

United States Patent

[11] 3,548,857

- [72] Inventors **Lewis G. Anderson**
Columbus, Ohio;
David J. Thomson, Summit, N.J.
- [21] Appl. No. **659,698**
- [22] Filed **Aug. 10, 1967**
- [45] Patented **Dec. 22, 1970**
- [73] Assignee **Bell Telephone Laboratories, Incorporated**
Murray Hill, Berkeley Heights, N.J.
a corporation of New York

- | | | | |
|-----------|--------|-----------------------|------------|
| 2,802,918 | 8/1957 | Boyle | 200/152.9X |
| 2,901,580 | 8/1959 | Kelley | 200/152.9 |
| 3,271,543 | 9/1966 | Schonfeld et al. | 200/81.6 |
| 3,422,259 | 1/1969 | Freeman | 235/201 |

OTHER REFERENCES

Truslove, D. J., Pneumatic Diode, in I.B.M. Technical Disclosure Bulletin, Vol. 6 No. 3, August 1963, p.30.

Primary Examiner—William R. Cline

Attorneys—R. J. Guenther and Edwin B. Cave

- [54] ELECTRICALLY RESPONSIVE FLUID LOGIC SYSTEM AND METHOD OF ASSEMBLY**
20 Claims, 7 Drawing Figs.

- [52] **U.S. Cl.**..... **137/251,**
137/13, 137/81.5; 251/129; 29/157.1, 235/201
- [51] **Int. Cl.**..... **F15c 3/06,**
F15c 5/00; F16k 9/00
- [50] **Field of Search**..... **137/81.5,**
251, 13; 251/129, 141, 65; 235/201; 200/81.6,
83.6, 152.9; 29/157.1, (Inquired)

References Cited

UNITED STATES PATENTS

- | | | | |
|-----------|--------|-------------------|------------|
| 2,312,672 | 3/1943 | Pollard, Jr. | 200/152.9X |
|-----------|--------|-------------------|------------|

ABSTRACT: A gas flow in a miniaturized fluid logic circuit is switched electrically by conducting gas flow into and out of the same end of an elongated chamber that holds a mercury ball which is movable from a flow-obstructing to a flow-releasing position, and by selectively moving the ball with the aid of both a constant magnetic field established across the ball's track and a varying current applied to the ball through contacts on the chamber walls. The action is made monostable by constricting the chamber to distort the ball in one of its positions. The distortion forces the ball back to the other position when no current flows.

