, and through drill stem 15, kelly bar 16, and swivel 17, is connected at the top through a suitable flexible connection or hose 31 and riser and connecting pipes 32 and 33, respectively, to the discharge connection 35 of a drilling fluid circulating pump 36. The drilling fluid circulating pump 36 takes suction through pipe 38 from a body of drilling fluid 39 contained in a mud reservoir or sump 40, as is conventional practice. The upper end of the before-mentioned surface casing 12, which provides a return path for circulating drilling fluid rising around the drill stem from the open borehole therebelow, is provided with a lateral or side outlet pipe 42 which extends to and discharges into the drilling fluid reservoir 40.

A surge chamber 45 or other suitable surge dampening means is preferably connected to the discharge 35 of the drilling fluid circulating pump 36 for the purpose of smoothing out or reducing the pump discharge pressure fluctuations.

A suitable pressure pickup device 47 is connected hydraulically to the fluid passage within the discharge pipe 33. The pressure pickup device 47 may be of any suitable type, but preferably one such as, for example, the Statham Laboratories Pressure Transducer, Model No. P10, adapted to convert fluid pressure communicated to it from pipe 33 into corresponding values of electric current or potential. This transducer may be energized by a suitable electric current supply such as a battery or other suitable current source illustrated at 48 in FIGURE 1, and when so energized is capable of producing an electric output signal which is a function of the instantaneous fluid pressure applied to it, which pressure in the present case is that appearing in pipe 33. The pressure pickup device 47 is connected through insulated conductors 49 to a suitable pressure measuring device 50 which may be a pressure indicator or preferably a recorder such as, for example, the Minneapolis-Honeywell Strip Chart Potentiometer manufactured by the Minneapolis-Honeywell Regulator Company, and by means of which the pressure variations or change in pressure throughout the drill stem, as it appears in pipe 33, may be continuously recorded on a chart 46 moving at a constant or suitable speed.

Referring now primarily to FIGURES 2 and 3, the drill collar 14 mentioned hereinbefore in connection with FIGURE 1 comprises a substantially solid, tubular, lower section 52 of suitable length and weight and a tubular upper section 53 formed with suitable annular chambers or cavities as shown at 54 and 55 for containing the electrical and mechanical apparatus hereinafter more fully described.

The upper end of the drill collar 14 is joined, by a suitable threaded connection or coupling 51, with the before-mentioned upwardly extending drill pipe 15, and the lower end of the drill collar is connected by the usual box and pin type of threaded tool joint or coupling 61 to the before-mentioned drill bit 13. The upper portion 53 of the drill collar 14 contains an inner, concentric liner member 64 which defines an upper drilling fluid

passage 56, and the lower portion 52 of the drill collar is provided with a central, longitudinally extending, lower drilling fluid passage 57 terminating at its upper end in an upwardly extending nipple 68. The lower end of the liner 64 constituting the upper fluid passage 56 and the upper end of nipple 68 of the lower fluid passage 57, as provided within the upper and lower portions of the drill collar as before described, terminate coaxially opposite one another as shown at 58 and 59, respectively, forming a gap therebetween which is interconnected by means of a resilient, tubular member 60. The upper and lower ends of the resilient, tubular member 60 make fluid-tight connection with the lower end 59 of the liner 64 and with the upwardly extending nipple 68, respectively, and are held in such fluid-tight connection by hose clamps, as illustrated at 62 and 63, or by other suitable connecting means. The resilient, tubular member 60 is preferably composed of rubber, neoprene, or other suitable resilient or rubber-like material, whereby it will be capable of being readily deformed to restrict the flow of fluid flowing through and between the fluid flow passages 56 and 57, as hereinafter more fully described.

Located within the before-mentioned apparatus chamber 55 is suitable hydraulically actuated means for constricting the hereinbefore-mentioned resilient sleeve member 60 to increase the resistance to flow of fluid there-through, as before mentioned. In the illustrated embodiment of this invention such means comprises a pair of oppositely positioned, approximately semicircular lever members 65 and 66 which together substantially encircle the midsection of the resilient, tubular member 60 intermediate the upper and lower ends thereof, as best shown in FIGURE 3. The lever members 65 and 66 are each hinged for scissor-like pivotal motion toward one another about a common hinge pin 67 which passes through one end of each of the aforesaid lever members 65 and 66 and through a supporting lug 69 attached to and extending inwardly from the inner wall of the chamber 55.

The opposite ends of the levers 65 and 66 are provided with overlapping gusset members 70 and 71 which terminate in laterally extending lugs 72 and 73, which are pin-connected as shown at 74 and 75 to a piston and a cylinder 76 and 77, respectively, of a hydraulically actuated unit. The internal clearance space between the head of the cylinder 77 and the piston 76 is connected through a suitable pressure tubing 79 to the pressure end of a hydraulic actuating cylinder 80 also located within the chamber 55.

The hydraulic actuating cylinder 80 is provided with a piston 81 which is connected through a piston rod 82 to the lower end of an annular-shaped armature 83 of a solenoid 85 which surrounds an intermediate portion of the liner 64. For this construction the liner 64 is composed of a suitable non-magnetic material such as stainless steel, Monel metal or the like. The solenoid 85 is provided with a ferro-magnetic shell 84 and core member 86 enclosing annular field windings 87, such that upon energizing the solenoid by passing a suitable electric current through the windings 87 the armature 83 is forcefully urged to move longitudinally upward into the windings and shell by the resultant magnetic forces within the solenoid.

