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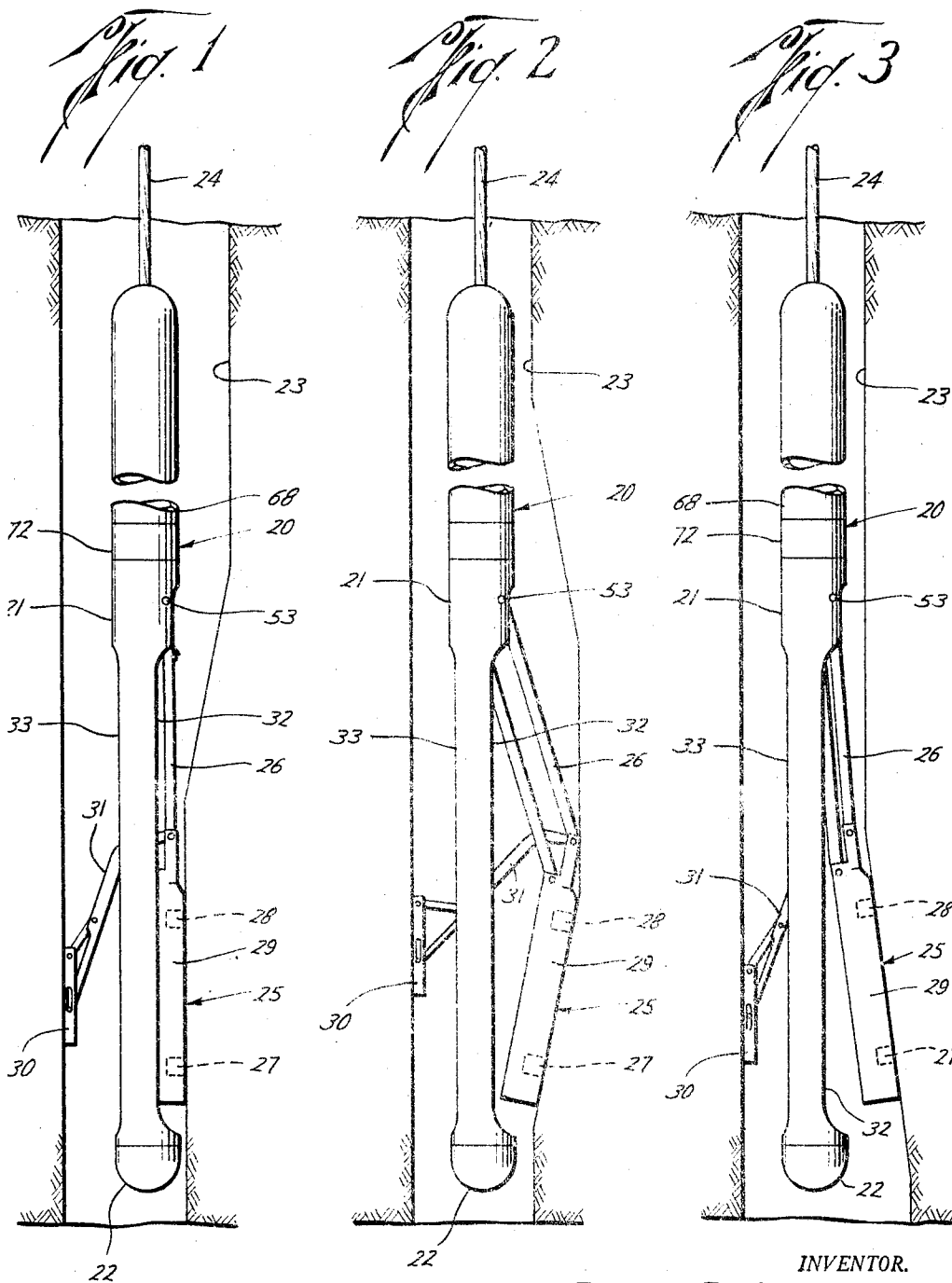
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CROSS REFERENCE

ARTICULATED GAMMA-GAMMA BOREHOLE LOGGING APPARATUS

Original Filed June 15, 1960

5 Sheets-Sheet 1



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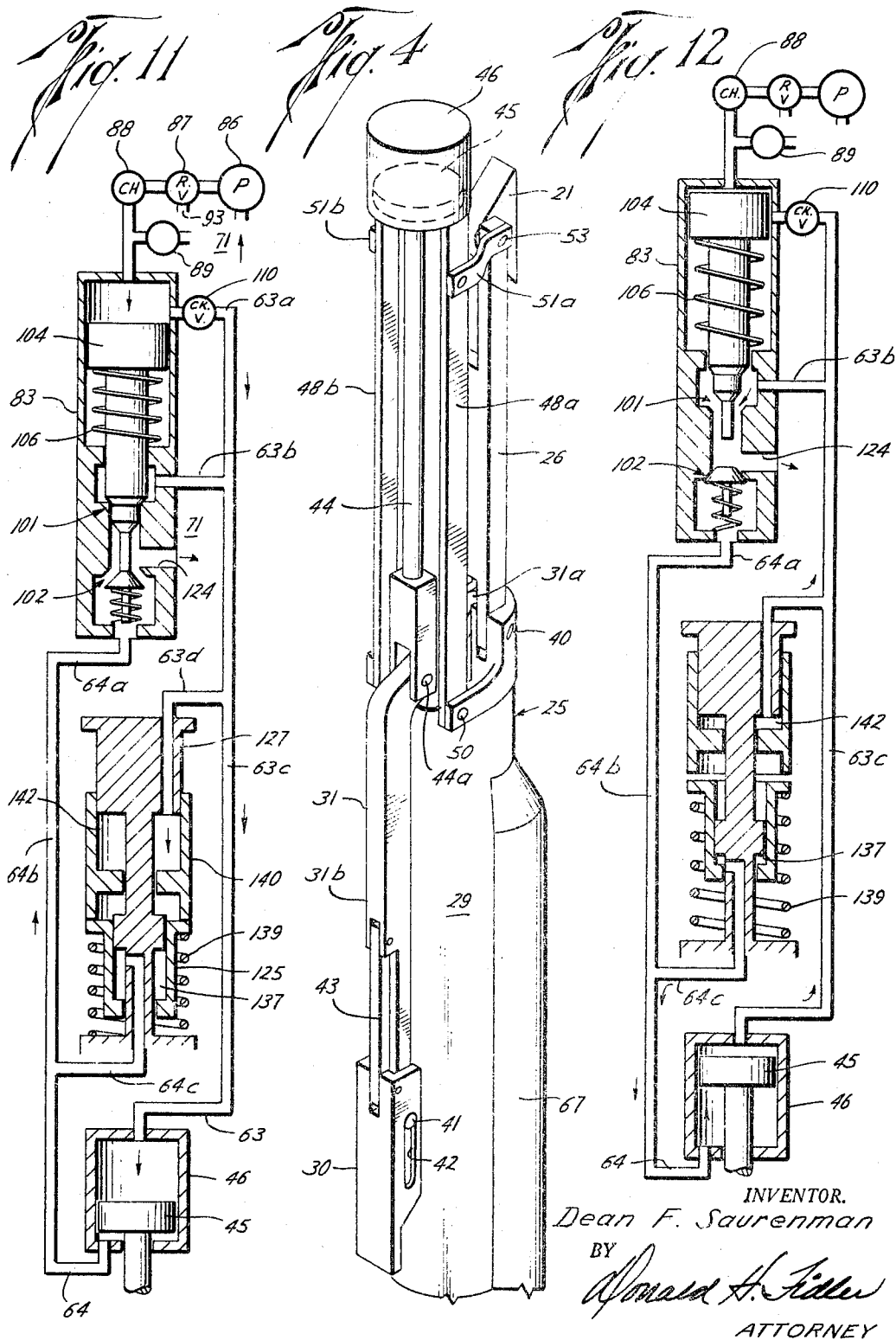
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ARTICULATED GAMMA-GAMMA BOREHOLE LOGGING APPARATUS