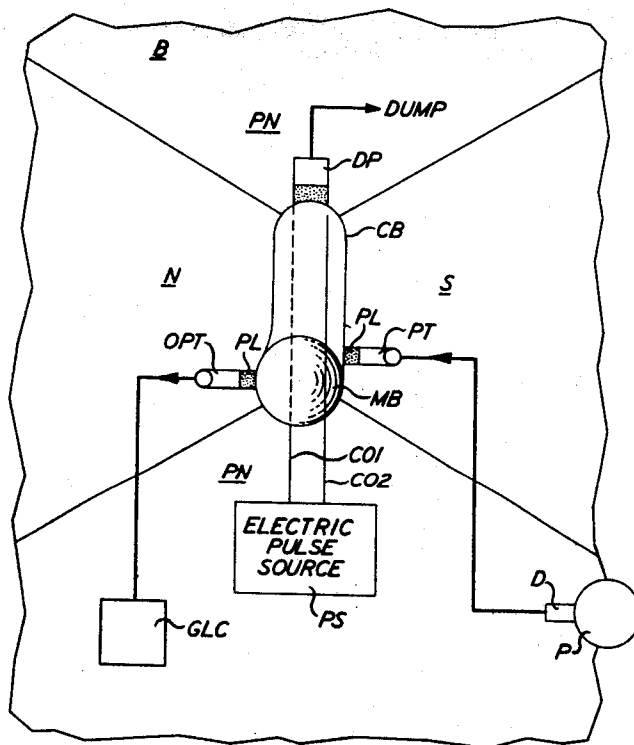


FIG. 1

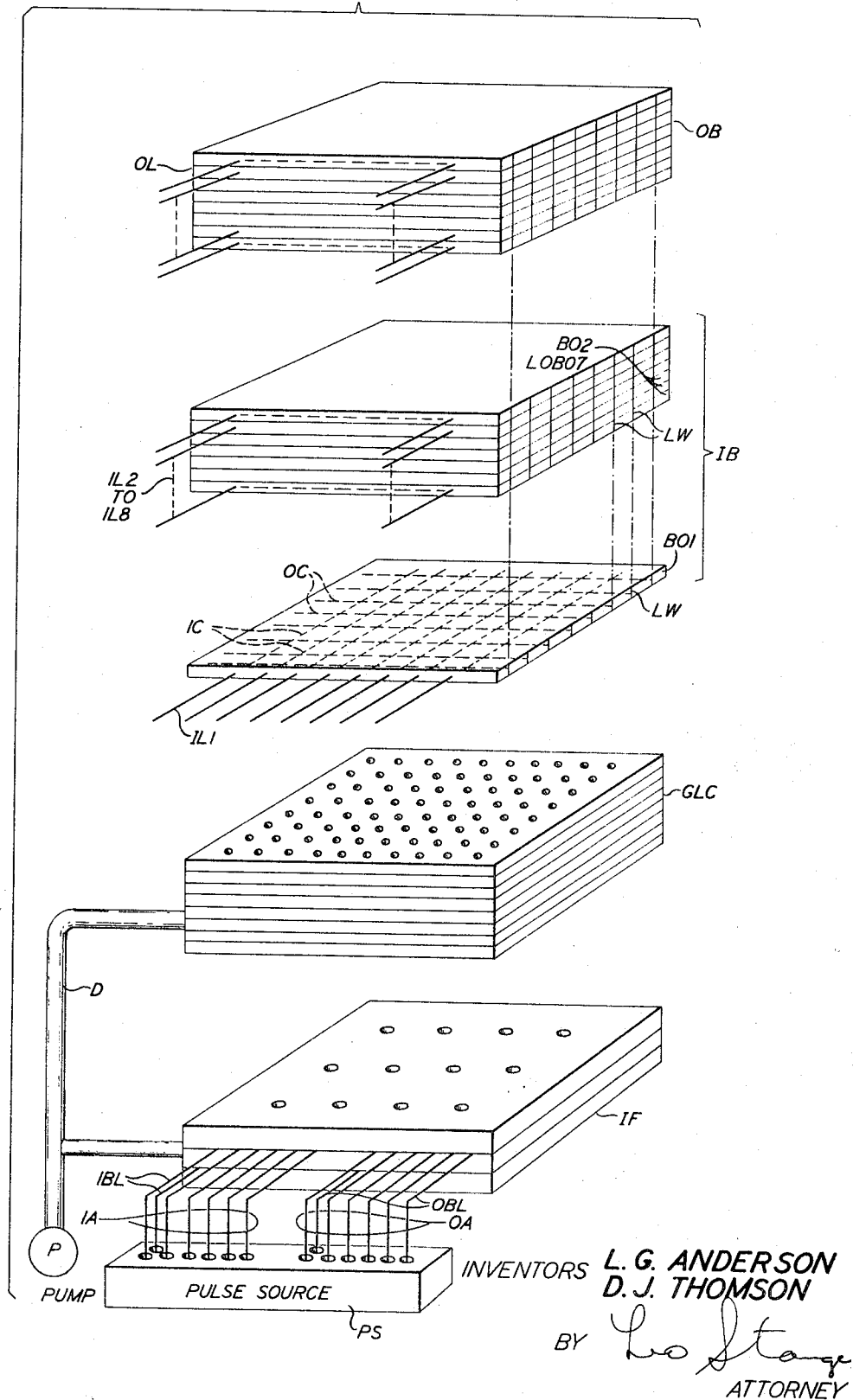


FIG. 2

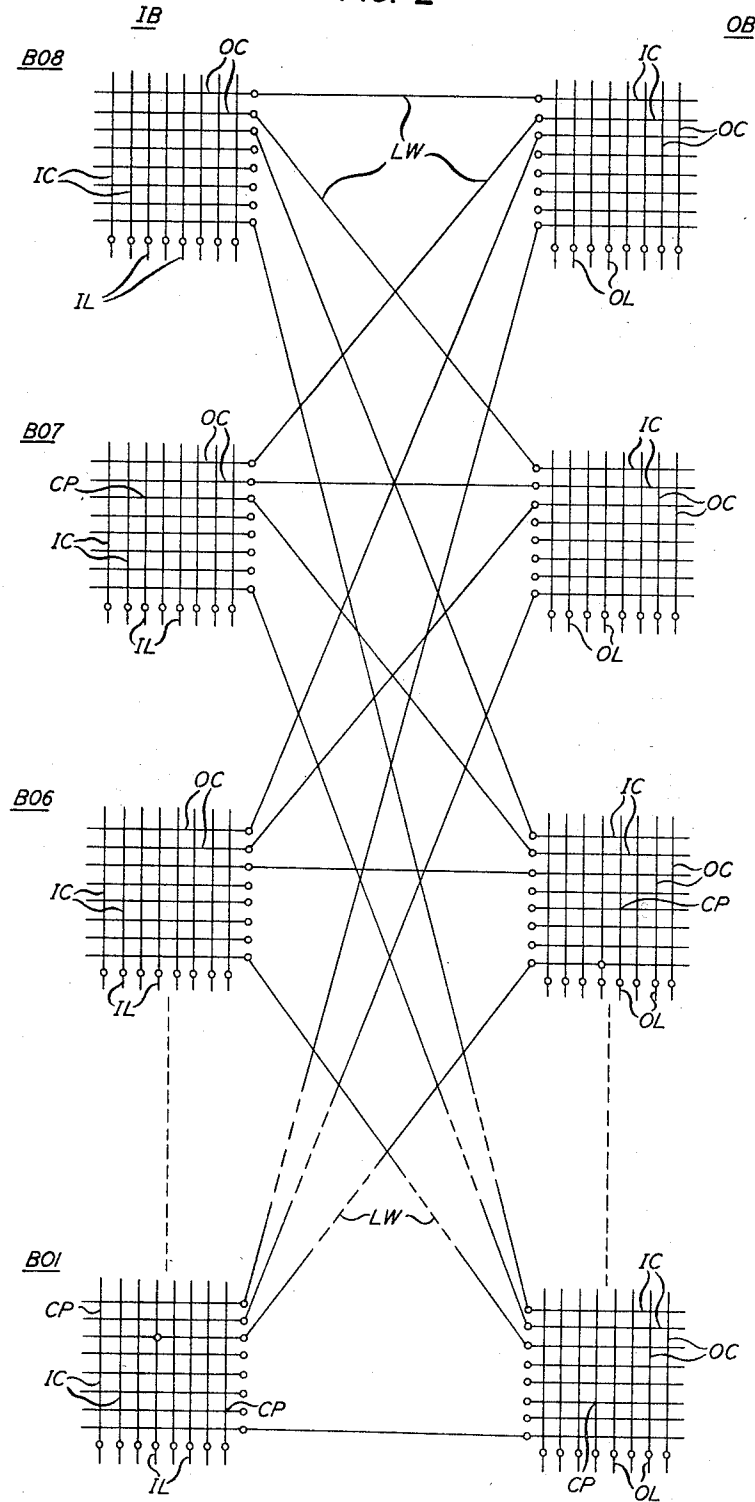


FIG. 3

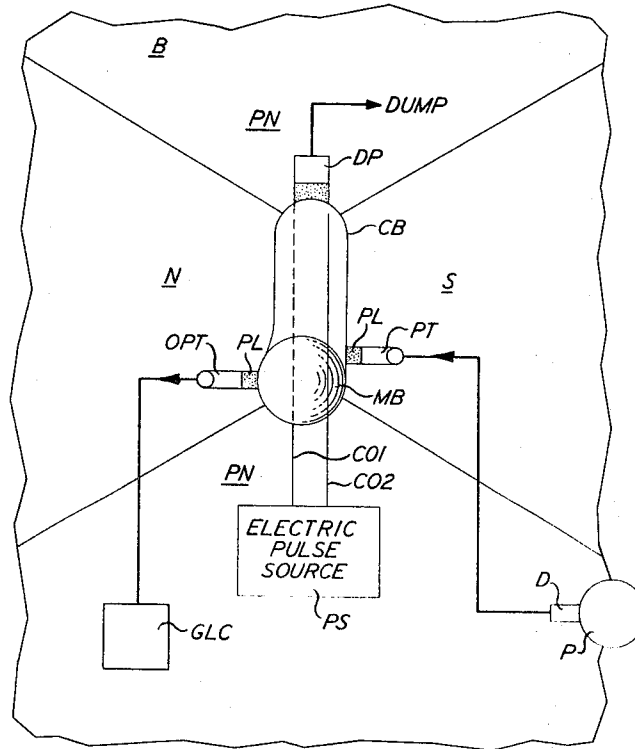


FIG. 4

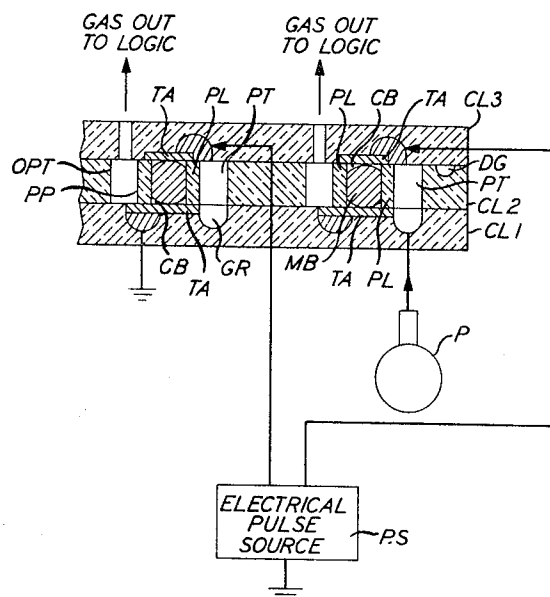


FIG. 5

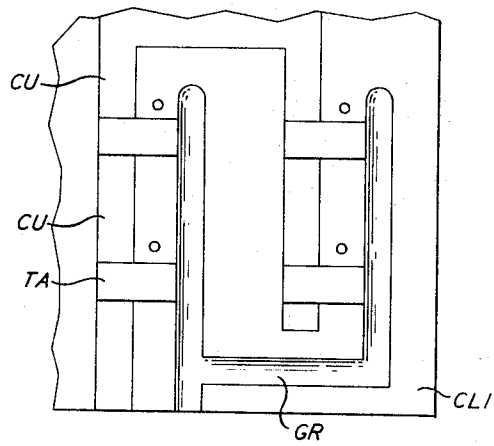


FIG. 6

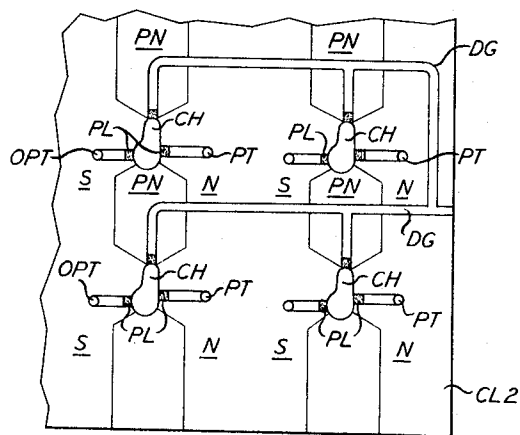
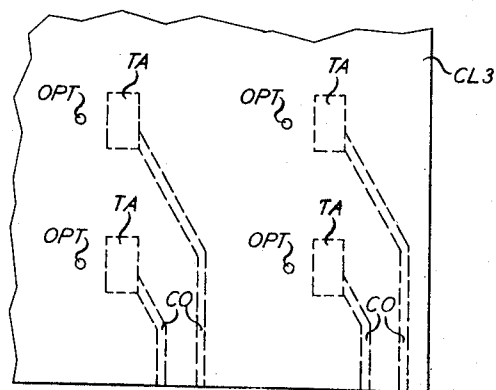


FIG. 7



ELECTRICALLY RESPONSIVE FLUID LOGIC SYSTEM AND METHOD OF ASSEMBLY

CROSS REFERENCE TO RELATED APPLICATIONS

This invention is related to that disclosed in the applications of H. Winter, Ser. No. 659,686, filed Aug. 10, 1967 and D. J. Johnson, Ser. No. 659,794, filed Aug. 10, 1967, both being filed concurrently herewith, and both being assigned to the same assignee as this invention.

BACKGROUND OF THE INVENTION

This invention relates to transducing electrical logic information into fluid logic information, particularly for fluidically actuating the connections at the crosspoints of arrays, or so-called switch blocks, that in stages selectively connect telephone subscribers to trunk lines in telephone-switching system.

