

[54] **FLUID LOGIC CONTROL SYSTEM**

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3,092,143 6/1963 Denman137/624.14
3,305,211 2/1967 Phillips251/368 X

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137/596
[51] Int. Cl.F16k 11/20
[58] Field of Search137/81.5, 624.14, 608, 561,
137/596, 613, 269, 552.5; 251/368, 367; 235/201

[56] **References Cited**

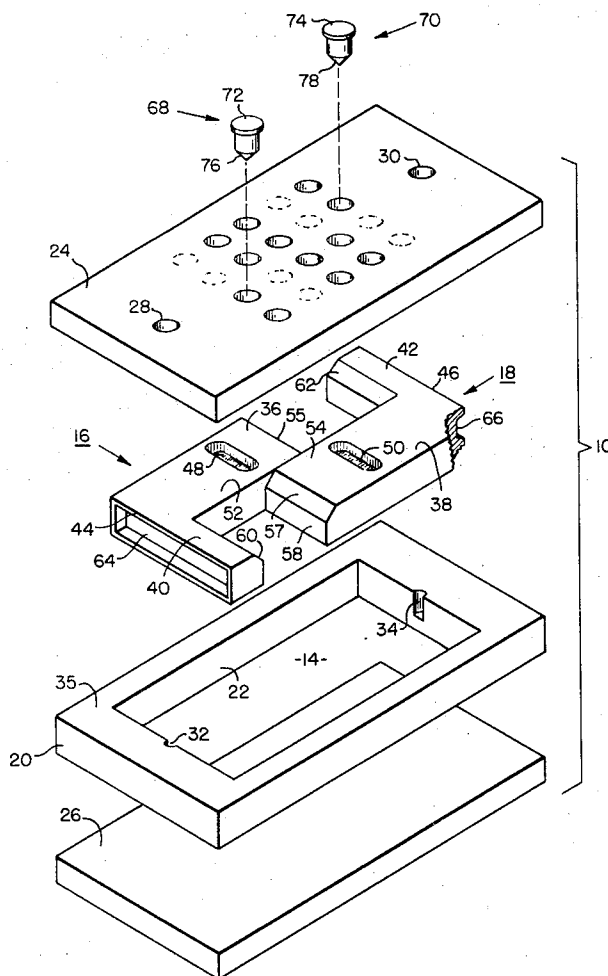
UNITED STATES PATENTS

2,904,070 9/1959 Lynott137/552.5
3,541,991 11/1970 Hartman235/201 X
3,057,551 10/1962 Etter137/81.5 X

[57] **ABSTRACT**

A fluid logic control system for controlling the operation of, for example, industrial machines. The system includes a plurality of fluid-operated components, each of which includes a casing having a chamber, a movable spool in the chamber, ports in the casing, and passageways in the spool. The components include: a fluid logic gate capable of performing any one of the four logic functions: AND, OR, NOT, NOR; a multiple pole relay; a differential pressure relay; a micro-valve differential pressure relay; a pilot light; a selector switch; and a push button relay. The spools are self-sealing and the casings are interchangeable.