The apparatus chamber 55 containing the sleeve member 60 and the before-described apparatus for constricting it is closed from all communication with the exterior of the apparatus except insofar as fluid pressures are transferred to it from the drilling fluid flow ducts through the flexible walls of the sleeve member 60, and is filled with liquid, preferably oil. This is an important feature of this embodiment of the invention herein illustrated for several reasons. First, the filling of the entire space 55 with liquid serves to maintain a necessary degree of equalization of the static fluid pressure on the exterior and interior surfaces of the sleeve member 60 regardless of the pressure exerted by the drilling fluid on the interior

thereof as the apparatus is lowered into the fluid in deep well boreholes. Second, in the absence of communication of the liquid filled chamber 55 with the fluid pressures exterior to the apparatus, except through the sleeve 60 itself as before mentioned, the sleeve member is imparted a support by such liquid, and at the same time a stability against substantially complete inward collapse once constriction thereof is initiated due to the dynamic fluid pressure differential set up between the interior and exterior surfaces thereof when drilling fluid is flowing therethrough. Such collapse of the sleeve 60, which otherwise occurs in the absence of the foregoing conditions, persists after the initial constricting force has been removed, and hence the restriction to flow once initiated cannot be removed.

However, the foregoing instability is prevented by maintaining the chamber 55 closed and filled with liquid, and under such conditions the constricting force applied thereto by the beforementioned lever members 65 and 66 serves to pinch the sleeve member 60 inward at the point of contact of the lever members 65 and 66 therewith and to cause an outward deflection of adjacent portions thereof such as to maintain the volume of liquid in the chamber 55 exterior to the sleeve 60 substantially constant. Under the latter conditions, the constriction of the sleeve 60 can be applied and removed at will, and stability will be maintained.

Within the upper apparatus chamber 54 within the drill collar, is contained an instrument housing 89, which may for convenience of installation be in the shape of an annulus or segment of an annulus and preferably fluid-tight, which contains the electrical apparatus illustrated herein and hereinafter more fully described in connection with FIGURES 7, 8, 9, and 10. The opposite ends of the windings 87 of the solenoid 85 are connected through suitable insulated conductors 90 and 91 which extend through suitable passages in the bulkhead separating the upper apparatus chamber 54 from the lower apparatus chamber 55 and into the beforementioned instrument case 89 to make connection with the electrical apparatus therein.

Supported concentrically within an intermediate portion of the flow passage 57 in the lower portion 52 of the drill collar 14, is a hollow cylindrical housing member 95. A plurality of thin, radial web members, as shown in longitudinal section at 97, serve to support and to retain the housing 95 centralized in the flow passage 57 with, in effect, an annular clearance space therearound for passage of fluid. The before-mentioned cylindrical housing 95 is formed with an inner, concentric, cylindrical-shaped chamber 96, out through the lower end of which extends a concentric bore 98 and through the upper end of which extends an opening 99. The upper opening 99 is covered and sealed over with a metal bellows 100 which makes fluid-tight connection at its lower end periphery with the upper end portion of the cylindrical housing 96, thereby placing the inside volume of the bellows in communication, through the opening 99, with the chamber 96. An elongated push rod 102 extends into the chamber 96 through the before-mentioned bore 98 within the chamber 96 in the housing 95 and is retained therein, with freedom for limited longitudinal sliding motion therein, by means of an annular stop washer 103 fixed upon a suitable, upwardly facing shoulder formed on and adjacent the upper end of the push rod. A helical spring 104 surrounding the upper end portion of the push rod 102 above the stop washer 103 acts in compression between the upper inside end portion of the chamber 96 and the upper face of the stop washer 103 to urge the push rod 102 downward through the bore 98. A stop lug 105 extending outward from the inside surface of the chamber 96 serves, by engaging the lower side of the stop washer 103, to limit the extent of downward motion of the push rod 102. The chamber 96 and bellows 100 are filled with

a liquid, preferably a non-conductive liquid such as oil, to equalize the internal and external pressures thereof when immersed in drilling fluid within a well borehole.

Longitudinally slidably retained upon push rod 102 above a lower stop washer member 107 is a tapered plug 108 having a downwardly converging frusto-conical exterior surface as shown at 109, making a substantially fluid-tight fit in a correspondingly shaped plug seat in a central opening formed in the bottom of the central fluid passage in the shank of the drill bit 13. A helical spring 110 acting under compression between the lower exterior end portion of the housing 95 and the upper annular surface of the tapered plug 108 serves to urge the plug 108 downward into seated position upon the before-mentioned correspondingly tapered seat in the drill bit 13 when the drill bit 13 is assembled to the drill collar as shown in FIGURE 2. Suitable O-ring seals are provided for maintaining a fluid-tight seal between the exterior of the plug 108 and its seat, between the push rod 102 and the tapered plug 108, and between the push rod 102 and the housing 95.

The minimum diameter of the lower end opening 111 of the tapered seat in the drill bit 13 is sufficient to permit the disconnection of the bit 13 from the drill collar 14 at threaded joint 61 and the withdrawal of the drill bit 13 over the lower stop washer member 107 and the lower end runner mechanism of the rod 102, hereinafter more fully described.

The lower end of the push rod 102 is curved slightly at an angle such as to direct the end thereof substantially perpendicularly toward the upper surface of rotation of the cutter teeth of the roller 115.

Attached to the lower end of the curved portion of the push rod 102 is a runner member 112 of sufficient length to extend circumferentially between and bridge the gap between two or more adjacent teeth of roller 115 of the drill bit 13. Normally, when the drill bit 13, in an unworn condition, is assembled to the lower end of the drill collar 14, as shown in FIGURE 2, the runner 112 bears lightly upon the tips of the cutter teeth of the roller, thereby holding the push rod 102 against the downward thrust of spring 104 in an upward position, substantially as shown in FIGURE 2. As wear of the teeth of the roller 115 progresses, the runner 112 bearing upon and following the shortening of the teeth, permits the push rod 102 to move progressively downward through the bore 98 relative to the housing 95 and thus to move the stop washer member 103 downward to a position, ultimately, in contact with the stop lug 105 under conditions of maximum bit wear.

