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2,952,574 9/1960 Pierce 174/108UX
3,153,696 10/1964 Blanchard 174/108
2,463,590 3/1949 Arutunoff 174/108
2,604,509 7/1952 Blanchard 174/108
3,259,675 7/1966 Bowers 174/108(X)

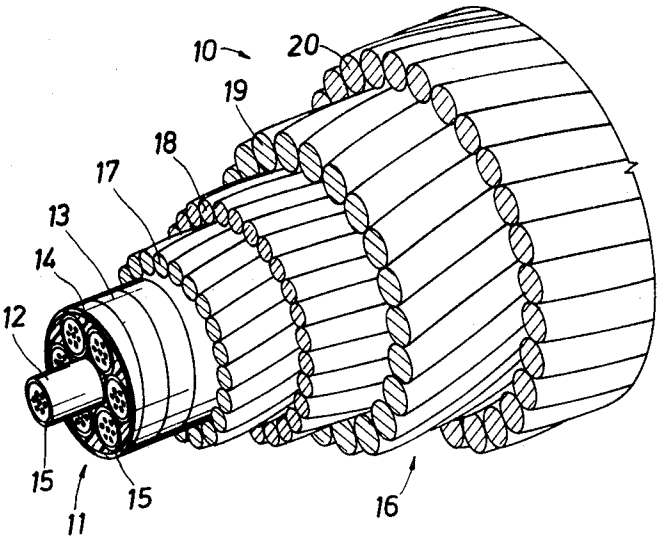
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[54] ELECTRICAL SUSPENSION CABLE FOR
FACILITATING THE DESCENT OF WELL TOOLS
SUSPENDED THEREFROM THROUGH DEVIATED
WELL BORES
20 Claims, 4 Drawing Figs.

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174/113
[51] Int. Cl. H01b 7/22
[50] Field of Search. 174/106,
108, 113, 115, 102.7

[56] References Cited
UNITED STATES PATENTS
2,886,631 5/1959 Muller 174/108

ABSTRACT: As one embodiment of the new and improved electrical logging cable disclosed herein, the cable is uniquely constructed to withstand limited axial compressive loading without undue lateral bending. In this manner, by selectively moving the suspension cable downwardly from the surface, corresponding axial forces are developed in the lower portion of the cable for assisting the continued descent of a logging tool dependently coupled thereto through substantially deviated well bore intervals.



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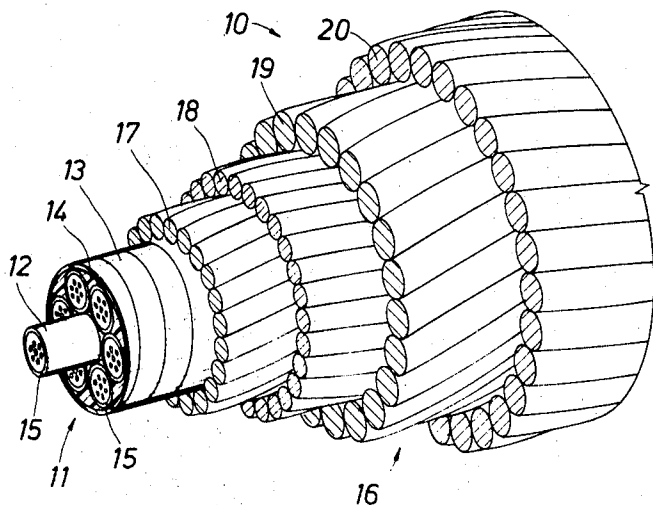


