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Pitts, Jr.

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[45] **Apr. 2, 1974**

[54] **FORMATION TESTING TOOL**

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[73] Assignee: **Texaco Inc.**, New York, N.Y.

[22] Filed: **Feb. 16, 1973**

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[52] **U.S. Cl.** ..... **166/65 R,** 166/106, 166/147

[51] **Int. Cl.** **E21b 43/00,** E21b 49/00

[58] **Field of Search** ..... 166/65 R, 68, 68.5, 72, 166/107, 147

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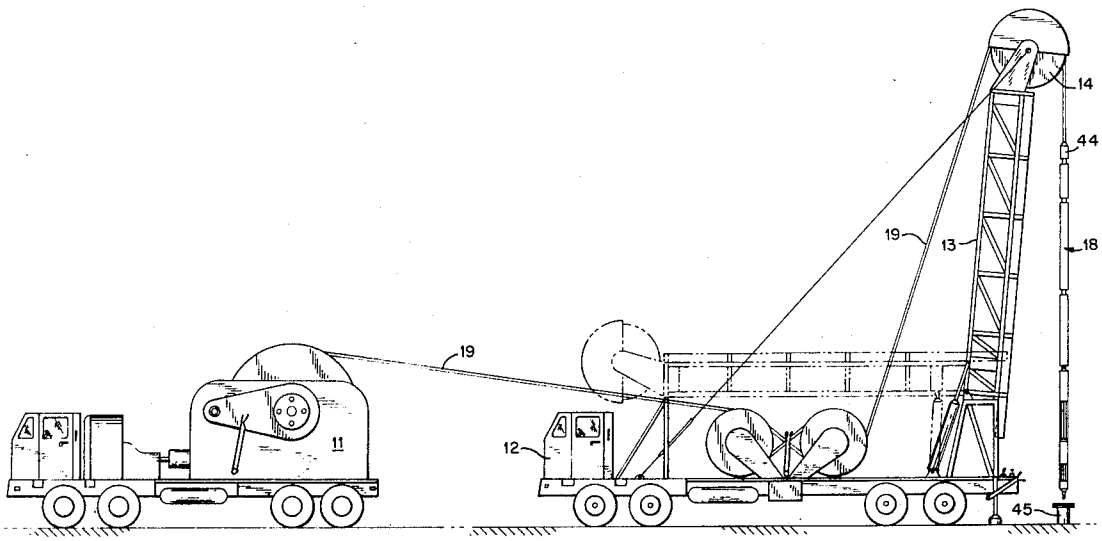
Primary Examiner—James A. Leppink

Attorney, Agent, or Firm—T. H. Whaley; C. G. Ries

[57] **ABSTRACT**

An oil-well-type tool which is adapted for use in deep wells. It cooperates with a reelable armored hose for connection with the surface, and it includes an electric motor driven by a positive displacement pump. There are solenoid valves and piping connections for carrying out surface-controlled test operations at different locations downhole.