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5 Sheets-Sheet 2



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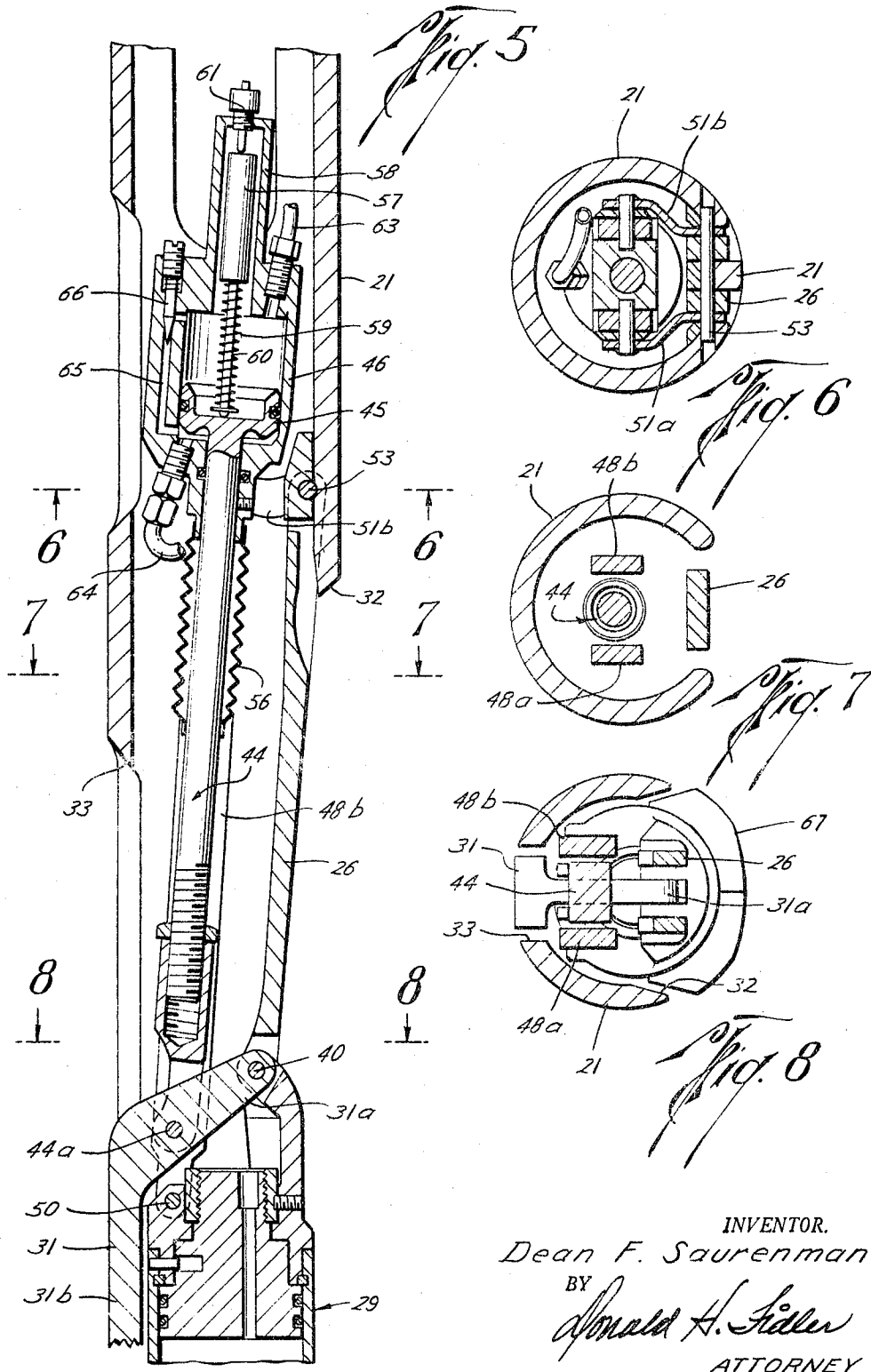
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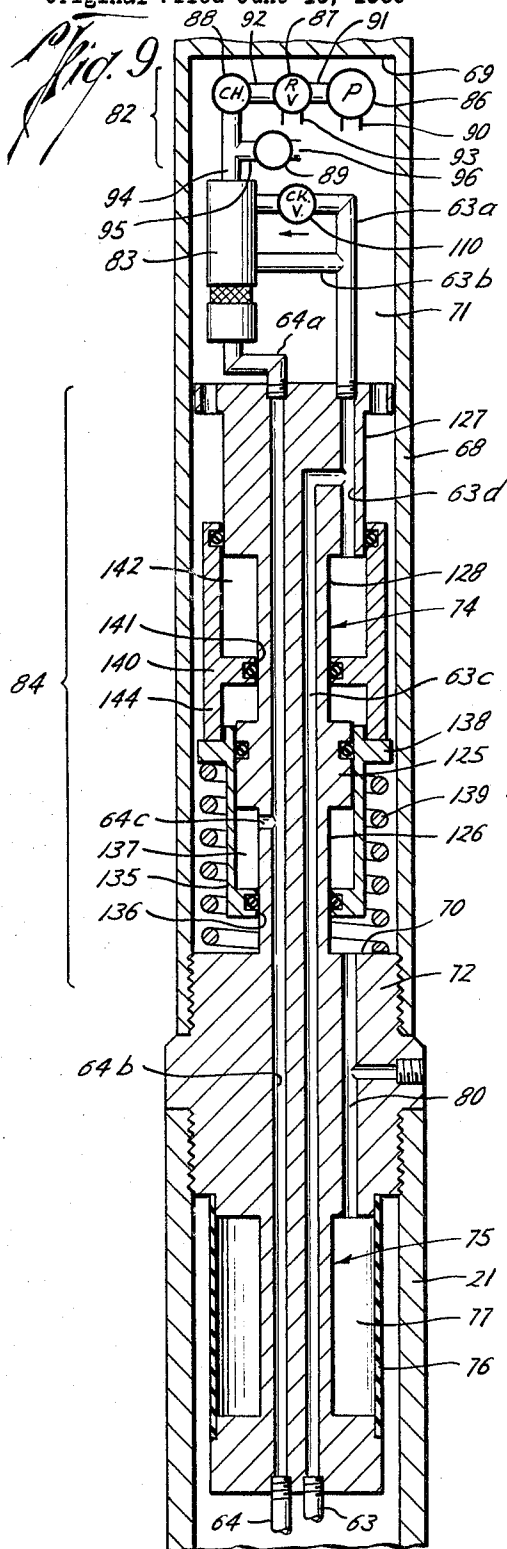
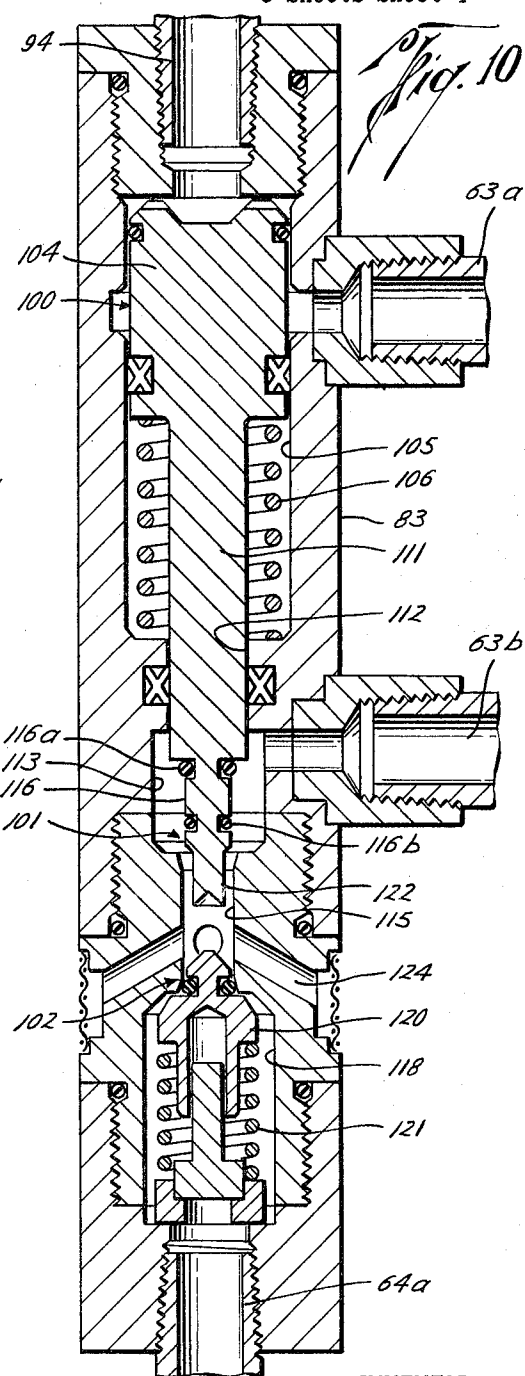
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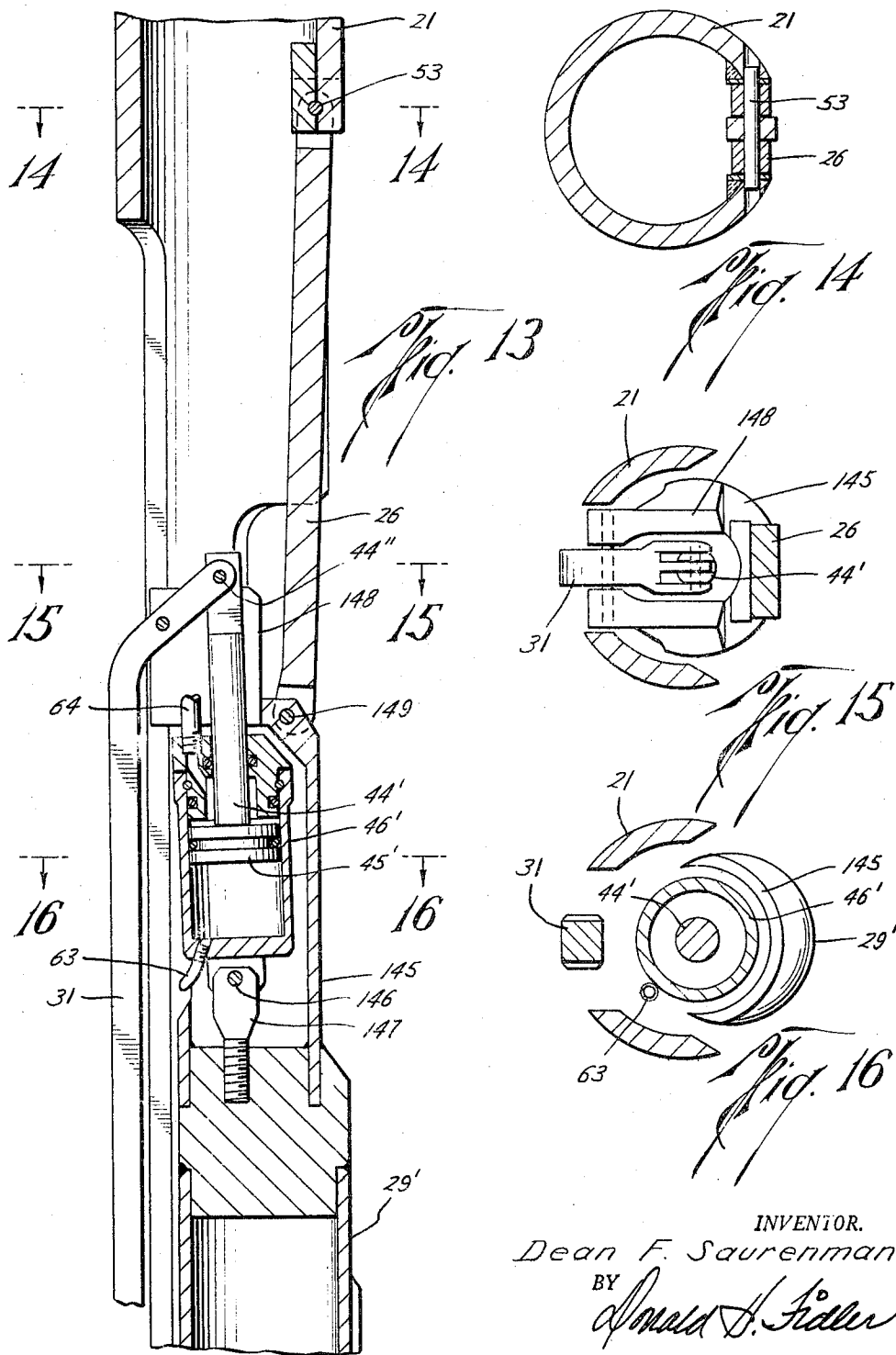
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5 Sheets-Sheet 5



