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(54) Control valve assembly for controlling gas flow in gas combustion systems

(57) A control valve assembly (22) includes an inlet (16) for receiving a gas flow and an outlet (20) for providing the gas flow to a gas burner (18). The assembly (22) also includes a positive-shutoff valve (24) for interrupting the gas flow from the inlet (16). A micro electromechanical system (MEMS) valve (26) is coupled in series to the positive-shutoff valve (24) between the inlet (16) and the outlet (20) for regulating the gas flow from the inlet (16) to the outlet (20).

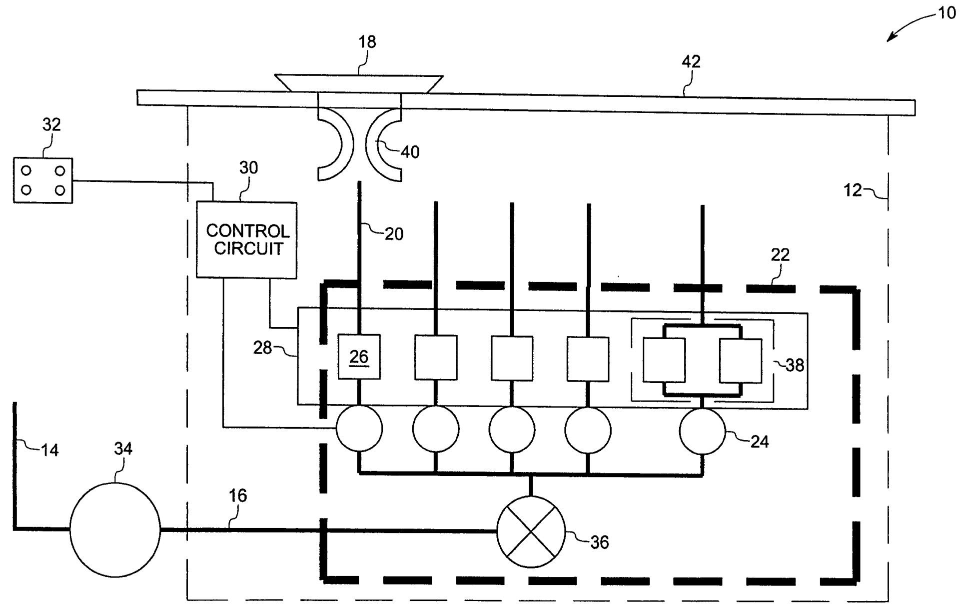

FIG.1

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Description

[0001] The invention relates generally to gas combustion systems, and more particularly, to control of gas flow in a gas combustion system.

[0002] Various gas combustion systems are known and are generally in use. For example, a gas cooking system receives a flammable gas flow from a supply and this flow of gas is directed to a gas burner of the gas cooking system. Downstream combustion components, such as burners, require large cross-sections in the flow circuit to accommodate flow rates that enable high heat output.

[0003] In general, the gas cooking system employs a flow control mechanism, such as a manual mechanical valve, for metering the gas flow from the supply to the gas burner. Certain other natural gas combustion systems employ electronic control via solenoid actuated valves to regulate large flows of gas. Such systems employ either a single continuously variable solenoid valve, or a series of on/off solenoid valves to regulate the flow.

[0004] Certain other natural gas combustion systems employ a micro electromechanical systems (MEMS) valve for electronic flow control. Such MEMS valves are manufactured by employing batch fabrication processes such as those employed in the integrated circuit industry to fabricate mechanical or coupled electromechanical devices. The use of such MEMS devices is advantageous for improved flow control at lower manufacturing cost. However, designing such systems is challenging due to large actuation displacement requirements that are required for such systems as a large cross section area may be required in the flow circuit to accommodate high levels of flow. Further, it is difficult to achieve large actuation displacements with a small MEMS device.

[0005] In systems where MEMS devices are employed for the gas flow control, it may be difficult to package and integrate a small size chip of the MEMS device as a part of a macro scale system. In addition, heat generated by an electrothermal actuator of the MEMS device during actuation may cause device failure. Therefore, it is desirable to transfer the generated heat away from the device. Further, use of electrothermal actuators for flow control requires individual calibration of the electrothermal actuators with supporting electronic feedback control for providing accurate low gas flows. Incorporation of individual calibration of the electrothermal actuators is a challenge due to costs and added complexity involved in such calibration arrangements.

[0006] Accordingly, it would be desirable to develop a system for flow control of a liquid or gaseous medium with a positive shutoff seal capability. It would also be advantageous to provide a system that could achieve an accurate low flow control and a high flow control up to a maximum designed flow for such medium. It would also be desirable to provide robust, fluidic and electrical connections for the flow control mechanism for efficient flow control of the liquid or gaseous medium in such system.

[0007] Briefly, in accordance with one aspect of the present invention a control valve assembly includes an inlet for receiving a gas flow and an outlet for providing the gas flow to a gas burner. The assembly also includes a positive-shutoff valve for interrupting the gas flow from the inlet. A micro electromechanical system (MEMS) valve is coupled in series to the positive-shutoff valve between the inlet and the outlet for regulating the gas flow from the inlet to the outlet.

[0008] In accordance with another aspect of the present invention a method of controlling a gas flow in a gas combustion system with a gas burner includes receiving the gas flow via an inlet and controlling the gas flow from the inlet by opening and closing a positive-shutoff valve. The method also includes regulating the gas flow from the inlet to the gas burner via a MEMS valve when the positive shutoff valve is open.

[0009] The invention will now be described in greater detail, by way of example, with reference to the drawings, in which:-

FIG. 1 is a diagrammatical representation of a gas burner system with a control valve assembly for controlling a gas flow to a gas burner in accordance with aspects of the present technique;

FIG. 2 is a diagrammatical representation of an exemplary control valve assembly for a gas combustion system in accordance with aspects of the present technique;

FIG. 3 is an exploded view of the control valve assembly of FIG.2;

FIG. 4 depicts an exemplary flow path of gas via the control valve assembly of FIG. 2;

FIG. 5 is a graphical representation of exemplary input voltage settings for the control valve assembly of FIG. 2 for a low flow control of gas in accordance with aspects of the present technique;

FIG. 6 is a diagrammatical representation of an exemplary substrate employed to mount MEMS valve dies in accordance with aspects of the present technique;

FIG. 7 is a diagrammatical representation of an exemplary sealing device for the substrate employed to mount the MEMS valve dies of FIG. 6 according to one aspect of the invention;

FIG. 8 is a sectional view of the sealing device of FIG. 7;

FIG. 9 is a diagrammatical representation of an exemplary substrate illustrating sealing features and assembly for the substrate of FIG. 6 according to another aspect of the invention;

FIG. 10 is a diagrammatical representation of an exemplary process for manufacturing of the substrate employed to mount the MEMS valve dies of FIG. 7 according to one aspect of the invention; and

FIG. 11 is a diagrammatical representation of an exemplary process for manufacturing of the substrate employed to mount the MEMS valve dies of FIG. 7 according to another aspect of the invention.