5 Claims, 13 Drawing Figures



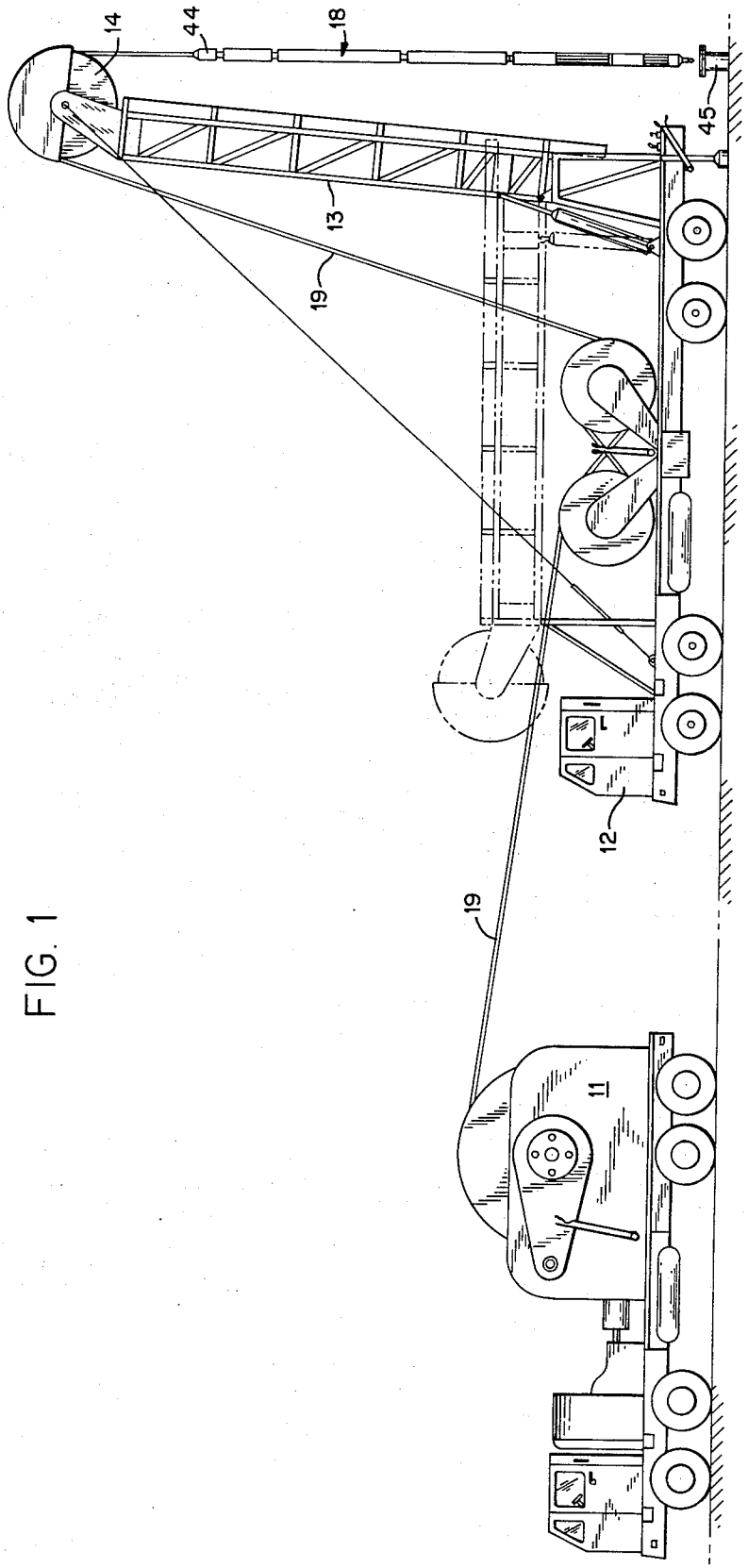


FIG. 1

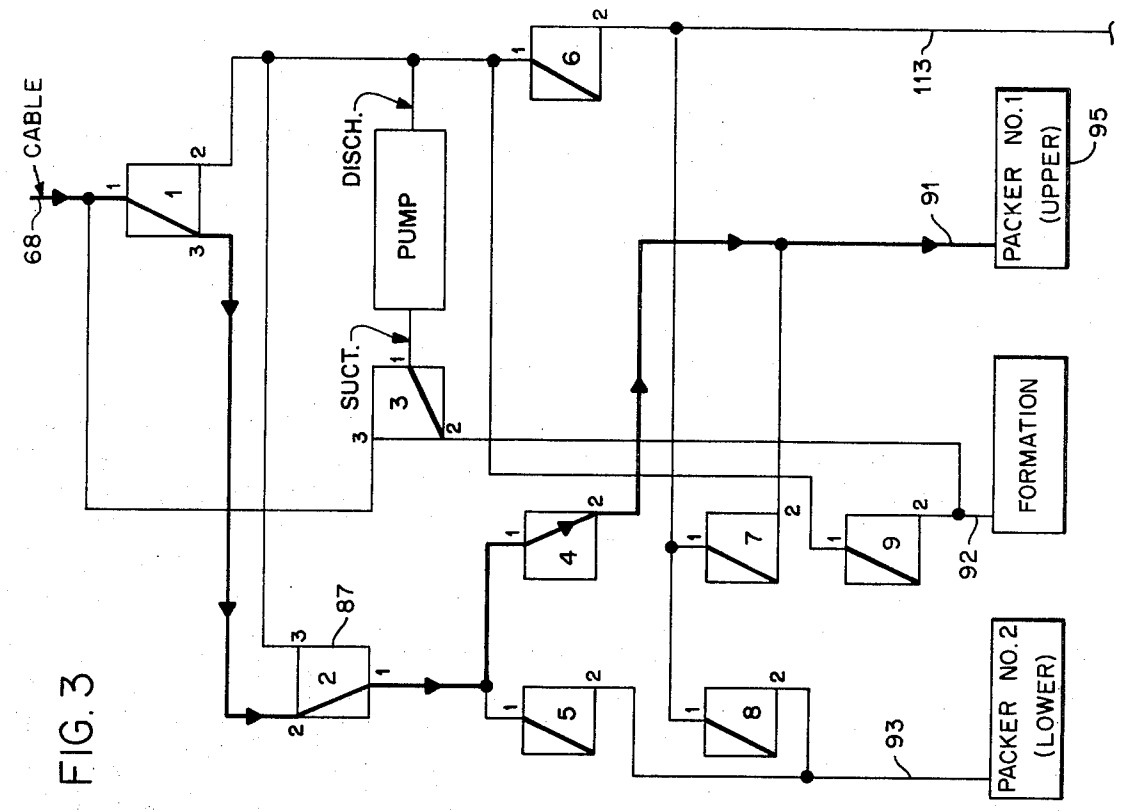

CABLE
68
DISCH.
PUMP
SUCT.
87
113
PACKER NO.1 (UPPER)
95
91
FORMATION
92
PACKER NO.2 (LOWER)
93

FIG. 3

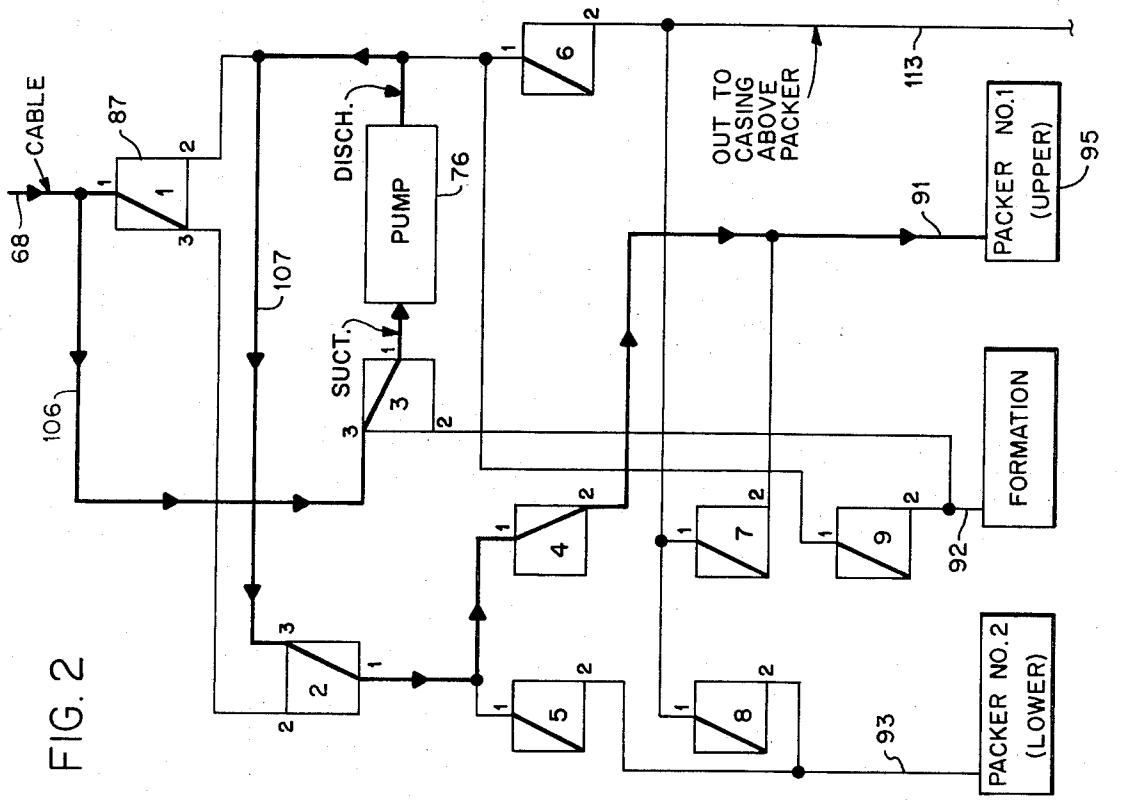

CABLE
68
87
DISCH.
PUMP
76
SUCT.
107
106
OUT TO CASING ABOVE PACKER
113
PACKER NO.1 (UPPER)
95
91
FORMATION
92
PACKER NO.2 (LOWER)
93