FIG. 1

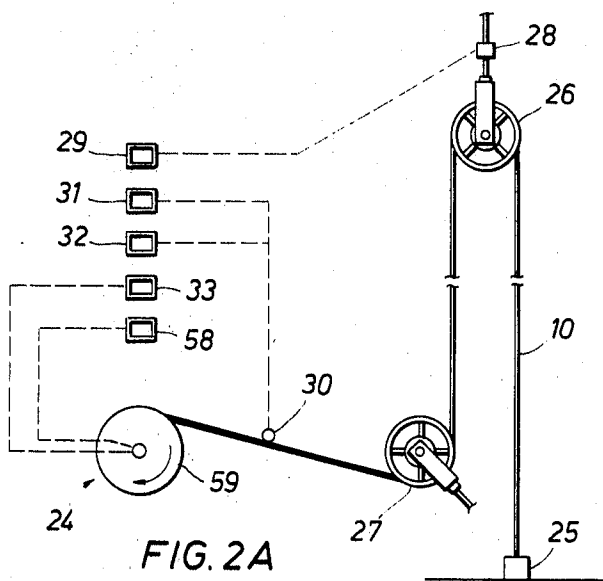


FIG. 2A

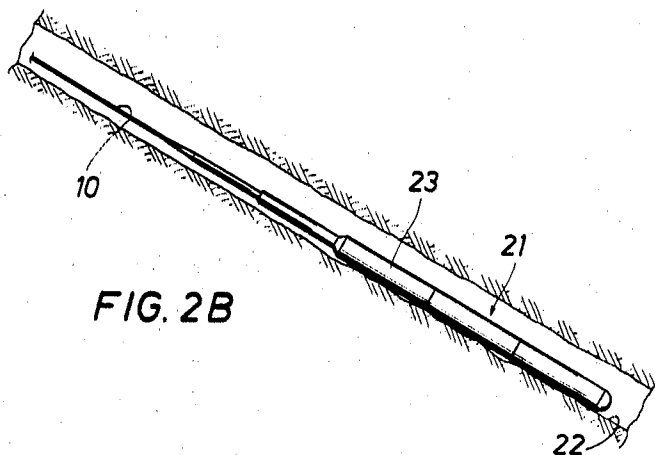
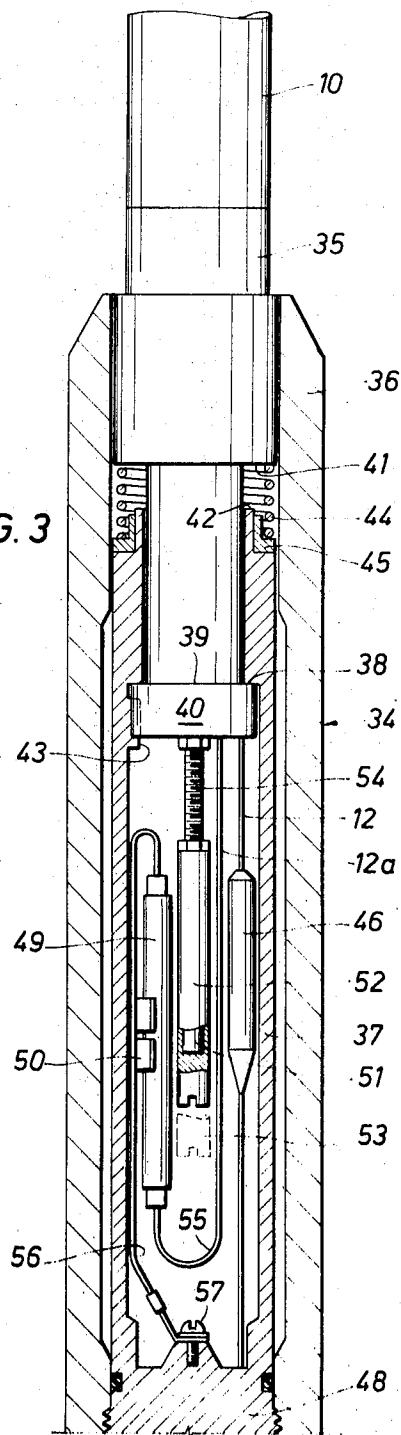


FIG. 2B

FIG. 3



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ELECTRICAL SUSPENSION CABLE FOR FACILITATING THE DESCENT OF WELL TOOLS SUSPENDED THEREFROM THROUGH DEVIATED WELL BORES

In some oil fields, it is not at all uncommon to find well bores having highly slanted intervals therein that may approach angles deviating from the vertical as much as 60° to 80°. It is, of course, impossible to simply lower a cable-suspended well tool to the bottom of such highly deviated well bores. It will be appreciated, therefore, that unless suitable techniques are devised for moving cable-suspended well tools through such highly deviated holes, they cannot be logged in the usual manner.