[0010] FIG. 1 illustrates a gas burner system 10 with a control valve assembly, according to an embodiment, for use in a gas operated cooking appliance, such as, but not limited to, gas stove, gas hobs, and gas ovens. In the embodiment illustrated in FIG. 1, the gas burner system 10 includes a series of components disposed in a housing 12. In a presently contemplated configuration, the gas burner system 10 receives a gas flow from a supply 14 via an inlet 16 and the gas flow is delivered to a gas burner 18 via an outlet 20 for use in various cooking activities. A valve assembly 22 with a positive-shutoff valve 24 and a micro electromechanical system (MEMS) valve 26 is coupled between the inlet 16 and the outlet 20 for regulating the gas flow from the inlet 16 to the outlet 20. It should be noted that, the MEMS valve 26 is coupled in series to the positive-shutoff valve 24. In this embodiment, the positive-shutoff valve 24 is disposed upstream of the MEMS valve 26. Further, the MEMS valve 26 is mounted on a heat sinking substrate 28 that would be described in a greater detail below. In one embodiment, the gas burner system 10 includes a plurality of MEMS valves 26 that is coupled in parallel to provide a desired gas flow to the gas burner 18.

[0011] In one embodiment, the MEMS valve 26 is an electrothermal actuated plate valve. The electrothermal actuated plate valve includes a plurality of slots disposed on a silicon die. In this embodiment, the gas flow via the slots may be regulated by opening or closing of the slots via a voltage input. In operation, two electrothermal beams are adapted to cover the slots for closing of the slots. In addition, the input voltage may result in thermal expansion of the electrothermal beams thereby opening the slots for passing the gas flow. Thus, the illustrated valve facilitates an accurate control of the gas flow at both low flow and maximum flow conditions.

[0012] Further, a control circuit 30 is coupled to the positive-shutoff valve 24 and to the MEMS valve 26 for controlling the gas flow via the positive-shutoff valve 24 and the MEMS valve 26. A user interface 32 may be coupled to the control circuit 30 for providing a user input to the control circuit 30. Examples of such user interface 32 include knob control, keypad control, wireless interface, internet connection and so forth. The user input may include parameters for controlling the operation of the positive-shutoff valve 24 and the MEMS valve 26. Further, a power supply (not shown) may be coupled to the MEMS valve 26 for controlling the actuation of the MEMS valve 26 via variable voltage, variable current or pulse width modulation (PWM). In the illustrated embodiment, the control circuit 30 is adapted to regulate a heat output of the gas burner 18 based upon the user input. The control circuit 30 may include a memory device (not shown) for storing internal references to control the gas flow to the gas burner 18 to achieve a desired burner output. The internal references may include lookup tables, analytical functions and so forth. The control circuit 30 utilizes the internal references to control the current, voltage or PWM for operating the MEMS valve 26 to achieve a desired burner heat output.

[0013] In operation, the gas burner system 10 receives a gas flow from the gas supply 14 for example, a gas supply network, gas cylinder, gas tank and so forth. A regulator 34 disposed up stream of the valve assembly 22 regulates the gas flow received from the gas supply 14 before providing the gas flow to the gas burner 18. According to one embodiment, a lock-out valve 36 may be disposed upstream of the positive-shutoff valve 24 and the MEMS valve 26 for interrupting the gas flow from the supply 14 to the gas burner 18. In one embodiment, the lock-out valve 36 is a solenoid valve.

[0014] In an open condition of the lock-out valve 36, the gas flow is directed to the positive-shutoff valve 24 that is adapted to interrupt the gas flow from the inlet 16. In this embodiment, the positive-shutoff valve 24 is a solenoid valve. However, other types of valves performing a similar function may be used. The gas burner system 10 may include a plurality of positive-shutoff valves 24 for interrupting the gas flow to a plurality of burners 18 employed in the gas burner system 10. In this embodiment, the operation of the positive-shutoff valve 24 is controlled by the control circuit 30 that controls the opening or closing of the positive-shutoff valve 24 as desired by a user of the gas burner system 10. In addition, when the positive-shutoff valve 24 is in an open position the control circuit 30 also controls the operation of the MEMS valve 26 to control the gas flow between the inlet 16 and the outlet 20. In operation, the MEMS valve 26 receives a continuous supply of power for regulating the gas flow between the inlet 16 and the outlet 20. The supply of power may result in generation of heat and it may be desirable to dissipate the generated heat away from the MEMS valve 26. In this embodiment, the heat generated by the supply of power may be dissipated via the heat sinking substrate 28.

[0015] As described above, the gas burner system 10 may employ a plurality of MEMS valves 26 coupled in parallel for providing a desired gas flow to the plurality of gas burners 18. Typically, the gas burner system 10 may include differently sized burners that may require different gas flows for their operation. It should be noted that, a plurality of MEMS valves 26 may be coupled together for providing a high gas flow to a gas burner 18. For example, two MEMS valves 26 may be coupled in parallel to form a high flow valve 38 that is adapted to provide a desired gas flow to the burner 18. It should be noted that, the two MEMS valves 26 coupled to form the high flow valve 38 may be controlled by a single input signal from the user interface 32. Further, the MEMS valve 26 may include an orifice that is adapted to provide a desired gas flow for a burner simmer setting of the gas burner 18. The size of the orifice may be decided based upon the desired gas flow for a burner simmer setting of the gas burner 18. Thus, where the positive-shutoff valve 24 is in an open position the gas flow for a burner simmer setting is provided to the gas burner 18 via the orifice. The regulated gas flow from the MEMS valve 26 may then be provided to a venturi assembly 40 of the gas burner 18 disposed over the cooktop 42.

[0016] FIG. 2 illustrates an exemplary control valve assembly 44 for the gas burner system 10 of FIG. 1. The control valve assembly 22 includes sealing devices 46 and 48 to seal the heat sinking substrate 28 with the MEMS valve 26 between the inlet 16 and outlet 20 of the control valve assembly 44. In addition, the control valve assembly 44 may also include additional components such as, a middle plate 50 and a support plate 52 for supporting the positive-shutoff valve 24. The assembly of these components is explained in a greater detail below with reference to FIG.3.

[0017] Referring now to FIG. 3, an exploded view 54 of the control valve assembly 44 of FIG. 2 is illustrated. In a presently contemplated configuration, the positive-shutoff valves 24 may be coupled to the inlet 16 via the support plate 52. Further, the middle plate 50 may be placed between the heat sinking substrate 28 and the inlet 16. A gasket 56 may be disposed between the middle plate 50 and the inlet 16 to seal the gas flow from the heat sinking substrate 28. As noted above, sealing devices 46 and 48 are provided adjacent to the heat sinking substrate 28 to seal the gas flow from the heat sinking substrate 28. In one embodiment, the sealing devices 46 and 48 are printed seals. In another embodiment, the sealing devices 46 and 48 are thermally conductive gaskets. Other suitable sealing devices may, of course, be employed.

[0018] As mentioned above, the gas flow to the gas burner 18 in the gas burner system 10 may be controlled by the control valve assembly 22. FIG. 4 illustrates the flow path 58 of gas in the control valve assembly 22 of FIG. 2. The gas flow is received from a supply, as represented by the arrow 60. This flow of gas then is directed in a direction 62 to the gas burner system 10 via the inlet 16. The gas flow 64 within the gas burner system 10 is then regulated by the MEMS valve 26 with the positive-shutoff valve 24 in an open position, and the regulated flow of gas 66 is then fed to the gas burners 18 of the gas burner system 10.