Within the chamber 96 of the housing 95 and electrically insulated therefrom is positioned an electric contactor 116 which is connected through an insulated electric conductor 117 to the electrical apparatus within the instrument housing 89. The insulated conductor 117 passes through suitable passages within the lower chamber 55 and thence through suitable passages as shown at 118 to the before-mentioned entrance into the instrument housing 89 located in the upper cavity 54.

As the push rod 102 moves downward following the progressive wear of the drill bit roller 115, the stop washer member 103 is finally brought into electrical contact with the contactor 116, whereby electrical connection is completed between the conductor 117, contact point 116, and the rod 102, which makes an electrical ground return connection through the housing 95 and other metal portions of the drill collar and bit.

The chamber 96 and the bellows 100 are filled with oil or the like non-conductive liquid. The chambers 54 and 55 surrounding the instrument housing 89 and surrounding the resilient sleeve 60 are also filled with oil or the like liquid to equalize the internal fluid pressures in the chambers and on the exterior of the resilient sleeve 60 with that of the circulating fluid in the liner 64 and passage 57.

Referring now primarily to FIGURE 4, a modified

form of the wear indicating apparatus is shown in the lower end of the drill collar. In this version of the apparatus, a tubular member 120 extends coaxially downward from and is supported at its upper end centrally within the lower portion of the fluid passage 57 by means of a pair or a plurality of radially extending web members 121 around which a clearance space is provided for passage of the circulating drilling fluid. Longitudinally slidably carried on the lower end portion of the tubular member 120 is a tapered plug 122 which is similar in form to plug 108 hereinbefore described in connection with the apparatus of FIGURE 2. The tapered plug 122 is urged downward into seating engagement within the before-described tapered seat 109 within the bottom of the fluid passage of the shank of the drill bit 13 by means of the helical spring 125 acting in compression between the upper surface of the plug 122 and the lower edges of the web members 121. Extending downward from the tubular member 120 is a ferro-magnetic projection or pole piece 126 of reduced diameter, curved adjacent its lower end in a manner similar to that of the push rod 102 hereinbefore described in connection with FIGURE 2, and which serves as a magnetic core for the windings of a surrounding inductor coil 127 fixed thereon. The inductor coil 127 comprises a plurality of turns of relatively small, insulated wire wound around the upper portion of the pole piece 126 and covered by a non-magnetic, fluid-tight case 128.

As before mentioned, the lower end of the pole piece 126 is curved or bent laterally at an angle such as to position the lower end thereof closely adjacent the tips of the cutting teeth of the roller 115. Sufficient clearance, however, is provided between the tips of the cutter teeth of a new, unworn roller or cone and the end of the pole piece 126 to just avoid contact therebetween. Attached to and forming a portion of the lower end of the pole piece 126 is a permanently magnetized member 129, the axis of the magnetic pole thereof being substantially coaxial with the axis of the lower end portion of the pole piece 126, whereby the magnetic flux induced by such permanent magnet will normally flow from the lower end of the permanent magnet through a substantially closed magnetic circuit comprising the cutter teeth of the roller or cone 115, through the body of the cone 115, through the cone shaft supporting legs of the drill bit 13, and return through the transverse lower portion of the drill bit 13, tapered plug 122, and the before-mentioned pole piece member 126.

One end of the winding (not shown) of the inductor coil 127 is suitably grounded to the case 128 or member 126, whereby it makes a ground return connection through the body of the drill bit. The other end of the winding of the coil 127 is connected to an insulated conductor which leads up through the passageway in the tubular supporting member 120, as shown at 130, and thence through a lateral passageway through web member 121, and makes connection with the insulated conductor 117 which leads to the electrical apparatus in the instrument housing 89, as described hereinbefore in connection with FIGURE 2.

Referring now primarily to FIGURE 5, in which still another modification of the apparatus of this invention is illustrated, a tubular supporting member 135 is supported coaxially within the lower portion of the fluid passage 57 in the drill collar by means of a transverse web member or radial web members 136 similar to that shown at 121 in FIGURE 4. The lower end of the tubular member 135 is provided with an enlarged, hollow, spherical end portion 138 which constitutes a gamma ray detector, as hereinafter described. Longitudinally slidably retained upon the tubular member 135 is a tapered plug member 140 similar in form to plug 108 or 122 as hereinbefore described in connection with FIGURES 2 and 4, and this plug is urged into fluid-tight seating position within the correspondingly shaped seat in the drill

bit shank, by means of the helical spring 142 also acting in a manner similar to that hereinbefore described in connection with the spring 125 of FIGURE 4. An electrode 139 located within the enclosure 133, and which enters the enclosure through a gas-tight insulating seal 144, is connected electrically through an insulated conductor 143 which extends through the passage in the tubular member 135 and thence through lateral passage 131 in the transverse web member 136 into electrical connection with the insulated conductor 117, which in turn extends to the electrical apparatus in the instrument chamber 89, as hereinbefore described.

The before-mentioned enlarged spherical portion 138 at the lower end of the tubular member 135 is made of a suitable metal and constitutes a gamma ray detector which may be either of the ionization chamber or Geiger counter type, and is filled with a suitable gas under suitable pressure as is well known in the art.