20 Claims, 22 Drawing Figures



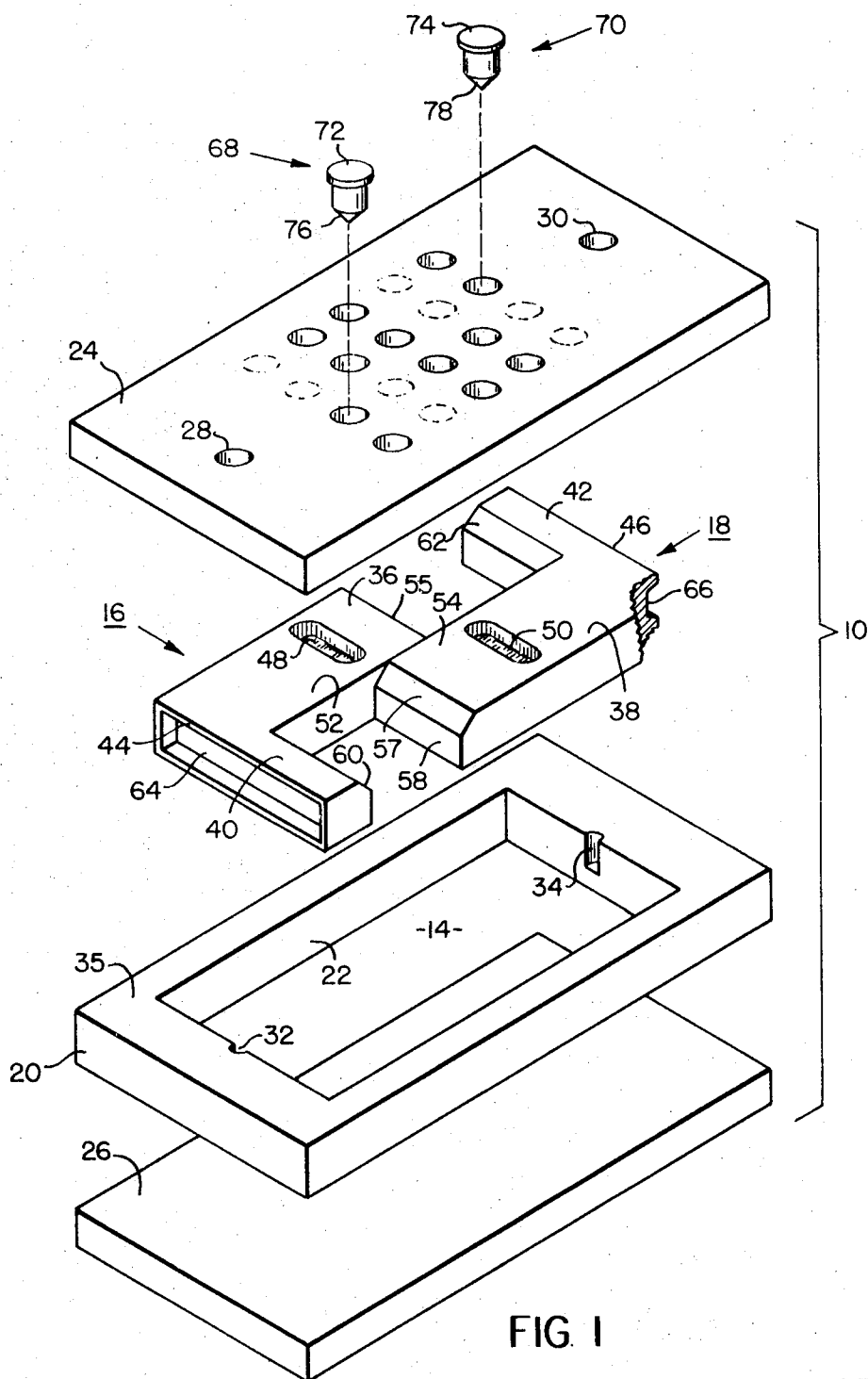


FIG. 1

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FIG. 2

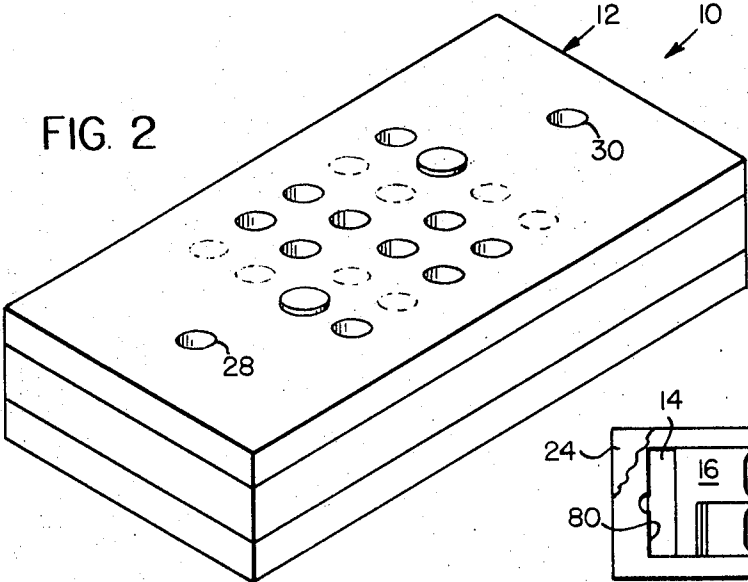


FIG. 3

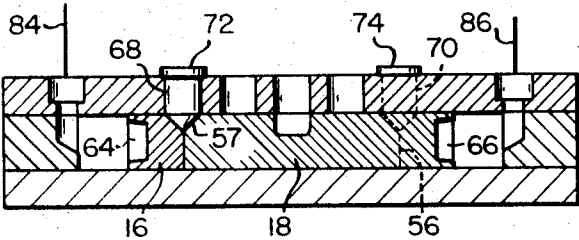


FIG. 4A

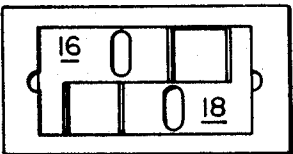


FIG. 4B

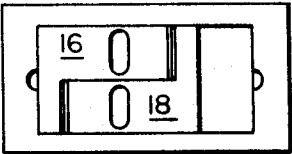


FIG. 4C

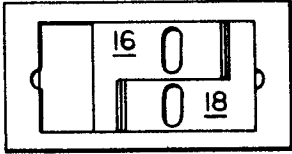


FIG. 4D

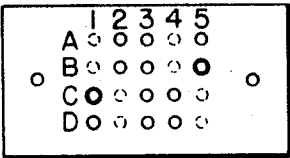


FIG. 5

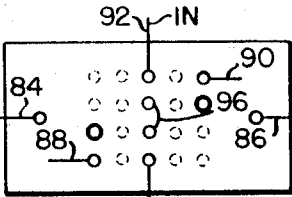


FIG. 6 AND

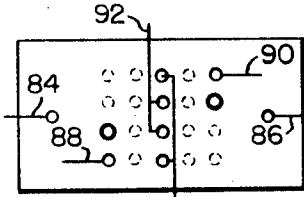


FIG. 7 OR

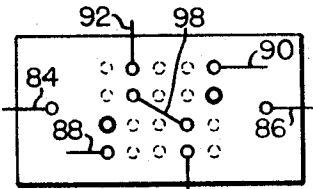


FIG. 8
NOT

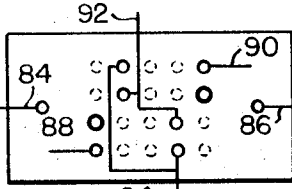
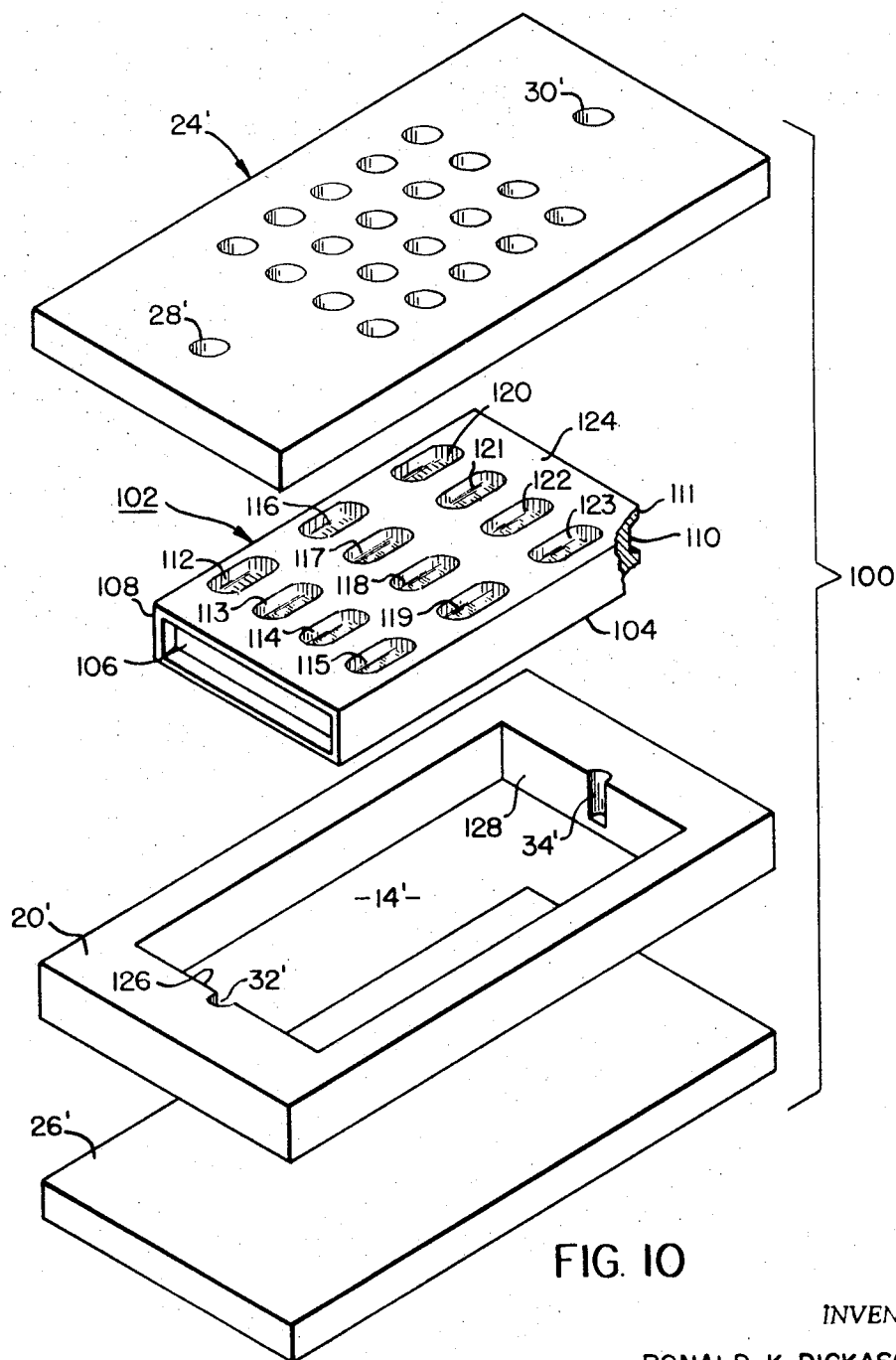


FIG. 9
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FIG. 11

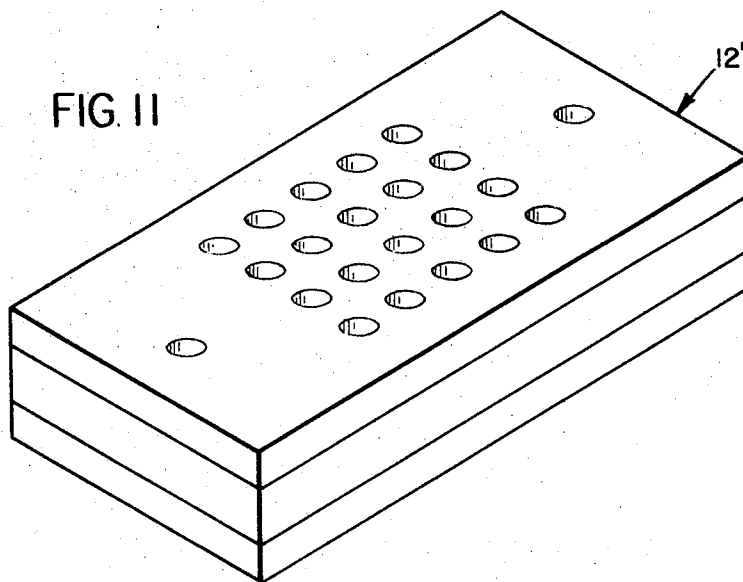


FIG. 12

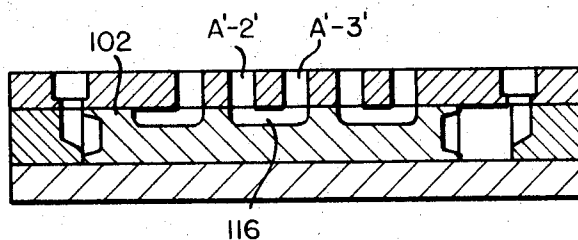
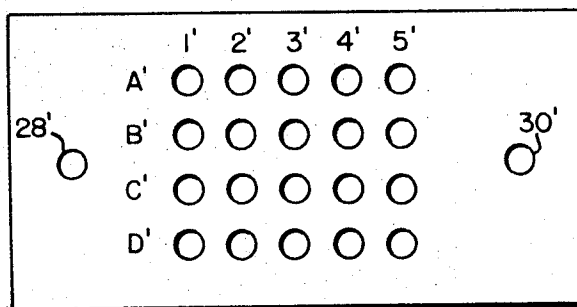


FIG. 13



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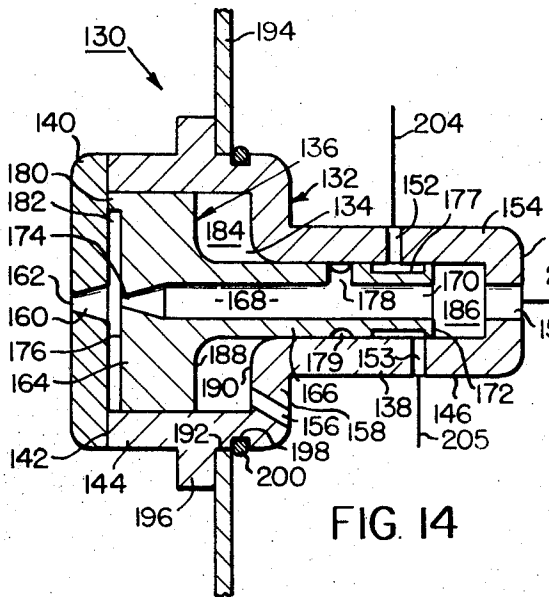


