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[54] **FLUIDIC APPARATUS FOR AIR-CONDITIONING SYSTEM**

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[*] Notice: The portion of the term of this patent subsequent to Aug. 1, 1989, has been disclaimed.

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[21] Appl. No.: **276,014**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 101,901, Dec. 28, 1970, Pat. No. 3,680,776, which is a continuation-in-part of Ser. No. 839,313, July 7, 1969, abandoned.

[52] **U.S. Cl.** **236/49;** 137/805; 137/826

[51] **Int. Cl.²** **F24F 7/00**

[58] **Field of Search** 137/805, 826, 8; 236/49, 236/79; 137/597

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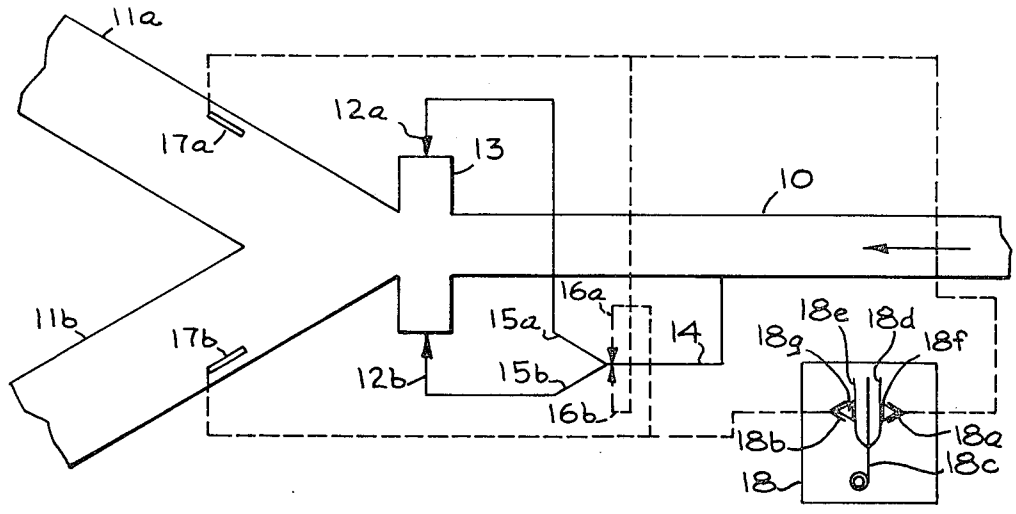
[57] **ABSTRACT**

The present invention provides a fluidic oscillator in an air-conditioning system to deliver bursts of air at full volume as the terminal unit oscillates in response to the room thermostat. These bursts of air, short or long, would fulfill the register's volume requirements, thus maintaining full room comfort.

46 Claims, 8 Drawing Figures



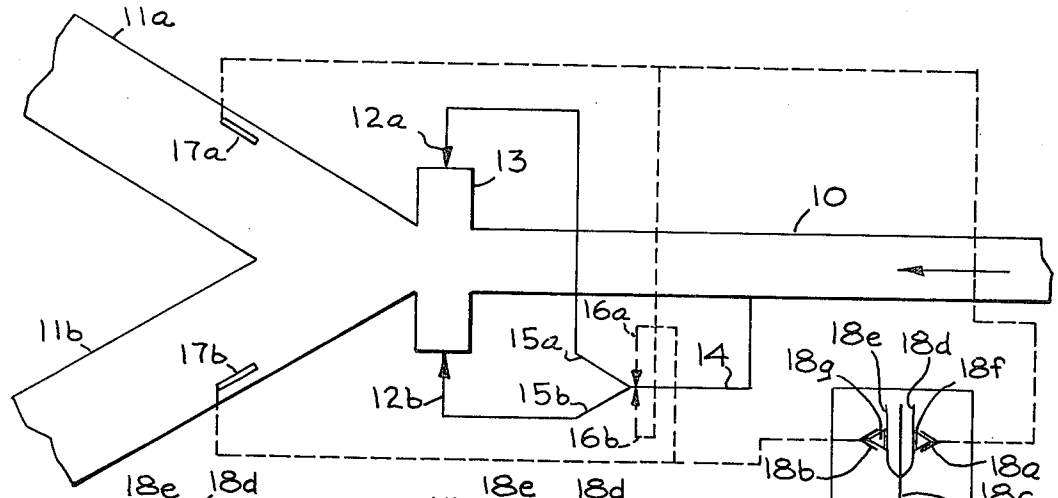


Fig. 1

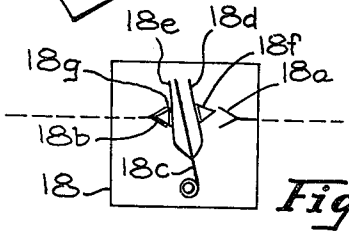


Fig. 1(a)