[0019] As described above with reference to FIG. 1, the MEMS valve 26 may include an orifice that is adapted to provide a desired gas flow for a burner simmer setting of the gas burner 18. FIG. 5 illustrates a graphical representation 68 of exemplary input voltage settings for the control valve assembly of FIG. 2 for a low flow control of gas in accordance with aspects of the present technique. In this embodiment, the abscissa axis 70 represents the input voltage for the operation of the control valve assembly 22 and the ordinate axis 72 represents the percentage of total flow of gas to the gas burner 18. The flow of gas in the gas burner system 10 with and without the orifice is represented by the curves 74 and 76 respectively. As can be seen from the curve 74, the flow of gas may be controlled accurately in a condition where an orifice is in an always-open condition to provide a desired gas flow 78 for a burner simmer setting. Alternatively, an accurate control of the input voltage settings may be required for low flow control of the gas when the orifice is not provided as can be seen from the curve 76.

[0020] FIG. 6 illustrates a diagrammatical representation of an exemplary mounting board 80 for mounting of the MEMS valves 26. The mounting board 80 includes a substrate 82 that is adapted to dissipate the heat generated by the MEMS valve 26. In one embodiment, the substrate 82 is aluminum. Further, a plurality of MEMS valves 26 may be mounted on the substrate 82 and traces 84 from each of the plurality of MEMS valves 26 are connected to an edge connector 86. The edge connector 86 may be coupled to the control circuit 30 (not shown) for controlling the operation of the plurality of the MEMS valves 26.

[0021] The substrate 82 with the MEMS valves 26 as described above may be sealed to seal the gas flow from the substrate 82 via a sealing device. FIG. 7 and FIG. 8 illustrate an exemplary substrate 88 with a sealing device 90. In this embodiment, the sealing device 90 is an O-ring seal printed on the substrate 82. Fig. 8 illustrates a sectional view 92 of the substrate 88 with the O-ring seal 90. In another embodiment, the sealing device 90 is a thermally conductive gasket. The substrate 82 may include thermally conductive gaskets on both front and back sides of the substrate 82. Alternatively, the substrate 82 may have an O-ring seal on one side and a thermally conductive gasket on the other side. FIG. 9 illustrates another exemplary sealing mechanism 94 for sealing the gas flow from the substrate 82. In this embodiment, the inlet 16 and the outlet 20 include grooves 96 and 98 milled or otherwise formed on the inlet 16 and the outlet 20 respectively. The grooves 96 and 98 may be used for positioning of the sealing device 90 on the inlet 16 and the outlet 20. Further, a printed circuit board 100 with metal interconnect layers may be disposed between the grooves 96 and 98 and a thermally conductive adhesive 102 or other joining device may be used to couple the printed circuit board 100 with the substrate 82. It should be noted that, the substrate 82 includes a dielectric polymer and metal interconnect layers disposed on the substrate 82 that will be described in detail below with reference to FIG. 10 and FIG. 11.

[0022] FIG. 10 illustrates an exemplary process 104 for manufacturing the substrate 80 of FIG. 6. The process begins at step 106 where substrate 108 is selected and a dielectric polymer 110 is disposed on the substrate 108. In this embodiment, the substrate 108 comprises aluminum. Next, as shown in step 112 a metallic interconnect 114 is disposed on the dielectric polymer 110 in a pre-determined pattern. In this embodiment, the metallic interconnect 114 comprises copper. However, other metals performing a similar function may be used. At step 116, a solder mask 118 is disposed on the metallic interconnect 114 and the dielectric polymer 110 in a pre-determined pattern. Next, as represented by step 120 a layer of gold 122 may be plated on the metallic interconnect 114. The gold layer 122 is adapted to perform the function of an edge connector. At step 124, the substrate 108 along with the dielectric polymer 110 may be diced to create a cavity 126.

[0023] Next, at step 128 a portion 130 of the dielectric polymer 110 may be milled out or otherwise removed. As subsequently represented by step 132, a MEMS die 134 is placed over the milled portion 130 of the dielectric polymer 110. Further, an adhesive 136 may be employed to couple the die 134 to the substrate 108. Finally, at step 138 the die 134 is coupled to the substrate 108 via wire bonds 140. The valve assembly manufactured by the process described above may be employed for regulating a flow of gas 142 in the gas burner system 10 of FIG.1.

[0024] FIG. 11 illustrates another exemplary process 144 for manufacturing the substrate 80 of FIG. 6. The process begins with step 146 where a substrate 148 may be diced to form a cavity. In this embodiment, the substrate 148 comprises aluminum. Next, at step 150 a printed circuit board (PCB) 152 is mounted on the substrate 148 via an adhesive material 154. Further, at step 156 a MEMS die 158 is placed on the substrate 148 via a thermally conductive adhesive material 160. Finally, at step 162 the MEMS die 158 is coupled to the PCB 152 via wire bonds 164. In addition, a protective lid 166 may be provided to seal the substrate 148.

[0025] As will be appreciated by those skilled in the art, the present system provides an efficient flow control of a gaseous medium with a positive-shutoff capability for a gas range or other system. The system provides an accurate low flow control and a high flow control up to a maximum designed flow for such medium in the gas range system. The various aspects of the method described hereinabove have utility in gas operated cooking appliances for example, gas cooktops, gas cookers, gas hobs, and gas ovens, among other applications. As noted above, the method described here may be advantageous for such systems for controlling the gas flow via the control valve assembly. In addition, the method also provides an efficient mechanism for dissipating heat generated via such control valve assembly.

[0026] While only certain features of the invention have been illustrated and described herein, many modifications and changes will occur to those skilled in the art. It is, therefore, to be understood that the appended claims are intended to cover all such modifications and changes as fall within the true spirit of the invention.

Claims

1. A control valve assembly (22) comprising:

an inlet (16) for receiving a gas flow;
an outlet (20) for providing the gas flow to a gas burner (18);
a positive-shutoff valve (24) for interrupting the gas flow from the inlet (16); and
a micro electromechanical system (MEMS) valve (26) coupled in series to the positive-shutoff valve (24) between the inlet (16) and the outlet (20) for regulating the gas flow from the inlet (16) to the outlet (20).

2. The assembly of claim 1, further comprising a control circuit (30) coupled to the positive-shutoff valve (24) and to the MEMS valve (26) for controlling the gas flow via the positive-shutoff valve (24) and the MEMS valve (26).

3. The assembly of claim 1, wherein the MEMS valve (26) comprises an orifice adapted to provide a desired gas flow for a burner simmer setting.

4. The assembly of claim 1, wherein a plurality of MEMS valves (26) is coupled in parallel to provide a desired gas flow to the gas burner (18).

5. The assembly of claim 4, wherein at least one positive-shutoff valve (24) is coupled in series to each of the MEMS valve (26).

6. The assembly of claim 1, wherein the MEMS valve (26) is mounted on a heat sinking substrate (28).

7. A gas cooking system (10)comprising:

a gas burner (18); and
a control valve assembly (22) comprising:
an inlet (16) for receiving a gas flow;
an outlet (20) for providing the gas flow to the gas burner (18);
a positive-shutoff valve (24) for interrupting gas flow from the inlet (16); and
a micro electromechanical system (MEMS) valve (26) coupled in series to the positive-shutoff valve (24) between the inlet (16) and the outlet (20) for metering the gas flow from the inlet (16) to the outlet (20).