Accordingly, it is an object of the present invention to provide new and improved electrical logging cables for facilitating the descent of well-logging instruments coupled thereto through highly deviated well bores.

This and other objects of the present invention are accomplished by operatively arranging inner and outer layers of helically wound armor strands around one or more electrical conductors to provide a relatively stiff electrical logging cable that is adapted to be spooled on a typical powered winch for dependently supporting logging tools coupled thereto. By arranging the outer armor layers at a substantially large pitch angle, the cable will be capable of withstanding limited axial compressive loads without undue lateral flexing. In this manner, when the cable is spooled on a winch and coupled to a well-logging tool, should the tool move into a highly deviated well bore interval, the cable is moved downwardly to reduce tensile forces therein and develop corresponding compressive forces in the lower portion of the cable. In this manner, since the new and improved cables of the present invention have sufficient lateral rigidity that they cannot be doubled back onto themselves within the confines of a well bore, axial compressive loads imposed thereon can be effectively transmitted to a logging instrument coupled thereto for promoting its further movement through a deviated well bore.

The novel features of the present invention are set forth with particularity in the appended claims. The invention, together with further objects and advantages thereof, may be best understood by way of the following description of exemplary apparatus employing the principles of the invention as illustrated in the accompanying drawings, in which:

FIG. 1 is an isometric view, partially in cross section, of a preferred embodiment of a new and improved electrical logging cable arranged in accordance with the principles of the present invention;

FIG. 2A depicts a typical arrangement of the surface equipment employed for imposing axial loads through a logging cable arranged in accordance with the present invention to a logging tool suspended therefrom in a deviated well bore;

FIG. 2B shows a logging tool as it may appear while being pushed through a deviated borehole by a logging cable of the present invention; and

FIG. 3 is a cross-sectioned view of the upper portion of a typical logging tool having force-responsive signalling means operatively coupled to a logging cable of the present invention.

Turning now to FIG. 1, an isometric view is shown of a preferred embodiment of an electrical logging cable 10 arranged in accordance with the present invention illustrating its unique construction. As seen there, the cable 10 has a central axial core 11 comprised of a plurality of externally insulated stranded electrical conductors 12 that are symmetrically grouped and encased in a suitable tubular sheath 13 which, for example, may be either braided nylon strands or spirally wrapped insulating tape. To give the core 11 a generally cylindrical form, the interstitial spaces between the electrical conductors 12 and the sheath 13 are filled with suitable materials such as, for example, cotton fillers 14. Where deemed desirable to reduce the effects of capacitive coupling between the several cable conductors 12, the outer surfaces of the insulating sheath 15 of each cable conductor 12 may be coated with a thin, electrically semiconductive film and the nylon braid 13 (or spiraled tape) and the cotton fillers 14 are impregnated

with an electrically semiconductive compound. Thus, in these instances, each insulated conductor 12 in the finished cable core 11 is surrounded by a semiconductive film which is electrically connected to the external armor 16 of the cable 10.

The external armor 16 of the central cable core 11 is comprised of a unique arrangement of four concentrically arranged layers 17-20 of metallic armor strands helically wound around the central core. The two innermost armor layers 17 and 18 are assembled onto the central core 11 in the usual manner. That is to say, the innermost armor layer 17 comprises a plurality of metallic strands wound in one so-called "lay" direction about the core 11; and the second armor layer 18 similarly comprises a plurality of metallic strands wound with an oppositely directed lay about the innermost armor layer. The number, size, and pitch or lay angle of the first and second inner layers are chosen so that the innermost layer 17 substantially covers the central core 11 and the second layer 18 substantially covers the first layer. As is customary, the design of these armor layers 17 and 18 have been optimized to perform the usual tension-bearing functions of the cable 10 as well as protect the central cable core 11 from damage.