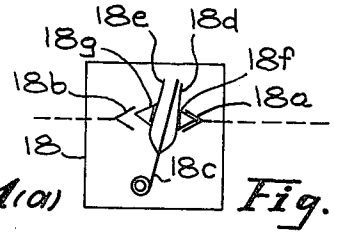


Fig. 1(b)

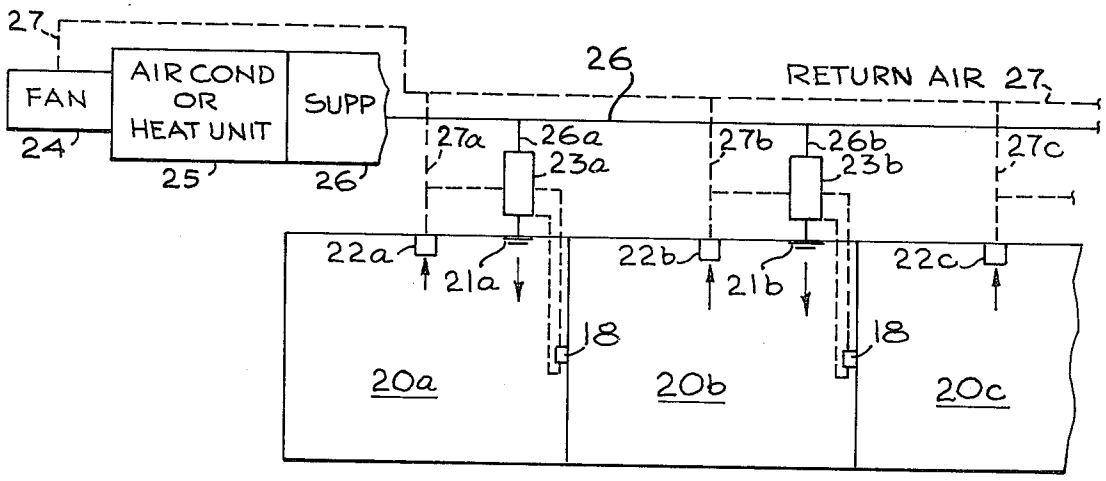


Fig. 2

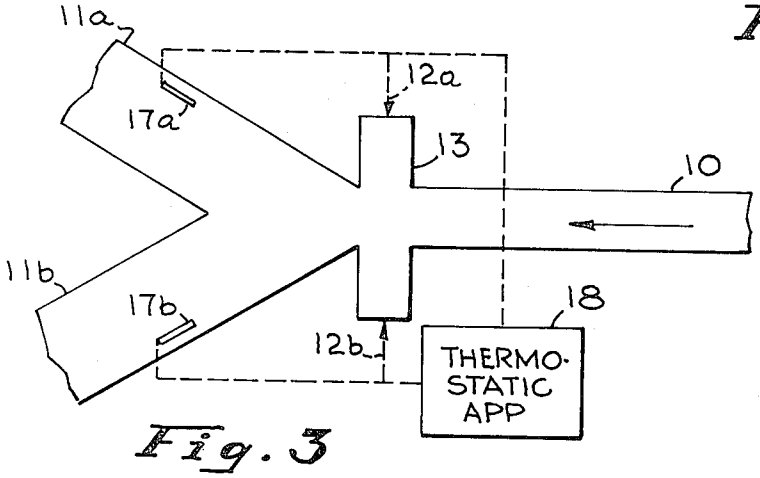


Fig. 3

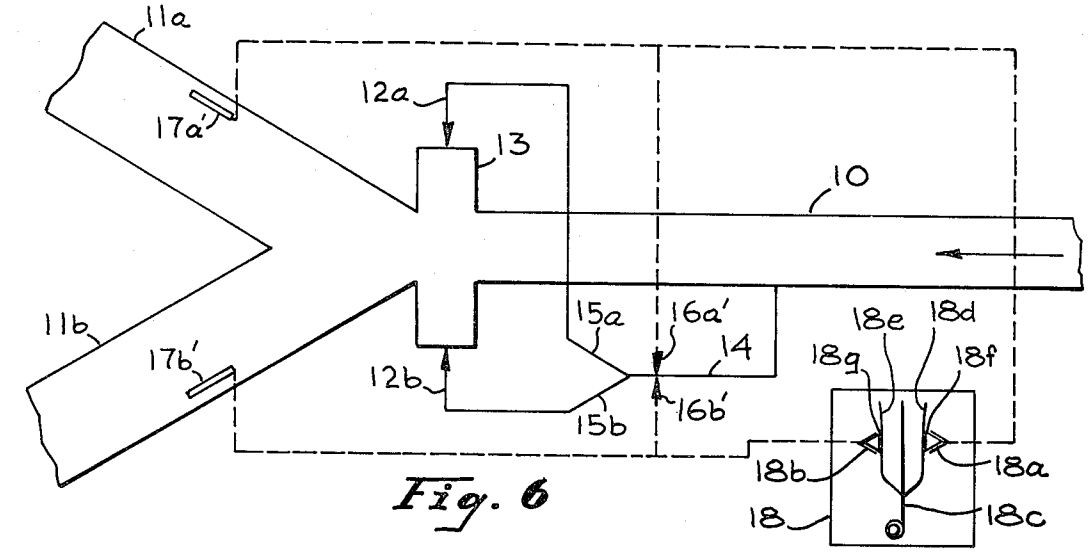


Fig. 6

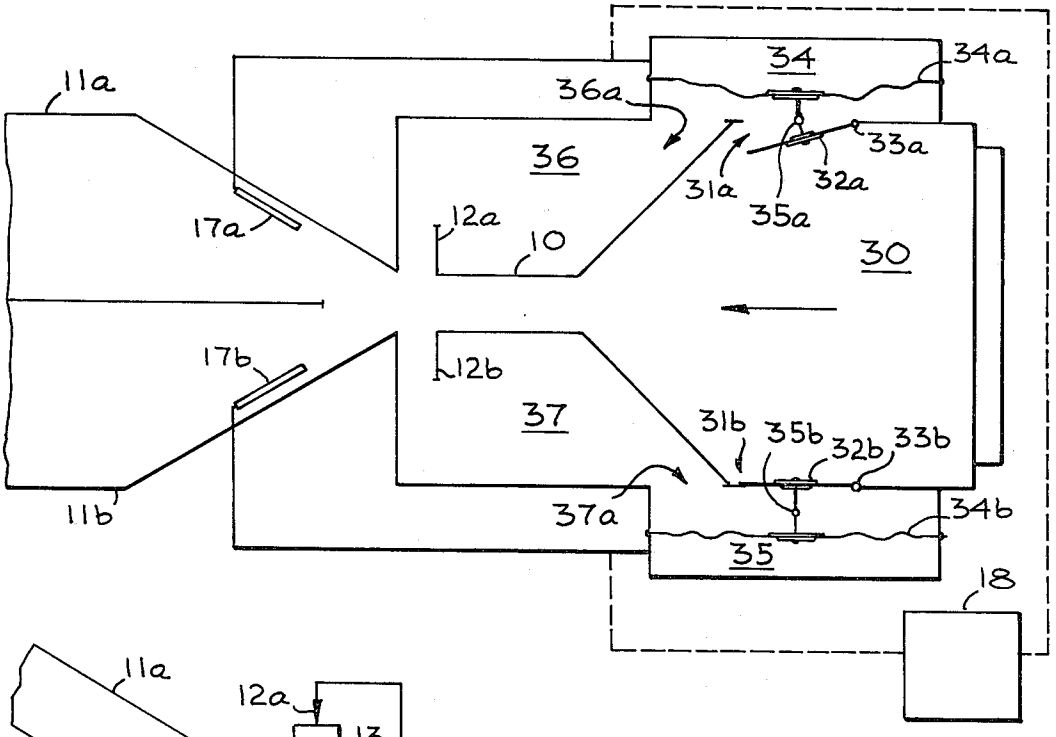


Fig. 5

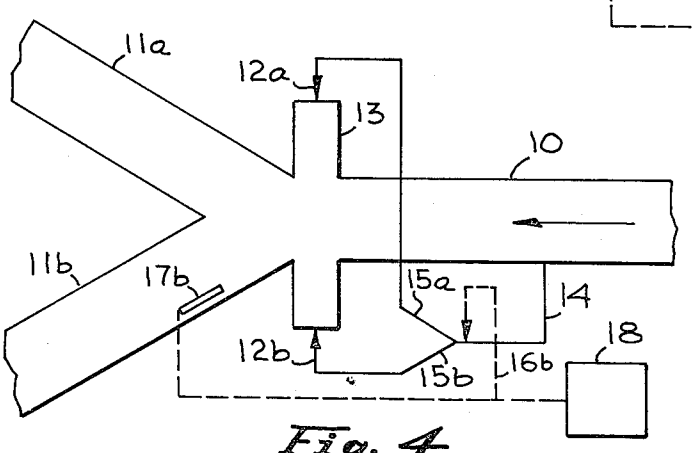


Fig. 4

FLUIDIC APPARATUS FOR AIR-CONDITIONING SYSTEM

This application is a continuation-in-part of application Ser. No. **101,901,** filed Dec. **28, 1970** now U.S. Pat. No. **3,680,776** which in turn is a continuation-in-part of application Ser. No. **839,313,** filed July **7, 1969,** now abandoned.