8. A micro electromechanical system (MEMS) valve assembly (94) comprising:

a heat sinking substrate (82);
a plurality of MEMS valves (26) disposed on the heat sinking substrate (82);
a first gas flow device (16) for receiving a gas

flow;
a second gas flow device (20) disposed downstream of the first gas flow device (16); and
a sealing device (90) adapted to seal the heat sinking substrate (82) between the first gas flow device (16) and the second gas flow device (20).

9. A method of controlling a gas flow in a gas combustion system with a gas burner comprising:

receiving the gas flow via an inlet;
controlling the gas flow from the inlet by opening and closing a positive-shutoff valve; and
regulating the gas flow from the inlet to the gas burner via a MEMS valve when the positive shutoff valve is open.

10. A method of manufacturing a control valve assembly for a gas combustion system comprising:

positioning a positive-shutoff valve adjacent to an inlet of the gas combustion system for controlling a gas flow through the assembly;
coupling a micro electromechanical system (MEMS) valve in series with the positive-shutoff valve for regulating flow through the assembly when the positive-shutoff valve is open; and
providing a sealing device adjacent to the MEMS valve, for sealing the gas flow through the MEMS valve.

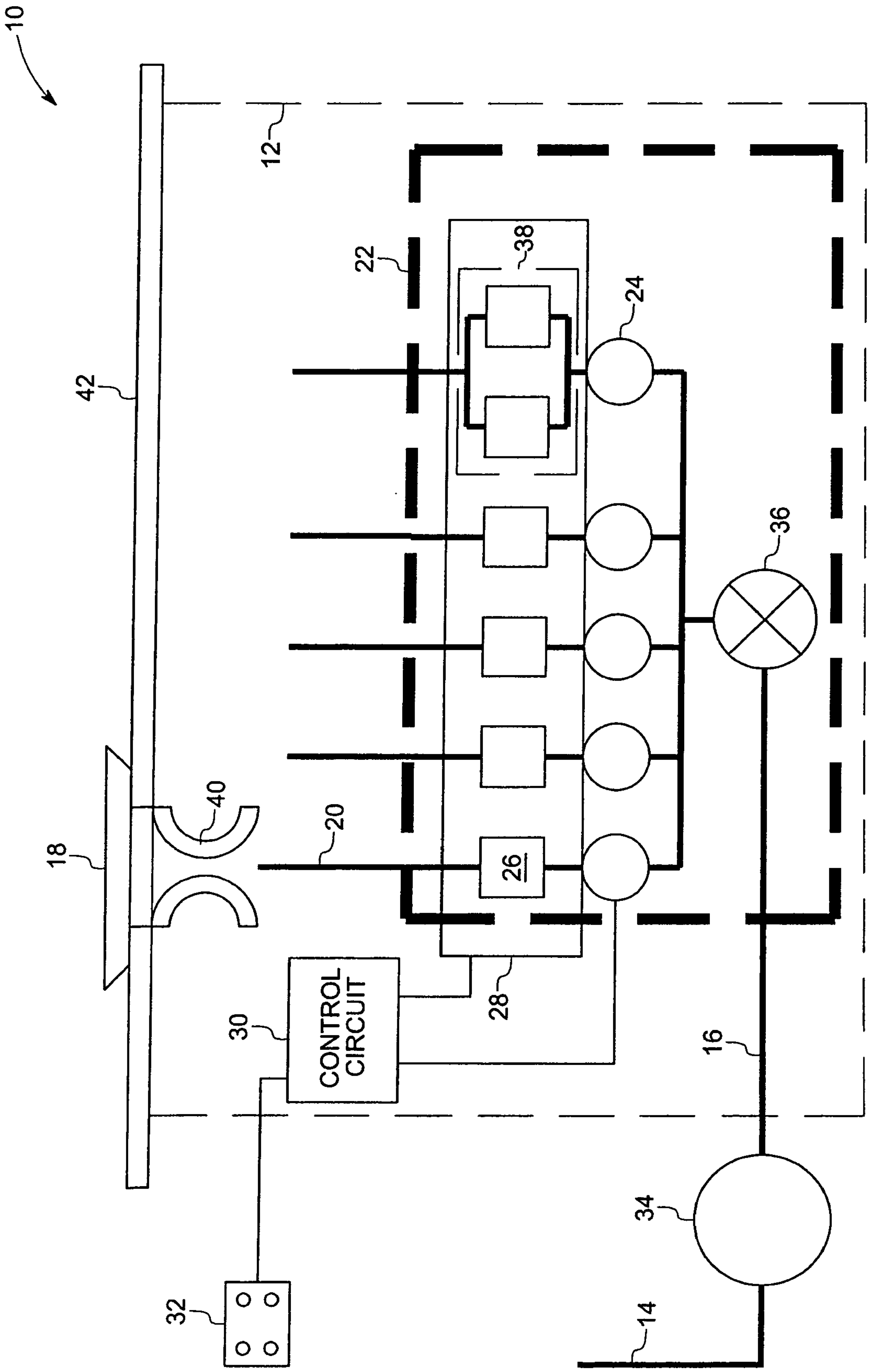

FIG.1

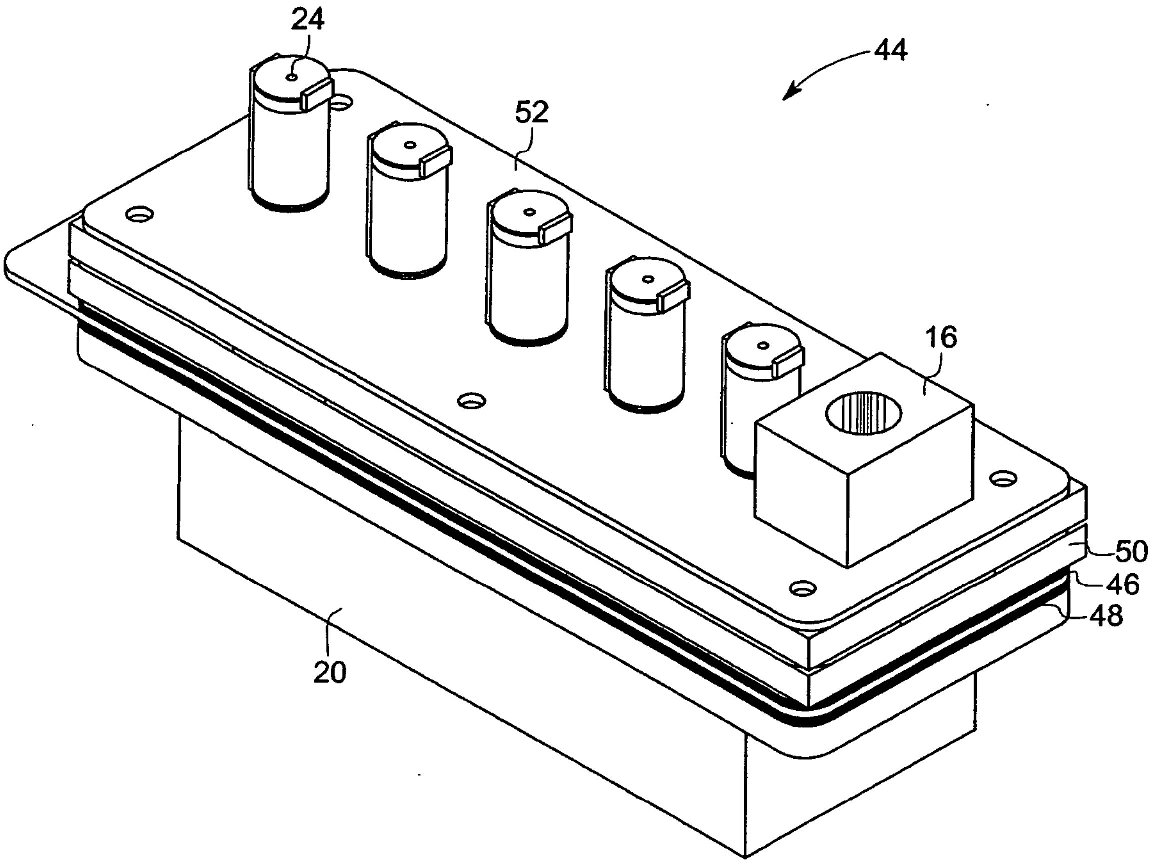

FIG.2

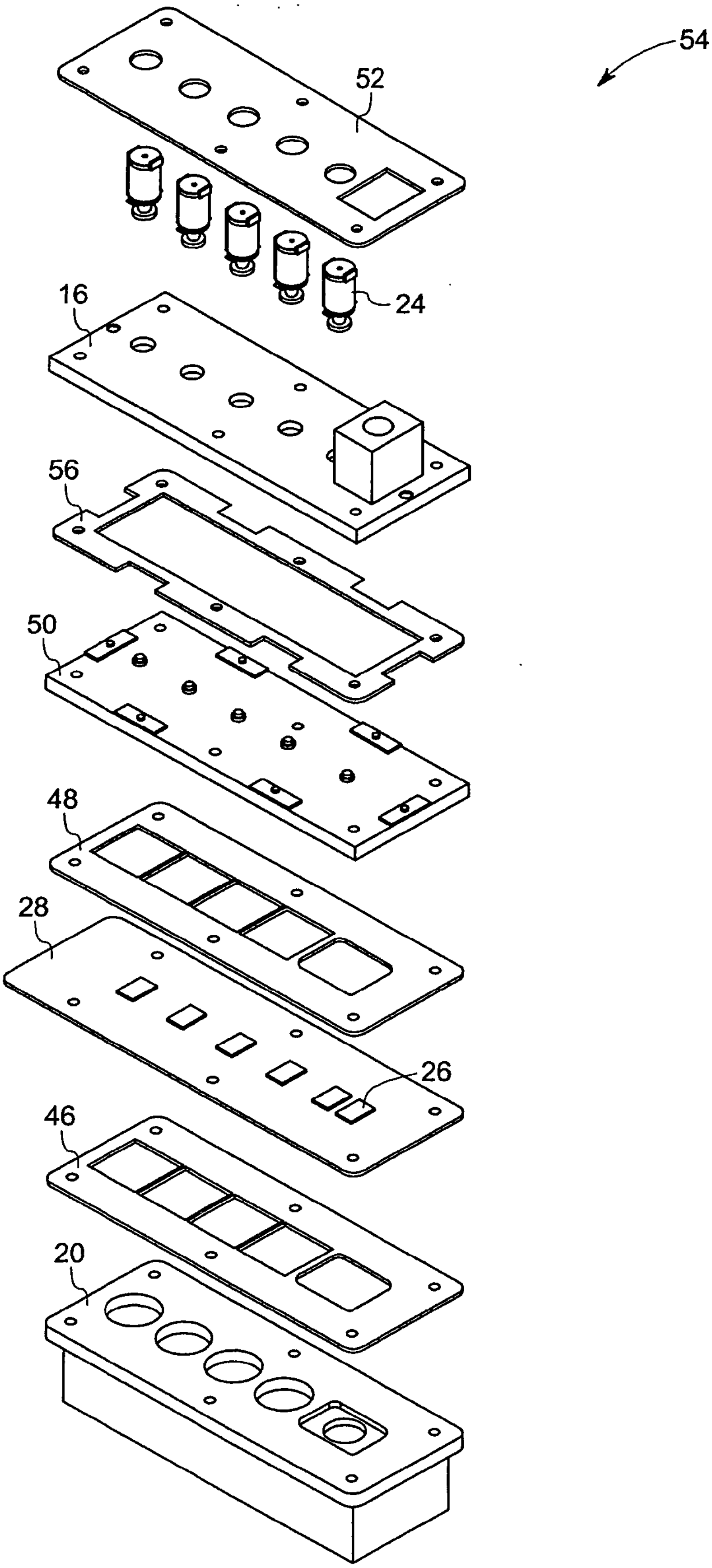

FIG.3

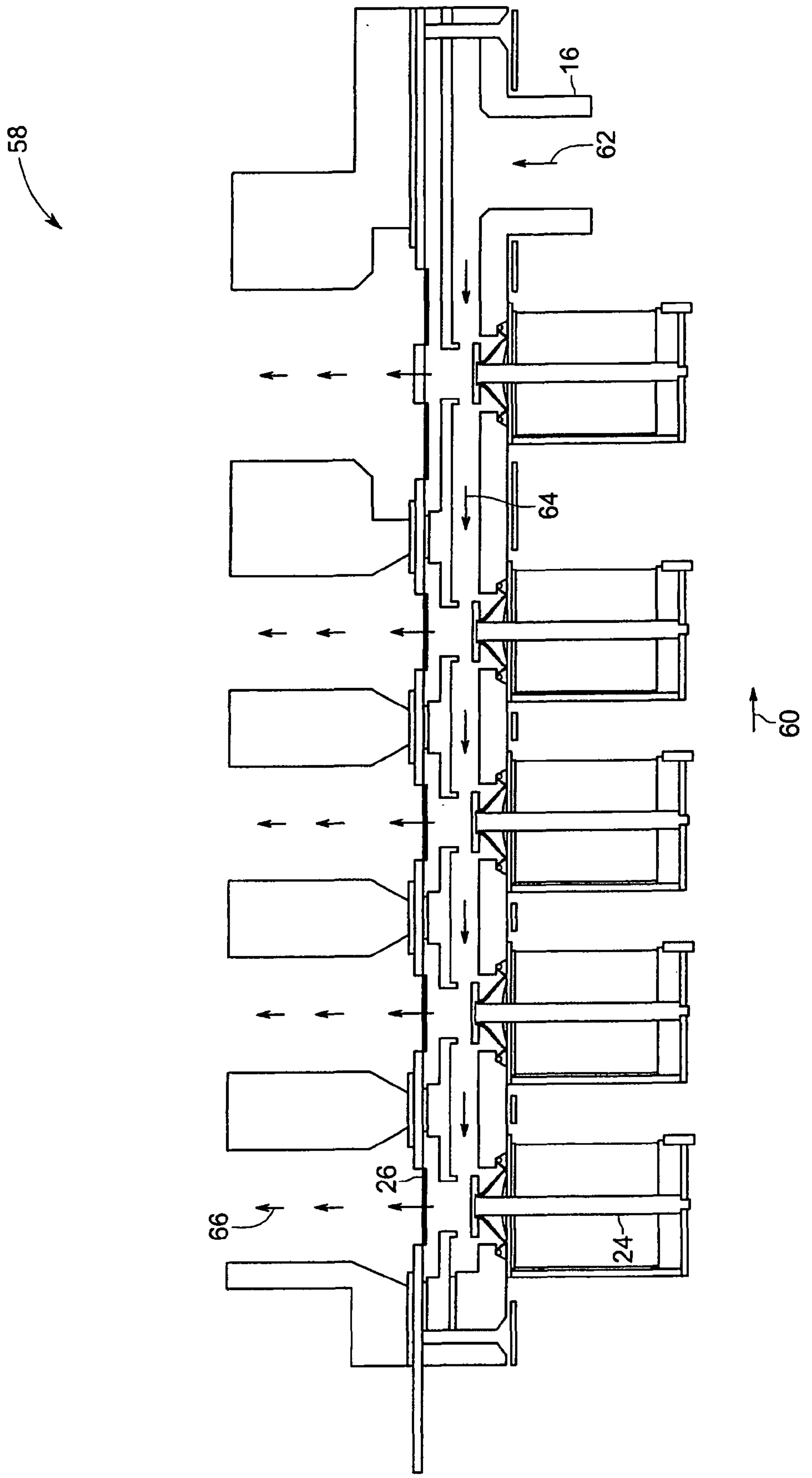

FIG.4

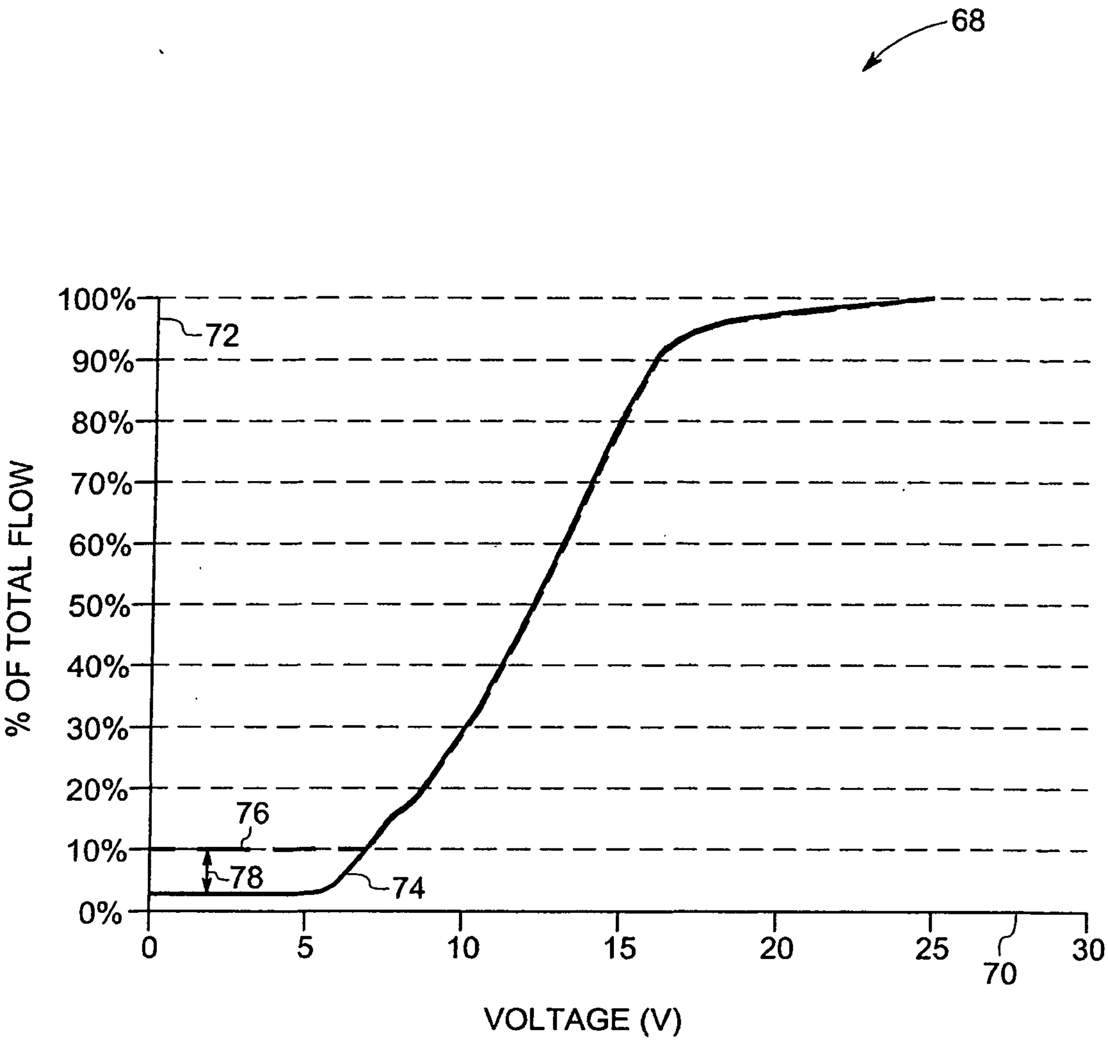
68
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
72
% OF TOTAL FLOW
76
78
74
0
5
10
15
20
25
30
70
VOLTAGE (V)