FIG. 2

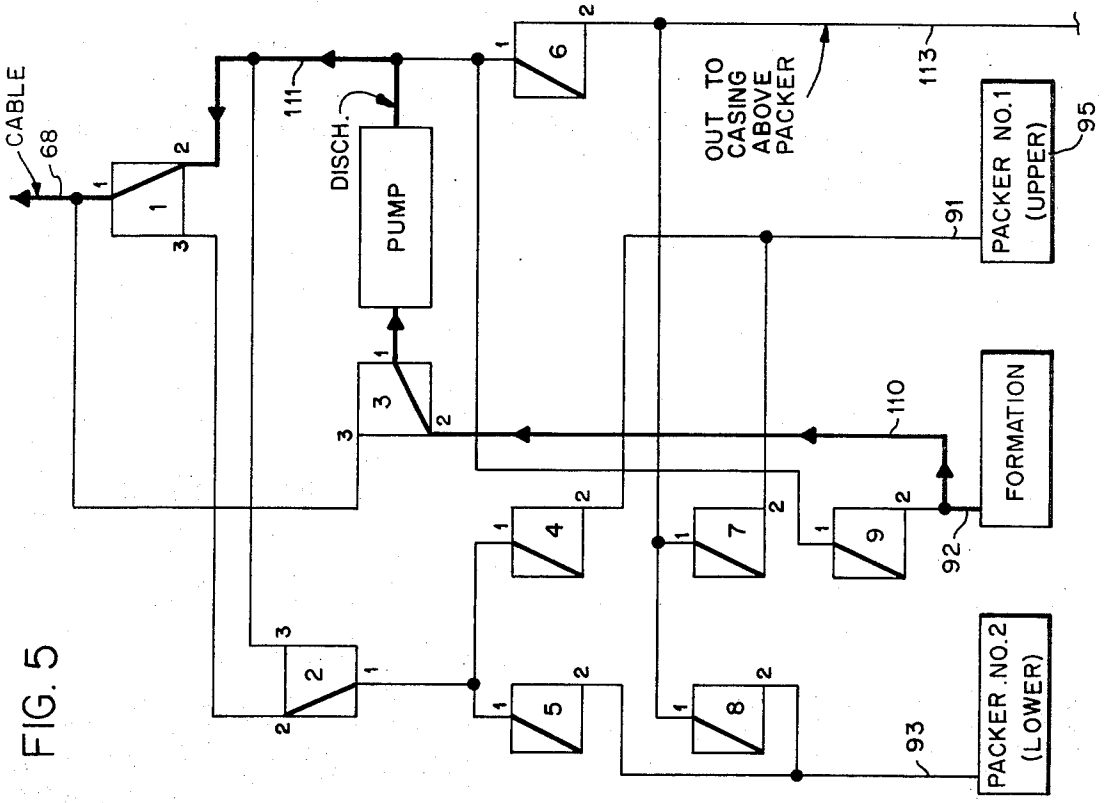

CABLE
68
DISCH.
PUMP
111
OUT TO CASING ABOVE PACKER
113
PACKER NO.1 (UPPER)
95
91
110
FORMATION
92
PACKER NO.2 (LOWER)
93

FIG. 5

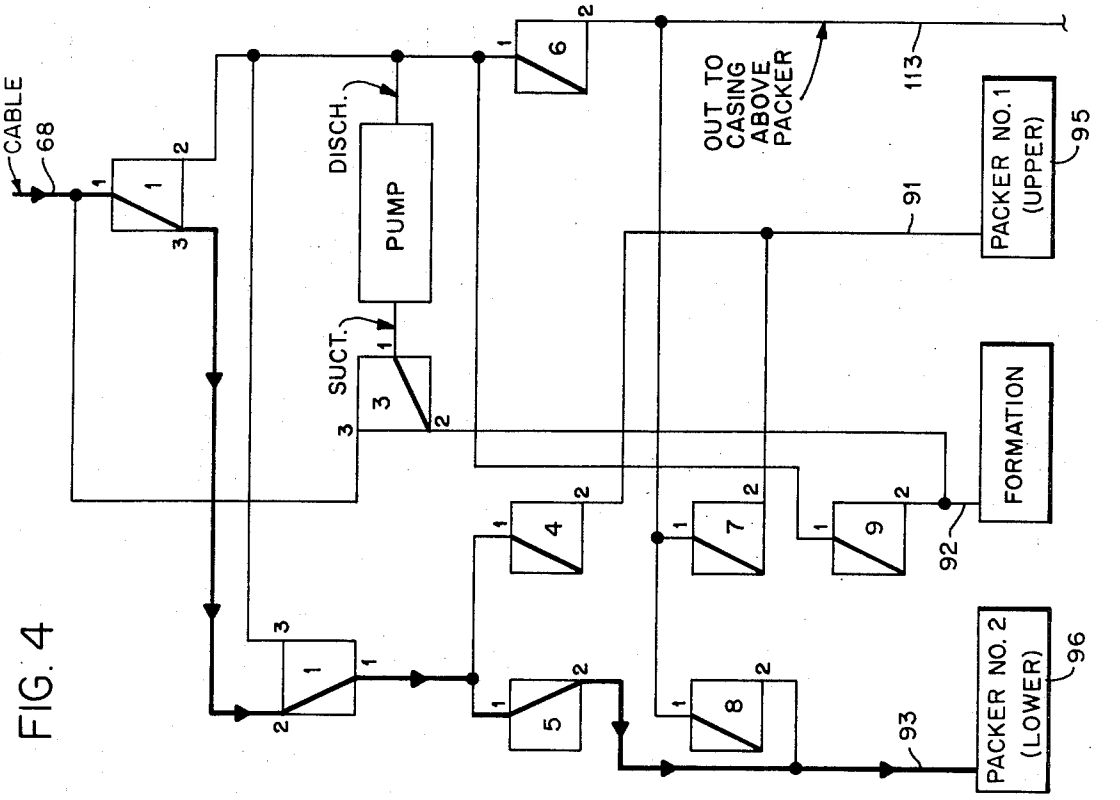

CABLE
68
DISCH.
PUMP
SUCT.
OUT TO CASING ABOVE PACKER
113
PACKER NO.1 (UPPER)
95
91
FORMATION
92
PACKER NO. 2 (LOWER)
96
93