Telephone central office-switching systems have in the past utilized electromagnets both for establishing connections and furnishing the information or logic by which the connections are selected. Such systems are slow and bulky. In newer systems electronically-developed control currents actuate electromagnets which open and close comparatively small relay contacts called ferreeds. When closed, these ferreeds interconnect electronically selected crosspoints between transverse sets of otherwise unconnected parallel coordinate conductors which form arrays. Successive arrays, or switch blocks, of this type then selectively connect an incoming or outgoing call to an incoming or outgoing trunk. However, reliable ferreeds are difficult to manufacture and require bulky envelopes and electromagnets.

Consideration has been given to connecting the crosspoints with semiconductor switches. However, no matter how effective these switches, each of them introduces an undesirable impedance at the crosspoints. Thus, if the number of arrays, and hence the number of crosspoints through which an incoming signal must pass from one telephone subscriber to another is great, considerable distortion and loss of signal is experienced.

The copending application of H. Winter Ser. No. 659,686, filed Aug. 10, 1967 being concurrently filed herewith and assigned to the same assignee of this application, eliminates many of these difficulties by fluidically actuating mercury balls that establish contact between the coordinate conductors or crosswires in arrays at the crosspoints without introducing additional resistances. The low-resistance contact afforded by such mercury balls between two metallic coordinate conductors is eminently suitable for such work. Moreover, the speed with which the fluid can actuate such mercury balls is more than adequate. However, the operation of such systems still depends upon actuating the fluid which moves the ball contacts with electrical input pulses. In the past, reasonably fast conversions from electrical pulses to fluid pulses have been difficult to obtain. Available solenoid-actuated fluid pulsers have been found far too bulky and expensive to use as electric-to-gas transducers, especially when compared to the compact fluid-actuated switching arrays described in the beforementioned application of H. Winter.