The present invention relates in general to air-conditioning systems and, more particularly, relates to fluidic apparatus for the improvement of air-conditioning systems.

In air-conditioning systems of the kind used in hotels, motels, office buildings, and the like, air flow to the conditioned space is restricted as the thermostat approaches satisfaction and, as is well-known, throttling is the means by which this is done. By throttling is meant that the quantity of air flowing in the supply duct is varied as thermostatically controlled dampers open and close. Unfortunately, however, this throttling of the air flow to the conditioned space produces a pressure imbalance in the system which makes suitable temperature control impossible without employing some form of complicated and relatively expensive apparatus to maintain constant volume control at the fans or discharge terminals. Furthermore, the room register has a fixed opening size governed by throw and sound requirements. As the air flow is restricted under thermostatic control, the register velocity falls below its design point, with the result that proper room conditioning cannot be provided because the air is not thrown across the room. Instead, air just runs out of the register and falls to the floor, thereby causing stratification, drafts and discomfort in the conditioned space.

The present invention, through the use of fluidic devices, is intended to and does alleviate these problems. More particularly, the present invention eliminates throttling altogether and this is achieved by means of fluid amplifier devices that act as by-pass valves. Instead of throttling, each by-pass valve, under control of a room thermostat, simply diverts the air to the return system, thereby providing substantially constant room or zone control. Thus, whereas in prior art systems the quantity of air flowing in the supply duct varies as thermostatically-controlled dampers open and close, in any arrangement according to the present invention once the system is balanced it will thereafter deliver a substantially constant air flow at the register on call from the thermostat.

Furthermore, through the use of certain types and arrangements of fluidic devices, a pulse modulation type of air-conditioning system is provided that will accomplish the same results as variable volume, but with better comfort characteristics. More specifically, because of the inherent flow characteristics of fluidic devices, particularly fluidic oscillators, an air-conditioning system according to the present invention delivers independent bursts of air at full volume as the terminal unit oscillates in response to the room thermostat. These bursts of air, short or long, fulfill the register's volume requirements, thereby maintaining the desired room comfort at all times.

It is, therefore, an object of the present invention to provide a pulse modulation type of air-conditioning system.

It is another object of the present invention to provide an air-conditioning system in which independent bursts of air at full volume are passed through the register.

It is a further object of the present invention to provide a pulse modulating control feature for air-conditioning systems.

It is an additional object of the present invention to provide an air-conditioning device programmed by a room thermostat to deliver bursts of air to the conditioned space.

It is still another object of the present invention to provide fluidic oscillator devices for air-conditioning purposes.

It is another and further object of the present invention to provide an air-conditioning system in which throttling is not used to control the air flow therein.

The novel features which are believed to be characteristic of the invention, both as to its organization and method of operation together with further objects and advantages thereof, will be better understood from the following description considered in connection with the accompanying drawings in which several embodiments of the invention are illustrated by way of example. It is to be expressly understood, however, that the drawings are for the purpose of illustration and description only and are not intended as a definition of the limits of the invention.

FIG. **1** is a first and preferred embodiment of a fluidic oscillator for use in an air-conditioning system according to the present invention, and illustrates the thermostat therein in a neutral or center condition in which both of its valves are closed;

FIG. **1**(*a*) is a schematic diagram of the thermostatic apparatus used in the FIG. **1** embodiment showing the thermostatic valves in one extreme condition, namely, one in which one of the valves is closed and the other fully open;

FIG. **1**(*b*) is a schematic diagram of the same thermostatic apparatus showing the thermostatic valves in another extreme condition, namely, one in which the other of the valves is closed and the first valve fully open;

FIG. **2** is a block diagram of an air-conditioning system in which a fluidic oscillator of the type illustrated in FIG. **1** is utilized;

FIG. **3** illustrates another embodiment of a fluidic oscillator according to the present invention;

FIG. **4** illustrates still a third embodiment of a fluidic oscillator of the monostable type;

FIG. **5** illustrates the use of a membrane in a fourth embodiment of the invention; and

FIG. **6** illustrates a modification of the FIG. **1** embodiment;