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3,254,221

ARTICULATED GAMMA-GAMMA BOREHOLE LOGGING APPARATUS

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Continuation of application Ser. No. 36,270, June 15, 1960. This application Jan. 4, 1965, Ser. No. 424,453
26 Claims. (Cl. 250—83.6)

This is a continuation of application Serial No. 36,270, filed June 15, 1960 now abandoned.

This invention relates to logging apparatus for well bores and, more particularly, to γ - γ radioactivity logging apparatus wherein a relatively short, heavy skid housing containing the logging apparatus is arranged to be suspended from a main housing and maintained in substantially constant contact relationship with the wall of the well bore independently of such main housing.

Heretofore, radioactivity logging apparatus has been mounted in an elongated tool housing, together with the necessary circuitry arrangements and urged against the wall of a well bore by bow springs. Because the housing is quite heavy, it gravitates to the lower side of the well bore and slides therealong. Obviously, where the well bore has sections of varying diameters or wash-outs, caves and the like, an elongated tool tends to bridge over such sections and, therefore, sections of the tool are separated from the wall of the well bore. In tools such as γ - γ logging device, wherein contact of the device with the well bore is essential for accuracy, it will be appreciated that such separations tend to give rise to some inaccuracy in the measurements.

Other types of well logging apparatus employ relatively small and light-weight "pads" carrying electrodes which are urged into contact with the wall of the well bore by bow springs or linkage attached to an elongated main housing. In this type of apparatus, the housing may be slid along the lower side of the well bore with a pad extended by linkage to the upper side of the well bore or two or more pads may be arranged to extend relative to the tool housing into contact with the well bore.

Accordingly, it is an object of the present invention to provide new and improved well logging device contained in a relatively short, heavy skid housing and adapted to be maintained in a substantially constant contact relationship with the wall of a well bore independently of a main support housing.

It is another object of the present invention to provide new and improved apparatus including a main housing, and suspended therefrom a γ - γ radioactivity logging device contained in a relatively short, heavy skid housing which is adapted to be maintained in a substantially constant contact relationship with the wall of a well bore and decoupled from moment forces between the main housing and skid housing.

A further object of the present invention is to provide new and improved linkage systems for maintaining a relatively short, heavy skid housing in a substantially constant contact relationship with the wall of the well bore.

A still further object of the present invention is to provide new and improved hydraulic systems for controlling the operation of a well logging tool.

In the present invention, a relatively short, heavy skid housing is suspended by a pivotally coupled link member from a main housing. A logging device such as a source and detector of radioactivity is contained within the skid housing. A wall-engaging member is linked to the skid housing for relative movement so that the wall-engaging member and skid housing can be urged into contact with the wall of the well bore. A linkage system

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is provided for the wall-engaging member and skid housing for developing the relative movement therebetween without the development of undesirable moment forces. The linkage system is powered by hydraulic means which are responsive to a hydraulic system in the main housing.

FIGS. 1-3 illustrates apparatus embodying the present invention in various positions in a well bore;

FIG. 4 is a perspective view of the linkage system as embodied in the present invention;

FIGS. 5-8 are various views in cross section of the linkage system, shown in FIG. 4, as embodied in the present invention;

FIG. 9 is a view in cross section of the hydraulic system as embodied in the present invention;

FIG. 10 is a view in cross section of a component of the hydraulic system as embodied in the present invention;

FIGS. 11 and 12 are schematic diagrams of the hydraulic system of the present invention in two different conditions of operation; and

FIGS. 13-16 are views in cross section of another embodiment of the present invention.

Referring now to FIGS. 1-3, apparatus embodying the present invention includes an elongated, cylindrical main housing assembly 20, which has, at its lower end, a tubular member 21 which is open on opposed sides and terminated with a bottom nose piece 22. The nose piece 22 and tubular member 21 form a generally protective cover for an exploratory apparatus or tool 25 which is preferably a γ - γ radioactivity device. Tool 25 is solely suspended from the main housing 20 by means of a pivotally connected support link member 26.