SUMMARY OF THE INVENTION

According to a feature of the invention these deficiencies of fluid-actuated switching systems are eliminated by routing the fluid, which is to actuate the crosspoint switches of the arrays, into and out of small elongated chambers that are cut in a block and that hold respective mercury balls each movable from a fluid-flow-obstructing to a flow-releasing position, and, while applying constant magnetic fields across the balls' tracks, also applying the electrical input signal currents through the respective balls by means of suitable contacts entering the chamber. The electric and magnetic fields then move the balls along the chambers and switch the fluid flows accordingly. Each chamber, its contacts, ports and magnets thus form a separate transducer.

According to another feature of the invention the switching operation of the resulting transducers is made monostable by constricting the chambers to distort each ball in one of its two positions. The distortion then forces the ball back to the other position when input current stops flowing. Preferably the thus-produced gas pulses are directed to the crosspoint switches of the arrays by means of fluid logic which decreases the number of needed transducers.

According to still another feature of the invention arrays of such transducers are formed into small blocks by depositing pluralities of such contacts on the inner surfaces of the outer ones of three overlying insulating layers, then punching the center layer to form chambers which register with grooves and ports in the outer layers, and applying magnets so that suitable mercury balls inserted in the chambers can be moved by the magnets and contacts.

According to another feature of the invention the magnetic fields are applied to each chamber in an array by forming on either side of the chambers in the center insulating layer, strips of elongated insulating magnetic material such as ceramic ferrite. The ferrite strips extend between rows of chambers. By virtue of this construction large numbers of such switches may be batch-manufactured and suitable connections and gas pressures applied.

These and other features of the invention are pointed out in the claims. Other objects and advantages of the invention will become better understood from the following detailed description when read in light of the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings:

FIG. 1 is an exploded perspective block diagram partially in schematic form of a telephone switching grid or system suitable for use in a telephone central office switching network;

FIG. 2 is a schematic diagram of the input and output switches forming the portion of the grid of FIG. 1;

FIG. 3 is a partially schematic detail of one transducer forming a crosspoint switch in FIGS. 1 and 2 and embodying features of the invention as well as illustrating its operation;

FIG. 4 is a section of a switch block in FIG. 1; and

FIGS. 5, 6 and 7 are respective top views of the bottom, middle and top layers of FIG. 4.

DESCRIPTION OF PREFERRED EMBODIMENT

In the telephone-switching system of FIGS. 1 and 2 eight input lines 111 arrive from individual telephone circuits. They terminate in eight parallel input coordinate conductors or coordinates IC printed, plated, or vapor deposited between the lower and upper surfaces of an array board BO1. With seven similar boards BO2 to BO7 at the end of lines IL2 to IL7, the board BO1 forms a coordinate input block IB in a switching system such as described in the beforementioned copending application of H. Winter Ser. No. 659,686, filed Aug. 10, 1967 filed concurrently herewith. The lines IL1 to IL8 and boards BO1 to BO8 are referred to generally as lines IL and boards BO. Eight lines IL terminate in input coordinates IC in each of the eight boards BO. This furnishes a total of sixty-four input lines IL. On each of the eight boards BO eight output coordinate conductors or coordinates OC, also between the bottom and top surfaces of the board BO but not contacting the input coordinates IC, terminate in link wiring LW. The latter connects the output coordinates OC, which are transverse to the input coordinates, to input coordinates on an eight-board output block OB.

The output block OB is constructed similar to the input block IB. It ends in sixty-four output lines OL coming from suitable output coordinates OC in the output block OB. On each board BO of the output block OB and input block IB mercury switches actuated pneumatically as disclosed in the copending Winter application appear at each crosspoint CP of the input coordinates IC and output coordinates OC in the input block IB and output block OB.

The switches at the crosspoints CP are energized by transducers in an input interface IF, through an intermediate gas-logic circuit GLC. The latter is pressurized by the pump P through a duct D. The duct D also forms a pressure path to the input interface IF that includes the transducers. The interface operates between the gas-logic circuit GLC and six input binary lines IBL from an electric computing pulse source PS. The pulsed lines IBL select which crosspoint on which board BO is to be closed in the input block IB. Six output binary lines OBL forming an output address OA and entering the interface IF from the source PS select on a binary basis which crosspoint on which board OB is to be switched in the block OB. The gas-logic circuit actuates the switches at the crosspoints on the basis of the selections of the binary lines.

FIG. 2 illustrates that the selection of one crosspoint CP in the input block IB and one crosspoint CP in the output block OB uniquely connects one input line IL to one output line OL. For example, closing the switch at the crosspoint marked with a circle, at the bottom left of FIG. 2, and closing the crosspoint in the middle right of FIG. 2 shown by a circle, connects one particular input line IBL to one selected output line OBL. On a binary basis three of the input binary lines IBL of the input address select the board BO of block IB on which the crosspoint is to be closed and the other three input binary lines IBL select which input coordinate IC the switch to be closed on the selected board will effect. Of the output binary lines OBL three lines select a board on the output block OB. Simultaneously, these selections serve to choose an output coordinate OC in the board BO on the input block IB as well as an input coordinate IC on the selected board of the output block. The remaining three output binary lines OBL select the coordinate of the board BO on the block OB and thus the desired output line. This connection process is similar to that used for connecting magnetic array switches. For example, the so-called No. 5 crossbar system for telephone lines operates on the principle.

