

Jan. 26, 1965

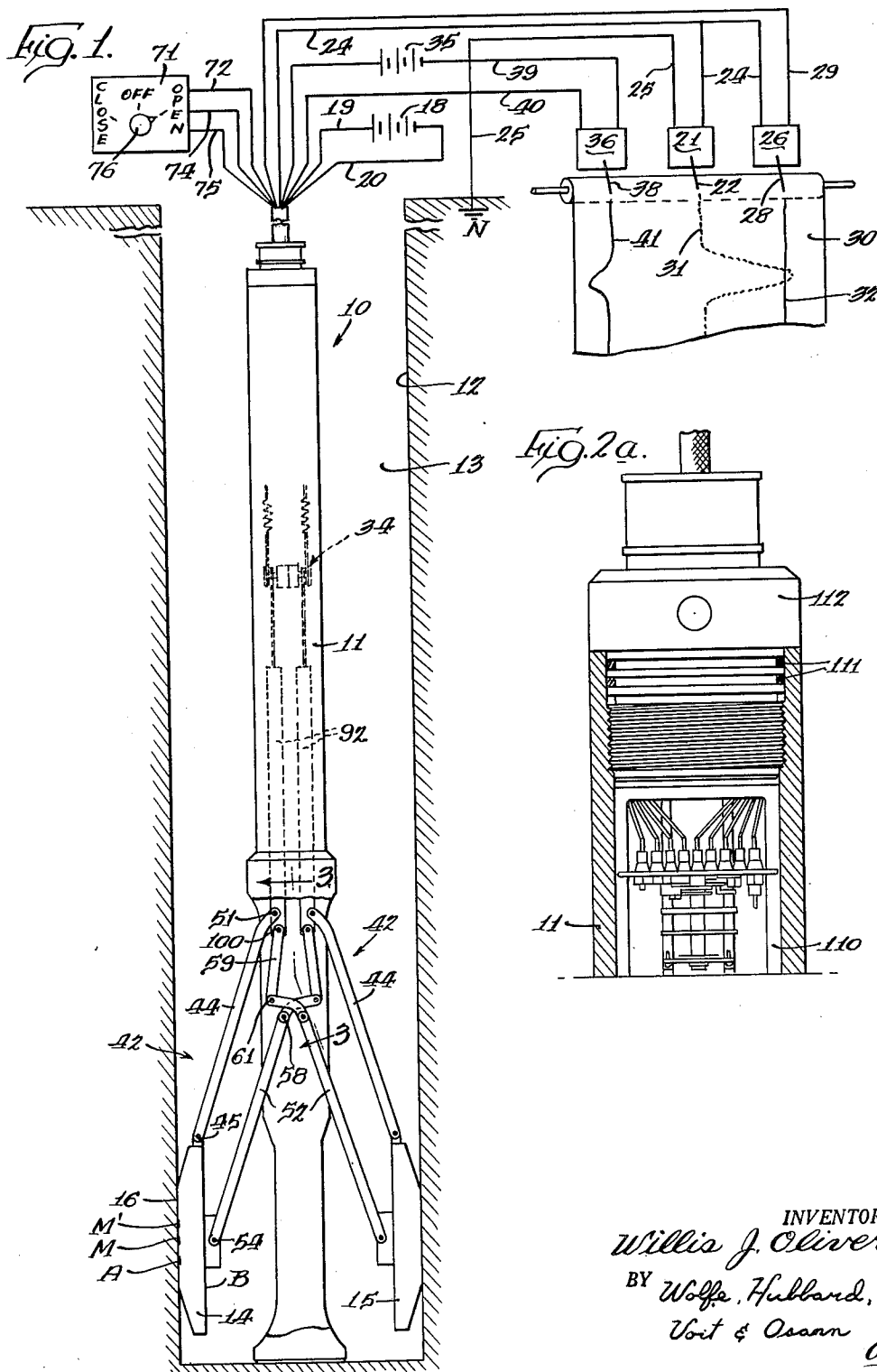
W. J. OLIVER

3,167,707

WELL LOGGING APPARATUS HAVING LATERALLY SHIFTABLE
WALL ENGAGEABLE ELECTRODE SUPPORTS

Filed Dec. 29, 1960

4 Sheets-Sheet 1



Jan. 26, 1965

W. J. OLIVER

3,167,707.

WELL LOGGING APPARATUS HAVING Laterally SHIFTABLE
WALL ENGAGEABLE ELECTRODE SUPPORTS

Filed Dec. 29, 1960

4 Sheets-Sheet 2

Fig. 2b.