FIG. 14

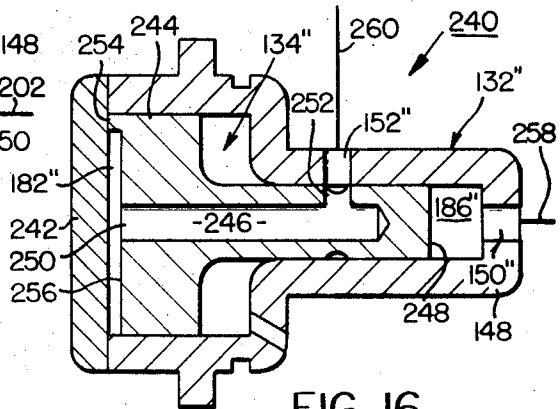


FIG. 16

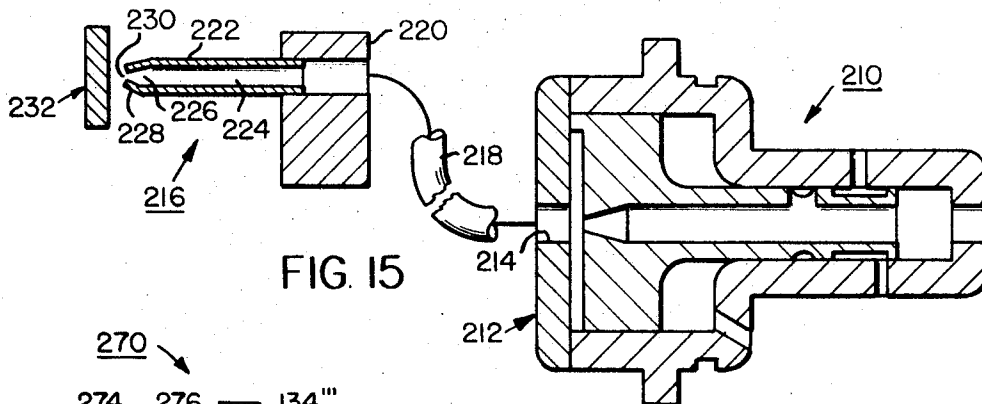


FIG. 15

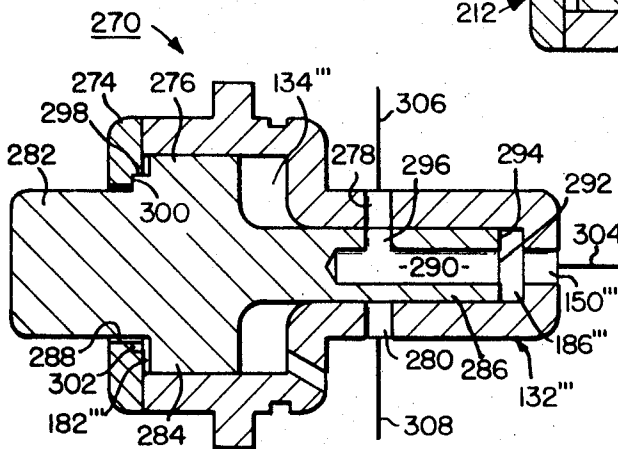


FIG. 17

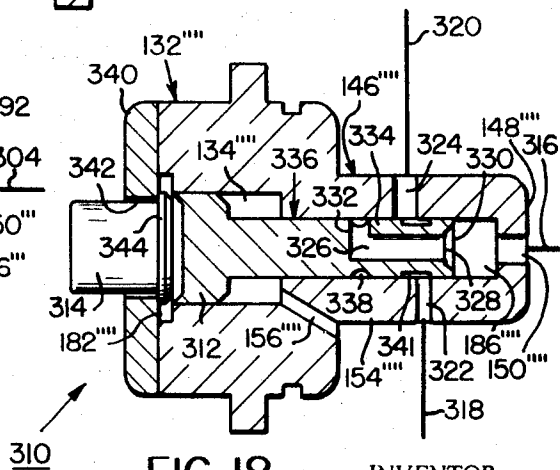


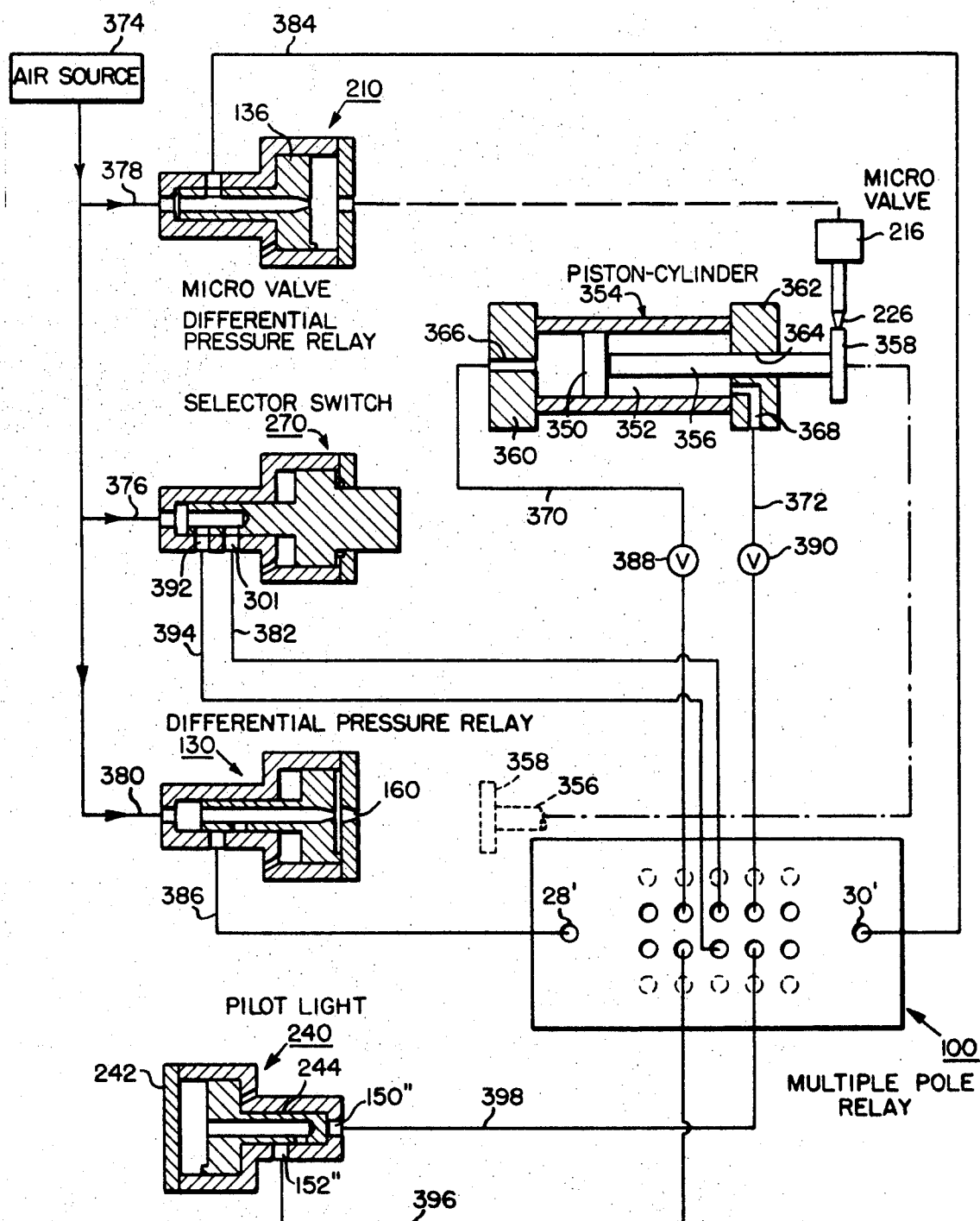
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FLUID LOGIC CONTROL SYSTEM

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a system of machine control and more particularly to a fluid logic control system.

2. Description of the Prior Art

Fluid type controls are known and are used in various applications in industry because they have various advantages over electrical and electronic controls. Some of the major advantages of fluid control systems are that they are: (1) less expensive to install; (2) less expensive to maintain; (3) more dependable (a particular component can average being 100 times more dependable than its electrical counterpart); (4) safer (there is no chance of electrical shock from a short-circuit); (5) simpler and easier to understand; and (6) they allow the use of pure circuits (pneumatic-hydraulic) throughout the entire system.

Two major approaches to fluid type controls have been taken. One approach is the use of pure fluidics and the second approach is the use of fluid logic control. The present invention relates to the realm of fluid logic control, however, it will be useful by way of background information to briefly mention the field of pure fluidics. Pure fluidics includes the use of devices such as fluid amplifiers using the Coanda effect (wall attachment) or laminar flow, as in turbulence amplifiers; such devices use very low fluid pressure ($\frac{1}{4}$ to 1 psig) and low flow. These devices are of the non-moving parts type and are very durable, however, they are difficult to manufacture and to use because, for example, they require very close tolerances and the components within a given system must be matched as to characteristics. Pure fluidics systems do not carry enough energy to directly control a system. They must be used with a transforming valve having moving parts, before use can be made of the signal in a pure fluidics control system. The dependability or durability of the pure fluidics system, therefore, is no better than that of the transforming valve.

The fluid logic control approach on the other hand, to which field the present invention relates, employs simple fluid logic elements, similar to control valves that have been available to the industry for years, with some special logic elements (AND, OR, NOT, NOR) added thereto. In most cases, the components in this type of system have only one moving part, and they are therefore very dependable. Such components are simple and easy to manufacture and to maintain and service.