In FIGS. 1 and 2 the switches at crosspoints CP constitute mercury balls encapsulated in suitable chambers each located so that an input coordinate IC and one output coordinate OC passes through the chambers at each crossover point. The chambers and the mercury balls are arranged so that gas flowing through suitable ports to the chambers pneumatically move the mercury balls into or out of contact with each of the crossbars in the input blocks and output blocks. By virtue of the immediate contact between the crossbars through the mercury balls, low ohmic connections are established between the desired input and output lines. Such pneumatic-switching systems may be manufactured cheaply by batch-processing and are extremely reliable. The workmanship and labor required to accomplish this is much less than that required for comparable magnetic or electromagnetic-switching systems.

To utilize the advantages of the pneumatic-switching system the electrical input signals are transduced into suitable pneumatic signals by constructing the interface IF from a number of transducers as illustrated schematically in FIG. 3. Here, a mercury ball MB rests in a horizontal chamber CB of a ceramic body B whose portions PN bounding the ends of the elongated chamber are magnetically neutral. The body's portions N and S bounding the elongated walls of the chamber CB are composed of insulating magnetic ferrites to form north and south poles. The main gas flow enters from the pump P through the duct D through a port PT. The latter ends at one end of the chamber CB in a porous plug PL. A second porous plug PL also at the same end of the chamber CB forms the start of an outlet port OPT which leads to the gas-logic circuit GLC. When the pulse source PS furnishes a pulse, conductors CO1 and CO2, shown schematically as lines, and extending respectively through the under and over side of the mercury ball MB, pass a current vertically through the ball MB. The horizontal magnetic field formed by the poles on the elongated sidewalls of the chamber CB combines with the current to move the ball along the chamber CB until it unblocks the path between ports PT and OPT. This movement of the mer-

cury ball releases the pressurized gas from the pump P. The gas flows to the gas-logic circuit GLC during the period of the electric pulse. A dump port DP having a ceramic porous plug releases to the atmosphere gas forced by entry of the ball MB from the now-occupied portion of the chamber.

In the quiescent position shown the input port PT communicates directly with the dump port DP so as to avoid forcing the ball MB in the direction of the dump port. The output port OPT is, however, covered by the ball MB. The port PT must still be close enough to the end of the chamber CB to allow the ball MB to clear both ports PT and OPT.

The chamber CB is constricted at one end to distort the ball MB as it is moved electromagnetically to that end. The distortion creates surface tension forces which constrain the ball to return to its initial position between the ports PT and OPT when the current therethrough ends. This again closes the path of gas from the pump P to the gas logic circuit GLC and produces a pulse of gas pressure corresponding to the electrical pulse from the source PS.

All the members into which the mercury ball comes in contact are composed of materials not wettable by mercury. The contacts CO1 and CO2 preferably consist of platinum or stainless steel on the upper and lower surfaces of the chamber walls.

Other details of the structure of the interface IF appear in FIGS. 4 to 7. FIG. 4 is a cross section of the interface IF. A plurality of chambers CB corresponding to those shown in FIG. 3 are formed by cutting or punching holes in a center ceramic layer CL2 of three ceramic layers CL1, CL2 and CL3 whose plan views appear in FIGS. 5, 6 and 7. The holes CH have the pear shapes shown in FIG. 3 and in the plan view of FIG. 6. Completing the upper and lower walls of the chamber CB are platinum tabs TA vapor-deposited, plated, or otherwise deposited on the upper surface of a ceramic layer CL1 and the lower surface of a ceramic layer CL3. A copper bar connector CU imbedded in the lower ceramic layers CL1 under an edge of each of the tabs TA connects the tabs to each other and to the edge of the layer where it may be grounded. The platinum material between the copper bar connector CU and the interior of the chamber furnishes the mercury ball MB with a surface which it cannot wet. The vertical chamber walls made of the ceramic material are also not wettable by the mercury material.