For a consideration of the invention in detail, reference is now made to the drawings wherein like or similar parts or elements are given like or similar designations throughout the several figures. Referring first to the fluidic valve arrangement illustratively presented in FIG. **1,** one valve is of the bistable kind and is shown to include an inlet channel **10** through which the stream of conditioned air flows from the air-conditioning system's supply duct, a pair of outlet channels respectively designated **11***a* and **11***b* by means of which the air that enters input channel **10** selectively flows either to the room or zone to be air-conditioned or to the system's return duct, a pair of control channels respectively designated **12***a* and **12***b* by means of which the abovesaid stream of air can be controlled so

as to selectively direct the air to one or the other of the outlet channels, and a chamber **13** located between the inlet and outlet channels and through which the air must pass in going from the inlet channel to the outlet channels. In the embodiment shown, control channels **12***a* and **12** *b* respectively lead to opposite sides of this chamber **13** in order to exercise the desired control over the air flow, as is well known and understood by those skilled in the art and as will more clearly appear later.

This FIG. **1** embodiment also includes a second bistable-type of fluidic valve device that is coupled between inlet channel **10** and the outlet channels **11***a* and **11***b* of the first fluidic valve. This second valve is schematically illustrated in the figure and, like the first device, includes an inlet channel **14,** a pair of outlet channels **15***a* and **15***b*, and a pair of control channels **16***a* and **16***b*. It also includes a chamber between its input and output channels but because the second valve is schematically illustrated, the chamber here cannot be presented. Suffice it to say, therefore, that control channels **16***a* and **16***b* are likewise coupled to opposite sides of this chamber in order to exercise the control on the air flowing through this second device necessary to direct the flow to one or the other of its outlet channels **15***a* and **15***b*. As shown in the figure, inlet channel **14** is coupled to inlet channel **10** so that a small percentage of the air entering input channel **10** is tapped off and enters input channel **14.** As is also shown, outlet channels **15***a* and **15***b* respectively connect to control channels **12***a* and **12***b*, with the result that air entering one or the other of outlet channels **15***a* and **15***b* will flow into and ultimately through its associated control channel to chamber **13.**

Finally, the FIG. **1** embodiment includes a pair of Pitot tubes **17***a* and **17***b* respectively mounted in outlet channels **11***a* and **11***b* and, as shown by the broken lines in the figure, these Pitot tubes are respectively connected to control channels **16***a* and **16***b*. These Pitot tubes are also respectively connected or coupled to a pair of thermostatically-controlled air escape valves **18***a* and **18***b*, the thermostat apparatus as a whole being designated **18.** The thermostat, which is located in the room or zone to be conditioned, includes the well known bi-metallic coiled strip **18***c* which moves in a clockwise or counterclockwise direction according to temperature conditions. In addition to the above, the thermostat also includes a pair of leaf or cantilever type spring members **18***d* and **18***e* on or to which are respectively mounted a pair of stops or elements **18***f* and **18***g* by means of which the valves **18***a* and **18***b* are closed and opened. As can be seen from the figure, members **18***d* and **18** *e* are attached or affixed at one of their ends to strip **18***c* and are free or unattached at the other of their ends, the stops or elements **18***f* and **18***g* being mounted intermediate these ends and in alignment with valves **18***a* and **18***b*.

The thermostatic apparatus schematically illustrated in the figure is well know and widely available in the commercial market place. Accordingly, a more detailed showing of it is not deemed necessary here. Suffice it to say, therefore, that in this kind of thermostatic apparatus, one or the other of escape valves **18***a* and **18***b* is closed or open depending upon the position of bi-metallic strip **18***c*, but in no event will both of them be open simultaneously. In this regard, it will be recognized that both valves may, however, be closed simultaneously. Further details concerning the construction and operation of thermostatic apparatus **18** will be provided as needed hereinbelow in connection with the described operation of the FIG. **1** embodiment.

Considering now the operation of this first embodiment, it will be assumed that outlet channel **11***a* leads to the room or zone to be conditioned, that outlet channel **11***b* leads to the air-conditioning system's return duct, and that the air flowing through the device, for example cold air, is initially exiting through outlet channel **11***b*. It will also be initially assumed that in the second fluidic valve device, the conditioned air flowing therethrough is exiting through outlet channel **15***a* and from this outlet channel to control channel **12***a* where it enters chamber **13** to impinge against one side of the main stream of conditioned air passing therethrough. Finally, it will be initially assumed that the temperature in the room or the zone to be conditioned is such that in the thermostat located therein, namely, thermostat **18,** bi-metallic strip **18***c* is in its center position, that is to say, in the position shown in FIG. **1,** with the result that valves **18***a* and **18***b* are both closed.