SUMMARY OF THE PRESENT INVENTION

A fluid logic control system for controlling machine operations and including a plurality of components using self-sealing spools and interchangeable casings. The system includes; a logic gate capable of performing any one of the four logic functions: AND, OR, NOT, NOR; a multiple pole relay; differential pressure relays; a pilot light; a selector switch; and a push button relay.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and additional objects and advantages of the present invention will be more fully understood by reference to the following detailed description when read in conjunction with the attached drawings, wherein like reference numerals refer to like elements and wherein:

FIG. 1 is an exploded view of a logic gate of the present invention;

FIG. 2 is a perspective view of the logic gate of FIG. 1;

FIG. 3 is a vertical, cross-sectional side view through the logic gate of FIGS. 1 and 2;

FIGS. 4A, 4B, 4C, and 4D, are top plan views of the logic gate of FIGS. 1-3 with the cover off showing the spools 16 and 18 in each of their four possible combinations of positions;

FIG. 5 is a top plan view of the cover of the logic gate of FIGS. 1-4 showing the ports therein and providing an identification system for referring to the various ports;

FIGS. 6 through 9 are top plan views schematically showing the logic gate of FIGS. 1-5 hooked up to provide the AND, OR, NOT, NOR logic functions, respectively;

FIG. 10 is an exploded view of a multiple pole relay according to the present invention; and

FIGS. 11 and 12 are perspective and cross-sectional side views, respectively of the multiple pole relay of FIG. 10;

FIG. 13 is a top plan view of the cover of the relay of FIG. 10 providing an identification system for referring to the various ports therein;

FIG. 14 is a cross-sectional view through a differential pressure relay according to the present invention;

FIG. 15 is a cross-sectional view through a micro-valve differential pressure relay according to the present invention;

FIG. 16 is a cross-sectional view through a pilot light according to the present invention;

FIG. 17 is a cross-sectional view through a selector switch according to the present invention;

FIG. 18 is a cross-sectional view through a push button relay according to the present invention; and

FIG. 19 is a schematic, partly cross-sectional, circuit diagram of a fluid logic control system using various components of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

FLUID LOGIC GATE 10

The structure of the fluid logic gate 10 is fully described in detail below. It is believed that a preliminary outline of the highlights of its operation, using reference numerals developed below, will be helpful to the reader prior to his reference to the following detailed description of the structure. Referring to FIGS. 1-9, the logic gate 10 is to be connected in a fluid logic control circuit of a machine or system being controlled. Information as to the occurrence or not of a particular event is fed into the gate 10 by way of air lines 84, 86, 88, and 90. This information is translated, in the gate 10, into various positions of the two spools 16 and 18; the spools 16 and 18 can exist in any one of the four positions shown in FIGS. 4A, 4B, 4C, and 4D. Depending upon which logic function is to be performed by logic gate 10, an input supply line 92 and an output line 94 are connected to certain of the ports (A-1 to D-5) in cover 24. A signal is produced in output line 94 if continuity (fluid communication) exists from input 92, through grooves 48 and/or 50 in spools 16 and 18, to the output line 94. And such continuity will only exist if the spools are forced into predetermined locations in gate 10 by and in response to the occurrence of predetermined events in the operation of the machine. When such events occur, gate 10 produces a signal and this signal can be used to effect some additional control of the operation of the machine being controlled.

The present invention is in a fluid logic control system which system is capable of using any of a great variety of fluids such as air, nitrogen, and many liquids. Since it is presently preferred that air be used, the following detailed description will specify air as the operating fluid, but it is to be understood that the present invention is in no way limited to use with air. The air control pressure used can be from 10 to 100 psig. and is preferably 20 psig.

Referring now in detail to the drawings, FIGS. 1 through 9 illustrate a fluid logic gate 10, constructed according to the present invention, and comprising a casing 12 having a central cavity or chamber 14 in which are positioned a pair of separate, unconnected movable spools 16 and 18. The term "unconnected" is hereby defined to mean that the spools are not connected together by means of a spring positioned therebetween. Referring to the exploded view in FIG. 1, the casing 12 comprises a block 20 having a central opening 22 therein, a cover 24, and a bottom plate 26. The bottom plate 26 is completely imperforate, while the cover 24 is manufac-

tured with 22 holes or ports therein. In manufacture, the spools 16 and 18 are placed in chamber 14 and the cover 24 and bottom plate 26 are then permanently sealed to the block 20 (as by gluing).

In order to identify a particular port in cover 24, reference is made to FIG. 5 showing a top plan view of cover 24. Twenty of the ports are arranged in a regular (as contrasted to an irregular or haphazard) rectangular array of four rows (A-D) and five columns (1-5). Any port can thus be identified by a reference consisting of one letter A-D followed by one numeral 1-5. In addition to these 20 ports are two end ports 28 and 30. All of the 20 ports A-1 through D-5, plus ports 28 and 30, are open to the chamber 14. The block 20 includes a pair of end passageways 32 and 34 semi-circular in horizontal cross section, which extend downwardly from top surface 35 of block 20 only part-way through the thickness of block 20. One side of each passageway 32 and 34 is open to chamber 14. The passageways 32 and 34 are aligned with ports 28 and 30 in cover 24.

The same casing 12 is used in another embodiment of the invention (see FIGS. 10-13). Certain of the ports are used in this embodiment and certain are used in the embodiment of FIGS. 10-13. Further, in this embodiment, different sets of the ports A-1 to D-5 are used depending upon which logic function is to be performed. It is desirable to manufacture the cover 24 with all 22 of the ports; those ports that are not being used in any particular operation (those shown in dotted lines in the drawings) may be plugged up or simply left open, unless they are so positioned that operating fluid could leak out. It is to be understood that it is also possible to only drill (or otherwise provide) those ports that are to be used for the particular operation. When the non-used ports are plugged, this can be done by, for example, gluing in plugs (not shown) similar to pins 68 and 70, but without the conical end thereof, so that the plugs do not interfere with the movement of the spools.

The two spools 16 and 18 are identical and comprise L-shaped members having main rectangular portions 36 and 38 respectively, and right-angled arm extensions 40 and 42, respectively integral with main portions 36 and 38 and adjacent the outer ends 44 and 46 respectively of the spools 16 and 18. Each of the spools 16 and 18 is provided with a single, transverse, elongated groove 48 and 50 respectively, in its upper surface 52 and 54 respectively. Each of the grooves 48 and 50 has a width substantially equal to the diameter of the ports A-1 to D-5 and has a length substantially equal to (1) the center-to-center distance separating two adjacent ports in a column plus (2) the diameter of a port. The ports can be spaced apart in the rows the same distance as they are in the columns, although this is not necessary.

Each of the top edges 55 and 57 of the inner ends 56 and 58 respectively of spools 16 and 18, respectively, are beveled, preferably at a 45° angle, as shown in FIGS. 1 and 3. The inside top edges 60 and 62 of the arm extensions 40 and 42 respectively, are similarly beveled for receiving stop pins 68 and 70 as described more fully hereinafter. Each of the outer ends 44 and 46 includes a groove 64 and 66 respectively. The grooves 64 and 66 communicate with passageways 32 and 34, respectively, so that when air is introduced through the passageway 32, for example, the air will fill the groove 64 to allow the air pressure to act over a relatively large area. This provides for a fast, positive response or movement of the spool 16 upon introducing air pressure into the chamber 14 through port 28.

With the spools 16 and 18 positioned in the chamber 14 with the orientation shown in FIG. 1, the cover 24 and bottom plate 26 are permanently sealed to block 20. A pair of stop pins 68 and 70 (see FIG. 3) are permanently positioned in ports C-1 and B-5 respectively. Each pin includes an enlarged head 72 and 74 respectively, and a tapered or conical end 76 and 78 respectively; the taper is preferably at 45°. As shown in FIG. 3, the pins 68 and 70 operate to limit the inward extent of travel of the spools 16 and 18. For example, spool 16 can travel from its outermost position adjacent end 80 (FIG. 4A)

of chamber 14, to its innermost position shown in FIGS. 3 and 4A, wherein pin 68 abuts beveled edge 60 and pin 70 simultaneously abuts beveled edge 55 of spool 16. Similarly, spool 18 can travel from its outermost position adjacent end 82 (FIG. 4A) of chamber 14 to its innermost position shown in FIG. 3, wherein pin 68 abuts beveled edge 57 and pin 70 abuts beveled edge 62 of spool 18.

Spool 16 is forced to move inwardly when air pressure is introduced into chamber 14 through line 84, port 28, passageway 32 and groove 64. Similarly, spool 18 is forced to move inwardly by air pressure introduced into chamber 14 through line 86, port 30, passageway 34 and groove 66. Both spools 16 and 18 are forced to move outwardly at the same time by air pressure introduced into chamber 14 through either port D-1 and line 88 or port A-5 and line 90.

Referring now to FIG. 4, the spools 16 and 18 are two-position spools; they each occupy one of two positions. FIG. 4A shows both spools 16 and 18 in their innermost position; FIG. 4B shows both spools 16 and 18 in the outermost position; FIG. 4C shows spool 18 in its innermost position and spool 16 in its outermost position; and FIG. 4D shows spool 18 in its outermost position and spool 16 in its innermost position.

When spool 16 is in its outermost position, the groove 48 is in register with, and provides fluid communication between, ports A-2 and B-2. When spool 16 is in its innermost position, the groove 48 is in register with and provides fluid communication between, the two ports A-3 and B-3. Similarly, when spool 18 is in its outermost position, groove 50 is in register with and provides fluid communication between the two ports C-4 and D-4. When spool 18 is in its innermost position, groove 50 is in register with, and provides fluid communication between, ports C-3 and D-3.