Furnishing the electrical pulses for conduction through each of the mercury balls on a selective basis are a plurality of conductors CO contacting the tabs TA on the lower surface of the upper ceramic layer CL3 and leading independently to the edge of the interface. There they connect to the lines IBL and OBL and to the electric pulse source PS in FIG. 1. The tabs TA and the connectors CU as well as the conductors CO correspond together to the schematically-illustrated conductors CO1 and CO2 of FIG. 3. A groove GR on the upper surface of the lower ceramic layer CL1 serves to lead pressurized gas from the pump P to the input or entrance ports PT of the individual chambers. These ports PT extend directly into the chambers CB although they are plugged by the porous plugs PL. The port PT in each case may be drilled or punched in the ceramic layer CL2. The gas output to the logic circuit GLC passes through the ports OPT punched in the layer CL2 and plugged with a porous plug PL at the edge of each chamber. The output port OPT continues through suitable openings also designated OPT punched in the upper ceramic layer CL3 that lead the intermittently obstructed gas flow to the logic circuit GLC of FIG. 1. A dump groove DG terminates at a porous plug PL at the smaller end of the chamber CH. It releases gas displaced by the mercury ball when the latter enters the smaller end of the chamber CH. The positions of the individual ports PT and OPT correspond to those shown in FIG. 3.

The magnetic field furnished by the N and S regions in FIG. 3 are formed in the layers CL2 by making the sections marked S and N from properly magnetized ceramic material and making the section marked PN from magnetically neutral material.

This can be accomplished by collecting portions of premagnetized layer material and bonding them together or by a process of properly magnetizing the material after it is heat-formed such as is done with magnetic tape.

As a result of the vertically traveling current from the pulse source PS passing through the mercury ball MB, and of the horizontal field established magnetically by the ceramic magnets, a horizontal force produces a motion of the mercury ball into the narrower end of the chamber CB in each of the switches of FIGS. 4 through 7. The pulse source remains in electrical contact with the mercury ball throughout its travel length. Thus since the field remains substantially the same throughout the travel length of the mercury ball, the horizontal forces remain applied to the ball until the pulse ends. Then the distortion constrained upon the ball by virtue of the constriction in the chamber CB at the end to which the ball has been forced causes the ball to return to its initial position. In its constrained position the ball releases flow of gas from the input port PT to the output port OPT. In its returned position flow of gas at the output port OPT is cut off because the ball obstructs flow there. In this way an electrical pulse is transduced into a pneumatic, or gas, pulse for the gas-logic circuit GLC.

The structures of FIGS. 4 to 7 may be batch-fabricated. This is accomplished by separately forming each of the layers in a ceramic press. The center layer CL2 may be formed by first fabricating the elongated shapes represented by the portions S and N and inserting therein the portions represented by PN. At first the chamber CH can be ignored. On the other hand, suitable results are available by forming a single ceramic layer CL2 directly and magnetizing it in the heating process or thereafter. In layers CL1 and CL3 the conductors CO and connectors CU may be imbedded by printed circuit techniques. Grooves GR, DG and the groove for carrying the conductors CO and connectors CU are formed in the pressing process. Suitable holes for the ports PT and OPT and chambers CH are punched into the ceramic layers and the tabs TA vapor-deposited, plated, or otherwise deposited in suitable locations. The process is completed by overlying the layers CL1 and CL2, bonding them under pressure, adding the mercury balls MB and then bonding the layer CL3 to the top of the layer CL2 under pressure.

The illustrated embodiments of the invention show the structure to be used with an 8 x 8 grid matrix. However, larger matrices are possible. Moreover, the layers may be manufactured in huge sheets having thousands of matrices and then cut as necessary. As a result extremely simple manufacturing operations can furnish multiplicities of switching elements for gas logic. This is possible because there exist considerable tolerances in the location of the input and output ports. The sizes of the input and output ports may also vary considerably and may be made any size suitable for the operating speed.

The direction of movement of each mercury ball MB need not necessarily be horizontal. By placing the tabs TA along the vertical sides of a vertically-elongated chamber so that current can be applied horizontally although transverse to the magnetic field, a ball may be made to move vertically. Monostable condition can be achieved by again restricting the upper end of the chamber so as to distort the ball or simply by allowing the effect of gravity to force it down in the absence of a magnetic field and electric current.

While embodiments of the invention have been described in detail, it will be obvious to those skilled in the art that the invention may be practiced otherwise without departing from its spirit and scope.

We claim:

1. A transducer for translating electrical signals to fluid flow signals comprising material means for forming an elongated chamber, said material means forming fluid ports to and from said chamber, metal means in the chamber having a liquid character and capable of forming a ball movable along said chamber between a position obstructing the ports and one releasing fluid flow through the ports, magnetic means for

forming a field transverse to the length of said chamber, conductive means for contacting the ball throughout its travel along said chamber and for applying a current through said ball transverse to the direction of the magnetic field and transverse to the length of the chamber, whereby electrical signals applied to the conductive means effect selective obstruction and release of the gas flowing through said ports.

2. A transducer as in claim 1 wherein said material means form a dump port entering said chamber at one end for releasing fluid moved by moving said metal means.