It will be appreciated, of course, that the two inner layers 17 and 18 of armor strands provide little or no longitudinal stability to the logging cable 10 for withstanding axial compressive loads applied thereto. Accordingly, inasmuch as the logging cables of the present invention must also be capable of transmitting minor axial compressive loads from the surface to a logging tool coupled thereto, the two outer armor layers 19 and 20 are uniquely arranged to transmit such nominal compressive loads without the cable 10 being doubled back onto itself within the diameter of a typically sized well bore; and, as a result, can cause damage to the core 11 and quite possibly allow the cable 10 to become stuck in the well bore. More significantly, these two outer armor layers 19 and 20 are uniquely wound in oppositely directed lay directions and respectively have relatively flat pitch angles in the order of about 30°-45° as compared to only about 18°-22° and 16°-20°, respectively, for the two inner armor layers 17 and 18.

In the preferred embodiment of the logging cable 10 depicted in FIG. 1, each of the four armor layers 17-20 are comprised of 24 strands; and, therefore, the diameters of the several armor strands are progressively increased from the innermost armor layer to the outermost armor layer to accommodate the increasing diameters. Thus, in this illustrated embodiment, the innermost armor strands 17 have a diameter of 0.039-inch; the next layer 18 is comprised of strands of 0.049-inch; the next layer 19 is comprised of strands of 0.055-inch; and the outermost layer 20 employs strands of 0.066-inch. All strands of the armor 16 are of galvanized steel, with these strands being preformed as required for the complete cable 10. It will, of course, be recognized that the size of the strands of the armor 16 will vary in accordance with the number of strands in each armor layer. It is important, however, that the outermost armor layer 20 be sized to facilitate the "stacking" or "locking" of the adjacent and normally touching strand coils when a compressive load is applied to the cable 10 and, therefore, prevent one strand coil from moving outwardly and downwardly over an adjacent strand coil in the outer armor layer 20.

Accordingly, by virtue of the substantially large or flat pitch angles of the two outer armor layers 19 and 20, the logging cable 10 will be incapable of doubling back on itself within the diameter of a typically sized well bore. Thus, when compressive loads are imposed on a portion of the logging cable 10, the contiguous coils of these outer layers 19 and 20 will instead to "stacked" and, in effect, be locked to one another to resist lateral bending of the cable in relation to its longitudinal axis. In this manner, compressive loads applied thereto will initially begin gradually bending this loaded portion of the cable 10 into a long helix. However, instead of easily doubling back on itself as would otherwise occur with a typical logging cable, the new and improved cable 10 will continue transmitting

modest axial compressive loads to a logging tool coupled thereto until it has been helically looped and the outer portions of each cable loop are gradually expanded into engagement around the perimeter of the well bore. Ultimately, of course, the frictional engagement of the helical loops of the cable 10 with the walls of the borehole will be sufficient to tightly wedge the cable so that further compressive loads cannot be imposed therethrough so long as the loops are against the borehole wall.

Turning now to FIG. 2B, a logging tool 21 is depicted as it is being moved through a highly deviated interval of a well bore which, in this instance, is illustrated as being an uncased borehole 22. Although the specific nature of the logging tool 21 is of no consequence to the present invention, it may be a typical logging instrument including a typical radioactivity detector or other measuring device 23 which will sense variations in some detectable characteristic of earth formations for providing indications at the surface that the tool is moving. The logging tool 21 is dependently coupled to the lower end of the uniquely constructed logging cable 10 which, as has already been explained, is appropriately arranged to withstand axial compressive loads without being doubled back onto itself within the confines of the borehole 22.

As seen in FIG. 2A, the logging cable 10 is spooled in the usual fashion on a powered winch 24 and has previously been directed into the surface casing 25 that customarily lines the walls of the upper portion of the borehole 22. As is typical, the winch 24 is positioned in a convenient location adjacent to the surface casing 25 and the cable 10 is preferably directed into the casing by means of upper and lower pulleys or sheaves 26 and 27 aligned with one another and the winch and respectively supported directly above the casing and to one side thereof. It will be appreciated, of course, that the winch 24 is operatively equipped with brakes and a driving mechanism (neither shown) by which the winch drum may be selectively driven in either rotative direction and at any suitable rotational speed. The upper sheave 26 is typically supported in a derrick (not shown) by a strain gauge 28 that is coupled to a suitable indicator 29 for measuring the tension forces on the logging cable 10. As is usual, a calibrated measuring wheel 30 that is frictionally driven by the running portion of the armored logging cable 10 is coupled to a totalizer 31 for measuring the length of the cable being reeled onto or off of the winch 24 and a tachometer 32 for indicating the speed of the cable. A suitable instrument 33 is electrically coupled by way of the cable 10 to the measuring device 23 in the logging tool 21.