The logic gate 10 can be hooked up in such a way as to perform any one of the four logic functions, AND, OR, NOT, NOR. In each case the ports A-1, B-1, C-2, D-2, A-4, B-4, C-5, and D-5 are plugged up (these ports are shown by dotted lines in the drawings). Ports C-1 and B-5 are plugged with stop pins 68 and 70 respectively. Further, depending on which of the four logic functions a particular gate 10 is to perform, additional ones of the ports may also be plugged, as will be pointed out below, with respect to each such logic function. Those ports that are not involved in the operation of the gate 10 when used for a particular purpose can either be left open or can be plugged. In some instances, certain ports should be plugged to prevent leakage of the operating fluid therefrom.

Throughout the following discussion there will be four different air pressure inputs capable of moving one or more of the spools 16 and 18. These inputs are connected to the gate 10 through input lines 84, 86, 88 and 90, connected to ports 28, 30, D-1, and A-5, respectively. Also, there will be an input line 92 supplying air pressure for the output response signal, which output signal will be transmitted through output line 94. In essence, the gate 10 will be hooked up in a fluid logic control circuit as an integral part thereof and will be receiving information from other components of the control circuit as to the functioning of the machine or system being controlled, the information being introduced as air pressure via inputs 84, 86, 88 and 90. Depending upon how the gate 10 is hooked up, as a set of events occur, the information fed into the gate 10 will be reflected by the position of the spools 16 and 18. An output signal may or may not be produced at line 94. When an output signal is generated, it can be used to provide some portion of the overall control of the machine or system, as will be understood by those skilled in the art.

AND

The AND logic function of gate 10 will now be described with reference to FIG. 6. In this use of gate 10, the following ports may be closed or plugged up (these are in addition to those specified above): A-2, B-2, C-4, and D-4. A jumper line 96 (an air pressure conduit similar to lines 84, 86, 88 and 90, for example), is connected between ports B-3 and C-3 to

provide fluid communication therebetween. A slight bias pressure (about 10 psig, enough to move the spools 16 and 18) is provided at lines 88 and/or 90. It is noted that, alternatively, the circuit can call for the use of a larger than bias pressure at 88 and/or 90. Now, given air inputs in lines 84 and 86 (we will assume throughout this discussion that an input is provided at line 92, of course), continuity through the gate 10 will be provided from input 92 to output 94, thus providing an output signal. An AND logic device produces an output signal only upon the simultaneous occurrence of two inputs (84 and 86). What occurs inside of gate 10 is that both spools 16 and 18 are forced to move inwardly due to the air pressure introduced at 84 and 86; this results in groove 48 connecting ports A-3, and B-3, and groove 50 connecting ports C-3 and D-3, thus providing fluid continuity between input 92 and output 94. It is to be understood that the above arrangement of gate 10 to provide the AND logic function is not the only manner in which the gate 10 can be used to provide the AND function.

OR

The OR logic function of gate 10 will now be described with reference to FIG. 7. In this use of gate 10, the following ports may be closed or plugged up (in addition to those specified above regarding the generic use of cover 24 for a logic gate 10): A-2, B-2, C-4, and D-4 (it is noted that these are the same ports closed to provide the AND logic function). The input line 92 is connected to the two ports B-3 and C-3, while the output 94 is connected to the two ports A-3 and D-3. A bias pressure is applied at lines 88 and/or 90 as described above. Now, given an input at either 84 or 86, continuity through the gate 10 will be provided from input 92 to output 94, thus providing an output signal. An OR logic device produces an output response upon the occurrence of any one of several inputs. Thus, the introduction of air pressure into gate 10 through either input 84 or 86 will move either of the spools 16 and 18 respectively to its innermost position thus providing fluid communication, via one of grooves 48 and 50, respectively, between the input 92 and output 94.

NOT

The NOT logic function of gate 10 will now be described with reference to FIG. 8. In this use of gate 10, the following ports may be closed or plugged up (in addition to those specified above that are plugged up in cover 24, when cover 24 is used in a logic gate): A-3, B-3, C-3, and D-3. A jumper line 98 is connected between ports B-2 and C-4 to provide fluid communication therebetween. A slight bias pressure (about 10 psig, enough to move the spools 16 and 18) is provided at lines 88 and/or 90. Now, given no input at either 84 or 86, continuity through the gate 10 will be provided from input 92 to output 94, thus providing an output signal.

A NOT logic device produces an output response only when there are no inputs (84 or 86). What occurs inside of gate 10 given no inputs at 84 or 86 is that both spools 16 and 18 are forced to move to their outermost positions due to the slight bias pressure provided at inputs 88 and/or 90. This results in groove 48 providing fluid communication between ports A-2 and B-2 and groove 50 providing fluid communication between ports C-4 and D-4, thus providing continuity from input line 92 through jumper line 98 to output line 94.

NOR

The NOR logic function of gate 10 will now be described with reference to FIG. 9. In this application of gate 10, the same ports may be plugged up as were plugged up in the NOT application described immediately above. There are no jumper lines in the NOR application of gate 10, however, the input line 92 is connected to the two ports B-2 and C-4, and the output line 94 is connected to the two ports A-2 and D-4. As in the NOT application described above, a slight bias air pressure is provided at lines 88 and 90. An output signal is obtained at output line 94 if there is no input signal at either one

of lines 84 or 86. Thus, with no input at 84 (and regardless of whether there is an input at 86), spool 16 would be at its outermost position providing fluid communication between ports A-2 and B-2, and this occurrence would produce an output signal 94 through groove 48. Similarly, no input at 86 would also provide an output signal in output line 94 by providing fluid communication between ports C-4 and D-4. If either one of these events occur, i.e. no input at 84 and no input at 86, an output signal will be produced at output line 94.

In the above discussion, it is noted that preferably a bias of about 10 psig is employed at lines 88 and 90 along with an operating pressure of about 20 psig at lines 84 and 86, so that the spools 16 and 18 automatically will resume a predetermined normal position when an input is released i.e. vented to atmosphere). It will be understood, of course, that the logic gate 10 can be used for only one of the above four logic functions at any one time. The bottom plate 26 can have the same ports as does cover plate 24 and the spools 16 and 18 can have grooves on their bottom faces so that one gate 10 can be used for two different logic functions from the same inputs, if desired.

The block 20, cover 24 and the two bottom plates 26 are preferably injection molded of a plastic material such as "Delrin," a trademark of duPont for a thermoplastic acetal resin material that is a polymerized formaldehyde derivative. The spools 16 and 18 are preferably molded of "Gylon," a trademark of Garlock, Inc. for a fibrous filled fluorocarbon plastic. The spools 16 and 18 are preferably self-sealing and self-lubricating in the chamber 14. Other materials can be used as will be discussed more fully below.

MULTIPLE POLE RELAY 100

FIGS. 10-13 show a multiple pole relay 100 of the present invention. Since the relay 100 employs the same casing 12' as does the logic gate 10 of FIGS. 1-9, the same reference numerals used to describe the casing 12 of gate 10 will be used here, but with a prime, for simplicity of description.

The relay 100 comprises a casing 12', which can be identical to casing 12 of the logic gate 10, except that ports C'-1' and B'-5' are not plugged with pins 68 and 70. The relay 100, however, does not employ the two spools 16 and 18 of the logic gate 10 but rather employs a single spool 102. The spool 102 comprises a rectangular block 104 provided with a groove 106 in one end 108 and a groove 110 in the other end 111 of spool 102. Grooves 106 and 110 communicate with passageways 32' and 34' and serve to allow the operating fluid (such as air) to spread over a relatively large area of the end wall of the spool for the same reasons described above with respect to grooves 64 and 66 of spools 16 and 18 in FIG. 1. Spool 102 has twelve elongated, longitudinal grooves 112-123 positioned in the top surface 124 of spool 102 and arranged in a rectangular array containing four rows and three columns. Each of the four rows of grooves is in register with one of the four rows of ports (A'-1' to D'-5') in the cover 24'. Each of the grooves has a width substantially equal to the diameter of any of the ports A'-1' to D'-5' and a length substantially equal to (1) the center-to-center distance separating two adjacent ports in a row, plus (2) the diameter of a port. The ports A'-1' to D'-5' are equally spaced in each row and the ports are also equally spaced in each column. The spacing in the rows is preferably identical to the spacing in the columns, however, this is not essential.

The grooves 112-123 provide fluid communication between different ones of the ports, as will be described below, depending upon the position the spool 102 occupies in the chamber 14'.

The spool 102 moves back and forth in the chamber 14' and always occupies one of the two possible end positions therein, i.e. the spool 102 is either in contact with an end wall 126 or with an end wall 128 of the chamber 14'. FIG. 12 is a cross-sectional side view through the relay 100 showing the spool

102 in a first position abutting end wall 126. In this position, groove 116, for example, provides fluid communication between ports A'-2' and A'-3'. When the spool 102 is caused to move to its second position abutting end wall 128, groove 116 will provide fluid communication between ports A'-3' and A'-4'.