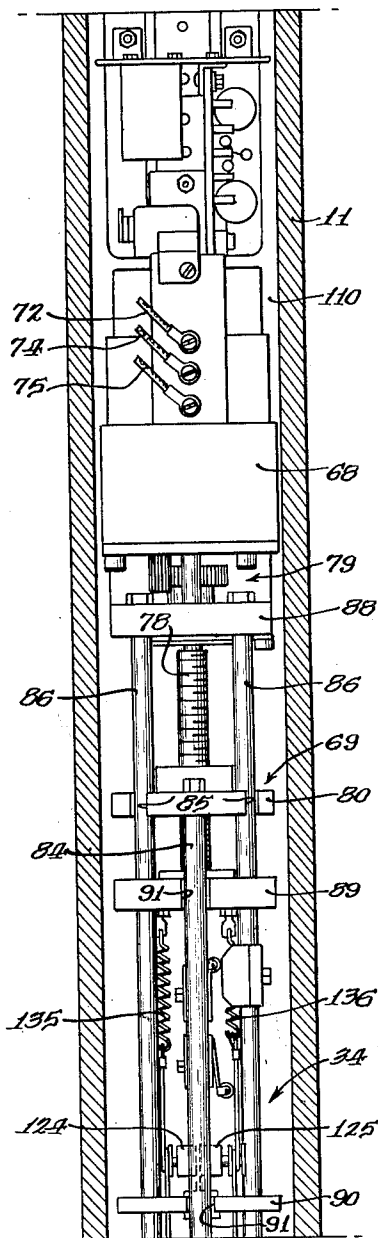
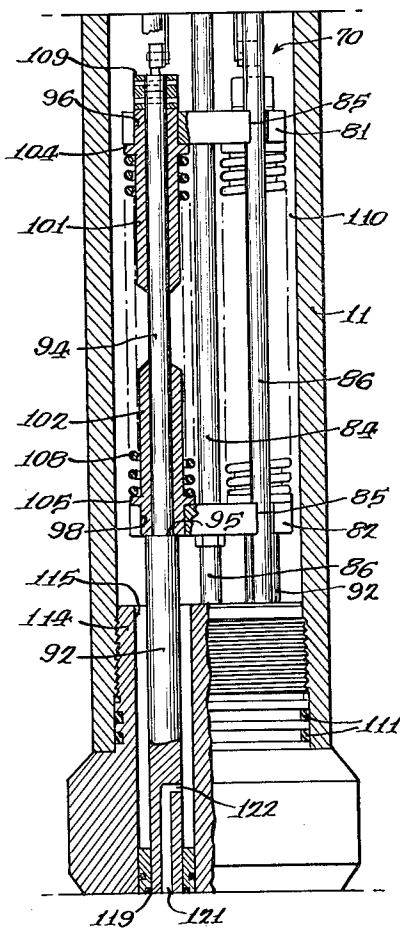


Fig. 2c.