FIG. 4

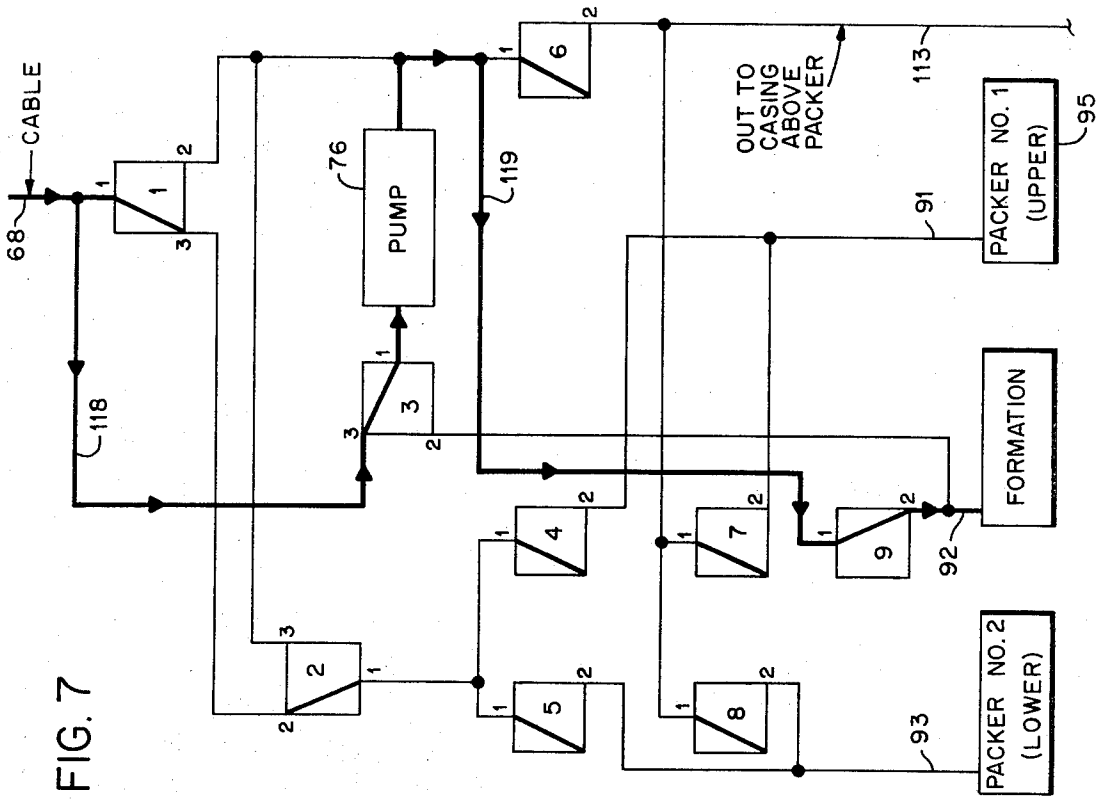

CABLE
68
PUMP
76
119
118
OUT TO CASING ABOVE PACKER
113
PACKER NO. 1 (UPPER)
95
91
FORMATION
92
PACKER NO. 2 (LOWER)
93

FIG. 7

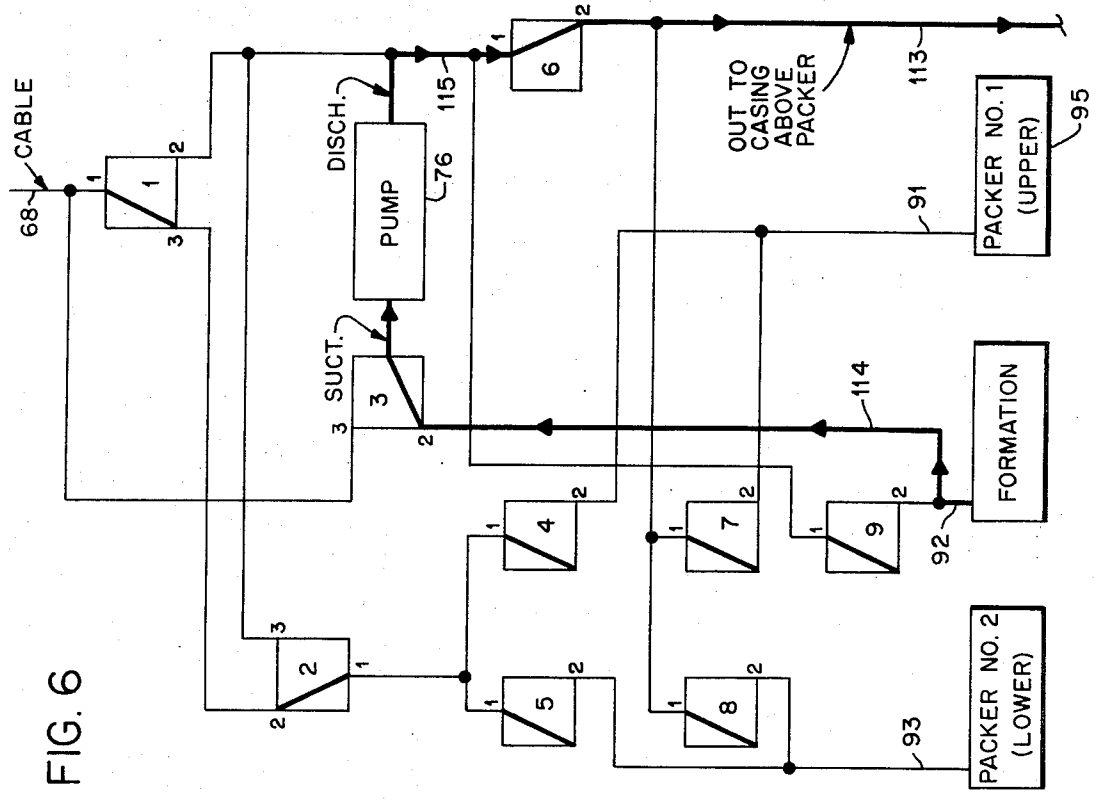

CABLE
68
DISCH.
PUMP
76
115
SUCT.
OUT TO CASING ABOVE PACKER
113
PACKER NO. 1 (UPPER)
95
91
114
FORMATION
92
PACKER NO. 2 (LOWER)
93