The spool 102 is caused to move by air pressure exerted through feed lines (not shown) connected to ports 28' and 30'. Various information concerning the operation of the machine being controlled is then available by properly hooking up fluid lines to the ports A'-1' to D'-5'. All or part of the ports can be used; the unused ports can be plugged (temporarily or permanently).

The spool 102 has a thickness and a width slightly greater than the corresponding dimensions of the chamber 14' such that spool 102 is self-sealing in the chamber 14'.

An example of how relay 100 can be hooked up in a fluid logic control circuit with other embodiments of the present invention, to control the operation of a machine, will be described below with respect to FIG. 19.

DIFFERENTIAL PRESSURE RELAY 130

FIG. 14 shows a differential pressure relay 130 embodiment of the present invention. The purpose of the differential pressure relay 130 is to provide fluid communication between two lines (202 and 204) when a certain condition occurs in the operation of the machine being controlled and to not provide fluid communication between lines 202 and 204 when such condition does not exist. This embodiment of the invention mechanically senses when some portion of the machine occupies a particular position; in this embodiment of FIG. 14 the position is that immediately adjacent the relay itself. The relay 210 of FIG. 15 is similar to relay 130 of FIG. 14; the difference being that relay 210 of FIG. 15 can sense said position at a point remote from the relay itself.

There are various ways in which the relay 130 can be arranged in a fluid logic control circuit to provide some measure of the overall control of the machine being controlled. One possible way is shown in the schematic circuit of FIG. 19.

Referring now in detail to the differential pressure relay 130 of FIG. 14, the relay 130 comprises a casing 132 having a chamber 134 and a spool 136 positioned within the chamber 134 for sliding movement therein between an upper and a lower location in chamber 134. The casing 132 comprises a hollow cylindrical body 138 and a cap 140 sealed to a large open end 142 of the body 138.

The body 138 is T-shaped in cross section, and comprises a larger cylindrical portion 144 and a smaller cylindrical portion 146 concentric with the larger portion 144. For convenience of reference the casing 132 will be referred to hereinafter in the specification and claims as though it stood upright like a "T," the top of the "T" being the top of the casing and the bottom of the leg portion of the "T" being referred to as the bottom of the casing 132 or the bottom of the relay 130. The bottom 148 of the casing 132, i.e., the smaller end of the body 138, is closed except for an axial opening 150 in fluid communication with chamber 134. The body 138 is provided with a pressure port 152 through a sidewall 154 of the smaller portion 146 and a vent port 153 through sidewall 154 offset from port 152 toward the bottom 148 such that port 153 cannot be in fluid communication with a passageway 178 of spool 136. The body 138 is also provided with a vent port 156 through a disc-shaped wall 158 connecting the larger cylindrical portion 144 with the smaller cylindrical portion 146 of the body 138.

The cap 140 is provided with an axially disposed port 160, which port 160 tapers from a larger opening inside the relay 130 to a smaller opening 162 on the outside surface of cap 140.

The spool 136 is dimensioned to slidably fit within the chamber 134 in sealing relationship with the walls defining chamber 134. The spool 136 is also T-shaped in cross section and comprises a head portion 164 and a leg portion 166. The

spool 136 is provided with an axial passageway 168 extending through the entire length thereof from an opening 170 in the bottom surface 172 of the leg portion 166 to an opening 174 in the top surface 176 of the head portion 164. The axial passageway 168 converges or tapers down to a smaller diameter adjacent opening 174. The spool 136 also includes a radial passageway 178, extending radially through one side of the leg portion 166 and is positioned so as to be in register with port 152 when the spool 136 is in its lowermost position in chamber 134, i.e., when the spool 136 is adjacent the bottom 148 of the casing 132. The spool also includes a circumferential groove 179 communicating with the passageway 178 to ensure communication between passageway 178 and port 152 regardless of the angular orientation of the spool 136. An upwardly extending spacer lug 180 is connected to top surface 176 and extends between the top surface 176 and the cap 140 to prevent top surface 176 from coming into contact with cap 140, to provide a chamber 182 in which the actuating fluid (air) can act against top surface 176 to force the spool 136 from its upper location (shown in FIG. 14) to its lower location, when opening 162 is blocked. In the lower location of the spool 136 in the chamber 134, the bottom surface 172 of the leg portion 166 of the spool 136 is spaced from the bottom 148 of casing 132 (see spool 136 in FIG. 19). This provides a chamber or air space in which the air pressure can act against the entire bottom surface of the spool to force the spool to its upper location in the chamber when the port 160 is open. The spool 136 also includes a relatively shallow and wide, circumferential groove 177 to provide fluid communication between ports 152 and vent port 153 when the spool 136 is in the position shown in FIG. 14. When spool 136 is in the bottom of the chamber 134, the vent port 153 dead heads against the outside surface of the spool 136 at a location below the groove 179.

The existence of the spool 136 in the chamber 134 effectively separates the entire chamber 134 into three separate volumes or chambers 182, 184 and 186. Chamber 182 was described above. Chamber 184 is positioned between a bottom surface 188 of head portion 164 of the spool 136, and an upper surface 190 of the wall 158. Chamber 184 communicates with atmosphere through vent port 156. Chamber 186 is positioned between the bottom 170 of spool 136 and the bottom end 148 of the casing 132. Chamber 182 is in fluid communication with chamber 186 via passageway 168. Chambers 182 and 186 are in communication with port 152 when the spool 136 is in its lowermost position in chamber 134.

The head portion 144 of the casing 132 includes means for mounting the relay 130 in an opening 192 in a panel 194, for example. The mounting means comprises a radial flange 196 and an annular groove 198 for receiving a locking spring 200, such as a bowed E-ring.

A fluid pressure line 202 (schematically shown) is connected to port 150 and a fluid pressure line 204 (schematically shown) is connected to port 152. A vent line 205 (schematically shown) is connected to vent port 153.

The operation of the differential pressure relay 130 is as follows: The relay 130 provides fluid communication between lines 202 and 204 when port 160 is closed. When the port 160 is open, lines 202 and 204 are not in fluid communication, although line 204 is in communication with vent line 205. Referring to FIG. 14, air from line 202 enters the relay through port 150, fills chamber 186, flows through passageway 168, enters chamber 182 and exits through opening 160. The flow is balanced by means of the tapering port 160 and the taper in passageway 168 to opening 174, such that the pressure in chamber 186 is greater than that in chamber 182, whereby spool 136 is forced to its uppermost position (shown in FIG. 4). Now consider the case when port 160 is closed; closing of port 160 can be accomplished, for example, by covering hole 162 with, for example, some movable element of the machine being controlled. When port 160 is closed the air pressure in chamber 182 builds up until the force of the air pressure in chamber 182 is greater than that in chamber 186 and spool 136 is forced to its lowermost position

in chamber 134, placing passageway 178 in register with port 152. Air from line 202 now flows out through line 204. When port 160 becomes unblocked, spool 136 will move back to its uppermost position, interrupting the air flow into line 204. Since chamber 184 is vented to atmosphere, the pressure therein remains substantially constant. FIG. 19 illustrates one way in which relay 130 can be connected in a fluid logic control circuit.

Because the following four embodiments of the present invention employ a casing similar to casing 132 of the relay 130 described above, the same reference numerals (with a first prime, second prime, etc. for each subsequent embodiment) will be used where possible, for ease of description and understanding.

MICRO-VALVE DIFFERENTIAL PRESSURE RELAY 210

FIG. 15 shows a micro-valve differential pressure relay 210 which is a modification of the differential pressure relay 130 of FIG. 14 providing for the remote positioning of the port 160. Relay 210 employs a cap 212 provided with a cylindrical port 214 rather than an outwardly converging port. A micro-valve 216 is connected to port 214 by a fluid pressure line 218. Micro-valve 216 comprises a main body 220 and a tube 222 and has a passageway 224 therethrough, converging at port 226 in tip 228 to a small opening 230. This relay 210 has the added flexibility over relay 130 of FIG. 14 in the ease and simplicity with which the control port 226 can be positioned in the desired location. The operation of relay 210 is identical to that of relay 130. FIG. 19 illustrates one way in which relay 210 can be used.

PILOT LIGHT 240

FIG. 16 shows a pilot light 240 embodiment of the present invention which employs a casing 132'' similar to that of the relay 130 of FIG. 14, however the pilot light 240 employs a different cap 242 and a different spool 244. The cap 242 is solid and is transparent. The spool 244 is identical to spool 136 except for the design of the passageway 246. Passageway 246 terminates short of the bottom end 248 of spool 244 such that passageway 246 is not in fluid communication with chamber 186''. At the other end of the spool 244, passageway 246 terminates in an opening 250 of the same diameter as the passageway 246; in this embodiment, there is no need for a converging port. Spool 244 is provided with a radial aperture 252 in fluid communication with the passageway 246. Radial passageway 252 is in register with the port 152'' when spool 244 is in its uppermost position (shown in FIG. 16).

When spool 244 is adjacent the transparent cap 242, the spool 244 is easily visible to the eye. The surface 256 of spool 244 can be painted an easily visible color, such as red or black, such that the location of the spool 244 adjacent the cap 242 will be readily apparent. When the spool 244 is in its lowermost position in chamber 134'' this fact will also make itself readily known by merely glancing at the window or cap 242.