INVENTOR:
Willis J. Oliver
BY *Wolfe, Hubbard,
Vort & Osann*
Attys

Jan. 26, 1965

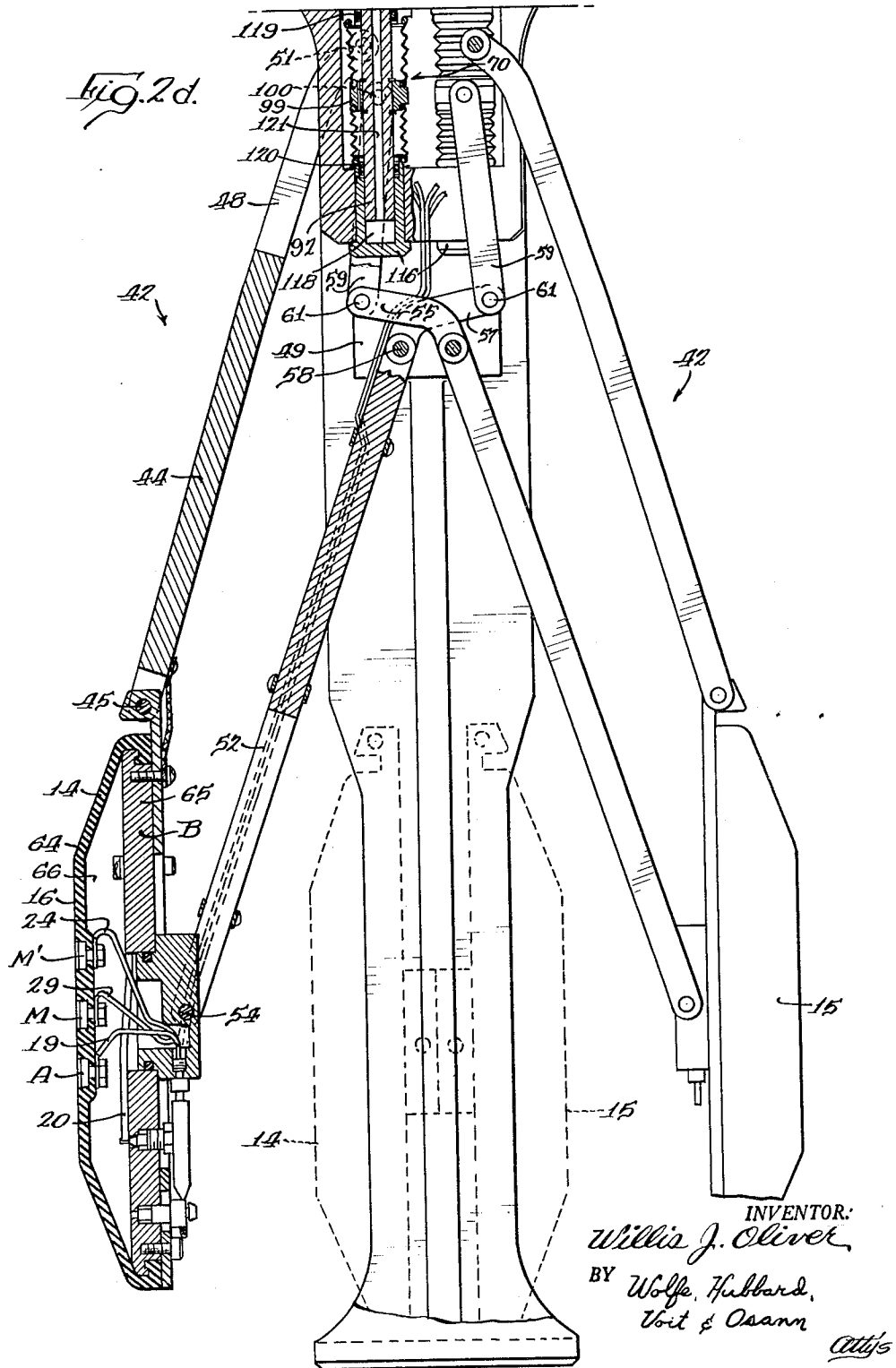
W. J. OLIVER

3,167,707

WELL LOGGING APPARATUS HAVING Laterally SHIFTABLE
WALL ENGAGEABLE ELECTRODE SUPPORTS

Filed Dec. 29, 1960

4 Sheets-Sheet 3



Jan. 26, 1965

W. J. OLIVER

3,167,707

WELL LOGGING APPARATUS HAVING LATERALLY SHIFTABLE
WALL ENGAGEABLE ELECTRODE SUPPORTS

Filed Dec. 29, 1960

4 Sheets-Sheet 4

Fig. 3.

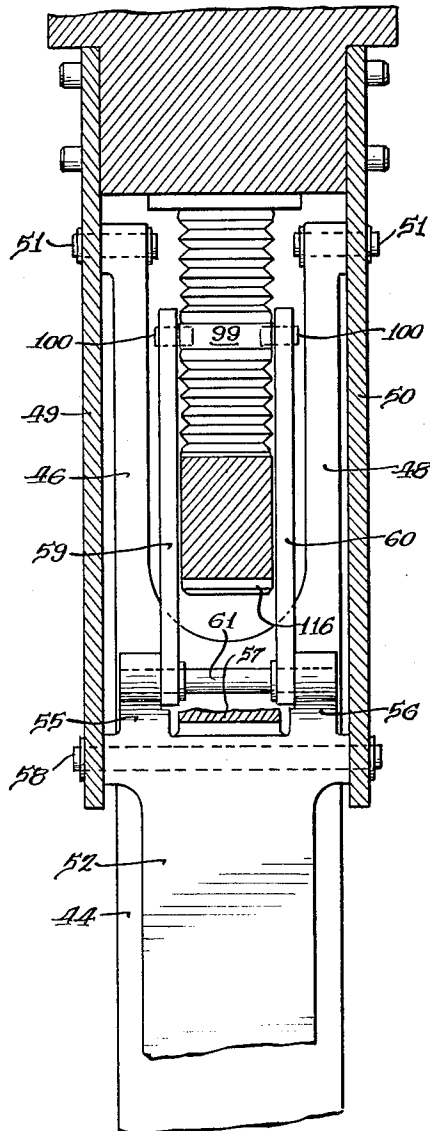
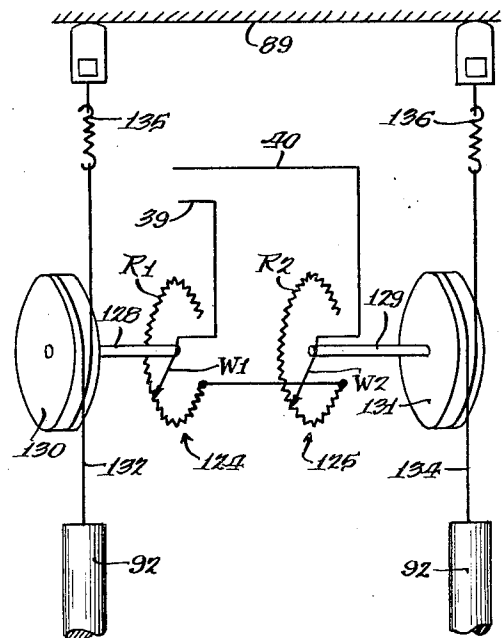


Fig. 4.



INVENTOR.

Willis J. Oliver
BY Wolfe, Hubbard,
Voit & Osann
Attys

1

3,167,707

WELL LOGGING APPARATUS HAVING LATERALLY SHIFTABLE WALL ENGAGEABLE ELECTRODE SUPPORTS

Willis J. Oliver, Derrick City, Pa., assignor to Seismograph Service Corporation, Tulsa, Okla., a corporation of Oklahoma

Filed Dec. 29, 1960, Ser. No. 79,276
10 Claims. (Cl. 324—1)

The present invention relates to contact well logging apparatus of a type which analyzes subterranean characteristics by electrical measurements and relates more particularly to a mechanism for maintaining well logging electrodes and their supporting pads in intimate face-to-face contact with the wall of a wet or mud-filled bore hole.

It is an object of this invention to provide a well logging tool wherein the electrode supporting pads can be selectively projected into contact with the bore hole wall or retracted from contact therewith while the tool is still in the well bore, yet wherein the pads have freedom for independent lateral movement.

It is another object of this invention to provide a contact logging tool in which the resilient electrode supporting pads can be maintained in vertical positions at all times without skewing when they encounter bore obstructions or wall irregularities, yet where the pads are characterized by their ability to move laterally independently when such obstructions or irregularities are encountered.

It is a more specific object to provide contact well logging apparatus whose operation is not impeded by the high bore hole pressures encountered in deep mud-filled bores.