Turning now to FIG. 3, the upper portion of the well tool 21 is shown in cross section to illustrate a unique signalling device 34 for indicating when an axial load is being effectively imposed through the logging cable 10 to the well tool. As illustrated, the lower end of the logging cable 10 is secured within a cylindrical body 35 that is slidably received within the open upper end of a tubular housing 36 coupled to the upper end of the well tool 21. To limit the upward longitudinal travel of the cylindrical body 35 in relation to the housing 35, an elongated sleeve 37 having an inwardly directed shoulder 38 is secured within the housing to position the shoulder above the upper face 39 of an enlarged diameter head 40 arranged on the lower end of the cylindrical body. Conversely, downward longitudinal travel of the cylindrical body 35 is limited by an enlarged diameter shoulder 41 arranged around an intermediate portion of the cylindrical body to engage an upwardly facing shoulder such as defined by the upper end 42 of the sleeve 37. To corotatively secure the cylindrical body 35 in relation to the housing 36, a longitudinal spline-and-groove arrangement, as at 43, is provided on the enlarged head 40 and internal wall of the sleeve 37.

Accordingly, it will be appreciated that the cylindrical body 35 is free to travel axially in relation to the housing 36 within the limits provided between the opposed upper shoulders 41 and 42 and the opposed lower shoulders 38 and 39. For reasons that will subsequently become apparent, the cylindrical body 35 is biased upwardly in relation to the housing 36 by

a compression spring 44 coaxially disposed within the tubular housing and yieldably restrained between the shoulder 41 and a ring 45 mounted around the elongated sleeve 37.

As seen in FIG. 3, the cylindrical body is not fluidly sealed in relation to the housing 36 so that the tubular housing will be filled with the borehole fluids. To prevent the borehole fluids from electrically shorting the various cable conductors, as at 12, the conductors are appropriately sealed within the cylindrical body 35 and connected, as at 46, to conductors, as at 47, leading to the interior of the logging tool 21 and brought through typical conductor seals (not shown) sealingly mounted in a transverse partition 48 across the lower end of the tubular housing 36. Accordingly, inasmuch as the hydrostatic pressure of the borehole fluids will be acting on both sides of the cylindrical body 35, there will be no unbalanced pressure forces affecting the relative longitudinal position of the cylindrical body in relation to the tool housing 36. Thus, imposition of a downwardly directed force through the logging cable 10 to the cylindrical body 35 will be effective to move the cylindrical body downwardly in relation to the housing 36 against the spring force of the compression spring 44. Similarly, in the usual situation, the weight of the logging tool 21 will be transmitted to the cable 10 by means of the opposed shoulders 38 and 39. Thus, it will be appreciated that so long as the logging tool 21 is dependently suspended from the logging cable 10, the shoulders 38 and 39 will be abutted; and a downwardly acting axial force at least as great as the potential spring force provided by the compression spring 44 will be required to shift the cylindrical body 35 downwardly in relation to the tool housing 36 so as to bring the shoulders 41 and 42 into abutment.

Accordingly, it will be appreciated that when the logging tool 21 is suspended, the cylindrical body 35 will be at its depicted upper position in relation to the tool housing 36 so that the full weight of the tool is supported by the shoulders 38 and 39. Similarly, as the tool 21 is moving through a deviated well bore, such as the borehole 22, upwardly directed forces on the housing 36 tending to slow or halt further progress of the logging tool 21 will be countered by the longitudinal or axial component of the weight of the tool. It will be seen, therefore, that when the cylindrical body 35 is elevated in relation to the tool housing 36, the summation of the downwardly acting forces on the logging tool 21 (such as the longitudinal component of the tool weight) are greater than the downwardly acting forces, if any, on the cylindrical body. Conversely, when the downwardly acting forces on the cylindrical body 35 are equal or greater than the upwardly directed forces on the tool housing 36 (such as frictional drag) tending to slow or halt the well tool 21 as well as the spring force of the spring 44, the cylindrical body will be shifted downwardly to bring the shoulder 41 into abutment with the shoulder 42. Thereafter, so long as these downwardly acting forces on the cylindrical body 35 predominate, these downwardly acting forces will be effective for pushing the well tool 21.