A plurality of the teeth of either or both of the cutter cones 115 and 115a of the bit 13 are made to contain radioactive material capable of radiating gamma rays, such as, for example, radium, and any one of a number of suitable radioisotopes such as, for example, cobalt 60 or cadmium 115. Such radioactive material is preferably mixed into the metal melt from which the cutter teeth are formed or included in the hard facing metal which is applied to the tips of the cutter teeth by the gas or electric welding methods commonly employed for such hard facing application. The ionization chamber or Geiger counter 138 is, as before described, positioned adjacent the cutter teeth of the cutter cones 115, whereby radiation from the radioactive material in the cutter teeth will activate the chamber 138 to a predetermined degree prior to the occurrence of any wearing away of the cutting teeth during drilling operations.

The radiation detector 138 is of such size, as shown, as to permit the drill bit 13 to be detached from the tool joint or lower end of the drill collar, allowing the plug 140 to be withdrawn from its seat and permitting the radiation detector 138 to remain suspended on the tubing member 135 at the lower end portion of the fluid duct 57. Removal and replacement of the drill bit 13 may thus be readily accomplished without the necessity of assembling or disassembling any of the apparatus, including the ionization chamber or Geiger counter 138 and supporting tubing 135, contained within the lower end of the drill collar.

Referring now primarily to FIGURE 6, in which a modified version of the apparatus of FIGURE 5 is illustrated, instead of the radiation detector 138 alone being suspended on the lower end of the tubular member 135, a metal container body, as shown at 150, is suspended at the lower end of the tubing member 135. The container member 150 contains within a suitable recess on one side thereof, as illustrated at 151, a quantity of radioactive material capable of producing gamma rays. On the opposite side of the container 150 and contained within a suitable recess therein, as illustrated at 152, is a suitable detector of gamma rays, such as preferably an ionization chamber or Geiger counter. The gamma ray source 150 and the detector 152 are thus separated as shown at 153 by a relatively thick body of shielding material preferably composed of steel or lead, whereby the ionization chamber or Geiger counter 152 is substantially shielded from the direct radiation from the gamma ray source 151.

The electrode (not shown) within the radiation detector 152 is connected through an insulated conductor 155 to the insulated conductor 117 which leads to the instrument housing 89 in the same manner as hereinbefore described in connection with FIGURES 2, 4, and 5.

Referring now primarily to FIGURE 10, in which the electromechanical portion of the actuating mechanism employed in connection with the apparatus of FIGURE 1 is schematically and diagrammatically shown, conductor 117, which leads from the contactor 116, as described in

connection with the apparatus of FIGURE 2, passes into the instrument housing 89 shown in FIGURE 2 and indicated by the dotted line enclosure 89 in FIGURE 10, and makes connection with one terminal of a suitable source of electric current such as one terminal of a battery B. The other terminal of battery B makes connection through conductor 91 to one end of the field winding 87 of the solenoid 85. The other end of the winding 87 is connected through conductor 90 to a suitable ground connection G within the housing 89. An electric circuit is thus formed from one terminal of the battery B through conductor 117 to the contact point 116, and when the circuit is completed between the contactor 116 and the contactor washer 103, as hereinafter more fully described, the circuit extends through the ground circuit through the metallic portions of the drill collar to the ground connection G, and from there in return through conductor 90, the winding 87 of the solenoid 85, and conductor 91 to the other terminal of the battery B.

Referring next to FIGURE 7, in which is illustrated the electromechanical apparatus employed in connection with the apparatus of FIGURE 4, the insulated conductor 117 leading from the inductor coil 127 passes into the housing 89 and makes connection with one input connection of an alternating current amplifier 160. The other input terminal of the amplifier 160 makes connection through the ground G and the metallic portions of the drill collar and bit to the grounded end of the inductor coil 127. The output from the alternating current amplifier 160 is connected through conductor 161, rectifier 162, conductor 163, to the windings of an electromagnet 165 of a relay 167 and return through conductor 166. An electric capacitor C is connected between conductors 163 and 166, across the windings of the electromagnet 165. The capacity of the capacitor C and the resistance of the windings of the electromagnet 165 are made such as to provide an electric time constant in the circuit comprising the capacitor C and the windings of the electromagnet 165 which is relatively long as compared to the frequency of the alternating current input to the amplifier 160, which is generated by the roller bit cutter teeth and the inductor coil 127 acting as a generator, as hereinafter more fully described.

The relay armature 168 is urged normally into electrical contact with contact point 169 by means of spring 170 when the electromagnet 165 is not energized. The armature 168 is connected through conductor 172 to one terminal of a suitable source of electrical current such as battery B. The other terminal of the source of electric current B is connected through conductor 91 to one end of the windings 87 of the solenoid 85. The other end of the windings 87 is connected through conductor 90 to the before-mentioned relay contact 169.

Referring now to FIGURE 8, in which an alternative version of the electromechanical portion of the actuating mechanisms which may be employed in connection with FIGURE 4 is illustrated, conductor 117 leading from the inductor coil 127 enters the instrument housing 89 and makes connection with one input terminal of an oscillation generator 175. The other input terminal of the oscillation generator 175 makes connection through the ground connection G and through the body of the drill collar and bit to the grounded end of the inductor coil 127 in the manner hereinbefore mentioned. The oscillation generator 175 may be of any suitable type, the frequency of which is capable of being controlled in accordance with the variations in reluctance of the magnetic path of the apparatus constituting, in effect, the magnetic core of the inductor coil 127. For example, in the present embodiment, the coil 127 constitutes an inductance in the oscillatory circuit of an electron tube oscillator of conventional design, whereby variation of the inductance of the inductor coil 127 will cause a corresponding variation in frequency of the oscillator. Considerable latitude in oscillator frequencies which may be employed is possible,

a frequency of 1000 cycles per second being suitable.