These and other objects and advantages of the invention will become apparent from the following detailed description taken in conjunction with the accompanying drawings, in which:

FIGURE 1 is a longitudinal diagrammatic view, including a schematic circuit diagram, of a well logging tool embodying the features of the present invention, with the tool cover partially cut away to illustrate the pivotal connections of the actuating linkage to the tool;

FIGS. 2a-2d are views in partial longitudinal section illustrating different portions of the well logging tool show in FIG. 1;

FIG. 3 is a longitudinal section of a portion of the tool taken substantially along the line 3—3 of FIG. 1;

FIG. 4 is a diagrammatic view of the bore hole caliper mechanism employed in conjunction with the well logging tool illustrated in FIG. 1.

While this invention has been described in connection with a preferred embodiment, it will be understood that it is not intended to be limited to this specific embodiment. On the contrary, it is intended to cover such equivalent and alternative constructions as may be included within the spirit and scope of the appended claims.

Referring first to FIG. 1, there is illustrated a well logging apparatus, generally indicated at 10, embodying the various features of the present invention and including a tool body 11, which is lowered into a bore hole 12 containing a conductive well fluid 13. The tool body 11 supports a pair of resilient pads 14, 15, of which pad 14 has embedded therein a plurality of electrodes in a manner commonly employed with well logging tools of this type.

While the present invention is suitable for use with a wide variety of well logging tools, it is herein illustrated and described with particularity for use in an electrical system employing a plurality of closely spaced, vertically aligned electrodes A, M and M' which are embedded in the wall-engaging face 16 of the pad 14 and which are

2

utilized in conjunction with a current return electrode B disposed on the back of the pad 14 and a remotely positioned potential measuring electrode N. The potential electrode N is here shown located in a mudpit at surface ground. Current electrodes A and B are respectively connected to a voltage source 18 by means of conductors 19, 20 (see FIGS. 1 and 2d). Current is emitted from the electrode A and the energizing circuit is completed through the return current electrode B. Electrodes M, M' and N are potential measuring electrodes which are utilized to measure the applied potentials present in the formation surrounding the tool 10, which measurements provide extremely useful data relating to the physical structure of the adjacent earth's strata and to the constituents present therein.

To convert the signals into useful logging data, the potential measuring electrodes M and N are connected in this instance as indicated in FIG. 1 to a resistance measuring and recording device 21 having a recording pen 22 by means of conductors 24 and 25 respectively. The potential measuring electrodes M and M' are connected to a similar resistance measuring and recording device 26 having a recording pen 28 by means of conductors 29 and 24 respectively. It will be understood, of course, that such devices may simply include means responsive to current flow for exhibiting a function of the measured potentials in visible form on a continuous log 30.

While it is not intended that the present invention be limited in its application to the particular disposition of electrodes here shown, a brief resume of the use of the exemplary tool will facilitate a preliminary understanding of the well logging apparatus 10.

In electrical well logging techniques, it has been long known that the resistivity of the surrounding formations can be determined by first establishing an electric field in the formation and then measuring the applied potential drop at a known distance from the current-emitting electrode which produced the field. It is further recognized that the measured potential drop is proportional to formation resistivity at a depth of lateral penetration dependent upon the spacing of the current emitting electrode and the potential measuring electrode. In one conventional well logging technique a pair of potential measuring electrodes are employed with one electrode M' positioned in proximity to the current electrode A and one electrode N positioned at substantially an infinite electrical distance from the current electrode. Theoretically, such a system has a depth of lateral penetration equal to twice the distance between the current electrode A and the potential measuring electrode M'. In a second conventional well logging technique, commonly referred to as a "lateral system," a pair of potential measuring electrodes M and M' are disposed in proximity to the current electrode A. This type of system has a depth of lateral penetration equal to the spacing between the current electrode and the midpoint of the potential measuring electrodes. It is also known that where it is desirable to determine formation resistivity in areas close to the bore hole, it is essential that the electrodes be isolated from the conductive well fluid present so that the readings will be truly reflective of formation resistivity.

With the foregoing in mind, it will be appreciated that in the exemplary apparatus of FIG. 1, the electrodes A, B, M' and N correspond to those of the first-mentioned technique in which the spacing between electrode A and electrode M' may be, for example, on the order of two inches. Thus, the potential drop measured between electrodes M' and N is proportional to formation resistivity at a lateral depth of approximately four inches. This information may be directly recorded on the continuous log 30 by recording device 21 as a line 31 which is proportional to formation resistivity at that depth. Similarly, the

electrodes A, B, M and M' constitute a "lateral" device in which the spacing between electrode A and the midpoint of electrodes M and M' may be, for example, one and a half inches. Thus, the recording device 26 will graphically present a visual indication 32 on the log 30 which is a function of formation resistivity at a lateral depth of one and a half inches.

It has also been found extremely helpful in the analysis of logs similar to the log 30, to directly record thereon a visual indication of the bore hole diameter. With a visual presentation of bore hole diameter in addition to formation resistivity at two distinct lateral depths of penetration, an analysis of the log will give an accurate indication of formation permeability, the presence or absence of a mud-cake, and much other useful information. In the present invention an improved calipering device, generally indicated at 34, is shown diagrammatically in FIG. 1 and will subsequently be described in greater detail. At this point, it should suffice to say that the calipering device 34 is connected to a voltage source 35 and a resistance measuring and recording device 36 having a recording pen 38 by conductors 39 and 40. As the description proceeds, it will become apparent that the recording device 36 graphically presents on the log 30 a continuous visual indication 41 which is directly proportional to the diameter of the bore hole.