FIG. 6

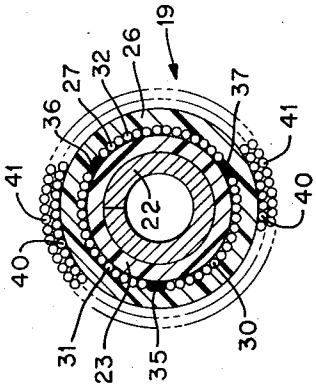

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35
30

FIG. 9

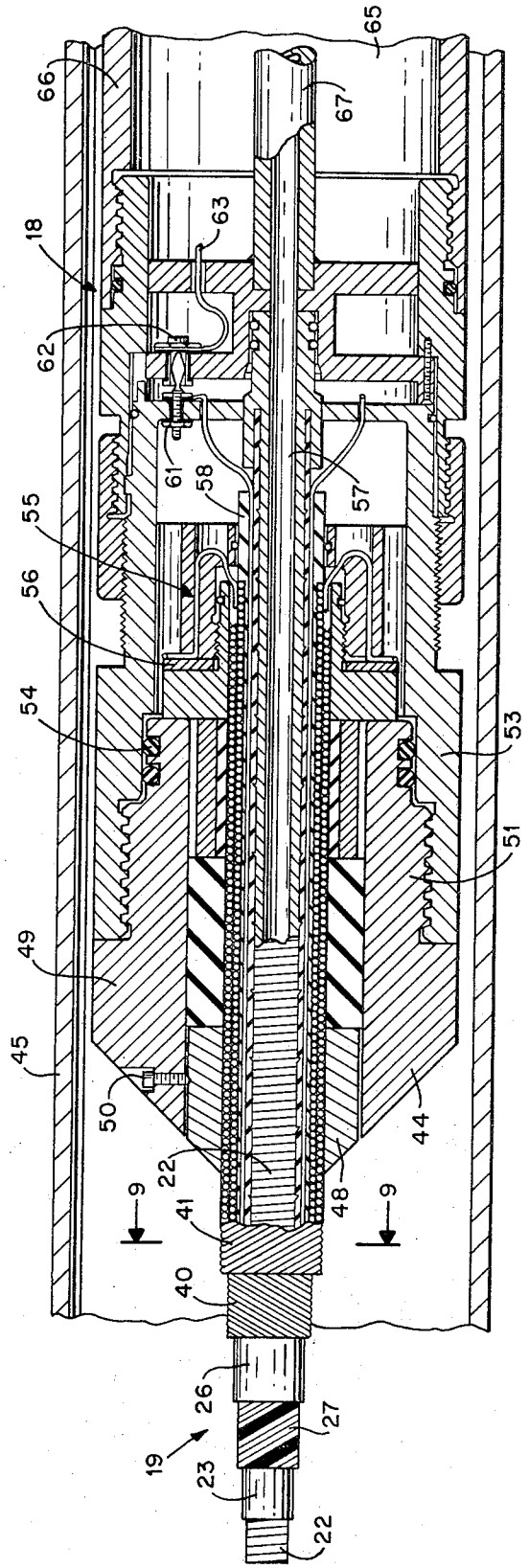

65
66
67
18
63
62
61
58
57
55
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54
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9
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41
40
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19
23
22