The alternating current output of such oscillator is fed through the pair of conductors 177, 178 to the input of a frequency discriminating circuit schematically illustrated at 181. Such frequency discriminating circuit 181 may be of any suitable or conventional type capable of producing preferably a D.-C. or unidirectional output signal or current having a value which is a function of the input frequency applied thereto through conductors 177 and 178, and in the present case such D.-C. or unidirectional output from the discriminator is applied through conductors 182 and 183 to the windings of the electromagnet 185 of relay 186.

Armature 195 of relay 186 is urged into its closed position with respect to contact point 197 by means of a spring 198. The armature 195 of relay 186 is connected through conductor 214 to one terminal of battery B and thence from the other terminal of battery B through conductor 91 to one terminal of the windings 87 of the solenoid 85. The contact point 197 of the relay 186 is connected through conductor 90 to the other end of the windings 87 of the solenoid 85 in the manner shown more completely in FIGURE 7.

Referring now to FIGURE 9, in which the electric circuit employed in connection with the apparatus of FIGURES 5 and 6 is illustrated, the conductor 117 leading from either the ionization chamber or Geiger counter 138 of FIGURE 5, or from the ionization chamber or Geiger counter 152 of FIGURE 6, enters the instrument housing 89 and makes connection with one input terminal of an electrometer or pulse counter 216 of suitable type. The other input terminal of the electrometer or pulse counter 216 makes a return connection with the grounded terminal of the ionization chamber or Geiger counter through ground connection G.

The electrometer or pulse counter 216 may be of any suitable or conventional type, which includes a suitable potential source for applying a relatively high potential difference between, for example, the electrode 139 and the surrounding envelope of the ionization chamber 138. The electrometer or pulse counter also may include conventional apparatus for producing preferably an A.-C. or pulsating D.-C. output signal in conductors 217 and 218 which is proportional to or a function of the ionization current or pulses in the before-mentioned radiation detectors 138 or 152.

The resultant A.-C. or pulsating D.-C. output signal from the electrometer or pulse counter 216 is applied through conductors 217 and 218 to the input terminals of an A.-C. amplifier 220, and from the amplifier 220 the A.-C. output signal from the amplifier is passed through conductors 221 and 222 and rectifier 229 and the resultant D.-C. signal to the windings of electromagnet 223 of the relay 224. The armature 225 of relay 224 is normally urged into a closed position with respect to contact point 226 by means of spring 227. The relay armature 225 is connected through conductor 228 to one terminal of a suitable source of electric current such as battery B. The other terminal of the source of electric current B is connected through conductor 91 to one terminal of the windings 87 of the solenoid 85, and the other terminal of the windings 87 of the solenoid 85 makes return connection through conductor 90 to the contact point 226 of the relay 224, as hereinbefore described more fully in connection with FIGURE 7.

The operation of the apparatus of the invention is as follows:

Referring first primarily to FIGURE 1, the drilling fluid, which is usually in the form of an aqueous drilling mud as commonly employed in the drilling industry, is continuously withdrawn from the reservoir or sump 40 through the suction pipe 38 of the drilling fluid circulating pump 36 and discharged under pressure from pump 36 through pipes 33 and 32, through the flexible hose 31, and thence through the swivel 17 into the fluid passage in

the kelly bar 16. The drilling fluid continues in its flow downward through the kelly bar 16, through the sections of the drill pipe 15 comprising the drill stem and through the passages 64 and 57 in the drill collar to the drill bit 13, from which it is discharged through the drill bit fluid outlet passages 23 into the bottom of the borehole surrounding the drill bit. From the bottom of the borehole the drilling fluid, together with cuttings from the drill bit, flows upward through the annular space in the borehole 10 surrounding the drill stem 15 and up through the surface string of casing 12, from which it overflows through the lateral or side outlet pipe 42 and returns to the sump 40.

The surge chamber 45 acts partially to absorb and smooth out the drilling fluid flow pressure fluctuations from the pump 36 resulting in flow of the drilling fluid from the pump to and through the drill stem having pressure pulsations and fluctuations which are of relatively low amplitude. Meanwhile, the rotation of the drill stem and drill bit by means of the rotary table 25 may or may not be simultaneously maintained, as the occasion dictates.

Referring now first primarily to the operation of the apparatus of FIGURES 1, 2, and 3, as the drill stem, drill collar, and drill bit 13 are rotated on bottom during drilling operations, the cutting tips of the cutter teeth on the rollers or cones 115 are subject to progressive wear, which gradually shortens them and causes a corresponding decrease in the effective diameter of their circle of revolution. As the diameter of the circle of revolution of the teeth of the cones 115 thus reduces, the runner 112, which rides lightly upon the ends of the cutter teeth, under the downward pressure exerted by spring 110, permits the rod 102 to move downward correspondingly gradually. When the diameter of the circle of revolution of the tips of the cutter teeth of the rollers 115 has thus reached a predetermined minimum, as determined by the initial adjustment of the position of the contactor point 116 in the chamber 96, the contact washer 103 will have then moved downward into electrical contact with the aforesaid contactor 116. At this point, electrical connection of the contactor 116 is made to ground through the rod 102 and return through the metallic portions of the drill collar, thereby completing the electrical circuit between the ground G and the conductor 117 shown in the wiring diagram of FIGURE 10. Current is thus permitted to flow from the current source B through conductor 91 to the windings 87 of the solenoid 85 and return through conductor 90 and ground G to conductor 117. The solenoid 85, thus energized, applies an upward force from the solenoid armature 83 through the piston rod 82 to the piston 81 in cylinder 80. The resultant upward motion of the piston 81 applies pressure to the liquid contained in the upper end of the cylinder 80, which pressure is transmitted through the tubing 79 to the inlet of the hydraulic cylinder 77. The resultant equal and opposite forces applied to the cylinder 77 and the piston 76 therein, as applied to the pin connections 75 and 74, respectively, cause the lug 72 to move upward and the lug 73 to move downward, as viewed in FIGURE 3 of the drawings, thereby causing the lever members 65 and 66, respectively, to pivot about pin 67 in scissor-like movement toward one another. Such pivotal motion of the lever members 65 and 66 toward one another brings them into contact with the exterior surface of the resilient sleeve member 60, thereby deforming the sleeve member 60 by depressing or pinching it inward in such a way as to reduce the cross-sectional area of the fluid flow passage therethrough, as illustrated by dotted lines 61. Constriction of the sleeve member 60 to produce a fluid pressure rise thereabove of from approximately 50 to 100 p.s.i. is usually sufficient.