The operation of the pilot light 240 is as follows: When air pressure is exerted through a line 258 connected to port 150'' spool 244 is forced to its uppermost position (shown in FIG. 16). When fluid pressure is exerted through line 260, the force within chamber 182'' and within passageway 246 is greater than that in chamber 186'' and the spool 244 is forced to its lowermost position adjacent end 148'' of the casing 132''.

SELECTOR SWITCH 270

FIG. 17 shows a selector switch 270 embodiment of the present invention. The purpose of the selector switch 270 is to allow an operator, by manually turning a knob 282, to select which, if any, of the air lines 306 and 308 is to be put in fluid communication with an air input line 304. The selector switch 270 employs a casing 132''' similar to casing 132 of the differential pressure relay 130 of FIG. 14 except that the casing 132''' employs a different cap 274, holds a different spool 276, and includes a plurality of circumferentially spaced-apart radial apertures 278 and 280.

The spool 276 comprises a knob 282, a head portion 284 and a leg portion 286. Knob 282 extends through an opening 288 in cap 274. Opening 288 is larger than the outside diameter of knob 282, thus venting chamber 182''' to atmosphere. The spool 276 has an axial passageway 290 extending part-way through the spool from an opening 292 in the bottom end 294 of the spool 276, and a radial passageway 296 in communication with axial passageway 290. Radial passageway 296 is axially located so as to be in register with one of the ports 278 and 280 when the spool 276 is in its uppermost position in chamber 134'''. The head 284 of the spool 276 is provided with a key 298 which fits in one of the two circumferentially spaced-apart slots 300 and 302; key 298 and slots 300 and 302 position passageway 296 in register with ports 278 and 280 respectively.

Air input line 304 is connected to port 150''' and air output lines 306 and 308 are connected to ports 278 and 280, respectively. Knob 282 can be manually grasped and by pushing in and then turning, the desired one of lines 306 and 308 can be placed in fluid communication with line 304. Since a certain amount of pressure is exerted in an upward direction (toward knob 282) by the air within the passageway 290 and in chamber 186''', some downward (inward) force must be exerted on the knob 282 to unseat the key 298 from its slot 300 or 302 before turning the spool 276 to the desired orientation. Indicia can be provided on the outside of the knob 282 and the cap 274, corresponding to the various ports 278 and 280.

More than two ports can be circumferentially spaced around the casing, if desired, and additional slots can be provided in cap 274 to properly orient the spool. Further, it may be desired to provide a slot to orient the passageway 290 against a solid wall such that line 304 is closed.

It is to be understood that the switch 270 can also contain a second (and third, etc.) series of ports and a passageway, axially spaced from the series of ports and a passageway shown in the drawings, to perform a plurality of switching functions at the same time. Such a structure is shown in FIG. 19 which also shows one way of connecting the selector switch 270 of the present invention in a fluid logic control system.

PUSH BUTTON RELAY 310

FIG. 18 shows a push button relay 310 embodiment of the present invention. Push button relay 310 comprises a casing 132'''' having a chamber 134''''', a spool 312 positioned in the chamber 134'''' and a push button 314. The push button relay 310 is connected to two fluid pressure lines 316 and 320 and to a vent line 318. When the spool 312 is in the position shown in FIG. 18, fluid communication is established between pressure line 320 and vent line 318. By pushing in on push button 314, such communication is interrupted and communication is provided instead between pressure lines 316 and 320.

Referring now in detail to the structure of the push button relay 310, the casing 132'''' includes a vent port 156''''', an axial port 150'''' in the bottom end 148'''' of the casing 132''''', and a pair of axially spaced-apart radial ports 322 and 324 extending through the sidewall 154'''' of the leg portion 146'''' of casing 132'''''. The spool 312 sealingly fits within the chamber 134'''' and is adapted to move back and forth therein. The spool 312 has an axial passageway 326 extending part way therethrough from a countersunk opening 328 in the bottom end 330 thereof. The passageway 326 is in fluid communication with a radial passageway 332 extending entirely through one sidewall 334 of the leg portion 336 of spool 312. The spool 312 is provided with a circumferential groove 338 in communication with passageway 332. The purpose of the groove 338 is to ensure communication between lines 316 and 320, when the spool 312 is in its lower position, regardless of the angular orientation of the spool 312. The passageway 332 is located such that it is in register with port 324 when the spool 312 is in its lowermost position within chamber 134'''' (i.e. when spool 312 is adjacent end 148'''''). Passageway 332 is never in communication with port 322.

Spool 312 is also provided with a relatively wide, relatively shallow, circumferential groove 341, wide enough to provide fluid communication between ports 322 and 324, when the spool 312 is in the position shown in FIG. 18.

The casing 132'''' includes a cap 340 having a central opening 342 therein to accommodate the push button 314. The push button is retained with the casing 132'''' by means of a retaining flange 344. The opening 342 is larger than the outside diameter of the push button 314 to provide a vent for chamber 182''''.

The push button 314 is adapted to slide axially through opening 342 such that when pushed in, it in turn pushes the spool 312 down to its lowermost position in chamber 134''''.

In operation, fluid pressure introduced through line 316 into chamber 186'''' will force the spool 312 up to its uppermost position (shown in FIG. 18), in which position line 320 is in fluid communication with vent line 318 via groove 341. Communication between lines 320 and 318 is interrupted by manually pushing in push button 314 causing spool 312 to occupy its lowermost position providing fluid communication between lines 320 and 316.

FLUID LOGIC CIRCUIT

FIG. 19 shows a fluid logic control circuit using five of the above-described embodiments of the present invention, illustrating one example of how such embodiments can be combined to control a machine operation. The machine operation in FIG. 19 is the reciprocating movement of a piston 350 inside of chamber 352 of cylinder 354. The piston 350 is connected through a piston rod 356 to a body 358 mounted on the opposite end of the rod 356. The ends of the chamber 352 are defined by first and second end plates 360 and 362. The piston rod 356 is supported for sliding movement through a cylindrical passageway 364 in end plate 362. Each of the end plates 360 and 362 is provided with a fluid passageway 366 and 368 respectively, connected to fluid lines 370 and 372, which lines are adapted to introduce air into the chamber 352, on one side or the other of piston 350. The fluid control circuit of FIG. 19 controls the reciprocating motion of the piston 350 by alternately introducing air into chamber 352 through lines 370 and 372.

The circuit includes an air pressure source 374, a multiple pole relay 100 (see FIGS. 10-13), a selector switch 270 (see FIG. 17), a pilot light 240 (see FIG. 16), a differential pressure relay 130 (see FIG. 14) and a micro-valve differential pressure relay 210 (see FIG. 15). The relays 210 and 130 are positioned to contact the body 358 at the left and right end points, respectively, of the travel of body 358, at which points body 358 closes ports 226 and 160, respectively.

The air pressure source 374 is connected directly to the inlet port of each of the selector switch 270 and the differential pressure relays 210 and 130 via lines 376, 378 and 380 respectively. In turn, the output lines 382, 384, and 386 respectively, from the switch 270 and the relays 210 and 130 are connected to the multiple pole relay 100, at ports B-3, 30' and 28' respectively.

The output lines 384 and 386 from the differential pressure relays 210 and 130 respectively, control the position of the spool 102 (see FIG. 10) within the multiple pole relay 100, by virtue of being connected to ports 30' and 28' respectively.

The output line 382 from the selector switch feeds air to one of the two passageways 366 and 368 of the cylinder 354, via the multiple pole relay 100. The manner in which the air flow is controlled to alternately feed air to the passageways 366 and 368 from line 382 (carrying air pressure from the source 374) is as follows: Output line 382 is connected to port B-3 of relay 100 and the feed lines 370 and 372 (to the cylinder 354) are connected to the ports B-2 and B-4 respectively.

In the position of the piston 350 shown in FIG. 19, the body 358 has been moving to the left and has just reached and closed the port 226 of the micro-valve 216, and has just forced spool 136 of relay 210 to its lower location, thus establishing

fluid communication between lines 378 and 384. Air pressure from line 384 enters port 30' of relay 100 forcing the spool 102 (not shown - see FIG. 12) to its leftmost location as viewed in FIG. 19. When spool 102 (not shown) reaches its leftmost location in relay 100, fluid communication will be established between ports B'-3' and B'-2'. Air pressure will then flow from source 374 through switch 270, through relay 100, through line 370, into passageway 366 and into chamber 352 forcing the piston 350 back to the right. At the same time, ports B'-4' and B'-5' are in fluid communication whereby the air in chamber 352 to the right of piston 350 is vented to atmosphere.

When body 358 reaches relay 130, relay 130 causes the spool 102 of relay 100 to move to the right, resulting in air pressure being introduced into chamber 352 through line 372 and passageway 368 in a similar manner to that described above. Also, the air in chamber 352 to the left of piston 350 is now vented to atmosphere through port B'-1' in relay 100.

In this way, the reciprocating motion of the piston 350 is controlled and maintained. Flow control valves 388 and 390 can be provided in lines 370 and 372, respectively, to control the speed of air flow to the cylinder 354 and thus the speed of reciprocation.