In order to obtain indications of formation density from which porosity determinations can be derived, the apparatus 25 is arranged for γ - γ logging and thus includes a gamma ray source 27 and a gamma ray detector 28 mounted in a skid housing 29 and shielded in a customary manner. It will be noted that the skid housing 29 is no longer than necessary to contain the source 27 and detector 28 and thus may follow changing contours of the wall of the well bore more faithfully than an extremely long tool would.

A wall-engaging shoe 30 and eccentricing arm 31 are pivotally connected to the skid housing 29 so that, in normal operation, the shoe 30 contacts one side of the well bore intermediate of the length of the skid housing 29 while the skid housing 29 is maintained in contact with the opposite side of the well bore. The tubular member 21 has elongated window-like openings 32 and 33 sized to permit both the shoe 30 and skid housing 29 to be retracted to a position within the general cylindrical confines of the tubular member 21. Thus, it will be appreciated that retraction of the shoe 30 and skid housing 29 to the tubular member 21 facilitates passage of the entire assembly into an empty or fluid filled well bore 23, the assembly being transported by means of a cable 24 and winch (not shown) in the customary manner.

As shown in FIGS. 2 and 3, the skid housing 29, when urged into contact with the wall of well bore 23, follows very closely along the contours of the well bore as the contours vary.

Referring more particularly to FIGS. 4-8, the various details and arrangement of the skid housing 29 relative to tubular member 21 will become more apparent. Support link member 26 has its lower end pivotally connected to the upper end of skid housing 29 by a pin 40 which also is pivotally connected to one end of the eccentricing arm member 31. The eccentricing arm member 31 is a bell crank, the short arm 31a of the bell crank being connected to the skid housing 29 by pivot pin 40 and the remaining long arm 31b having at its remaining end a

pivot pin 41 which is slidably received in elongated slots 42 in the shoe 30. A link member 43 is pivotally connected between the long crank arm 31b and the upper end of shoe 30. Link member 43 guides and pulls on the shoe 30 as the shoe pivots about the end of crank arm 31b so that the flat face of the shoe 30 is maintained substantially vertical and parallel to the skid housing 29 as the eccentricing arm 31 is pivoted about pin 40 relative to the skid housing 29. Thus, the face of the shoe 30 and the face of the skid housing 29 are normally arranged to be substantially parallel as shown in FIG. 1, but are movable relative to one another to remain in contact with the sidewalls of a varying well bore as clearly shown in FIGS. 2 and 3.

The short crank arm 31a, near the junction of the long and short crank arms 31a, 31b is pivotally connected to one end of a push-pull rod assembly 44 by a pin 44a while the other end of the assembly 44 terminates at a piston 45 slidably received by a double-acting, hydraulic cylinder 46. The cylinder 46 is connected to the skid housing 29 by means of reaction link members 48a, 48b suitably fixed to the cylinder 46 and pivotally connected to an end of skid housing 29 by a pin 50, the reaction link members 48a, 48b and push-pull rod assembly 44 substantially lying in a plane of action or operation. To support the cylinder 46, cylinder supporting links 51a, 51b are pivotally connected between the reaction link members 48a and 48b, respectively, and the main housing pivot connection 53 substantially perpendicular to the aforesaid plane of action. The main pivot connection 53 also couples the upper end of the support link 26 to the main housing 21.

From the foregoing, it will be appreciated that the double-acting cylinder 46 is held in place by cylinder supporting links 51a, 51b which position the cylinder but do not rigidly restrict it. The two reaction links 48a, 48b are connected between the skid housing 29 and the double-acting cylinder 46 and are positioned on two sides of the pull rod. The purpose of the reaction links 48a, 48b is to transmit to the skid housing 29 all cylinder body forces which are exactly opposite to the forces transmitted by the pull rod assembly 44. The forces via the pull rod assembly 44 and the opposing forces via the reaction links 48a, 48b are maintained balanced with respect to the plane through assembly 44 transverse to the pivotal axes. Hence, the forces are in the same general geometric plane so that they will not impose undesirable moments on the skid housing 29.

Other details of the apparatus of FIGS. 4-8 include a rod seal boot 56 filled with clean oil installed between the bottom end of the double-acting cylinder 46 and the pull rod assembly 44 simply as a means of keeping clean the seal between the cylinder and the pull rod. A caliper potentiometer 57 is mounted in a potentiometer housing 58 which is also the head or closure of the double-acting cylinder 46. A spring 59 is mounted on the potentiometer shaft 60 to keep the shaft extended and in contact with the top surface of the piston 45 in the cylinder 46. An adjustment screw 61 is installed in the top end of the potentiometer housing 58 to permit adjustment of the potentiometer 57.

At the upper end of cylinder 46 is a flexible conduit 63 for passing fluid to one side of the piston 45 while at the lower end of cylinder 46 is a flexible conduit 64 for passing fluid to the other side of the piston 45. Conduits 63 and 64 are coupled to the hydraulic system which will hereinafter be explained. A bypass conduit 65 is also provided in the cylinder 46 for permitting fluid communication between both sides of piston 45. Conduit 65 is normally closed by a needle valve 66.

The skid housing 29 contains the detector cartridge 28 which may, for example, be a scintillation device (FIG. 1), and the source 27 which may, for example, be cesium 137. Except for the space for the cartridge 28 and source 27, the skid housing 29 is filled with heavy shielding ma-

terial such as lead. Mounted on the skid housing is a shoe surface 67 (FIG. 4). This shoe surface 67, for example, is made of tungsten heavy metal so treated that the surface that contacts the well bore is tungsten carbide which furnishes a very wear resistant surface.

Referring now to FIG. 9, a hydraulic system is provided for actuating power means, i.e., the hydraulic cylinder 46 and piston 45. The housing assembly 20 includes a tubular member 68 which is closed off by upper and lower walls 69, 70 to form a fluid reservoir 71 which contains oil or other suitable fluid. The lower wall 70 is formed from the upper end of a coupling sub 72 which is connected between the upper tubular member 68 and the lower tubular member 21. Sub 72 has an upper, cylindrically shaped, extension 74 extending into upper tubular member 68 and a lower, cylindrically shaped, extension 75 extending into the lower tubular member 21. The lower extension 75 has a recess surrounded by a flexible diaphragm 76 to form a pressure balance chamber 77. Well fluid in the well bore, if present, is admitted through openings 32, 33 in member 21 to one side of diaphragm 76 while the interior of chamber 77 is coupled to the reservoir 71 by a passageway 80 in sub 72. Hence, the pressure in the reservoir 71 is balanced with respect to hydrostatic pressure of the well fluid on the exterior of the housing 20.

The upper end of tubular member 68 contains, of course, the electronic cartridges for the γ - γ tool which need not be further elaborated herein, since it may be composed of conventional apparatus.

Within the housing 20 (and in reservoir 71) is a hydraulic system which includes a hydraulic power section 82, a control valve assembly 83 and a hydraulic control section 84 for the double-acting cylinder 46 and piston 45.

Included in the power section 82 are a pump and motor 86, a relief valve 87, a check valve 88, and a solenoid valve 89. The pump and motor 86 has an inlet line 90 open to oil reservoir 71 in the housing 20 and an outlet coupled by a conduit 91 to the relief valve 87. The relief valve 87 is coupled by a conduit 92 to the check valve 88 and includes a valve portion (not shown) arranged to couple the conduit 91 to a reservoir outlet 93 whenever a predetermined maximum pressure in the hydraulic system is reached. The check valve 88 is coupled by a conduit 94 to the control valve assembly 83 and operates to permit fluid flow in one direction and prevent flow in a reversed direction. Thus, fluid under pressure supplied by the pump and motor 86 to the control valve assembly 83 cannot be bled off through the pump after it has stopped operating. The solenoid valve 89 has an inlet 95 coupled to the conduit 94 between the check valve 88 and control valve assembly 83 and an outlet 96 to the reservoir 71. As could be surmised, the solenoid valve 89 is normally closed and, when actuated, serves to bleed off the fluid pressure from control valve assembly 83. From the foregoing, it will be appreciated that the power section 82 permits fluid from the reservoir 71 to be supplied to the control valve assembly 83 and provides for selective coupling of the control valve assembly 83 to the reservoir 71.