FIG. 8

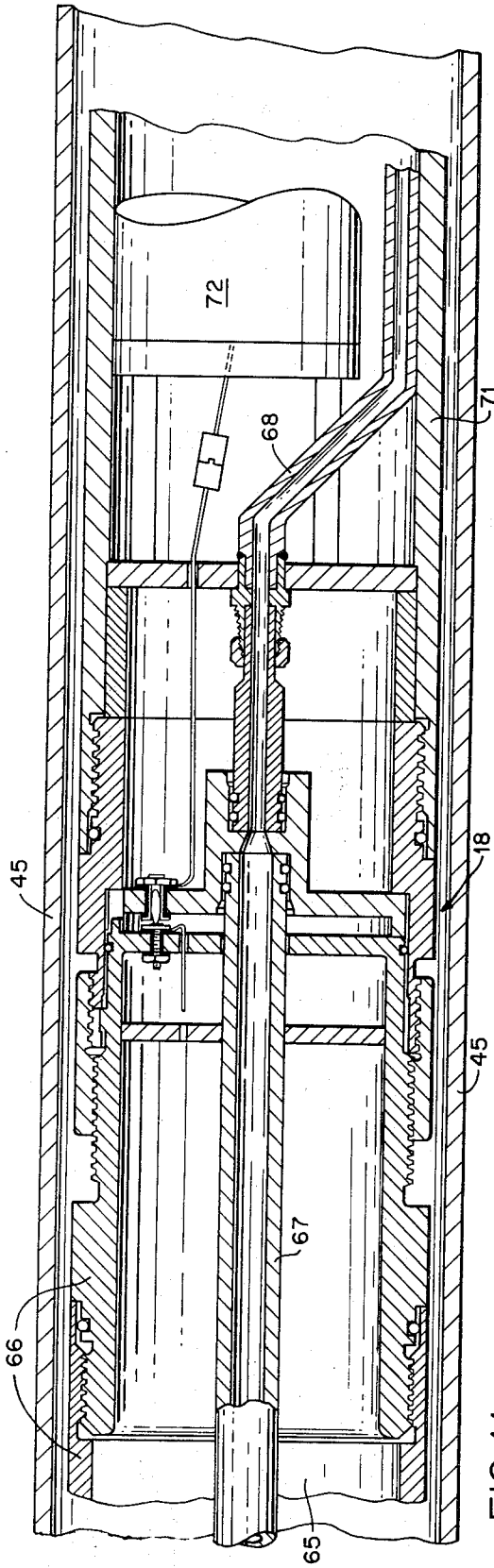

72
71
68
18
45
45
67
66
65

FIG. 10

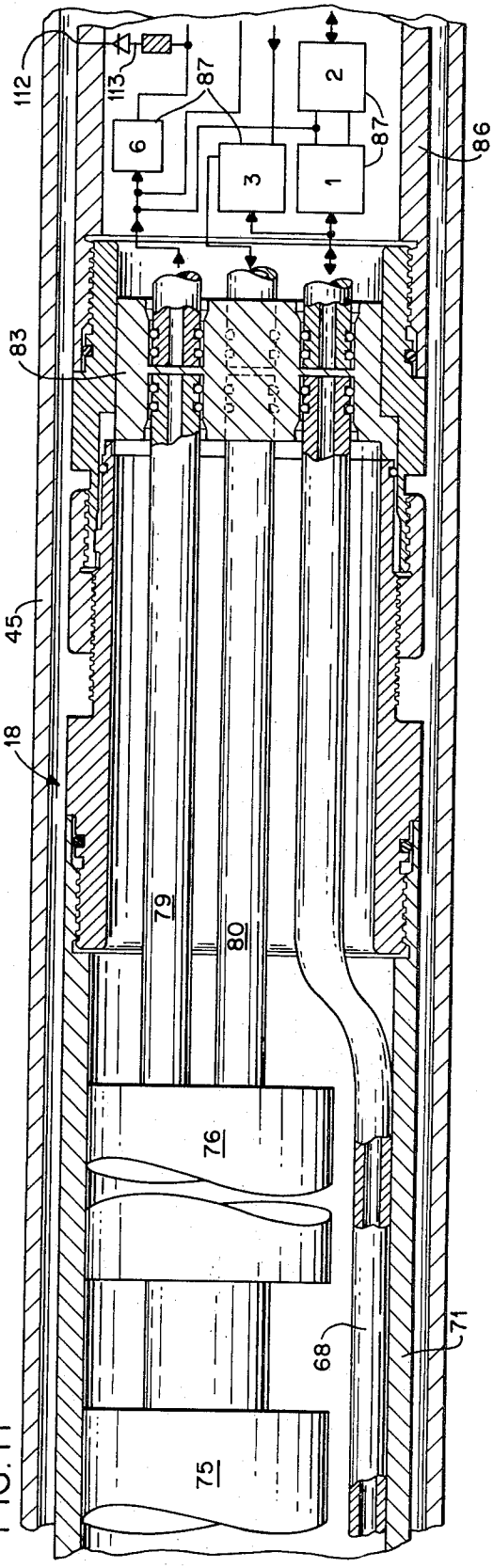

112
113
87
6
3
2
1
87
86
83
45
18
79
80
76
75
68
71

FIG. 11

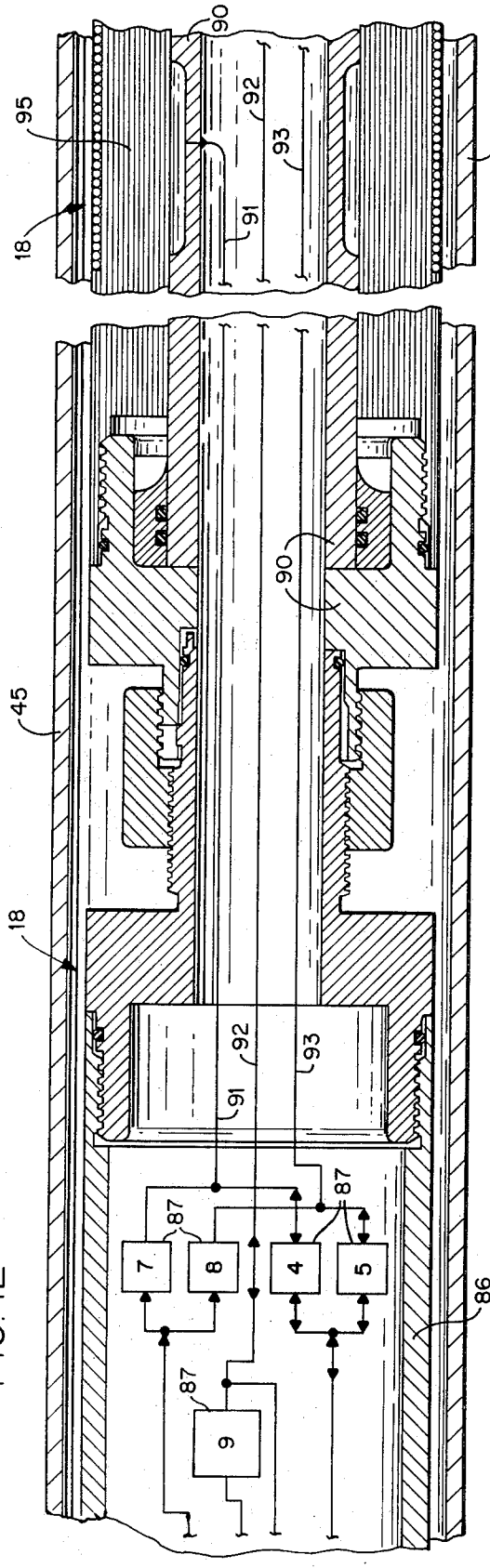

90
95
92
93
45
18
91
45
18
90
45
92
93
91
87
87
87
7
8
4
5
9
86

FIG. 12

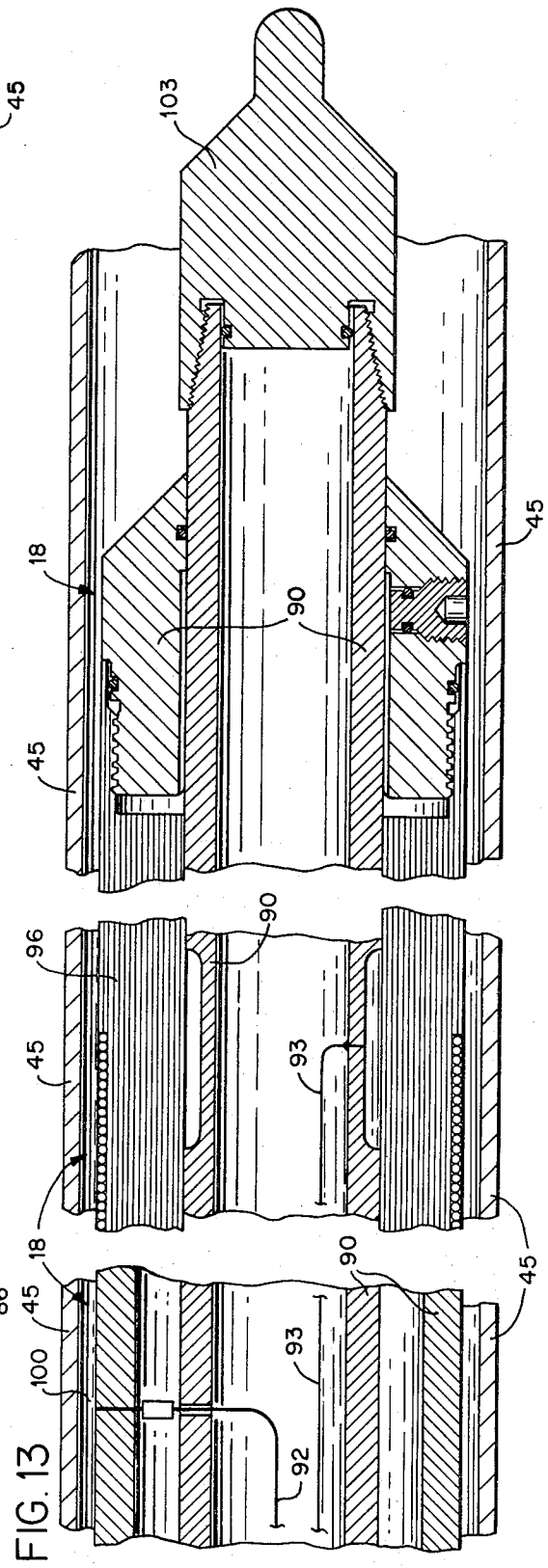

103
18
90
45
90
96
45
93
18
45
90
45
100
93
92

FIG. 13

FORMATION TESTING TOOL

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention concerns oil-well-type tools, in general. More specifically, it relates to a formation-testing tool that is particularly applicable to testing incased wells.

2. Description of the Prior Art

While there have been various tools proposed for making formation tests in one manner or another, nothing has been developed that has all of the attributes of a tool according to this invention. The conventional testing tool is supported by a wire line and, consequently, the formation sample is very limited. On the other hand, a so-called drill-stem test is limited to the use of a drill string in the hole. Furthermore, no known practical tool has the complete versatility of this invention.

Thus, it is an object of this invention to provide a comprehensive formation-testing tool that can accomplish a substantial number of different kinds of tests while being able to be shifted from one location to another downhole.

SUMMARY OF THE INVENTION

Briefly, this invention concerns a formation-testing tool that comprises in combination armored-hose means for connecting said tool with the surface, including electrical conductors for supplying power downhole, and a pump in said tool. It also comprises electric-motor means for driving said pump, a plurality of inflatable packers spaced longitudinally apart along said tool, and first conduit means in said tool for connecting the outside of said tool between said packets to said hose for fluid connection to the surface. It also comprises second conduit means in said tool for connecting said packers to said pump for applying fluid pressure to inflate the packers, valve means for controlling interconnections of said first and second conduit means with said hose and said pump for inflating said packers and for drawing formation fluid from the annulus between the packers to be carried to the surface for testing, and means for controlling actuation of said valve means.