Accordingly, in the preferred arrangement of the signalling device 34 for indicating the position of the cylindrical body 35 in relation to the tool housing 36, a proximity switch, such as a so-called "reed switch" 49 adapted for remote magnetic actuation, is encapsulated in a suitable pressure-resistant case and secured, as by spring clips 50, within the elongated sleeve 37. To actuate the encapsulated proximity-sensing switch 49, a magnet 51 is encapsulated in a suitable case 52 and dependently secured below the cylindrical body 35 for movement thereby into and out of the operating proximity of the switch. In the preferred embodiment, the switch 49 is normally open and the magnet 51 is longitudinally positioned in relation thereto for actuating the switch upon movement of the cylindrical body 35 to its lower position to shift the magnet case 52 to the position shown by the dashed lines at 53.

To provide means for adjusting the relative longitudinal positions of the magnet 51 and switch 49, a depending rod 54 supporting the magnet case 52 is preferably threaded so that the magnet case can be screwed upwardly and downwardly

along the rod. One lead 55 from the switch 49 is connected to a selected conductor 12a in the suspension cable 10 and another switch lead 56 is electrically connected to another cable conductor or to the tool housing 36 as at 57. Since the armor of the logging cable 10 is electrically connected to the housing 36, the cable armor will serve as a return path. In this manner, so long as the switch 49 is open, the cable conductor 12a will not be connected to any other cable conductors; and upon movement of the magnet 51 to its lower position 53, the switch will close to connect the cable conductor 12a to the tool housing 36. Thus, by connecting a suitable electrical instrument such as, for example, an ohmmeter 58 between the cable armor and the conductor 12a at the surface, a surface indication will be provided representative of the longitudinal position of the cylindrical body 35 in relation to the tool housing 36.

With the unusual lateral stiffness of the cable 10 in mind, it will, therefore, be appreciated that as the logging tool 21 is progressively moved downwardly through the borehole 22, axial compressive loads can be imposed thereon by way of the cable. Thus, the logging tool 21 is lowered into the borehole 22 at, preferably, as high a speed as can be attained by free fall of the tool through the borehole fluids. This will, of course, mean that for most situations, the winch 24 will be allowed to freewheel so that the weight of the logging tool 21 and the progressively increasing weight of the cable 10 hanging in the borehole 22 will be effective for carrying the tool to as great a depth as is possible. It will be recognized, of course, that so long as the logging tool 21 is moving relatively freely, the switch 49 will remain open. Once the logging tool 21 enters a relatively deviated interval of the borehole 22 as shown in FIG. 2B, the tool will, of course, ultimately be halted and come to rest in a position such as that illustrated. If the tool 21 does halt, this will be apparent at the surface since the electrical signal provided by the logging device 23 will now show an unvarying signal on the instrument 33 in contrast to the usual varying signals that normally occur as the logging tool is moving.

When the operator at the surface has ascertained that the tool 21 has in fact come to rest, the winch 24 can be powered forwardly (as at 59) in such a manner as to unreel an additional length of the cable 10. Inasmuch as the portion of the cable 10 running over the sheaves 26 and 27 and a substantial proportion of its length within the borehole 22 will be under extreme tension, powering of the winch 24 will in effect merely reduce this tension load in the major portion of the logging cable. At some point, however, very near to the tool 21, the tensile load on this lower portion of the cable 10 will be zero so that any further downward force on the cable will induce a compressive force in that portion therebelow. Thus, the lowermost portion of the new and improved logging cable 10 of the present invention will instead have an axial compressive load imposed thereon which is, of course, transmitted downwardly to the slidable cylindrical body 35 in the upper end of the tool housing 36.