The control valve assembly 83 (FIG. 10) includes an operator 100, a first upper valve 101 and a second lower valve 102. The operator 100 consists of a piston 104 in a cylinder 105, the piston being movable in the cylinder between spaced upper and lower portions. The cylinder 105 is open at its upper end to the conduit 94 from the power section 82 and a spring 106 in the cylinder 105 serves normally to bias the piston 104 to an upper position adjacent the conduit connected end of the cylinder 105. Intermediate of the upper and lower positions of the piston 104, the cylinder 105 is opened to a conduit 63a. Thus, when fluid is supplied to the control valve assembly 83 from the power section 82, the piston 104 is moved from its normal upper position to a lower position, thereby compressing the spring 106 and coupling the power section 82 to conduit 63a. Conduit 63a, as will

be explained hereinafter, is coupled to the upper end of the double-acting cylinder 46 to move the piston 45 therein. Cylinder 105 has ports (not shown) at its lower end so that movement of piston 104 is not impeded by entrapped fluid.

Coupled to the lower side of the piston 104 is a smaller diameter, cylindrical extension 111 which is slidably and sealingly received in a bore 112 in the control valve assembly 83. Below the bore 112 is a cylindrical chamber 113 of larger diameter than the bore 112, the cylindrical chamber 113 adjoining a valve seating bore 115 of smaller diameter than the bore of the chamber 113. The valve seat bore 115 is coupled by openings 124 to the reservoir 71 while the first valve chamber 113 is coupled to conduit 63b. Conduit 63b is opened into conduit 63a. Valve 101 includes a first valve member 116 provided at the lower end of the extension 111 replete with upper and lower seals 116a, 116b to close the valve bore 115 when the piston 104 is moved toward its lowermost position. Lower seal 116b is so arranged relative to piston 104 so that the valve member 116 is sealingly received in the valve seating bore 115 closing off a conduit 63b from the openings 124 to the reservoir 71 before fluid communication is established between the conduits 94 and 63a in the upper end of cylinder 105 above piston 104. Further downward movement of piston 104 moves the upper sealing element 116a on valve member 116 into valve seating bore 115 and permits complete fluid communication between conduits 94 and 63a.

At the lower end of the valve seat bore 115 is a second cylindrical valve chamber 118 which opens at its lowermost end to a conduit 64a. Conduit 64a, as will hereinafter be more fully explained, is coupled to the lower side of the double acting cylinder 46. The valve 102 includes a second valve member 120 in the second valve chamber 118 which is biased into a normally closed position relative to the valve seat bore by means of a spring 121 disposed in the second valve chamber 118. A smaller diameter, valve-actuating extension 122 depends from the first valve member 116, so that after the first valve 101 is closed the second valve 102 is opened by removing the valve member 120 from the valve seat bore 115 which thereby compresses spring 121. The opening of valve 102 couples the conduit 64a to the reservoir 71 via conduits 124. Conversely, when the operation of control valve assembly 83 is reversed so that piston 104 moves upward, valve 102 closes before valve 101 opens to assure the precise, proper operation of the hydraulic control section 84. A check valve 110 (FIG. 9) is also disposed in conduit 63a adjacent to the opening from the control valve assembly 83.

Turning now to the hydraulic control section 84, the upper extension 74 of sub 72 has a first piston 125 spaced from the end wall 70 of sub 72 by a cylindrical section 126 of reduced diameter. A second piston 127 is spaced from the first piston 125 by a cylindrical section 128 of reduced diameter and the second piston 127 has a larger diameter than the first piston 125 for reasons which will become apparent hereinafter. Upper and lower extensions 74 and 75 of sub 72 have a first passageway or conduit 63c coupling conduits 63a of the control valve to conduit 63 of cylinder 45 and a second passageway or conduit 64b coupling conduit 64a of the control valve to conduit 64 of cylinder 45. Passageway 63c also has an extension 63d opening into the spacing formed by the cylindrical section 128 between the first and second pistons 125 and 127 while passageway 64b has an extension 64c opening in the space formed by the cylindrical section 126 between the first piston 125 and the wall 70 of sub 72.

A first cylinder 135 is slidably and sealingly received over the first piston 125 and has an opening 136 in its lower end sized and arranged to be sealingly and slidably received by cylindrical section 126 so as to form a first annular, expansible chamber 137 which is in communication with the extension 64c of conduit 64b. The cylinder 135 also has an annular flange 138 at its upper end and

a main spring 139 is received between the annular flange 138 and wall 70 of the sub 72 normally to bias cylinder 135 toward an upper location relative to the fixed position of the piston 125, thereby normally tending to decrease the volume of the expansible chamber 137. A second cylinder 140 is slidably and sealingly received over the second piston 127 and has an opening 141 intermediate of its ends slidably and sealingly received by cylindrical section 128 so as to form a second expansible, annular chamber 142 which is in communication with the extension 63d of conduit 63c. The second cylinder 141 has a tubular extension 144 which may bear upon the flange 138 of the first cylinder 135.

Turning now to the operation of the above-described apparatus, in accordance with the present invention, the linkage system to develop relative movement between shoe 30 and skid housing 29 will be discussed first and thereafter the hydraulic system will be explained.

In the linkage system, when the piston 45 is in a lowermost position in cylinder 46, the shoe 30 and skid housing 29 are retracted relative to one another and, conversely, when piston 45 is in an uppermost position in cylinder 46, the shoe 30 and skid housing 29 are extended relative to one another. The uppermost and lowermost positions of piston 45 in cylinder 46 represent the extreme relative positions of the shoe 30 and skid housing 29. Hence, it will be appreciated that, for an average diameter of a borehole, the piston 45 will be in an intermediate position in cylinder 46.

As shown in FIGS. 4 and 5, when piston 45 in cylinder 46 is moved under pressure toward its lowermost position, the rod assembly 44 "pushes" on arm 31 against the "pull" of the reaction links 48a, 48b on housing 29 so that eccentricing arm 31 is forced to a position adjacent to skid housing 29. The assembly in this condition may be lowered into the well bore to the level where commencement of the logging operation is desired.

To extend the arm 31 and skid housing 29, relative to one another, the pressure on piston 45 in cylinder 46 is reversed so that the piston 46 is now urged toward an uppermost position in cylinder 46. Hence, rod assembly 44 now "pulls" on arm 31 against the "push" of the reaction links 48a, 48b on housing 29 and the arm 31 pivots about pin 40 until the shoe 30 on arm 31 and housing 29 on link 29 are urged into contact with the wall of the well bore. It should be noted particularly that moment forces due to the extension and retraction of arm 31 and housing 29 are not imparted to housing 21. This is because the push-pull rod assembly 44 and reaction links 48a, 48b remain substantially in a single plane of operation so that the main moment forces cancel out, leaving only relatively negligible moment forces imposed upon housing 29. Hence, housing 29 is free to pivot about pivot 40 to the supporting link 26 and support link 26 is free to pivot about pivot 53. This permits housing 29 to follow the inclinations of the wall of the borehole free and independent of forces or positioning of housing 21 in the well bore.

From the foregoing, it will be appreciated that piston 45 in cylinder 46 provides for the actuation of the arm 31 and housing 29. The operation of a hydraulic system can best be understood by reference to the hydraulic flow diagrams shown in FIGS. 11 and 12 of the drawings. In FIG. 11, the operation to move piston 45 to its lowermost position in cylinder 46 is as follows. The pump 86 provides oil from the reservoir 71 to the control valve assembly 83 moving the control valve piston 104 from its upper position to its lower position. Thus, oil is supplied to the second expansible chamber 142 via extension 63d of conduit 63a and is also supplied to the top end of the double-acting cylinder via conduits 63a, 63c and 63. At this time, in the control valve assembly 83, first valve 101 is closed while second valve 102 is open. Hence, conduits 64a, 64b, 64c and 64 are opened to the reservoir 71 via conduit 124 in valve assembly 83. The pump 86 supplies

fluid until the piston 45 is in its lowermost position in cylinder 46 and chamber 142 between piston 127 and cylinder 140 is expanded so that cylinder 125 is moved downwardly and the main spring 139 is compressed, the chamber 137 between piston 125 and cylinder 135 being expanded. When the spring 139 is completely compressed to its desired compression, the relief valve 87 opens the pump 86 to the reservoir 71, via outlet 93 and the check valves 88 and 110 prevent any reduction of the pressure in the chamber 142 and the upper end of cylinder 46.