Again, briefly, the invention concerns a formation-testing tool that comprises in combination a reelable armored hose for making a fluid-flow connection with the surface from said tool, said hose having a plural layered armor-wire covering, coiled-spring inner wall stiffener, and at least three separately insulated electrical conductors embedded between two layers of impervious plastic material forming the walls of said hose. The tool also comprises a hose-coupling end for mechanically joining said layered armor wires to said tool and for making a fluid-tight coupling with the interior of said tool, and a housing section containing electronic control means. It also comprises a first conduit in said tool being joined to said hose coupling, a three-phase AC pump motor mounted in said tool, and a positive displacement pump mounted in said tool, and having a suction port and a discharge port. It also comprises reduction-gear means for connecting said motor to said pump, and second and third conduits in said tool being joined to said suction port and discharge port, respectively. It also comprises a plurality of solenoid-actuated valves, and upper and lower inflatable packers on said tool separated longitudinally for straddling a producing zone. It also comprises fourth and fifth conduit means in said tool for applying fluid pressure to said packers, respectively, and a sixth conduit being connected to the outside of said tool between said packers, and a plurality of conduit connections interconnecting said valves with said sixth conduit whereby desired formation tests may be carried out.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and other objects and benefits of the invention will be more fully set forth below in connection with the best mode contemplated by the inventor of carrying out the invention, and in connection with which there are illustrations provided in the drawings, wherein:

FIG. **1** is a schematic elevation illustrating typical equipment to be used with a tool according to the invention;

FIGS. **2–7** are schematic flow diagrams illustrating the valve positions and flow paths for carrying out various functions of the tool;

FIG. **8** is a longitudinal cross-sectional view showing the upper, or head end of the tool according to the invention;

FIG. **9** is an enlarged transverse cross-section taken along the line **9—9** on FIG. **8**, and looking in the direction of the arrows;

FIGS. **10–13** are longitudinal cross-sectional showings, illustrating the remaining elements of a tool according to the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIG. **1**, there is shown some typical equipment which may be employed in connection with making use of a tool according to this invention. Thus, there is shown a reel truck **11** located in front of a hoist truck **12** which has a foldable mast **13** thereon with a pulley **14** at the free end of the mast. The pulley acts to guidably support a tool **18** that is suspended at the end of a hose **19** which is specially constructed, as will appear more fully hereinafter.

Referring to FIGS. **8** and **9**, it will be noted that the hose **19** is made up of a coiled-spring inner-wall stiffener **22.** This is preferably a rectangular cross-section spring metal which is coiled tightly so as to provide maximum stiffening while permitting adequate flexibility. Next outside of the inner-wall coil **22,** there are a plurality of layers (not shown) of steel wire and plastic interwound to form an hydraulic hose or layer **23.** This layer **23** is preferably constructed like a standard hydraulic hose with as many as six layers (not shown) of counterwound wire sealed with neoprene or other suitable plastic material. A principal function of this layer **23** is to provide capability to withstand internal pressure in the hose **19.** Outside the layer **23,** there is another similar insulating-material layer **26** with a coiled electrical conductor layer **27** in between.

It will be noted that the layer **27** is made up of three groups of adjacent electrical conductors **30, 31,** and **32** (see FIG. **9**). These groups are laterally separated (peripherally around the layer) by insulators **35, 36,** and **37,** which are illustrated as solid circles in FIG. **9.** It will be appreciated that these conductors and insulators may be formed on the layer **23** by running the core

through a cable machine in order to wind the various wires and insulators in the respective positions relative to one another. In this manner, there are provided three separate electrical conductor groups, i.e., **30, 31,** and **32,** which may supply electric power for the pump and other elements in the tool.

Outside of the outer insulation layer **26,** there are a pair of armor-wire layers **40** and **41** which are wound in opposite direction spirals for providing strength with flexibility to the hose.

Hose **19** is anchored to the tool **18** by providing the tool with a head end or coupling member **44.** It will be noted that in FIG. **8** (as well as in FIGS. **10–13**) the tool **18** is shown inside of a casing **45.** It will be understood, however, that under appropriate circumstances the tool may be designed for operating in an uncased hole.

The head-end member **44** has appropriate structure for securely fastening the hose **19** to the tool as well as for permitting an uncoupling of the body of the tool from the head member. Thus, there is a tapered tip **48** which is part of the head end **44** and is closely fitted around the outer layer of armor wire **41.** Also, a larger-diameter nose piece **49** is held in place around the tip **48.** This nose portion **49** has a complimentary taper with the tip **48** and is fastened to the tip **48** by a set screw **50,** as illustrated. There is a reduced-diameter threaded extension **51** of the nose piece **49.** This is adapted to receive a body extension **53.** Extension **53** is threaded internally to mesh with the threads on nose extension **51,** and it has a smooth internal surface for cooperating with appropriate seals, such as O-rings **54.** These maintain fluid-tight conditions between the exterior of the tool **18** and its interior where the hose **19** is attached. The attachment of the hose **19** includes appropriately constructed clamp structure **55,** as illustrated. It will be observed that the ends of the armor-wire layers **40** and **41** are securely held by clamping action against a washer **56.**

There is an inner metallic sleeve **57** that butts against the end of the coiled spring **22.** These have the same inside diameter for providing a continuous fluid-flow path connecting with the inside of the hose **19.** The sleeve **57** has an extension of the insulation layer **23** securely attached to the outside thereof, and there are a plurality of barbs **58** to assist in holding this insulation layer against tensile longitudinal forces.

The ends of the electrical conductors **30, 31,** and **32** are brought out and fastened to electrical connectors, e.g., a banana-plug connector **61,** that makes electrical connection by cooperating with a female connector **62** from which the electrical connector path is continued by a wire **63.** It will be appreciated by one skilled in the art that individual strands of the conductor groups **30, 31,** and **32** may be electrically joined together as desired for any particular power requirements, while unused strands might be individually insulated (not shown) if separate low-power circuits should be desired.

The head end **44** of the tool is joined onto a housing section **66** that contains electronic control means (not shown) in annular interior space **65** that surrounds a fluid conduit **67.** At the other end of the section **66** (see FIG. **10**), the conduit **67** is coupled to another conduit **68.**

Here, there is a succeeding section **71** (FIGS. **10** and **11**) of the tool **18.** This section contains an electrical pump motor **72** (schematically indicated). While this might be various types of motor, it is preferably one manufactured by the Reda Pump Division of TRW of Bartlesville, Okla. Specifically, it might be a **10.5** horsepower motor from the **375** series, rated at **400** volts and three-phase sixty cycles.