In accordance with one of the important aspects of the present invention, there is provided a novel arrangement for affirmatively projecting and retracting a plurality of resilient pads, at least one of which supports a plurality of electrodes, and for simultaneously maintaining the pad parallel to the longitudinal axis of the well logging tool 10 at all lateral positions of the pads, yet wherein the pads have freedom for independent lateral movement. In the preferred embodiment of the present invention, illustrated particularly in FIG. 2d, this is accomplished by mounting the pads 14 and 15 on separate parallelogram-like linkages, generally indicated at 42, and by providing a driving mechanism for effecting pivotal movement of the linkages in a desired direction. Since the linkages and the driving mechanisms are substantially identical for each of the pads 14 and 15, the ensuing discussion will be limited to a single pad 14 and its associated driving mechanism, it being understood that the description is equally applicable to the pad 15.

Referring to FIGS. 2d and 3, the pad 14 is pivotally mounted to the lower end of a link 44 (hereafter referred to as outer arm 44) by a pivot pin 45. The upper end of the outer arm 44 is bifurcated to form a pair of laterally spaced fingers 46, 48 (FIG. 3) which are respectively connected to a pair of downwardly extending plates 49, 50 integral with the tool body 11, by pivot pins 51. A second link 52 (hereafter referred to as inner arm 52) is pivotally mounted at its lower end to the pad 14 by a pivot pin 54. The upper end of one inner arm 52 is bifurcated to form a pair of laterally spaced fingers 55, 56, while the upper end of the other inner arm 52 has formed thereon a centrally disposed finger 57 positioned to interlace with the fingers 55 and 56. Each inner arm 52 is pivotally mounted on the plates 49, 50 by a pivot pin 58 extending transversely therethrough. The upwardly projecting fingers 55, 56 and 57 are bent at generally right angles to the plane of their respective inner arms 52 (FIG. 2d) and the laterally extending portions of the fingers 55, 56 are respectively connected to a pair of force transmitting links 59, 60 by means of a pivot pin 61 while the finger 57 is connected to a second pair of force transmitting links 59, 60 by a similar pivot pin 61.

It will be appreciated that the pivotal connections 51, 58 for the outer arm 44 and the inner arm 52, respectively, are fixed pivots, while the pivotal connections 45, 54 and 61 are all floating pivots. Moreover, the pivot pin 58 defines a fulcrum about which the inner arm 52 is pivoted under the influence of forces transmitted by the links 59, 60. Thus, there is provided a simple, yet highly effective,

interconnecting linkage 42 for selectively driving the pads 14 and 15 into intimate engagement with the wall of the bore hole 12, and wherein the pads are maintained in a generally vertical position parallel to the longitudinal axis of the tool body 11 by virtue of the parallelogram-like nature of the links.

In order to promote intimate contact of the pad 14 and its electrodes A, M and M' with respect to the wall of the bore hole 12, the electrodes are embedded in a resilient insulating member 64 which is securely mounted on a backing plate 65 and defines a cavity 66 therebetween. The backing plate 65 may also serve as the current return electrode B. The cavity 66 is filled with a nonconductive fluid, for example, oil. Thus, due to the resilient nature of the flexible member 64 and the ability of the fluid in the cavity 66 to be displaced, the pad 14 is ideally suited for conformation with any slight irregularities that may be present on the wall of the bore hole 12. At the same time, the parallelogram-like linkage serves to prevent the pad 14 from becoming skewed, thus minimizing the danger of conductive well fluid 13 contacting the electrode during a logging operation.

In carrying out the present invention, provision is made for selectively transmitting force to the links 59, 60 in either of two directions so that the inner arms can be pivoted in either a clockwise direction or a counterclockwise direction (as viewed in FIG. 2d). Thus, the pads 14, 15 can be affirmatively projected into contact with the wall of the bore hole or retracted from contact therewith. In the preferred embodiment, the driving mechanism includes a reversible electric motor 68 (FIG. 2b) which is drivingly coupled, through a motor-to-arm connector assembly 69, to an actuating piston, or plunger assembly 70 (FIGS. 2c and 2d). In order that the motor 68 may be driven in either direction to selectively open or close the arms 44, 52, a motor controller 71 is provided having an energizing source (not shown). The controller is electrically coupled to the motor 68 by means of conductors 72, 74 and 75. In the exemplary apparatus, the controller 71 includes a switch 76 so that the arms 44, 52 may be manually opened and closed.

In order to provide an effective driving connection for converting the rotary torque of the motor to lineal movement of the arm actuating assembly 70, the motor 68 is here illustrated as drivingly engaged with a screw 78 through suitable gear reducing apparatus, generally indicated at 79. The screw 78 is threadingly coupled with a force transmitting top plate 80 rigid with the motor-to-arm connector assembly 69. The connector assembly 69 also includes an intermediate transverse force transmitting plate 81 and a bottom force transmitting plate 82 (FIG. 2c). For holding the vertically spaced force transmitting plates 80-82 together in a single unit, a pair of diametrically opposed vertically disposed tie bolts 84 are provided, there being one such tie bolt illustrated in FIGS. 2b-2c.

For preventing rotational motion of the connector assembly 69 and insuring lineal movement thereof when the screw 78 is rotated, the transverse plates 80-82 are provided with a plurality of sets of vertically aligned slots 85, through which extend a plurality of elongated guide posts 86. The guide posts are integral with the tool body 11 and carry fixed transverse support plate 88, 89 and 90, the latter two plates 89, 90 having oversized openings 91 formed therein for slidably receiving the tie bolts 84. It will be appreciated that the foregoing arrangement insures that rotational motion of the screw 78 is converted to lineal movement of the connector assembly 69. Thus, when the motor 68 is driven in one direction, the connector assembly 69 and its associated force transmitting plates 80-82 are driven downwardly to actuate the plunger assembly 70. When the motor 68 is driven in the opposite direction, the connector assembly 69 is driven upwardly to actuate the plunger assembly.