Accordingly, with these assumptions in mind, a small portion of the air flowing in outlet channel **11***b* is picked up by Pitot tube **17***b* wherein it then travels both to control channel **16***a* and to valve **18***b*. Since, as previously assumed, valve **18***b* is closed, this air that is fed back to it cannot escape and it therefore enters control channel **16***a* wherein the full force thereof is applied to the stream flowing through the chamber of this second fluidic device. As a result and in accordance with well known and established fluidic principles, the direction of this second stream of air is switched from outlet channel **15***a* to outlet channel **15***b*. When this happens, this second stream of air is then directed through control channel **12***b* against the main stream flowing through chamber **13** and this, in turn, causes the main stream to switch its flow from outlet channel **11***b* to outlet channel **11***a*. As desired, the conditioned air is now going to the room or zone to be conditioned.

However, it will be recognized that just as soon as the air begins to flow in outlet channel **11***a*, Pitot tube **17***a* picks up a small portion of this air and channels it back both to control channel **16***b* and to valve **18***a*. Since valve **18***a* is also completely closed, the air thusly sent back likewise cannot escape through valve **18***a* and, therefore, the air ends up entering control channel **16***b* wherein the full force thereof is once again applied to the stream flowing through this second fluidic device to switch it from outlet channel **15***b* back to outlet channel **15***a*. When this occurs, this second stream of air is once again directed through control channel **12***a* to chamber **13,** thereby causing the main air stream to return to its initially assumed flow pattern, namely, to outlet channel **11***b*.

The cycle of operation described above repeats itself over and over again so long as thermostat strip **18***c* is centered and both thermostat valves thereby closed. In short, the two fluidic devices and the thermostat cooperate to produce a pulsed oscillation in which the main air stream switches back and forth equally between oulet channels **11***a* and **11***b* and, therefore, equally between the room or zone to be conditioned and the system's return duct. Under the conditions just described, namely, where both thermostatic valves **18***a* and **18***b* are closed, the pulses are of equal duration. It should also be mentioned that in accordance with the concept

of the invention, the pulses of air to the room or zone to be conditioned are always injected at full volume.

For a further understanding of the operation of the present invention, assume now that bi-metallic strip **18***c* is in its extreme counterclockwise position, as is illustrated in FIG. **1**(*a*). In this position of strip **18***c*, valve **18***b* is closed and valve **18***a* is totally open. As before, it will also be assumed that the conditioned air is initially exiting through outlet channel **11***b* to the system's return duct. Accordingly, a small portion of the air flowing in outlet channel **11***b* is picked up by Pitot tube **17***b* by means of which it then flows both to control channel **16***a* and valve **18***b*. However, since valve **18***b* is closed, this air that is fed back enters control channel **16***a* to cause the second stream of air to switch from outlet channel **15***a* to outlet channel **15***b*. when this happens, this second stream of air is directed through control channel **12***b* into chamber **13** where it impinges against the main air stream flowing therethrough to cause it to switch from outlet channel **11***b* to outlet channel **11***a* and from thence to the room or zone to be conditioned.

With the main stream of air now flowing in outlet channel **11***a*, Pitot tube **17***a* picks up a small portion of this air and feeds it back to control channel **16***b* and valve **18***a*. However, since valve **18***a* is now completely open, the air fed back to it by Pitot tube **17***a* escapes through it, with the result that very little if any of this air enters control channel **16***b*. Consequently, the main stream of air does not switch back to outlet channel **11***b* but, rather, continue to flow through outlet channel **11***a*, and it continues to flow through outlet **11***a* to the room or zone to be conditioned so long as valve **18***a* remains in this completely open state. In other words, so long as valve **18***a* is entirely open, **100%** of the conditioned air goes to the room or zone to be conditioned and **0%** goes to the return duct. Of course, valve **18***a* does not remain completely open for too long a time under these conditions, but what happens when valve **18***a* is neither fully closed nor open but, rather, somewhere in between, will be taken up later.

Considering now the operation with the bi-metallic strip **18***c* in its extreme clockwise position, as is illustrated in FIG. **1**(*b*), which means that valve **18***b* is now the one that is totally open, and assuming again that the conditioned air is initially exiting through outlet channel **11***b*, a small portion of the air flowing through outlet channel **11***b* is picked up by Pitot tube **17***b* and fed back to control channel **16***a* and valve **18***b*. In this instance, however, valve **18***b* is fully open and valve **18***a* closed, with the result that all the air fed back to valve **18***b* by Pitot tube **17***b* escapes through the valve. In consequence thereof, extremely little if any of this air enters control channel **16***a*, so that the air streaming through the second fluidic device continues to flow through its outlet channel **15***a* instead of flipping to outlet channel **15***b*. As will immediately be recognized, therefore, the main stream of air likewise continues to flow through outlet channel **11***b* to the system's return duct, and this will continue so long as valve **18***b* remains in this fully open state. Thus, under these conditions, namely, with valve **18***a* closed and valve **18***b* fully open, **100%** of the conditioned air goes to the return duct and **0%** goes to the room or zone to be conditioned. Here again, of course, valve **18***b* doesn't remain fully open for very long but, rather, moves towards some condition that is intermediate being fully open or closed.