If this compressive load is less than the opposing spring force provided by the compressive spring 44, a corresponding downwardly directed force will be transmitted by way of the spring to the tool housing 36 which, hopefully, will be sufficient to move the well tool 21 still further. If, on the other hand, this downwardly acting compressive load on the logging cable 10 is greater than the opposing spring force provided by the spring 44, the cylindrical body 35 will move downwardly in relation to the tool housing 36; and, once the magnet 51 reaches the position 53 opposite the switch 49, the switch contacts will close and provide an indication at the surface on the ohmmeter 58 that such has occurred. This information will, therefore, advise the operator at the surface that a force of at least as great as the spring force of the spring 44 is being applied to the tool 21 for moving it further downwardly in relation to the borehole 22. If the logging tool 21 does in fact begin to move further downwardly, the logging device 23 will again provide varying electrical signals indicative of the dif-

ferent formation materials being passed by the moving tool. On the other hand, if the downward force is not sufficient to move the logging tool 21, the steady reading on the instrument 33 provided by the logging device 23 will advise the operator that the tool is still not moving. Moreover, the ohmmeter 58 will provide an indication of whether these downward forces are actually being imposed on the tool 21. Then, the winch 24 can be driven forwardly, as at 59, to insure that the cable 10 is hanging free which will be indicated by substantial flexing of the running portion of the cable between the lower sheave 27 and the winch. Once the cable 10 has been significantly flexed in this running portion of the cable, the cable can be pushed downwardly by hand or some cable-pushing device at the surface to impose a maximum load to on the tool 10. It is, of course, impossible to impose further loading through the cable onto the logging tool 21 unless the cable is partially respooled onto the winch 24 and then the tool is again relowered in an attempt to gain sufficient momentum to pass the impediment.

It has been found, however, in actual situations that where a borehole, such as at 22, is substantially deviated, with ordinary logging cables it has not been possible to get logging tools, as at 21, to intervals in the borehole beyond the uppermost highly deviated portions thereof. On the other hand, by employing the new and improved logging cable 10 of the present invention, a significant aid is provided in facilitating the descent of these logging tools. Usually, by watching the recording instrument 33 connected to the logging device 23, an operator will be advised that the logging tool 21 is beginning to slow. When this is noticed, the winch 24 may be powered forwardly, as at 59, to begin driving the logging cable 10 to supplement the gravitational and inertial forces moving the logging tool 21 downwardly through the borehole 22. In this manner, by taking advantage of the motional inertia of the logging tool 21, often the added impetus provided by positively driving the winch 24 to impose axial compressive forces on the moving tool will carry the tool along substantially deviated intervals and on into more vertical intervals therein.

Accordingly, it will be appreciated that the present invention has provided new and improved logging cables for facilitating the descent of logging tools through highly deviated well bores. Thus, although changes and modifications may be made in the principles of the invention as set out in the claims, by providing the laterally stiffened logging cable, logging tools coupled thereto may be moved thereby through even highly deviated boreholes to greater depths than has heretofore been attainable.

I claim:

1. An electrical logging cable adapted for coupling to a logging instrument to be passed through a well bore having a deviated interval therein and comprising: electrical conductor means arranged along a longitudinal axis; a plurality of first strands helically wound around said electrical conductor means at a first pitch angle of less than about 22° for providing at least one concentric inner layer of said first strands adapted to carry tensile loads applied to said cable; and a plurality of second strands helically wound about said first strands at a second pitch angle of greater than about 30° for providing at least one concentric outer layer of said second strands adapted to support compressive loads applied to said cable.

2. The logging cable of claim 1 wherein said first pitch angle is about 18° and said second pitch angle is about 35°.

3. The logging cable of claim 1 wherein said first metallic strands are smaller than said second metallic strands.

4. An electrical logging cable adapted for coupling to a logging instrument to be passed through a well bore having a deviated interval therein and comprising: electrical conductor means arranged along a longitudinal axis; a plurality of first and second metallic strands helically wound in opposite directions in relation to one another around said electrical conductor means with each being at a pitch angle of between about 16° to 22° for providing concentric inner armor layers adapted for carrying tensile loads applied to said cable; and a plurality of third metallic strands helically wound around said

inner armor layers at a pitch angle of between about 30° to 45° for providing at least one concentric outer armor layer adapted for supporting axially directed compressive loads applied to said cable.