3. A transducer as in claim 1 wherein said metal means comprises a mercury ball.

4. A transducer as in claim 1 wherein said material means and said conductive means contact said metal means only with materials not wettable by said metal means.

5. A transducer as in claim 1 wherein said magnetic means form a portion of said material means.

6. A transducer as in claim 1 wherein said chamber is narrower at one end than the other so as to distort said metal means when said metal means moves into said narrower end and thereby force said metal means back into said wider end when no electromagnetic force is applied to said metal means.

7. A transducer as in claim 1 wherein said material means comprise three-stacked and interbonded ceramic layers, said magnetic means forming a portion of the center one of said layers.

8. An interface for an electrical input to a fluid control system comprising insulating block means, a plurality of elongated chambers formed in said block means, magnetic means in said block means for establishing respective magnetic fields across the length of each of said chambers, said block means forming a plurality of gas ports to be pressurized at one end and terminating at a portion of said block means so as to form gas port outputs, said ports each passing through an end of respective ones of said chambers, liquid conductor means in said chambers having a convex meniscus relative to the materials of the walls of said chambers so as to form a ball which does not wet said walls said liquid conductor means being movable along said chambers from positions obstructing gas flow through said ports to positions permitting flow through said ports, and conductive means extending through said block means and along respective lengths of said chambers for applying to said liquid conductor means input signal currents transverse to the direction of said field and transverse to the lengths of said chambers, whereby signals applied to respective ones of said conductive means moves said ball means between obstructing and nonobstructing positions in said chambers relative to said ports.

9. An interface as in claim 8 wherein said chambers are narrower in one end than the other so as to bias said ball means toward the wider end.

10. An interface as in claim 8 wherein gas lines communicating with one end of said chambers releases gas caused by motion of said ball means.

11. An interface as in claim 8, wherein said block means include three stacked and interbonded insulating layers, the center one of said layers having a plurality of openings punched through to form the chambers, said center layer having continuous strips of magnetic material bordering on said chambers.

12. An interface as in claim 11 wherein said conductive means include tab means on the inner surfaces of said outer layers extending into the chambers for contacting said ball means together with current-carrying means embedded in the inner surfaces of the outer layers and connecting said tab means to the edge of said block means.

13. An interface as in claim 11 wherein said layers include grooves and open portions in registration for forming said port means.

14. An interface as in claim 11 wherein said ball means are composed of mercury, said block means of ceramic and said tab means of platinum.

15. A fluid control system comprising fluid logic means, electrical means for responding to said fluid logic means, insulating block means, a plurality of elongated chambers formed in said block means, magnetic means in said block means for establishing respective magnetic fields across the length of each of said chambers, said block means forming a plurality of gas ports, gas pressure means connected to said ports for inducing flow therein, said gas ports terminating at a portion of said block means so as to form gas port outputs, said ports each passing through an end of respective ones of said chambers, liquid conductor means in said chambers forming a convex meniscus relative to the materials of the walls of said chambers so as to form a ball which does not wet said walls, said liquid conductor means being movable along said chambers from positions obstructing gas flow through said ports to positions permitting flow through said ports, conductive means extending through said block means and along respective lengths of said chambers, electrical input means connected to said conductive means for applying to said liquid conductor means input signal currents transverse to the direction of said field and transverse to the lengths of said chambers, whereby signals applied to respective ones of said conductive means moves said liquid conductor means between obstructing and nonobstructing positions in said chambers relative to said ports, said gas output ports communicating with said fluid logic circuit to form an input thereto.

16. A system as in claim 15 wherein said chambers are narrower in one end than the other so as to bias said ball means toward the wider end.

17. A system as in claim 15 wherein said conductive means

include tab means on the inner surfaces of said outer layers extending into the chambers for contacting said ball means together with current-carrying means embedded in the inner surfaces of the outer layers and connecting said tab means to the edge of said block means.

18. The method of forming an interface between a fluid control system and an electrical input, which comprises forming two ceramic layers, forming a third ceramic layer having a plurality of magnetic fields established therein, forming openings and grooves in said ceramic layers so that respective openings and grooves register, when said third layer is placed between the other two-forming elongated chamber openings in the third of said layers transverse to said magnetic fields and to register with said grooves and openings, applying conductors to two of said layers so that said conductors terminate at said chambers, assembling one of said layers with said third layer, depositing liquid conductive balls into said chambers, assembling the remaining layer with said two layers, and bonding said layers together.

19. The method as in claim 18 wherein said step of forming the third ceramic layer comprises forming elongated magnetic members extending between a plurality of adjacent pairs of chambers, forming magnetically neutral portions and assembling and bonding said members and said portions.

20. The method as in claim 18 wherein said step of forming the third ceramic layer comprises assembling the constituents of said ceramic layer, magnetizing strips of said constituents while heating said constituents under pressure.

35

40

45

50

55

60

65

70

75