Thus far, the operation has been described with valves **18***a* and **18***b* both closed, with valve **18***a* fully open and valve **18***b* closed, and with valve **18***a* closed and valve **18***b* fully open, and it was explained that when both valves are closed, the embodiment oscillates with equal pulses of air alternately being directed through outlet channels **11***a* and **11***b*, that when valve **18***a* is fully open the air flows in a D.C. (Direct Current) pattern through outlet channel **11***a*, and that when valve **18***b* is fully open the air flows in a D.C. pattern through outlet channel **11***b*. It was also explained that the two last mentioned conditions don't remain that way very long and that after awhile an intermediate condition is reached as determined by temperature considerations.

More particularly, when strip **18***c* is somewhat left of center, that is to say, has moved somewhat in a counterclockwise direction, so that valve **18***b* is closed and valve **18***a* is somewhere between being closed and fully open, a constriction exists at valve **18***a* so that the air fed back to it by Pitot tube **17***a* cannot escape as easily as it did before when valve **18***a* was fully open. As a result, some of this air enters control channel **16***b* and a back pressure begins to build there, and when this pressure reaches the appropriate level it causes the stream of air in outlet channel **15***b* to flip or switch to outlet channel **15***a* which, in turn, causes the main stream of air in outlet channel **11***a* to flip or switch to outlet channel **11***b*, as previously described. The abovesaid appropriate pressure level to bring about these changes is determined by the design considerations of the fluidic devices, as will be recognized by those skilled in the art.

With the main air stream now flowing in outlet channel **11***b*, some aie will be fed back by Pitot tube **17***b*, as already mentioned. However, with valve **18***b* closed, the air immediately enters control channel **16***a* and, as previously described in detail, this quickly leads to the main air stream being switched back to outlet channel **11***a*. Hence, with valve **18***b* closed and valve **18***a* being neither closed nor fully open, once again a pulsed or pulse modulated operation exists but this time, however, the pulses are not of equal duration as they were when both valves were closed. Rather, an oscillation exists in which unequal bursts or pulses of air emanate from outlet channels **11***a* and **11***b*, a relatively short pulse out of outlet channel **11***b* to the return duct and a longer pulse out of outlet channel **11***a* to the room or zone to be conditioned. Of course, the relative pulse durations will depend on the position of strip **18***c* which, in turn, will depend on the temperature conditions in the room or zone to be conditioned. For example, in this kind of situation, the air exiting from outlet channels **11***a* and **11***b* may be doing so at an **80** to **20** ratio, **80%** of the air through outlet channel **11***a* and **20%** of the air through outlet channel **11***b*, or in a **60** to **40** ratio, **60%** of the air through outlet channel **11***a* and **40%** of it through outlet channel **11***b*, etc., the particular ratio of these pulses of air at any time depending on how nearly the thermostatic conditions of the room or zone to be conditioned are satisfied. Needless to say, the further away they are from being satisfied, the longer the pulses through outlet channel **11***a*, but they become shorter and shorter as the temperature conditions in the room or zone to be conditioned approach the thermostatic setting in that room or zone. At the

end, when the temperature conditions in the room or zone are substantially the same as the pre-set thermostatic conditions, the pulses of conditioned air to the room or zone will only be long enough to maintain this substantially satisfied state.

Finally, considering the situation when strip **18***c* is somewhat to the right of center, that is to say, has moved somewhat in a clockwise direction, so that valve **18***a* is closed and valve **18***b* is somewhere between being closed and fully open, a constriction now exists at valve **18***b* so that the air fed back to it by Pitot tube **17***b* cannot escape freely as it did when the valve was fully open. Accordingly, for the same reasons as previously presented in connection with valve **18***a*, namely, a buildup in pressure to the appropriate level, the air flowing through outlet channel **15***a* flips to outlet channel **15***b* and, when this occurs, the air flowing through outlet channel **11***b* flips to outlet channel **11***a*. At this point, Pitot tube **17***a* feeds back air to control channel **16***b* and valve **18***a* which is closed, with the result that the air flow in outlet channel **15***b* flips back to outlet channel **15***a*. Correspondingly, the main air flow flips back to outlet channel **11***b* and the whole above-described cycle starts all over again. Thus, here again, an oscillatory condition exists in which bursts or pulses of air of unequal duration emanate from outlet channels **11***a* and **11***b* with the pulses out of outlet channel **11** *a* being of shorter duration than those out of outlet channel **11***b*. As before, the relative pulse durations will depend on the position of strip **18***c* at any one time which, it will be remembered, depends on the temperature conditions in the room or zone to be conditioned as compared to the temperature to which thermostat **18** has been set.