In order to indicate to an operator, what the position of the piston 350 is at any time, a pilot light 240 can be used as follows. The selector switch 270 is provided with a second outlet port 392, axially spaced from port 301. A line 394 is then connected between port 392 of switch 270 and port C-3 of relay 100. Port 152'' of pilot light 240 is connected to port C-2 of relay 100 via line 396. Port 150'' of pilot light 240 is connected to port C-4 of relay 100 via line 398. When the body 358 reaches the position shown, the relay 210 forces spool 102 to the left to provide fluid communication between lines 394 and 396 to force the spool 244 of the pilot light 240 from its upper to its lower location (FIG. 19 shows spool 244 after it has just moved to the lower location). At this time, air below spool 244 vents to atmosphere through port C'-5' in relay 100. When the piston 350 reaches the right side of cylinder 354 as viewed in FIG. 19, spool 244 will be forced to its upper location, indicating through the transparent cap 242 the position of the piston 350. At this time air above spool 244 vents to atmosphere through port C'-1' of relay 100.

The various air lines in all of the above embodiments are conveniently plastic tubing, such as vinyl plastic. The tubing can be connected to the ports of the various components by any known means, such as by brass fittings which are screwed into the ports. Other fluids than air can be used, such as nitrogen and various liquids, for example. The casings are preferably injection molded of a plastic material such as "Delrin," a trademark of duPont and the spools are preferably "Gylon" a trademark of Garlock, Inc. for a fibrous filled fluorocarbon plastic. In all of the embodiments described above, the various spools are preferably made of a resilient material and are of a diameter (or of a width and thickness) slightly larger than the inside diameter of the chamber such that the spool is self-sealing in the chamber. Also it is preferred to use a plastic material of the type that is self-lubricating; such materials are well known. Other materials, such as metal, can be used with appropriate sealing means.

The invention has been described in detail with particular reference to preferred embodiments thereof, but it will be understood that variations and modifications can be effected within the spirit and scope of the invention as described hereinabove.

I claim

1. A fluid logic gate comprising:

- a casing having a chamber therein, said chamber being enclosed except for the hereinafter recited fluid ports;
- a plurality of ports in said casing in fluid communication with said chamber;
- a pair of separate, unconnected, independently movable spools in said chamber, each spool being positioned for sliding movement in said chamber only between first and

second locations, each spool always being in slidable contact with the other spool, each spool having a height substantially equal to the height of said chamber and being in side-by-side sliding contact with the other spool, each spool being completely contained within said chamber, and each spool being slidable only in response to fluid pressure in said chamber; and

d. stop means fixedly positioned in said chamber contacting said spools when said spools are in said second location.

2. The apparatus according to claim 1 wherein said plurality of spools comprises a pair of spools always in side-by-side slidable contact with each other.

3. The apparatus according to claim 2 wherein each of said spools includes at least one passageway for providing fluid communication between predetermined ones of said ports.

4. The apparatus according to claim 3 including a fluid input signal line connected to at least one of said ports, a fluid output signal line connected to at least one of said ports, and fluid pressure lines connected to said ports for moving said spools to their various locations in said chamber.

5. The apparatus according to claim 4 including fluid communication means in said spools for providing fluid communication between said input and output signal lines when said spools are in a predetermined location in said chamber.

6. The apparatus according to claim 2 wherein said spools are self-sealing and self-lubricating in said chamber.

7. The apparatus according to claim 2 wherein said spools are moveable together and separately and when moved together are moveable in the same and in different directions.

8. A fluid logic gate for use in a fluid logic control system comprising:

a. a casing having an elongated chamber therein, said chamber being enclosed except for the hereinafter recited fluid ports;

b. a plurality of ports in said casing in fluid communication with said chamber;

c. a pair of separate, unconnected spools movably positioned in said chamber, each of said spools being independently movable between first and second locations in said chamber, said spools being always in slidable, side-by-side contact with each other and being in sealing relationship with each other and with the walls of said chamber, each spool having a height substantially equal to the height of said chamber, each spool being completely contained within said chamber, and each spool being slidable only in response to fluid pressure in said chamber;

d. each of said spools having at least one passageway therein in fluid communication with a first set of said ports when in a first location and with a second set of said ports when in a second location in said chamber; and

e. stop means fixedly positioned in said chamber contacting said spools when said spools are in said second location.

9. The apparatus according to claim 8 wherein said spools are resilient and are self-sealing in said chamber.

10. The apparatus according to claim 8 wherein each of said spools is movable between a first location adjacent a respective end wall of said chamber toward a second location adjacent the center of said chamber, and including stop means contacting said spools at said second locations.

11. A fluid logic gate for use in a fluid logic control system comprising:

a. a casing having a chamber therein;

b. a plurality of ports in said casing in fluid communication with said chamber;

c. a pair of separate spools movably positioned in said chamber, each of said spools being independently movable between two different locations in said chamber, said spools being in sealing relationship with the walls of said chamber;

d. each of said spools having at least one passageway therein in fluid communication with a first set of said ports when in a first location and with a second set of said ports when in a second location in said chamber;

e. wherein each of said spools is movable between a first location adjacent a respective end wall of said chamber toward a second location adjacent the center of said chamber, and including stop means contacting said spools at said second locations;

f. wherein said casing includes a cover having certain of said ports arranged therein in a regular, rectangular array comprising a series of rows and a series of columns;

g. wherein each of said spools is identical, is L-shaped, and is positioned in reverse orientation to the other spool in said chamber;

h. wherein each spool has a single transverse groove in its upper surface providing communication between two adjacent ports in the same column and in adjacent rows; and

i. wherein the width of an arm extension of the "L" of each spool is substantially equal to the width of said chamber and is positioned adjacent the end of said chamber.

12. A fluid logic gate for use in a fluid logic control system comprising:

a. a casing having an elongated chamber therein;

b. a plurality of ports in said casing in fluid communication with said chamber;

c. a pair of separate, unconnected spools movably positioned in said chamber, each of said spools being independently movable between two different locations in said chamber, said spools being always in slidable, side-by-side contact with each other and being in sealing relationship with each other and with the walls of said chamber;

d. each of said spools having at least one passageway therein in fluid communication with a first set of said ports when in a first location and with a second set of said ports when in a second location in said chamber; and wherein said plurality of ports includes:

e. a first fluid pressure input port through which fluid under pressure can be introduced for moving one of said spools from its first to its second location in said chamber;

f. a second fluid pressure input port through which fluids under pressure can be introduced for moving the other of said spools from its first to its second location in said chamber;

g. a third fluid pressure input port through which fluid under pressure can be introduced in said chamber for simultaneously moving both of said spools from their second location to their first location;

h. at least one fluid input signal port in communication with said chamber; and

i. at least one fluid output signal port in communication with said chamber.

13. The apparatus according to claim 12 including fluid pressure conduit means connected to certain of said ports for biasing said spools to their first locations respectively.

14. The apparatus according to claim 13 wherein said passageways are located so as to provide fluid communication between said input signal port and said output signal port when said spools are in a predetermined position in said chamber.

15. The apparatus according to claim 13 including means providing fluid communication between said input and output signal ports only when both of said spools are in their second positions, whereby said gate can perform AND logic functions.

16. The apparatus according to claim 13 including means providing fluid communication between said input and output signal ports when at least one of said spools is in its second position, whereby said gate can perform OR logic functions.

17. The apparatus according to claim 13 including means providing fluid communication between said input and output signal ports only when neither of said spools is in its second location, whereby said gate can perform NOT logic functions.

18. The apparatus according to claim 13 including means providing fluid communication between said input and output signal ports when at least one of said spools is in its first position, whereby said gate can perform NOR logic functions.

19. A fluid logic gate for use in a fluid logic control system comprising:
- a. a casing having an elongated chamber therein;
 - b. a plurality of ports in said casing in fluid communication with said chamber;
 - c. a pair of separate, unconnected spools movably positioned in said chamber, each of said spools being independently movable between two different locations in said chamber, said spools being always in slidable, side-by-side contact with each other and being in sealing relationship with each other and with the walls of said chamber;
 - d. each of said spools having at least one passageway therein in fluid communication with a first set of said ports when in a first location and with a second set of said ports when in a second location in said chamber;
 - e. a first fluid pressure input line connected to at least one of said ports for moving one of said spools from its first location to its second location in said chamber;
 - f. a second fluid pressure input line connected to at least one of said ports for moving the other of said spools from its first to its second location in said chamber;
 - g. a third fluid pressure input line connected to at least one of said ports for simultaneously moving both of said spools from their second location to their first location;
 - h. a fluid input signal line connected to at least one of said ports; and
 - i. a fluid output signal line connected to at least one of said ports.

20. A fluid operated device for use in a fluid logic control system for performing any one of the four logic functions AND, OR, NOT, NOR, comprising:
- a. a casing having a chamber therein, said chamber being enclosed except for the hereinafter recited fluid ports;
 - b. a plurality of ports in said casing in fluid communication with said chamber said plurality of ports including all of the ports necessary for said device to perform each one of said logic functions;
 - c. a pair of separate, unconnected independently movable spools in said chamber, each spool being positioned for sliding movement in said chamber only between first and second locations, said spools being always in slidable contact with each other, each spool having a height substantially equal to the height of said chamber and being in side-by-side sliding contact with the other spool, each spool being completely contained within said chamber, and each spool being slidable only in response to fluid pressure in said chamber;
 - d. each of said spools having at least one passageway for providing fluid communication between predetermined ones of said ports;
 - e. fluid pressure lines connected to predetermined ones of said ports for performing a predetermined one of said four logic functions, and
 - f. stop means fixedly positioned in said chamber contacting said spools when said spools are in said second location.

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