The above-described conditions exist when the skid housing 29 and eccentricing arm 31 are in a retracted condition within the housing 21. As shown in FIGS. 4 and 5 and described heretofore, the effect of the rod assembly 44 pushing while the reaction links 48a, 48b pull in the same plane of operation is to collapse the eccentricing arm 31 to the tool housing 29.

Also, with the above-described conditions, the lower end of the double-acting cylinder 46, the chamber 137 in cylinder 125, and conduits 64, 64a, 64b and 64c are pressure balanced to reservoir 71 through open valve 102 and thus to the fluid in the well bore through reservoir 71 and equalizing diaphragm 76 (FIG. 9). Inasmuch as oil volume is influenced by pressure and temperature, the equalizing of the volume of oil to the conditions of temperature and pressure assures precise repeatability of the hydraulic and hydraulic-mechanical functions.

Referring now to FIG. 12, to extend the eccentricing arm and housing 29 for logging operations, the solenoid valve 89 is opened to release the fluid under pressure in the control valve assembly 83 to the reservoir 71, the check valve 110 preventing immediate loss of pressure in the upper end of cylinder 46 or chamber 142. The spring 106 in the control valve assembly 83 turns the piston 104 to its uppermost position and, in so doing, the second valve 102 closes, blocking the conduits 64a, 64b and 64 to the lower end of the double-acting cylinder 46. Shortly after valve 102 closes, the first valve 101 opens to couple conduit 63b to the reservoir 71 via conduit 124 so that the chamber 142 and the upper end of the double-acting cylinder 46 thereby are opened to the reservoir 71. Since the hydraulic pressure in chamber 142 no longer overcomes the spring force of the main spring 138, the spring 139 expands and chambers 142 and 137 are contracted. The contraction of chamber 137 produces pressure in the conduit 64c which is applied to the lower side of piston 45 via conduit 64b, 64 thereby moving piston 45 upwardly.

As explained heretofore, piston 45 moves upwardly until the eccentricing arm 31 and skid housing 29 on link 26 are urged into contact with the wall of the well bore. For the average diameter borehole, the piston 45 will be in an intermediate position of the cylinder 46, its upward movement under the influence of the main spring 139 and the fluid in the system being checked by the contact of the shoe 30 and skid housing 29 with the walls of the well bore. Thus, should the well bore diameter decrease, piston 45 would be moved downwardly to further compress the spring 139 while, if the well bore diameter increases, piston 45 would be moved upwardly under the influence of spring 139. The spring 139 has a spring constant defining a linear relationship between force and deflection or length-force function. The relative angular and positional disposition of pivots 40, 44a and 50, and the bell crank 31a and long arm 31b of eccentricing arm 31 compensate for the linearity of the length-force spring function so that a relatively uniform force is applied to hold the shoe 30 and the skid housing 29 against the walls of the well bore over the range of well bore diameters in which the tool is intended to operate.

The diameter of the well bore is measured by the potentiometer 57 (FIG. 5) which measures the travel of piston 45 in cylinder 46, the travel of piston 45 being proportional to the relative spacing between the shoe 30 and skid housing 29.

In summary of the above-described operation, the sequence of operating steps will be described:

To insert in well bore

- (1) Pump and motor 86 are operated to actuate control valve assembly 83;
- (a) control valve assembly 83 operates
 - (1) to couple fluid under pressure to the upper end of cylinder 46 while the lower end of cylinder 46 is opened to reservoir 71 thereby moving piston 45 downwardly relative to cylinder 46, and
 - (2) to couple fluid under pressure to chamber 142 and open chamber 137 to reservoir 71 thereby permitting main spring 139 to be compressed;
- (b) movement of piston 45 downwardly, through rod assembly 44 and reaction links 48a, 48b, retracts arm 31 and skid member 29 into housing 21;
- (c) when pressure rating of hydraulic system reaches predetermined amount, relief valve 87 opens pump 86 to reservoir 71, check valve 88 prevents loss of fluid pressure in system, and main spring 139 is fully compressed.
- (2) Pump and motor 86 are shut off, check valve 88 prevents loss of pressure in system.
- (3) Tool assembly is lowered in borehole to the logging depth.

To log in well bore

- (1) Normally closed valve 89 is opened to actuate control valve assembly 83;
- (a) control valve assembly 83 operates
 - (1) to couple upper end of cylinder 46 and chamber 142 to reservoir, and
 - (2) to couple lower end of cylinder 46 to chamber 137, the fluid in chamber 137 being responsive to the force of main spring 139 to urge piston 45 upwardly in relation to cylinder 46;
- (b) movement of piston 45 upwardly, through rod assembly 44 and reaction links 48a, 48b, extends arm 31 and skid member 29 into contact with the walls of the well bore.
- (2) The tool assembly 20 is raised to log the well bore, the arm 31 and skid member 29 moving inwardly and outwardly relative to one another at sections of the well bore having different diameters. Inward relative movement compressing main spring 139 by expansion of chamber 137, outward relative movement being accomplished by the force of the main spring 139 in contracting chamber 137. Movement of piston 45 in cylinder 46 is measured by potentiometer 57 to obtain indications of diameter of the well bore. The source and detector of radioactivity 27 and 28 in skid housing 29 are held in close proximate contact with the sidewall of the well bore, the skid housing 29 being freely supported on link member 26 so as to follow changes in the contour of the well bore and held in proximate contact with the well bore by arm 31 and shoe 30.
- (3) After the traversing of the section of well bore which is being logged, the pump and motor 86 are operated and the arm 31 and skid housing 29 again retracted, as described above, and the assembly 20 retrieved from the well bore.

Referring now to the embodiment of FIGS. 13-16, another arrangement for independently supporting an exploratory tool relative to a main housing is illustrated. In FIG. 13, skid housing 29' has, at its upper end, an elongated, semi-circular, shell member 145 which is open toward the rearward side of the housing 29' and offset inwardly from the outer contacting surface of housing 29'. A double-acting cylinder 46' and a piston 45' therein are received within the shell member 145 with the cylinder 46' having one end pivotally connected by a pin

146 to a bifurcated stud 147 attached to housing 29'. Piston 45' has a piston rod 44' directly connected by a pivot pin 44'' to the short arm 31a of the eccentering arm 31. The eccentering arm 31 is pivotally mounted, near the junction of the short and long arms of arm 31 to a stirrup 148 which is suitably secured to the shell member 145. The shell member 145 is connected at its upper end to the support link 26 by a pivot connection 149. By coupling the piston 45' and cylinder 46' between the housing 29' and arm 31, moment forces relative to the main housing 21 are eliminated. Hence, it will be appreciated that the principle of decoupling the operation of the eccentering arm and skid housing from the main housing involves the application of opposing forces to the arm and skid housing in a single plane of operation and suitable linkage is provided to achieve the relative extension and retraction of the eccentering arm and skid housing.

Since the operation of the embodiment of FIGS. 13-16 involves similar principles to those previously described, a further description would be cumulative to the disclosure and need not be further elaborated upon.

It will also be appreciated from the foregoing that centralizers may be employed with main housing and other tools; for example, an electrical surveying device, a sonic measuring device, a radioactive logging device, etc. may be selectively arranged in the upper end of the main housing assembly 20 to operate in conjunction with the γ - γ tool to provide combination measurements of the various parameters of the earth formations. It will also be apparent that pad 30 may carry electrodes or the like for detecting other properties of the formation, thereby further increasing the versatility of the apparatus.

While particular embodiments of the present invention have been shown and described, it is apparent that changes and modifications may be made without departing from this invention in its broader aspects and, therefore, the aim in the appended claims is to cover all such changes and modifications as fall within the true spirit and scope of this invention.

What is claimed is:

1. Apparatus for use in a well bore comprising: a first elongated housing adapted for passage through a well bore by means of a cable or the like; a depending, second elongated housing for engagement with a wall of the well bore; a link member pivotally connected at its ends to said first and second housings to permit said second housing to pivot relative to said first housing; an arm member pivotally connected to said second housing so that a portion of said arm member is movable between a normally retracted position adjacent said second housing and an extended position relative to said second housing; and actuating means coupled between said second housing and said arm member and operable to displace said arm member portion from said retracted position toward said extended position into engagement with the wall of the well bore, thereby to provide a reaction force to urge said second housing into engagement with the wall of the well bore.