The resultant increased pressure drop through the sleeve 60 causes a corresponding pressure increase thereabove throughout the fluid passage in the drill stem, and this fluid pressure increase is communicated through the

swivel 17, the flexible hose connection 31, and riser and connecting pipes 32 and 33 to the discharge of the fluid circulating pump 36. The pressure rise thus communicated to the pipe 33 is detected by the pressure pickup device 47 and converted into a corresponding electrical signal which may be utilized to operate any desired type of audible or visible signaling device. In the embodiment herein illustrated, this signal is recorded on the moving chart 46 of recorder 50 as a line appearing substantially as illustrated at P in FIGURE 1. The occurrence of such a pressure change as is illustrated by the offset line at P on the chart 46 then indicates to the driller that the wear on the rollers of the bit has progressed to the predetermined point at which replacement of the bit with a new bit should be made. The drill stem may then be withdrawn from the borehole, and the worn drill bit replaced by a new drill bit, as required.

Reference is now made primarily to the operation of the apparatus of FIGURES 4 and 7. Rotation of the drill bit on bottom during drilling operations causes the rollers 115 to rotate relative to the stationary electromagnet 128 carried on the lower end of the pole piece 126. As the cutter teeth on the rollers 115 are thus caused to move past the lower end of the magnet 128, the periodic variation in the gap or spacing therebetween causes a correspondingly periodic variation in the reluctance of the magnetic flux path through the circuit consisting of the pole piece 126, the permanent magnet 129, the cone 115, the cone-supporting legs and shank of the drill bit, and return through the plug 122 and the lower end portion of the tubular member 120. Such periodic variation in the reluctance of the magnetic flux path causes a corresponding variation in the flux passing through the inductor coil 127, which in turn results in inducing an alternating electric potential in the windings thereof, which is applied through the conductor 117 to the input of the alternating current amplifier 160 and return through the ground connection G and through the body of the drill collar and bit. The resultant alternating current output from the amplifier 160 is rectified at 162, and the resulting unidirectional current flows through conductor 163 to the windings of the electromagnet 165 of the relay 167, and return through conductor 166. The capacitor C is charged at a potential equal to the potential drop across the windings of the electromagnet 165. As hereinbefore mentioned, the time constant of the electrical circuit consisting of the capacitor C and the windings of the electromagnet 165 is relatively long as compared to the frequency of the alternating current normally applied to the amplifier 160 and thus relatively long as compared to the resultant pulsations in the unidirectional current resulting from the rectification of the output from the amplifier 160 by the rectifier 162. The relay 167 will thus not be actuated by any of the individual pulsations of the pulsating unidirectional current applied to it.

As the cutter teeth of the roller 115 progressively wear shorter and shorter during drilling operations, the gap separating the lower end of the magnet 129 from the tips of such cutter teeth will gradually increase, and at the same time the resultant blunting of the cutter teeth by such wear will result in a decreased range and rate of variation of the reluctance of the before-mentioned magnetic flux path as the cutter teeth are rotated past the lower end of the magnet 129. All of these effects result in a corresponding decrease in amplitude of the alternating voltage or current induced in the inductor coil 127, for a given rate of drill bit rotation and corresponding rate of cutter roller or cone rotation, which in turn results in a correspondingly decreased rectified unidirectional potential output from the amplifier 160 and rectifier 162 being applied across the capacitor C and across the windings of the electromagnet 165 of the relay 167. By adjustment of the tension of spring 170, the armature 168 of relay 167 is made to move into contact with contactor point 169 at a predetermined minimum current

through the electromagnet 165. Thus, when such a predetermined minimum current through the electromagnet 165 has been reached, as the alternating signal input to the amplifier 160 decreases due to wear of the cutter teeth on the roller 115, as before described, the armature 168 of relay 167 moves into contact with contactor point 169, thereby completing the electrical circuit from the battery B through the windings 87 of the solenoid 85. The current thus applied to the windings 87 of the solenoid 85 causes the solenoid armature 83 to move upward, thereby moving the piston rod 82 and the piston 81 in the cylinder 80 upwardly, thereby in turn applying pressure through the tubing 79 to the hydraulic cylinder 77 of the valve mechanism in the same manner and with the same results as hereinbefore described in connection with FIGURES 2 and 3.

Since the amplitude of the signal induced in the inductor coil 127 will not only vary as the wear of the cutter teeth varies, but also will vary as the speed of rotation of the cutter cone varies, it will be necessary to standardize on the speed of rotation of the drill bit at which it is desired to determine whether or not the drill bit has reached the degree to which the apparatus is adjusted to actuate the signaling means, as before described.