5. The logging cable of claim 4 further including means defining an annular core between said electrical conductor means and said inner armor layers for supporting said armor layers.

6. The logging cable of claim 4 wherein said pitch angle of said inner armor layers is about 18° and said pitch angle of said outer armor layers is about 35°.

7. An electrical logging cable adapted for coupling to a logging instrument to be passed through a well bore having a deviated interval therein and comprising: a plurality of electrical conductors arranged in a helix along a longitudinal axis; means defining an axial core surrounding said electrical conductors; a plurality of first metal strands helically wound along said axial core at a first pitch angle of less than about 22° for providing a first concentric armor layer adapted to carry tensile loads applied to said cable; a plurality of second metal strands helically wound along said first armor layer in an opposite pitch direction thereto and at a second pitch angle of less than about 20° for providing a second concentric armor layer adapted to carry tensile loads applied to said cable; a plurality of third metal strands helically wound contiguous to one another along said second armor layer at a third pitch angle of about 30° to 45° for providing a third concentric armor layer adapted to support compressive loads applied to said cable; and a plurality of fourth metal strands helically wound contiguous to one another along said third armor layer in an opposite pitch direction thereto and at a fourth pitch angle of about 30° to 45° for providing a fourth concentric armor layer adapted to support compressive loads applied to said cable.

8. The logging cable of claim 7 wherein said first pitch angle is greater than about 18° and said second pitch angle is greater than about 16°.

9. The logging cable of claim 7 wherein said third and fourth pitch angles are about 35°.

10. The logging cable of claim 7 wherein said first and second pitch angles are about 18°.

11. The logging cable of claim 7 wherein said first and second pitch angles are about 18° and said third and fourth pitch angles are about 35°.

12. The logging cable of claim 7 wherein said third and fourth metal strands are larger than said first and second metal strands.

13. The logging cable of claim 12 wherein said fourth metal

strands are larger than said third metal strands.

14. The logging cable of claim 7 wherein said first metal strands are equal in number to said second metal strands and said second metal strands are larger than said first metal strands so as to substantially cover said first armor layer.

15. The logging cable of claim 7 wherein said third metal strands are equal in number to said fourth metal strands and said fourth metal strands are larger than said third metal strands so as to substantially cover said third armor layer.

16. The logging cable of claim 15 wherein said first metal strands are equal in number to said second metal strands and said second metal strands are smaller than said fourth metal strands but larger than said first metal strands so as to substantially cover said first armor layer.

17. An electrical logging cable adapted for coupling to a logging instrument to be passed through a well bore having a deviated interval therein and comprising: a plurality of electrical conductors arranged in a helix along a longitudinal axis; means defining an axial core surrounding said electrical conductors; a plurality of first metal strands of a first diameter helically wound contiguous to one another along said axial core at a first pitch angle of less than about 18° to 22° for providing a first tightly wound concentric armor layer adapted to carry tensile loads applied to said cable; a plurality of second metal strands of a second diameter greater than said first diameter helically wound contiguous to one another along said first armor layer in an opposite pitch direction thereto and at a second pitch angle of less than about 16° to 20° for providing a second concentric armor layer adapted to carry tensile loads applied to said cable; a plurality of third metal strands of a third diameter greater than said second diameter helically wound contiguous to one another along said second armor layer in an opposite direction thereto at a third pitch angle of about 30° to 45° for providing a third concentric armor layer adapted to support compressive loads applied to said cable; and a plurality of fourth metal strands of a fourth diameter greater than said third diameter helically wound contiguous to one another along said third armor layer in an opposite pitch direction thereto and at a fourth pitch angle of about 30° to 45° for providing a fourth concentric armor layer adapted to support compressive loads applied to said cable.

18. The logging cable of claim 17 wherein said third and fourth pitch angles are about 35°.

19. The logging cable of claim 17 wherein said first and second pitch angles are about 18°.

20. The logging cable of claim 19 wherein said third and fourth pitch angles are about 35°.

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