FIG.5

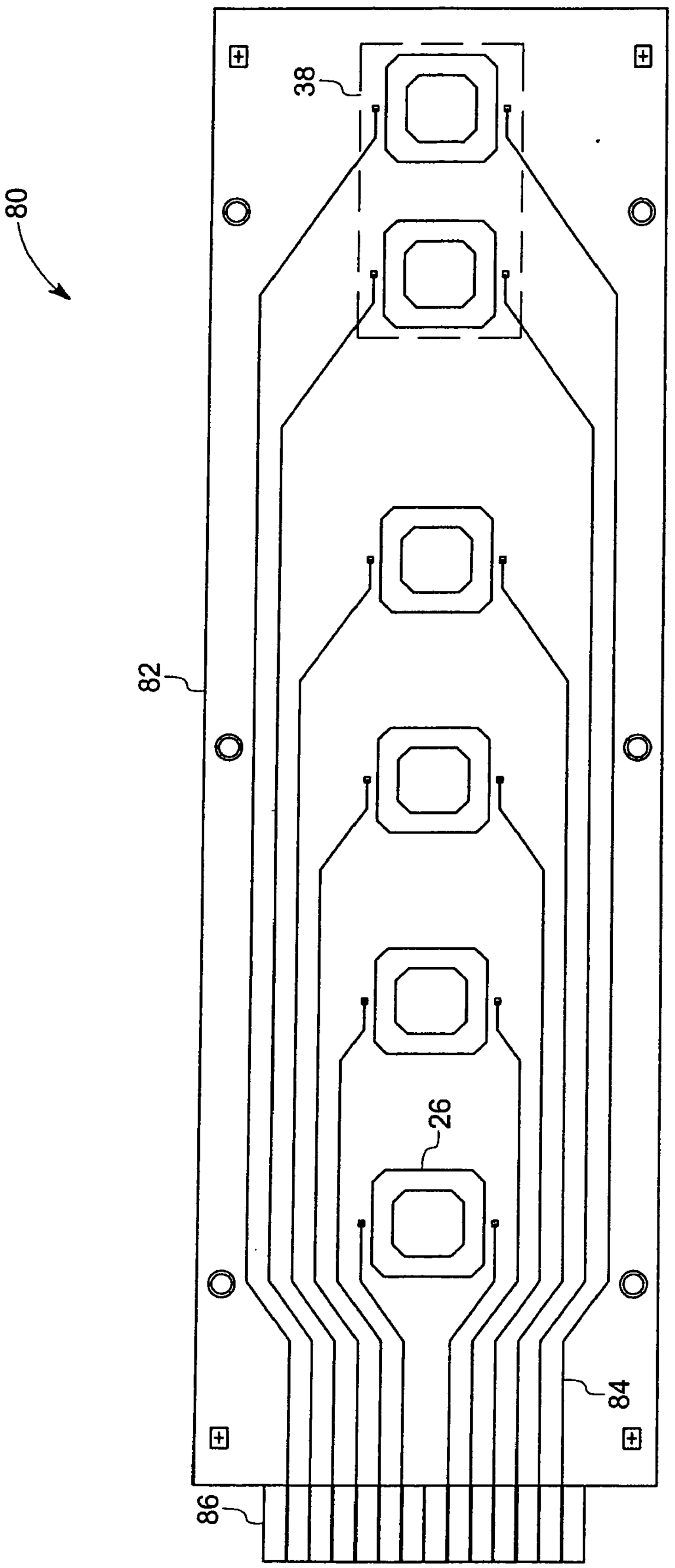

FIG.6

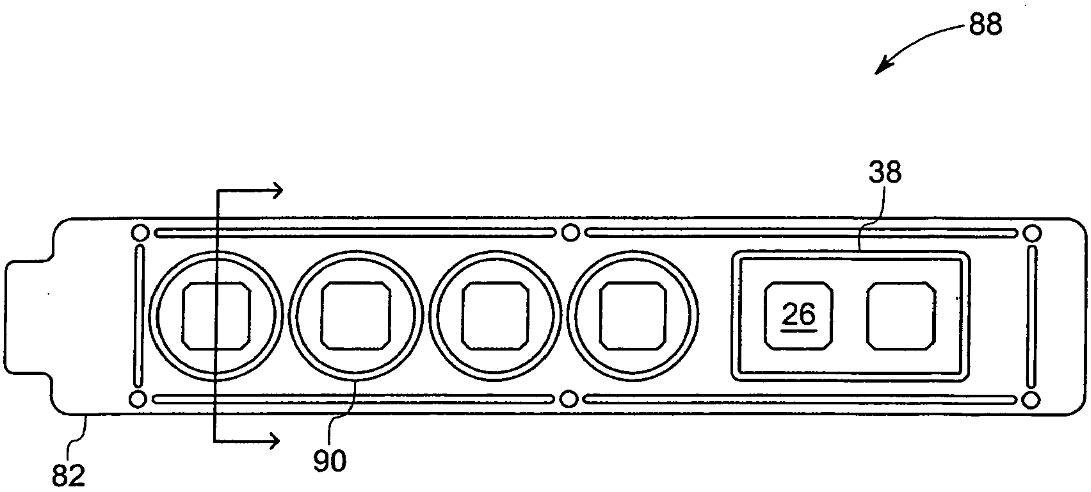

FIG.7

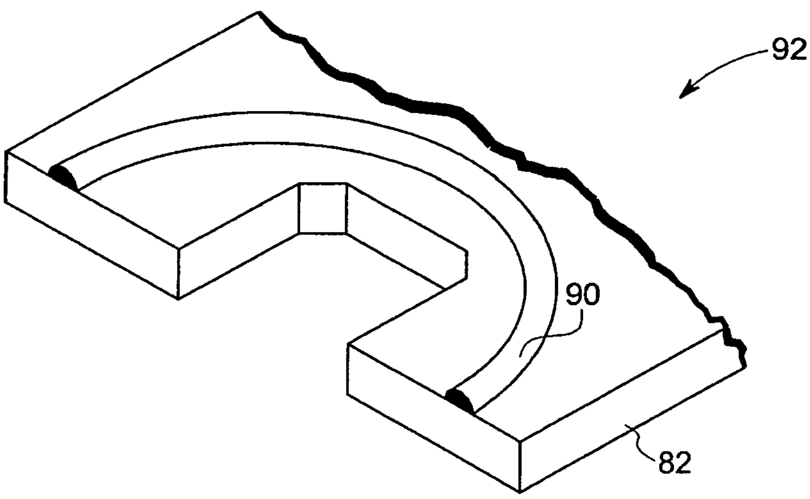