If, for any reason, such as damage or wear to the roller bit, the cone 115 ceases to rotate, the alternating potential ordinarily induced in the inductor coil 127 will likewise cease, resulting in actuation of the electrical circuit as before described and the constriction of the resilient sleeve 60, in turn causing a pressure rise to occur throughout the drill stem which is detected and recorded by the recorder as shown at P.

Reference is now made primarily to the operation of the apparatus of FIGURES 4 and 8. In the operation of this apparatus, the inductor coil 127 is connected through conductor 117 and the ground return connection to the input connections of an oscillation generator 175, as hereinbefore described. Rotation of the roller 115 relative to the pole piece 126 and the resultant variation in the reluctance of the magnetic flux path through the inductor coil 127 result in a corresponding periodic change in the inductance of coil 127. Since the inductance of coil 127 constitutes a controlling factor in the oscillatory circuit of the oscillation generator 175, as before described, the frequency of oscillation thereof is thereby modulated at a frequency corresponding to the frequency of passage of the cutter teeth past the lower end of the pole piece 126 and at a frequency modulation range which is a function of the shape of the cutter teeth, the maximum range occurring with sharp, unworn teeth and decreasing with wear and blunting thereof. In this arrangement, the lower end portion 129 of the pole piece 126 need not be a permanent magnet, but may be merely a piece of ferromagnetic material such as soft iron or steel. The thus modulated alternating current output from the oscillation generator 175 is applied through conductors 177 and 178 to the input of the frequency discriminator 181, which produces an output signal therefrom which is a function substantially only of the range of variation of frequency of the alternating current input and which is substantially independent of the modulation frequency over a wide range of frequencies above very low frequencies.

When the cutter teeth are sharp and of maximum angularity of form, the rotation of the rollers during drilling produces the maximum range of variation of inductance of coil 127, thereby producing the maximum range of frequency of modulation of the oscillator 175. As the cutter teeth become blunted in form due to wear during drilling, they produce a correspondingly reduced range of variation of inductance of coil 127, whereby the frequency range of modulation correspondingly becomes progressively lower until, if such wear were allowed to continue indefinitely, the ultimate result would be the entire removal of the teeth with resultant zero range of

modulation of the oscillator. The resultant signal output from the discriminator 181 therefore correspondingly varies from a maximum value when the cutter teeth are new and sharp to a minimum value when the cutter teeth are worn and blunt, with a theoretical ultimate lower limit of zero signal when the teeth are entirely worn away.

The condition of maximum allowable wear lies somewhere between these two extreme conditions, and by suitable adjustment of the relay 186, as, for example, by adjustment of the tension of spring 198, the relay is set to open or close when the signal fed to it through conductors 182 and 183 from the discriminator 181 is greater or less, respectively, than a predetermined arbitrary value corresponding to a predetermined cutter teeth wear condition.

Thus, so long as the signal fed to the relay 186 has a value above the predetermined value, the relay will remain open. When, due to cutter teeth wear as before described, the signal fed to the relay 186 from the discriminator falls below the predetermined value, the relay will close, that is, the armature 195 will move into contact with contact point 197, and the electrical circuit will thereby be completed from one terminal of battery B through conductor 91 to the windings 87 of the solenoid 85 and return through conductor 90, contactor point 197, armature 195, and conductor 214 to the opposite terminal of battery B.

If for any reason, such as damage, breakage, or freezing of the bearings, the cutter roller 115 ceases to rotate, variation of the inductance of the coil 127 will correspondingly entirely cease, in turn resulting in lack of any modulation of the output of the oscillation generator 175. Such resultant unmodulated alternating current applied from the oscillation generator 175 to the input of the discriminator circuit 181 will result in the absence of any output signal from the output of the frequency discriminator. The electromagnet 185 of the relay 186 will thus be deenergized, permitting the armature 195 to move into contact with the contactor point 197, thus closing the electrical circuit between conductors 214 and 197 and thereby in turn energizing the solenoid 85 as before described.

Therefore, so long as the roller 115 continues to rotate properly and so long as the wear of the cutter teeth does not exceed a predetermined amount, relay 186 will be sufficiently energized to maintain the contacts thereof open, and the solenoid 85 will remain unenergized. If, however, as before mentioned, due to damage or breakage, the roller 115 ceases to rotate, then the oscillation generator 175 will cease to be modulated, and an unmodulated alternating signal will be communicated from the output thereof through conductors 178 and 180 to the input of the frequency discriminator circuit 181. Since under such condition the input to the frequency discriminator circuit 181 is unmodulated, there will be no output signal therefrom through the conductors 182 and 183, and the relay 186, thus being deenergized, will permit the contact between armature 195 and contactor point 197 to close, thereby energizing the windings 87 of the solenoid 85 and in turn thereby actuating the hydraulic system to cause the resilient sleeve 60 to be deformed sufficiently to cause a pressure rise in the fluid flow there-through.

In event either one or both of the before-described conditions occurs, that is, if the roller 115 either ceases to rotate or if it incurs excessive wear, a pressure pulse will thus be transmitted and received at the top of the well and will be indicated or recorded as shown at P on the chart 46 of recorder 50.