For affirmatively and simultaneously actuating the arms

5

44, 52 for each of the resilient pads 14, 15, while at the same time insuring that the pads are free for independent lateral movement, the plunger assembly 70 (FIG. 2c) includes a pair of elongated resilient or compressible elements, one of which is interposed in the driving mechanism between the motor 68 and each of the inner arms 52. In the illustrative form of the invention, a pair of identical elongated plungers 92 are provided, each having a portion of reduced diameter 94, the junction of the reduced portion 94 and the enlarged portion defining a shoulder 95 (FIG. 2c). The reduced plunger portion 94 extends upwardly through oversized openings 96, 98 in the force transmitting plates 81, 82 respectively. As clearly indicated in FIG. 2c, the openings 96, 98 have a greater diameter than the diameter of the enlarged portion of the plunger 92. The enlarged portion of each plunger is provided with a cylindrical collar 99 (FIGS. 2d and 3) to which the force transmitting links 59, 60 are coupled by means of pivot pins 100.

A pair of cylindrical spring followers 101, 102, each having an enlarged circumferential flange 104, 105 respectively, are slidably mounted on the reduced plunger portions 94. The external diameter of the followers is selected such that they are loosely received within the openings 96, 98 while the diameter of the plunger flanges is greater than the diameter of the openings. An elongated spring 108 is concentrically mounted about the followers 101, 102 and the reduced plunger portion 94, with the opposite ends of the spring engaged with the flanges 104, 105, thus tending to urge the follower flanges 104, 105 into engagement with force transmitting plates 81, 82 respectively. A cylindrical sleeve 109 is rigidly mounted on the end of the reduced plunger portion 94 for selective contact with spring follower 101.

In operation, and assuming that the connector assembly 69 is moving downwardly to project the pads 14, 15 laterally outward into contact with the wall of the bore hole 12, it will be apparent that the force transmitting plate 82 will have no effect upon the plungers 92 due to the oversized openings 98 formed therein. However, the force transmitting plate 81 engages the flange 104 on each spring follower 101 and, through coaction of the spring 108 and the flange 105 on follower 102, urges each follower 102 downwardly into driving engagement with the shoulder 95 on the associated plunger. Thus, the plungers 92 are forced downwardly and the force transmitting links 59, 60 (FIGS. 2d and 3) effect clockwise movement of the arms 44, 52.

When it is desired to close the arms, the motor 68 is driven in the opposite direction and the connector assembly 69 moves upwardly under the influence of screw 78. In this instance, the oversized openings 96 in the force transmitting plate 81 are larger than the sleeve 109 so that the plate 81 has no effect upon the plungers 92. However, the force transmitting plate 82 now acts against the flange 105 on each follower 102 and, through coaction with spring 108 and flange 104 on follower 101, the followers 101 are urged upwardly into engagement with their associated sleeve 109, thus driving each plunger 92 upwardly. As the plungers move up, the arms 44, 52 are rotated in a counterclockwise direction and the pads 14, 15 are retracted.

It will be appreciated that since each plunger 92 is drivingly connected to a different pad and since each plunger is driven through a compressible spring, the pads are free to move laterally independently. Should the pad 15, for example, encounter an obstacle, its associated spring 108 would be compressed to a higher degree than would the spring 108 associated with pad 14. Moreover, since the springs are extremely long, the pads 14 and 15 are held against the bore hole wall with substantially constant pressure regardless of bore hole diameter.

In order that the plungers 92 will be free to reciprocate without being impeded by the high bore hole pressures that are often encountered in logging operations, provi-

6

sion is made for isolating the actuating plungers from bore hole pressure. This is accomplished in the preferred embodiment, by forming the tool body 11 with a sealed chamber 110 in which the upper ends of the plungers are received. To this end, suitable O ring seals 111 are mounted between the side walls of the tool body 11 and its top end 112 (FIG. 2a) and the bottom end 114 (FIG. 2c) respectively. A pair of openings 115 (one of which is illustrated in FIG. 2c) are formed in the bottom end 114 of the tool body for reception of the respective plungers 92. To isolate the lower ends of the plungers 92 from bore hole pressures, each is slidably received within a cylinder 116 which is rigidly mounted on the well logging tool 10 and which is closed at one end to define a chamber 118. Suitable seals 119, 120 are respectively provided in the openings 115 and the cylinders 116 to maintain the chambers 110 and 118 at pressures substantially below those encountered in the bore hole.

Provision is made for venting each of the cylinders 118 to the pressure present in the main tool body 11. To this end a bleed port 121 extends longitudinally through each plunger 92 from the lower end thereof and communicates with a radial bleed port 122 in the portion of the plungers received within chamber 110. Since the chambers 110 and 118 are in communication with one another through the bleed ports, pressure therebetween is maintained substantially constant, and at a value considerably below that of bore hole pressure, thus insuring that high bore hole pressure will not impede lineal movement of the plungers. Incidentally, it has been found that the pressure-tight integrity of the tool is promoted by positioning the motor 68 and other driving components in one of the sealed chambers, for example, chamber 110.