FIG.8

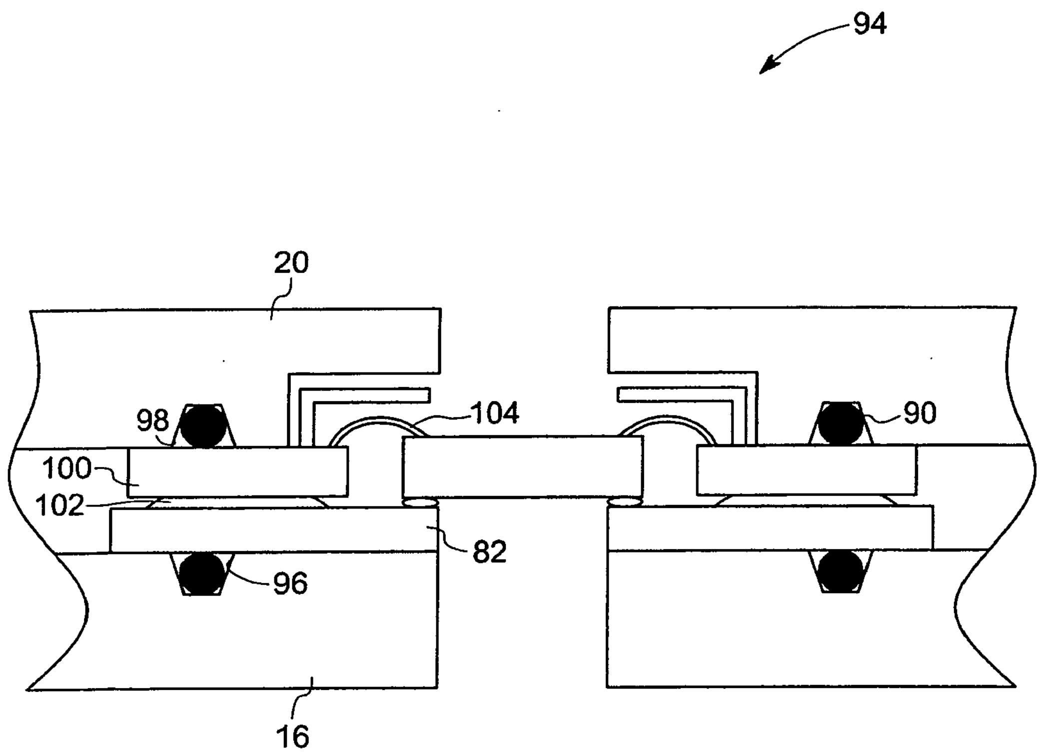

FIG.9

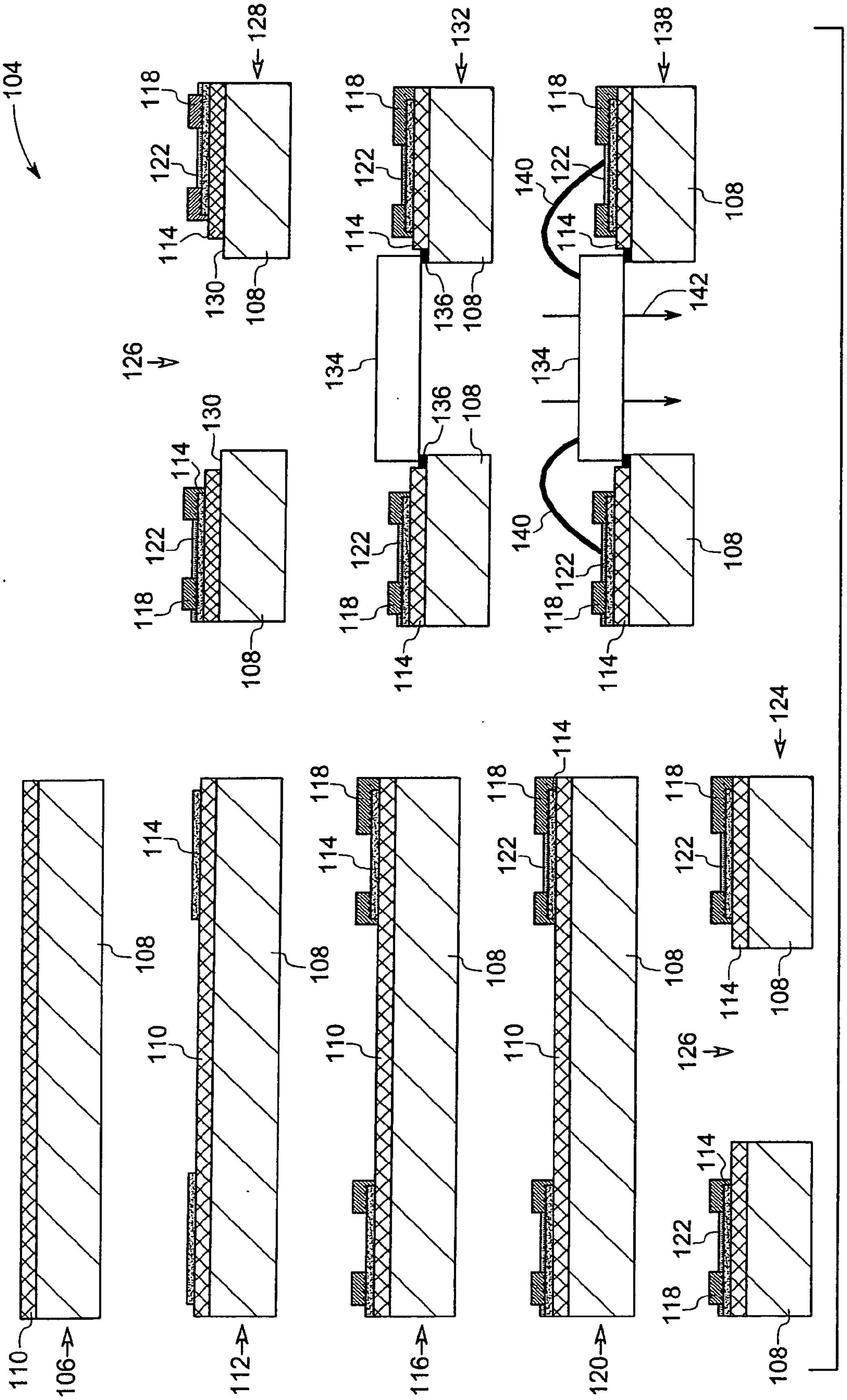

FIG.10

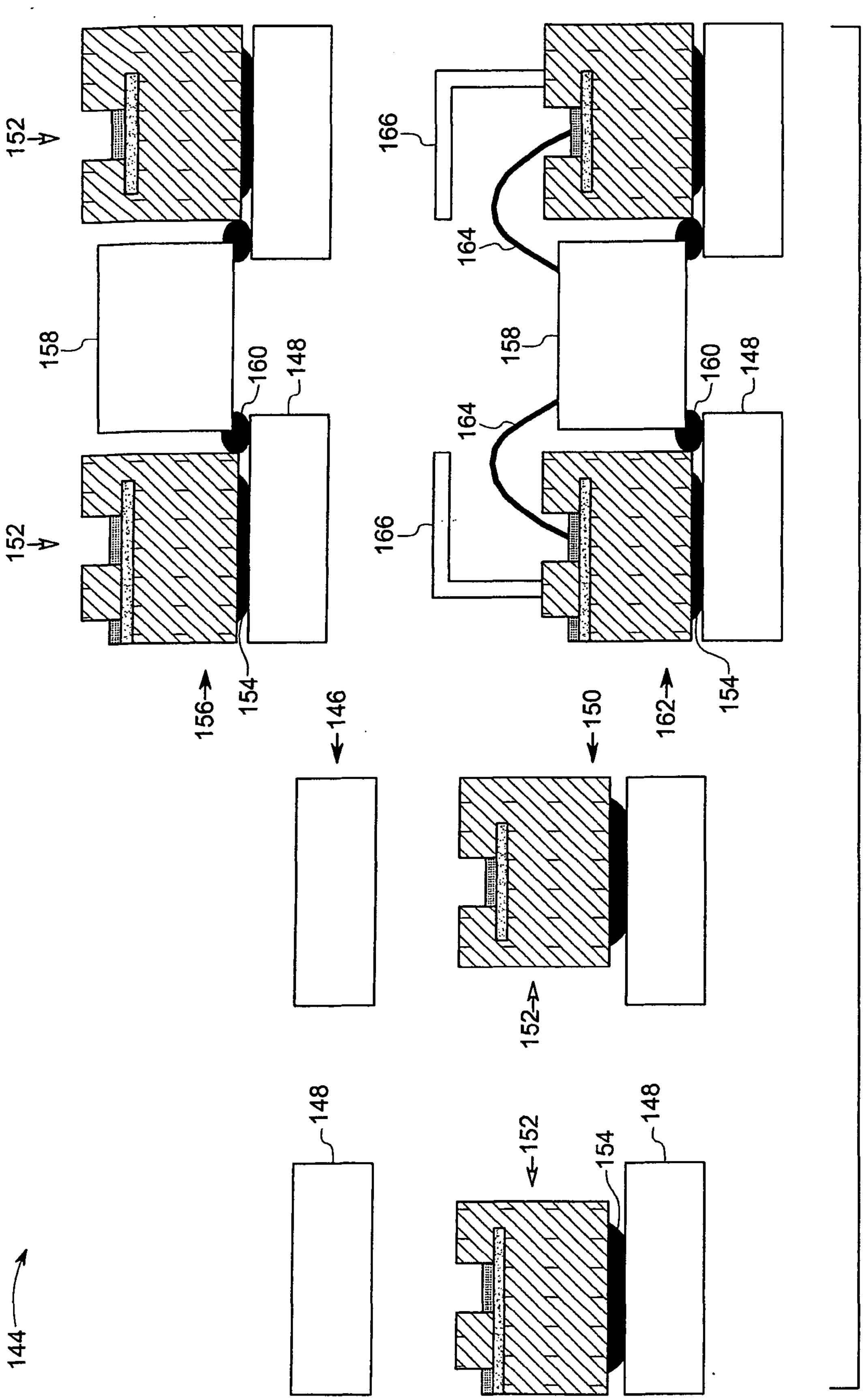

FIG.11