2. Apparatus for use in a well bore comprising: a first elongated housing adapted for passage through a well bore by means of a cable or the like; a depending, second elongated housing for engagement with a wall of the well bore; a link member pivotally connected at its ends to said first and second housings to permit said second housing to pivot relative to said first housing; an arm member pivotally connected to said second housing so that a portion of said arm member is movable between a normally retracted position adjacent said second housing and an extended position relative to said second housing; and actuating means mounted on said link member and coupled between said second housing and said arm member and operable in a single plane of operation to displace said arm member portion from said retracted position toward said extended position into engagement with the wall of the well bore, thereby to provide a reaction

force to urge said second housing into engagement with the wall of the well bore.

3. Apparatus for use in a well bore comprising: an elongated support housing having a first longitudinal axis and adapted for passage through a well bore by means of a cable or the like; an elongated, depending, second housing having a second longitudinal axis; a link member pivotally connected at its ends to said first and second housings, thereby permitting said second longitudinal axis to be aligned with, parallel to or displaced angularly relative to said first longitudinal axis; an arm member pivotally connected to said second housing so that a portion of said arm member is movable between a normally retracted position adjacent said second housing and an extended position relative to said second housing; and actuating means coupled between said second housing and said arm member and operable to displace said arm member portion from said retracted position toward said extended position so that said arm member is extended relative to said second housing until both the arm member and said second housing are in engagement with the wall of the well bore.

4. Apparatus for use in a well bore comprising: a first elongated housing adapted for passage through a well bore by means of a cable or the like; a depending, second elongated housing having an elongated contacting surface for engagement with a wall of the well bore; a link member pivotally connected at its ends to said first and second housings to permit said second housing to move independently relative to said first housing; an arm member pivotally connected to said second housing so that an end portion of said arm member is movable between a normally retracted position adjacent said second housing and an extended position relative to said second housing, said end portion being disposed generally midway of the length of said contacting surface; and actuating means coupled between said second housing and said arm member and operable to displace said arm member portion from said retracted position toward said extended position until engagement with the wall of the well bore, thereby to provide a reaction force to urge said second housing into engagement with the wall of the well bore.

5. Apparatus for use in a well bore comprising: a first elongated housing adapted for passage through a well bore by means of a cable or the like; a depending, second elongated housing for engagement with a wall of the well bore; a link member pivotally connected at its ends to said first and second housings to permit said second housing to move independently relative to said first housing; a bell crank member with a short arm pivotally connected to said second housing and a long arm arranged to be movable between a normally retracted position adjacent said second housing and an extended position relative to said second housing; and actuating means coupled between said second housing and said bell crank and operable to displace said long arm from said retracted position toward said extended position into engagement with the wall of the well bore, thereby to provide a reaction force to urge said second housing into engagement with the wall of the well bore.

6. Apparatus for use in a well bore comprising: a first elongated housing adapted for passage through a well bore by means of a cable or the like; a depending, second elongated housing for engagement with a wall of the well bore; a link member pivotally connected at its ends to said first and second housings to permit said second housing to move independently relative to said first housing; a bell crank with a short arm pivotally connected to said second housing and a long arm arranged to be movable between a normally retracted position adjacent said second housing and an extended position relative to said second housing; and actuating means including a push-pull means coupled between said second housing and said bell crank and operable to displace said long arm from said retracted position toward said extended position into engagement with the wall of the well bore,

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thereby to provide a reaction force to urge said second housing into engagement with the wall of the well bore.

7. Apparatus for use in a well bore comprising: a first elongated housing adapted for passage through a well bore by means of a cable or the like; a depending, second elongated housing for engagement with a wall of the well bore; a link member pivotally connected at its ends to said first and second housings to permit said second housing to move independently relative to said first housing; a bell crank with a short arm pivotally connected to said second housing and a long arm arranged to be movable between a normally retracted position adjacent said second housing and an extended position relative to said second housing; and actuating means including a push linkage and a pull linkage, a piston and a cylinder respectively coupled to one of said linkages, said linkages also being respectively coupled to said second housing and said bell crank and operable to displace said long arm from said retracted position toward said extended position into engagement with the wall of the well bore, thereby to provide a reaction force to urge said second housing into engagement with the wall of the well bore.

8. Apparatus for use in a well bore comprising: a first elongated housing adapted for passage through a well bore by means of a cable or the like; a depending, second elongated housing for engagement with a wall of the well bore; a link member pivotally connected at its ends to said first and second housings to permit said second housing to move independently relative to said first housing; a bell crank with a short arm pivotally connected to said second housing and a long arm arranged to be movable between a normally retracted position adjacent said second housing and an extended position relative to said second housing; and actuating means including a push linkage and a pull linkage lying in a single plane of operation, a piston and a cylinder respectively coupled to one of said linkages, said linkages also being respectively coupled to said second housing and said bell crank and operable to displace said long arm from said retracted position toward said extended position into engagement with the wall of the well bore, thereby to provide a reaction force to urge said second housing into engagement with the wall of the well bore.

9. Apparatus for use in a well bore comprising: a first elongated housing adapted for passage through a well bore by means of a cable or the link; a depending, second elongated housing for engagement with a wall of the well bore; a link member pivotally connected at its ends to said first and second housings to permit said second housing to move independently relative to said first housing; a bell crank with a short arm pivotally connected to said second housing and a long arm arranged to be movable between a normally retracted position adjacent said second housing and an extended position relative to said second housing; and actuating means including a push linkage coupled between said second housing and a cylinder, a pull linkage coupled to a piston in said cylinder and said bell crank, said linkages lying in a single plane of operation, supporting means coupling said cylinder to said link member, said piston and cylinder being operable to displace said long arm from said retracted position toward said extended position into engagement with the wall of the well bore, thereby to provide a reaction force to urge said second housing into engagement with the wall of the well bore.

10. Apparatus for use in a well bore comprising: a first elongated housing adapted for passage through a well bore by means of a cable or the like; a depending, second elongated housing for engagement with a wall of the well bore; a link member pivotally connected at its ends to said first and second housings to permit said second housing to tilt and move laterally relative to said first housing; a bell crank with a short arm pivotally connected at its end to said second housing and a long arm arranged to

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be movable between a normally retracted position adjacent said second housing and an extended position relative to said second housing; and actuating means including a push linkage coupled between a hydraulic cylinder and said second housing, a pull linkage coupled between a piston in said hydraulic cylinder and said short arm of said bell crank, said linkages being arranged for operation in a single plane, means including said push linkage forming a parallelogram linkage with said link member having a single pivoted connection with said first elongated housing at the upper end of said link member, said piston and hydraulic cylinder being operable to displace said long arm from said retracted position toward said extended position into engagement with the wall of the well bore, thereby to provide a reaction force to urge said second housing into engagement with the wall of the well bore.

11. A hydraulic actuating system for a double-acting, hydraulic cylinder and piston comprising: a first piston and cylinder containing fluid and coupled for fluid communication to one side of said hydraulic cylinder; spring means mechanically coupled between said first piston and cylinder tending to decrease the volume between said first piston and cylinder, thereby urging said piston in said hydraulic cylinder in one direction; a second piston and cylinder coupled to the other side of said hydraulic cylinder, said first piston and cylinder being mechanically responsive to relative movement of said second piston and cylinder so that an increase in volume between said second piston and cylinder develops an increase in volume between said first piston and cylinder; a source of hydraulic power; and a reservoir filled with fluid; hydraulic control means selectively operable at a first condition for coupling said source of hydraulic power to said other side of said hydraulic cylinder while opening said one side of said hydraulic cylinder to said reservoir, thereby urging said piston in said hydraulic cylinder in an opposite direction and operable at a second condition for closing said one side of said hydraulic cylinder from said reservoir while opening said other side of said hydraulic cylinder to said reservoir, thereby permitting said spring means to urge said piston in said hydraulic cylinder in said one direction.