Section **71** also contains a reduction gear box **75** (schematically indicated) that connects the motor **72** with a positi e displacement pump **76** (also schematically indicated). Connected to the pump, there is a pair of conduits **79** and **80** that each connect to the suction port and discharge port, respectively, of the pump **76.** It will be observed that the conduit **68** is continued along one side of the interior of this section **71** of the tool. At the end of section **71** adjacent to the pump **76,** there is a joint **83** where the conduit **68** along with the conduits **79** and **80,** are all coupled to continuations on into another section **86** of the tool **18.** Section **86** (FIGS. **11** and **12**) contains a plurality of electrically controlled solenoid valves **87** that are schematically indicated and have been identified in the drawings by the numbers **1** to **9.**

FIG. **12** illustrates the connection of the section **86** of the tool to a lowermost (when vertical, e.g. as suspended from the hose **19**), or end section **90** that is shown in broken portions thereof in FIGS. **12** and **13.** This section contains three conduits **91, 92,** and **93** that are illustrated schematically by single-line showings in FIGS. **12** and **13,** as well as in FIGS. **2–7.** The conduits **91, 92,** and **93** are interconnected from various of the valves **87,** and conduit **91** leads to an upper one of two expansible packers **95** (FIG. **12**) and **96** (FIG. **13**) for inflating and deflating same. Conduit **93** leads to the lower packer **93,** while the third conduit **92** leads to an exterior port **100,** as schematically indicated in FIG. **13.** The latter permits the sampling of well fluid from the exterior of the tool at a location longitudinally spaced between the two packers **95** and **96.** It will be understood that the drawings illustrate only broken sections of the tool in order to conserve space in the illustration.

The extreme free end of the tool (when connected to hose **19**) has a solid tip **103** that is attached to the section **90** of the tool using fluid seals as indicated.

Referring to FIGS. **2–7** it will be appreciated that these schematic diagrams illustrate fluid-flow paths for a number of different functions which may be carried out with the tool described above. Thus, for example, referring to FIG. **2,** the electrically controlled valves **87** may be set to the positions schematically indicated in order to inflate the upper packer **95** by applying pressure from the pump **76** with its supply being taken from the cable, i.e., conduit **68.** It will be observed that the fluid-flow paths are indicated by heavy lines. Thus, fluid from the cable, or hose **19** will flow via a path **106** to valve No. **3** and from there to the suction conduit leading to the pump **76.** Thereafter, from pump discharge, a fluid-flow path **107** leads to the upper packer **95** via valves **2** and **4** and the conduit **91.**

As an alternative, and with reference to FIG. **3,** the valve interconnections may be set so that pressure fluid from the surface (as applied to the hose **19,** or cable via conduit **68**) may be applied directly to the upper packer **95** via the dark-line flow paths indicated. These paths proceed through valve nos. **1, 2** and **4** to the conduit **91.**

FIG. **4** illustrates the flow paths for applying surface-generated fluid pressure via the conduit **68** to the lower

packer **96.** This employs the dark-line flow paths shown that proceed via valves nos. **1, 2,** and **5** to the conduit **93.**

FIG. **5** illustrates the flow-path connections that would be employed to draw a formation sample from the exterior of the tool **18** via the port **100** located between the packers. Thus, a flow path begins at the port **100** and goes through the conduit **92** to a flow path **110** which leads from the formation to valve No. **3** where it is connected to the suction side of the pump **76.** The discharge side of the pump is connected via another flow path **111** to valve no. **1** where it is connected to conduit **68** for transmittal to the surface.

FIG. **6** illustrates the flow connections that may be employed in order to provide for producing the formation into the annuus of the well which surrounds the tool **18** and the hose **19.** For accomplishing this, there is another port **112** (see FIG. **11**) which is located above the upper packer **95,** and another conduit **113** (FIG. **11**) which is only schematically indicated in FIG. **11** as well as in the flow diagrams of FIGS. **2–7.** Thus, formation fluid from between the packers is connected via the conduit **92** and a flow path **114** to valve No. **3.** From there the fluid flow proceeds via the pump **76** to an exit flow path **115** that leads to valve No. **6.** After valve No. **6,** there is a fluid-flow path out via the conduit **113** to the casing above the upper packer.

FIG. **7** illustrates still another flow-path connection that may be employed. This path would be used for pumping fluid from the surface into the formation between the packers. Thus, from the conduit **68,** there is a fluid-flow path **118** that leads to valve No. **3** and from there to the suction port of pump **76.** Thereafter, the pump discharge leads to a flow path **119** that goes to valve No. **9** which connects it to the formation via the conduit **92** and the port **100.**

It will be observed that while some of the various combinations have been illustrated in the FIGS. **2–7,** there are many more variations which may be employed. Thus, by having the electrical control signals transmitted down through the electrical conductors and via the electronic control section of the tool **18,** various predetermined arrangements or settings of valve positions (valves **87**), i.e., valves Nos. **1–9,** may be made. Also, of course, the energization of the pump **76** will be carried out when appropriate to provide fluid flow and/or fluid pressure, as desired.

While the invention has been described above in considerable detail and in accordance with the applicable statutes, this is not in any way to be taken as limiting the invention but merely as being descriptive thereof.

I claim:

1. A formation testing tool, comprising in combination

armored-hose means for connecting said tool with the surface including electrical conductors for supplying power downhole,

a pump in said tool,

electric motor means for driving said pump,

a plurality of inflatable packers spaced longitudinally apart along said tool,

first conduit means in said tool for connecting the outside of the tool between said packers to said hose for fluid connection to the surface,

second conduit means in said tool for connecting said packers to said pump for applying fluid pressure to inflate the packers,

valve means for controlling interconnections of said first and second conduit means with said hose and said pump for inflating said packers and drawing formation fluid from the annulus therebetween to be carried to the surface for testing, and

means for controlling actuation of said valve means.

2. A formation testing tool according to claim **1,** wherein

said pump is a positive displacement type.

3. A formation testing tool according to claim **2,** wherein

said pump has a suction port and a discharge port, and said first and second conduit means comprise a plurality of conduits interconnecting said pump ports and said hose with said valve means.

4. A formation testing tool according to claim **3,** wherein

said valve means comprises a plurality of solenoid-actuated valves, and

said means for controlling actuation of said valves means comprises circuit means including said hose electrical conductors and electronic means for controlling energization of said solenoids.

5. A formation testing tool, comprising in combination

a reelable armored hose for making a fluid-flow connection with the surface from said tool,

said hose having a plural-layered armor-wire outer covering, a coiled-spring inner wall stiffener and at least three separately insulated electrical conductors embedded between two layers of impervious plastic material forming the walls of said hose,

a hose-coupling end on said tool for mechanically joining said armor-wire layers to said tool and for making a fluid-tight coupling with the interior of said tool,

a housing section containing electronic control means,

a first conduit in said tool being joined to said hose coupling,

a three-phase AC pump motor mounted in said tool,

a positive displacement pump mounted in said tool and having a suction port and a discharge port,

reduction gear means for controlling said motor to said pump,

second and third conduits in said tool being joined to said suction port and said discharge port, respectively,

a plurality of solenoid-actuated valves,

upper and lower inflatable packers on said tool separated longitudinally for straddling a producing zone,

fourth and fifth conduits in said tool for applying fluid pressure to said packers, respectively,

a sixth conduit being connected to the outside of said tool between said packers, and

a plurality of conduit connections interconnecting said valves with said sixth conduit whereby desired formation tests may be carried out.

* * * * *