In keeping with the present invention, the bore hole caliper device 34 shown in FIGURE 2b provides an accurate indication of the bore hole diameter regardless of the position of the tool body 11 relative to the axis of the bore hole 12. For this purpose, the resistance values of a pair of variable resistance devices 124 and 125 which are mounted on brackets 126 rigid with the support plate 90 (FIG. 4), are varied linearly with the displacement of the respective plungers 92. Since the movements of the pads 14 and 15 are linearly proportional to the movement of the respective plungers 92, the total resistance of the two variable resistors 124 and 125 varies directly with the lateral displacement of the tool pads 14 and 15 relative to each other. This displacement is, of course, the bore hole diameter, and the sum of the displacements of the respective pads relative to the axis of the tool is necessarily the same whether or not the tool body 11 is centered in the bore hole.

As further shown in FIG. 4, variable resistors 124 and 125 of the caliper device 34 suitably take the form of linear rotary rheostats of the same total resistance. In each the adjustment of the resistance is conventionally provided by a wiper arm or tap W_1 , W_2 having an angular position on arcuate resistance element R_1 , R_2 . The angular displacement of each wiper is determined by its associated wiper shaft 128, 129. In order that the angular displacement of each wiper shaft will be linearly proportional to the amount of lateral extension of its associated pad, each shaft 128, 129 is mechanically coupled with a respective one of the plungers 92. To this end, pulleys 130, 131 are rigidly mounted on the respective shafts 128, 129 and rheostat cables 132, 134 rigidly attached to the upper end of the respective plungers 92. The cables 132, 134 each make one complete turn about their associated pulleys with the free cable ends respectively secured to springs 135, 136 which are rigid with support plate 89. It will be understood that the springs 135, 136 serve to keep their associated cables taut and tightly wound on the respective pulleys.

In operation of the caliper device 34, the resistance change in resistors 124 and 125 is a given number of ohms per inch of lateral displacement of the respective

pads 14 and 15. At the fully extended position of the pad, the associated rheostat wiper arm establishes its rheostat resistance at the maximum utilized value. This is suitably the total rated rheostat resistance. The minimum resistance tap position corresponding to the fully retracted position of a pad is suitably a value equal to the product of the tool body-to-pad inches radius at that position and the given ohms per inch ratio. With the two resistors R_1 and R_2 in series and connected by leads 39 and 40 in circuit with the voltage source 35 and a current responsive device 36, a signal or record proportional in amplitude to the well bore is readily obtained. It will be appreciated that the calibration of such a device may also be in terms of diameter beyond a given minimum. In such a case the resistance R_1 and R_2 of the rheostats at the retracted pad position may be suitably established at zero or other convenient minimum resistance reference level.

It will be appreciated that variations in off-center position of the tool body as it is pulled up the bore during a logging operation do not affect the caliper accuracy, and, of course, that the caliper device functions for all well-bore sizes in which the tool body can be employed.

I claim as my invention:

1. In well logging equipment of the type employing a pair of resilient pads mounted on a tool body for lateral movement relative to said body, and a plurality of electrodes mounted in at least one of said pads for face-to-face engagement with the wall of a bore hole during vertical transit of said body, apparatus for urging each of said pads laterally relative to said body comprising, in combination, a first pair of links each pivotally connected at one end to said body and at the other end to a respective one of said pads, a second pair of links each pivotally connected at one end to a respective one of said pads, means mounted on said body and extending through each of said second pair of links intermediate their ends and defining a fulcrum therefor, a pair of plungers carried by said body, means pivotally connecting said plungers to the other end of respective ones of said second pair of links, reversible power means carried by said body, said power means drivingly coupled to each of said plungers through resilient means for effecting simultaneous and independent lineal movement of said plungers in a desired direction to cause said second pair of links to pivot about their fulcrums, and means responsive to the lateral positions of said pads when engaged with the bore hole wall for indicating the diameter of the bore hole.

2. In well logging equipment of the type employing a pair of elongated resilient pads mounted on a tool body for lateral movement relative to said body, and a plurality of vertically aligned electrodes mounted in at least one of said pads for face-to-face engagement with the wall of a bore hole during vertical transit of said body, apparatus for simultaneously urging each of said pads laterally relative to said body comprising, in combination, a first pair of links each pivotally connected at one end to said body and at the other end to a respective one of said pads, a second pair of links each pivotally connected at one end to a respective one of said pads, means mounted on said body and extending through each of said second pair of links intermediate their ends and defining a fulcrum therefor, a pair of pistons carried by said body, means pivotally connecting said pistons to the other end of respective ones of said second pair of links, and reversible power means carried by said body for effecting simultaneous lineal movement of said pistons in a desired direction to cause said second pair of links to pivot about their fulcrums, said power means respectively coupled to each of said pistons by a compressible element so that the lineal movement of one piston is independent from the lineal movement of the other piston.

3. In a well logging tool, the combination comprising,

a tool body, a pair of elongated pads carried by said body for vertical movement within a bore hole, a plurality of vertically aligned electrodes carried by at least one of said pads for selective engagement with the bore hole wall, reversible power means associated with said body for simultaneously urging said pads laterally into engagement with the wall of the bore hole and for simultaneously retracting said pads laterally from engagement with the wall of the bore hole, said reversible power means including a pair of resilient elements each associated with a respective one of said pads so that said pads move laterally independently, and means for maintaining said electrode carrying pad parallel with the axis of said tool body during vertical movement of the body within said bore hole.