Reference is now made primarily to the operation of the apparatus of FIGURES 5, 6, and 9. Interception of gamma rays by the radiation detector chamber 138 from the radioactive material placed in the cutting edges of the cutting teeth of the rollers 115 and 115a, or the interception of gamma rays by the radiation detector 152 resulting

from the scattering of gamma rays radiated from the source 151, such scattering being caused by the presence of the adjacent cutter teeth of the rollers 115 and 115a, results in a current flow through conductor 143 in the apparatus of FIGURE 5 or through conductor 155 in the case of the apparatus of FIGURE 6 and thence through conductor 117 to the input of the electrometer or pulse counter 216 as shown in FIGURE 9. The output from the electrometer or pulse counter 216 is applied through conductors 217 and 218 to the input of amplifier 220, and the output in turn of the amplifier 220 is applied through conductors 221 and 222 to the electromagnet 223 of the relay 224. Normally, prior to the occurrence of substantial wearing away of the radioactivity-containing tips of the cutter teeth on the cones 115 and 115a, or due to the reduction in scattering of gamma rays, also due to such wearing away of the metal of the cutter teeth, the gamma rays intercepted by either of the radiation detectors 138 or 152 will be sufficient to result in maintaining the relay 224 open, thus maintaining the solenoid 85 deenergized, in turn resulting in the absence of any fluid pressure signal being transmitted. However, upon a predetermined degree of wearing away of the cutter teeth on the cones 115 and 115a, sufficient radioactive material is removed and carried away or sufficient metal which causes scattering of the gamma rays is also removed and carried away to reduce the ionization chamber current or Geiger counter pulse rate below a predetermined value. The current thus applied from either of the radiation detectors, as the case may be, through the conductor 117 to the electrometer or pulse counter 216 is thus reduced to a value below that resulting in the minimum current required in the windings of the electromagnet 223 to maintain the contacts of the relay 224 open, thereby permitting the armature 225 of the relay 224 to move into closed contact with the contactor point 226. The electrical circuit is thereby completed from the battery B through the conductors 90 and 91 to the windings 87 of the solenoid 85, causing movement of the piston 81 in the cylinder 80, thereby in turn applying pressure to the hydraulic cylinder 77. Such pressure applied to the hydraulic cylinder 77 causes the constriction of the resilient sleeve 60 resulting in a fluid pressure signal being transmitted to the instruments at the surface of the drilling well, as hereinbefore described.

Much of the apparatus has been herein described as located within the drill collar. However, the term "drill collar" as herein used is not necessarily to be limited to the exact construction or location conventionally employed for drill collars, but shall mean any suitable container forming a part of the drill stem, drill collar, or drill bit, but usually located in the lower part of the drill stem adjacent or close to the drill bit.

It is to be understood that the foregoing is illustrative only, and that the invention is not to be limited thereby, but includes all modifications thereof within the scope of the invention as defined in the appended claims.

What is claimed is:

1. In a rotary drill string having a fluid flow duct there-through and a rotatable cutting member journaled thereon for rotational cutting contact with formations being drilled, said cutting member having a cutter surface subject to wear by said cutting contact, the combination comprising: sensing means carried by said drill string and positioned adjacent the said cutting surface, said means being responsive to changes, due to wear, in location of said cutting surface relative to said drill string; signal means in said drill string adjacent said cutting member,

actuatable to effect a change in resistance to flow of fluid flowing through said duct at a location adjacent said cutting member; and means controlled by said sensing means to actuate said signal means when said cutting surface has incurred a predetermined change in location corresponding to a predetermined amount of wear, wherein said sensing means comprises: a movable runner member; and means urging said runner member into engagement slidably with said cutting surface whereby the position of said runner member relative to said drill string changes as the location of said cutting surface changes due to wear.

2. Apparatus according to claim 1, in which said means to actuate said signal means comprises electromagnetic means operatively coupled to said signal means, and in which said means controlled by said sensing means comprises an electric current source, and switching means for controlling the connection of said current source to said electromagnetic means, said switching means being actuated by said movable runner member when said runner member has incurred a predetermined change in location.

3. Apparatus according to claim 2, in which said signal means comprises movable means in said flow duct movable by said electromagnetic means to partially restrict flow of fluid through said duct.

4. In a rotary drill apparatus, the combination comprising: a drill collar; a drill bit detachably coupled coaxially to the lower end of said drill collar, said drill bit and said drill collar being provided with interconnecting, axial, fluid flow passages through said drill collar and said drill bit; a rotatable cutting member journaled on said drill bit for rotational cutting contact with formations being drilled, said drill bit being provided with an axial opening in said drill bit interconnecting the axial fluid flow passage thereof with the exterior underside of said drill bit adjacent said cutting member; a supporting member attached adjacent one end of said drill collar fluid flow passage to the inner walls of said drill collar fluid flow passage and extending axially therefrom through said opening in said drill bit to a position at which the other end thereof is adjacent said cutting member; sensing means carried adjacent the said other end of said supporting member; signal producing means attached to said sensing means by said supporting member, said signal producing means being adapted to produce a signal indicative of a change in the degree of wear of said cutting member due to cutting contact with formations being drilled; and closing means carried on an intermediate portion of said supporting means to detachably close said opening whereby, upon disconnection of said drill bit from said drill collar, said closing means is withdrawn from said opening and said supporting member and said sensing means thereon may be withdrawn from said drill bit through said opening and retained on said drill collar.

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UNITED STATES PATENT OFFICE  
CERTIFICATE OF CORRECTION

Patent No. 3,058,532

October 16, 1962

Robert Lee Alder

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 2, line 60, after "mechanism" insert -- employed --; column 9, line 45, for "witth" read -- with --; column 13, line 12, for "upwardly" read -- upward --; line 20, for "cone" read -- cones --; line 22, after "bit" insert -- wear --; column 14, line 2, for "corespondingly" read -- correspondingly --.

Signed and sealed this 7th day of May 1963.

(SEAL)

Attest:

ERNEST W. SWIDER  
Attesting Officer

DAVID L. LADD  
Commissioner of Patents

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