12. A hydraulic actuating system for a double-acting, hydraulic cylinder and piston comprising: a first piston and cylinder containing fluid and coupled for fluid communication to one side of said hydraulic cylinder; spring means mechanically coupled between said first piston and cylinder tending to decrease the volume between said first piston and cylinder, thereby urging said piston in said hydraulic cylinder in one direction; a second piston and cylinder coupled to the other side of said hydraulic cylinder, said first piston and cylinder being mechanically responsive to relative movement of said second piston and cylinder so that an increase in volume between said second piston and cylinder develops an increase in volume between said first piston and cylinder; a source of hydraulic power; and a reservoir filled with fluid; hydraulic control valve means selectively operable in response to said hydraulic power to a first condition to sequentially couple said source of hydraulic power to said other side of said hydraulic cylinder and open said one side of said hydraulic cylinder to said reservoir, thereby urging said piston in said hydraulic cylinder in an opposite direction; means to release said hydraulic power from said control valve means to place said control valve means in a second condition wherein said one side of said hydraulic cylinder is first closed from said reservoir and said other side of said hydraulic cylinder is next opened to said reservoir, thereby permitting said spring means to urge said piston in said hydraulic cylinder in said one direction.

13. Well apparatus comprising an elongated main housing arranged to be suspended from its upper end for movement through a well, and an assembly supported by said housing solely through a single pivotal connec-

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tion therewith, said assembly comprising an elongated first wall-engaging member, a second wall-engaging member, a first link supported from said single pivotal connection and pivotally connected with said first member to support said first member for tilting and lateral movement relative to said housing, a second link pivotally connected with said first member and supporting said second member for movement relative to said first member between retracted and wall-engaging positions, and power means connected between said second link and said first member for moving said members selectively to either of said positions.

14. Well apparatus, as defined in claim 13, including third and fourth links having a common pivotal connection and pivotally connected respectively to said housing and said first member and forming with said first link a parallelogram linkage, said power means being connected to said first member through said common pivotal connection and said fourth link.

15. Well apparatus, as defined in claim 13, wherein said first member houses a radioactive source and detector and heavy shielding thereabout, and said power means applies a substantially constant outwardly directed force to said members in their wall-engaging position irrespective of well diameter changes.

16. Well apparatus comprising an elongated housing arranged to be suspended from its upper end for movement through a well, an elongated first wall-engaging member, a supporting link having a pivotal connection with said first wall-engaging member and with said housing to support said first member for tilting and lateral movement relative to said housing, a second wall-engaging member supported by said first wall-engaging member for movement relative thereto, said first and second wall-engaging members being movable relative to one another between a retracted position for free movement through a well and an extended position in contact with the walls of the well, power means for selectively moving said first and second wall-engaging members to either of said relative positions, and means providing a force transmitting connection between said power means and each of said wall-engaging means which is torque-free relative to the pivotal connection between said housing and said supporting link.

17. Radioactivity logging apparatus comprising an elongated main housing adapted for connection with a cable to be moved through a well, a skid housing, link means providing said skid housing with a doubly articulated connection with said main housing through a single supporting pivot thereon, a gamma ray source and a gamma ray detector supported within said skid housing in spaced shielded relation from one another, a back-up shoe movably carried by said skid housing so as to be supported through said articulated connection by said elongated main housing and movable relative to said skid housing, and means connected between said back-up shoe and said skid housing for selectively urging said back-up shoe and said skid housing to move relative to one another to engage the walls of a well.

18. Well apparatus comprising a main housing adapted to be moved through a well, a first wall-engaging member having a doubly articulated connection with said main housing, through a single pivot point thereon, a second wall-engaging member carried by said first wall-engaging member so as to be supported through said articulated connection by said main housing, said second wall-engaging member being movable with respect to said first member, hydraulic power means carried by said first wall-engaging member and supported by said main housing through said articulated connection for urging said first and second wall-engaging members to move relative to one another into an engagement with the walls of the well bore, and hydraulic control means in said main housing flexibly connected with said power means for controlling said power means.

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19. A well apparatus for use in a well bore comprising first and second elongated support housings, a supporting link member pivotally coupled between said housings to permit said housings to tilt and move laterally relative to one another, and selectively operable means carried by said second housing for urging said second housing into proximate contact with the wall of a well bore and for retracting said second housing from contact with the wall of said well bore, said second housing carrying a source and detector of radioactivity in spaced shielded relationship from one another.

20. In an apparatus for use in a well bore and having a first elongated housing adapted for passage through a well bore by means of a cable or the like and a depending, second elongated housing for engagement with the wall of the well bore, the combination of means for manipulating the second elongated housing in the well bore without transmitting torque to the first elongated housing, which means comprises: a link member pivotally connected at its ends to said first and second housings to permit relative movement therebetween; an arm member pivotally carried by said second housing so that a portion of said arm member is movable between extended and retracted positions relative to said second housing; hydraulic actuating means carried by said link member and coupled between said second housing and said wall-engaging member; a hydraulic operating system for positively actuating said hydraulic means to retract said second housing and wall-engaging member; and spring means operable to extend said second housing and wall-engaging member relative to one another.

21. In an apparatus for use in a well bore and having a first elongated housing adapted for passage through a well bore by means of a cable or the like and a depending, second elongated housing for engagement with the wall of the well bore, the combination of means for manipulating the second elongated housing in the well bore without transmitting torque to the first elongated housing, which means comprises: a link member pivotally connected at its ends to said first and second housings to permit relative movement therebetween; an arm member pivotally carried by said second housing so that a portion of said arm member is movable between extended and retracted positions relative to said second housing; hydraulic actuating means carried by said link member and coupled between said second housing and said wall-engaging member and operable in a single plane of action; a hydraulic operating system for positively actuating said hydraulic means to retract said second housing and wall-engaging member; and spring means operable to extend said second housing and wall-engaging member relative to one another.

22. In an apparatus for use in a well bore and having a first elongated housing adapted for passage through a well bore by means of a cable or the like and a depending, second elongated housing for engagement with the wall of the well bore, the combination of means for manipulating the second elongated housing in the well bore without transmitting torque to the first elongated housing, which means comprises: a link member pivotally connected at its ends to said first and second housings to permit relative movement therebetween; an arm member pivotally carried by said second housing so that a portion of said arm member is movable between extended and retracted positions relative to said second housing; hydraulic actuating means coupled between said second housing and said well-engaging member; a hydraulic system for actuating said hydraulic means including a first cylinder and piston forming a first chamber and a second piston and cylinder forming a second chamber, said first and second pistons and cylinders being mechanically coupled to one another so that an increase in volume in said first chamber increases the volume in said second chamber, said second piston and cylinder having a spring mechanically coupled therebetween tending to decrease

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the volume of said second chamber, said first chamber being connected to one side of said hydraulic cylinder so that an application of hydraulic pressure increases the volume of said first chamber, thereby compressing said spring and moves said piston in said hydraulic cylinder in a first direction, said second chamber being coupled to the other side of said hydraulic cylinder so that when such hydraulic pressure is released from said first chamber and one side of said hydraulic cylinder, said spring may provide the actuating pressure to move said piston in said hydraulic cylinder in a second direction.

23. A well apparatus for use in a well bore comprising first and second elongated housings, a supporting link member having a pivotal connection with each of said housings, the pivotal connection with said first housing providing the sole supporting connection with said second housing to permit said housings to tilt and move laterally relative to one another, and means carried between said first and second housings for urging said second housing into proximate contact with the wall of a well bore.

24. Well apparatus comprising an elongated main housing arranged to be suspended from its upper end for movement through a well, and an assembly supported by said housing solely through a single pivotal connection therewith, said assembly comprising an elongated first wall-engaging member, a second wall-engaging member, a first link supported from said single pivotal connection and pivotally connected with said first member to support said first member for tilting and lateral movement relative to said housing, a second link pivotally connected with said first member and supporting said second member for movement relative to said first member between retracted and wall-engaging positions, and power means connected between said main housing and said first member for moving said members selectively to either of said positions.

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25. Well apparatus comprising an elongated main housing adapted for connection with a cable to be moved through a well, a skid housing having an articulate connection through a pivotal link member with said main housing for tilting and lateral movement relative thereto, a back-up shoe movably carried by said skid housing so as to be supported through said articulate connection by said elongated main housing and movable with respect to said skid housing, and power means connected between said housings for selectively urging said back-up shoe and said skid housing to move relative to one another to engage the walls of a well.

26. A well apparatus for use in a well bore comprising first and second elongated housings, a supporting link member having a pivotal connection with each of said housings, the pivotal connection with said first housing providing the sole supporting connection with said second housing to permit said housings to tilt and move laterally relative to one another, and means carried by said second housing for urging said second housing into proximate contact with the wall of a well bore.

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