4. In a well logging tool of the type employing a plurality of electrodes mounted on a resilient support, apparatus for effecting lateral movement of said support relative to said tool comprising, in combination, an elongated tool body having first and second sealed chambers therein, a plunger mounted in said body with its opposite ends respectively projecting into said chambers, means defining a communicating passageway formed in at least one of said body and said plunger and extending between each of said chambers for maintaining substantially equal pressures therein, reversible power means in one of said chambers coupled to said plunger for effecting lineal movement thereof, and means coupling said plunger to said support for effecting lateral movement of the latter in response to lineal movement of the plunger.

5. In a well logging tool of the type employing a plurality of electrodes mounted on a resilient support, apparatus for effecting lateral movement of said support relative to said tool comprising, in combination, an elongated tool body having first and second sealed chambers therein, a plunger mounted in said body with its opposite ends respectively projecting into said chambers, means defining a communicating passageway formed in at least one of said body and said plunger and extending between each of said chambers for maintaining substantially equal pressures therein, reversible power means in one of said chambers, resilient means drivingly interposed between said power means and said plunger for effecting lineal movement of the latter, and means coupling said plunger to said support for effecting lateral movement of the latter in response to lineal movement of the plunger.

6. In a well logging tool of the type employing a pair of resilient supports having a plurality of electrodes mounted on at least one support, apparatus for effecting simultaneous lateral movement of said supports relative to said tool comprising, in combination, an elongated tool body having first, second and third sealed chambers therein, a pair of plungers mounted in said body with one end of each plunger projecting into said first chamber and opposite end of each plunger respectively projecting into said second and third chambers, means defining a pair of communicating passageways formed in at least one of said body and said pair of plungers and extending between said first chamber and respective different ones of said second and third chambers for maintaining substantially equal pressures therein, reversible power means in said first chamber, resilient means drivingly interposed between said power means and each of said plungers for effecting independent lineal movement of said plungers, means coupling each of said plungers to a respective one of said supports for effecting lateral movement of the latter in response to lineal movement of the plungers.

7. In a well logging tool of the type employing a plurality of electrodes mounted on a resilient support, apparatus for effecting lateral movement of said support relative to said tool comprising, in combination, an elongated, cylindrical tool body, said body having a first sealed chamber, a plunger mounted in said body having

9

one end projecting into said chamber, the opposite end of said plunger being received within a second sealed chamber, means defining a communicating passageway formed in at least one of said body and said plunger and extending between each of said chambers for maintaining substantially equal pressures therein so that said plunger is not affected by high bore hole pressures, power means in said body coupled to said plunger for effecting lineal movement thereof, means coupling said plunger to said support for effecting lateral movement of the latter in response to lineal movement of the plunger.

8. Well logging apparatus for transiting a bore hole comprising, in combination, an elongated tool body for carrying a pair of elongated pads, said body having an enclosed chamber, a pair of pistons mounted in said chamber with their lower ends projecting through apertures formed in said body at the bottom of said chamber, sealing means mounted in each of said apertures surrounding said pistons, the lower end of each of said pistons slidably mounted within an associated cylinder, means defining a pair of communicating passageways formed in at least one of said body and said pair of pistons and extending between each of said cylinders and said chamber for maintaining the pressure in said cylinders substantially equal to the pressure in said chamber, means coupling said pistons to respective ones of said pads for effecting lateral movement of said pads upon lineal movement of their associated pistons, and reversible power means mounted in said chamber and coupled to said pistons for effecting lineal movement of said pistons in a desired direction.

9. Well logging apparatus for transiting a bore hole comprising, in combination, an elongated tool body for carrying a pair of elongated pads, a plurality of electrodes carried by at least one of said pads, said body having an enclosed chamber, a pair of pistons mounted in said chamber with their lower ends projecting through apertures formed in said body at the bottom of said chamber, sealing means mounted in each of said apertures surrounding said pistons, the lower end of each of said pistons slidably mounted within an associated cylinder, means defining a pair of communicating passageways formed in at least one of said body and said

10

pair of pistons and extending between each of said cylinders and said chamber for maintaining the pressure in said cylinders substantially equal to the pressure in said chamber, means coupling each of said pistons to a respective one of said pads for effecting lateral movement of said pads upon lineal movement of their associated pistons, reversible power means mounted in said chamber, resilient elements drivingly interposed between said power means and each of said pistons so that said power means effects independent lineal movement of said pistons and their associated pads, and means responsive to the lateral positions of said pads for indicating the diameter of the bore hole.

10. Well logging apparatus for transiting a bore hole comprising, in combination, an elongated tool body for carrying a pair of elongated pads, a plurality of electrodes carried by at least one of said pads, a source of current connected to two of said electrodes, said body having an enclosed chamber, a pair of pistons mounted in said chamber with their lower ends projecting through apertures formed in said body at the bottom of said chamber, sealing means mounted in each of said apertures surrounding said pistons, the lower end of each of said pistons slidably mounted within an associated cylinder, means defining a pair of communicating passageways formed in at least one of said body and said pair of pistons and extending between each of said cylinders and said chamber for maintaining the pressure in said cylinders substantially equal to the pressure in said chamber, means coupling each of said pistons to respective ones of said pads for effecting lateral movement of said pads upon lineal movement of their associated pistons, reversible power means mounted in said chamber and coupled to said pistons for effecting lineal movement of said pistons in a desired direction, and recording means connected to two other of said electrodes for exhibiting a function of the electrical resistivity in a zone surrounding said last named electrodes.

References Cited in the file of this patent

UNITED STATES PATENTS

2,876,413	Saurenman et al. -----	Mar. 3, 1959
2,899,633	Smith et al. -----	Aug. 11, 1959