It should be mentioned that whether valve **18***a* or valve **18***b* is open is determined by whether the thermostat is set to a temperature that is below the temperature of the room or zone to be conditioned or above it. More specifically, valve **18***b* will be closed and valve **18***a* open if the thermostat is set below the temperature in the room so that the longer pulses of conditioned air will enter the room or zone. On the other hand, valve **18***a* will be closed and valve **18***b* open when the thermostat is set above the temperature in the room. In this latter case, it will be the shorter pulses of conditioned air that go to the room or zone.

Finally, it should also be mentioned that although the operation of the embodiment was described using cold air, the same applies using hot air as the conditioned air.

Reference is now made to FIG. **2** wherein the utility of a device according to the present invention, such as the FIG. **1** embodiment, is illustrated in an overall air-conditioning system in which a number of rooms or zones to be conditioned are designated **20***a*, 20*b*, 20*c*, etc. The thermostats in the rooms or zones are of the same type as thermostat **18** in FIG. **1** and they are, therefore, likewise designated **18** in FIG. **2.** In each room there are also input and return ports or registers, the input registers in the several rooms respectively being designated **21***a*, 21*b*, etc. and the return registers therein respectively being designated **22***a*, 22*b*, 22*c*, etc. In or in close proximity to each room or zone is a fluidic valve arrangement according to the present invention, for example the fluidic valve device shown in FIG. **1,** and these are respectively designated **23***a*, 23*b*, etc. Finally, as is usually the case, the system includes a fan **24,** a cooling or heating unit **25,** a supply duct **26,** and a return duct **27.** Supply duct **26** is the main supply duct, but there are also tributary supply ducts leading to the input channels of fluidic devices **23***a*, 23*b*, etc. and these tributary supply ducts are respectively designated **26***a*, 26*b*, etc. Similarly, there are tributary return ducts and these are respectively designated **27***a*, 27*b*, 27*c*, etc. As is shown in the FIGURE, return duct **27** is coupled to fan **24** and its tributary ducts are respectively coupled both to the return registers and to one of the outlet channels in the fluidic devices, such as outlet channel **11***b*, in FIG. **1.** On the other hand, the other of the outlet channels of the various fluidic devices, such as outlet channel **11***a*, in FIG. **1,** are respectively coupled to the input registers by means of which the conditioned air is fed to the various rooms or zones. By the same token, the air leaves the rooms or zones by way of the abovesaid output registers.

Assuming that the FIG. **1** embodiment is being used in the FIG. **2** system, each of the fluidic devices **23***a*, 23*b*, etc. is exactly as shown in FIG. **1** and functions the same way too. Thus, conditioned air is fed into the input channels of fluidic devices **23***a*, 23*b*, etc. and this is respectively done via ducts **26***a*, 26*b*, etc. Similarly, this air that flows through these fluidic devices respectively flows either to rooms **20***a*, 20*b*, etc. by way of input registers **21***a*, 21*b*, etc. or else back to return duct **27** via ducts **27***a*, 27*b*, 27*c*, etc. Of course, this is all done under the respective control of thermostats **18** and in just the same manner as was described in connection with FIG. **1.** It should be pointed out, however, and most emphatically so, that each of the fluidic devices acts independently of every other such device, which means not only that they may be operating out of phase with one another but also that their cycle times may be different. It all depends upon the needs of each room or zone to be conditioned, as detected by the thermostat in each room or zone.

For sake of convenience and clarity, it is considered worthwhile to proceed now to FIG. **6** wherein a modified version of the FIG. **1** embodiment is shown. More particularly, the arrangement in FIG. **6** is identical with that of FIG. **1** except in two respects, namely, the direction of Pitot tubes **17***a* and **17***b* have been reversed which, in turn, has necessitated a corresponding reversal in the coupling of control channels **16***a* and **16***b* with the chamber in the second fluidic valve in the embodiment. Stated differently, whereas Pitot tubes **17***a* and **17***b* point upstream in FIG. **1,** they point downstream in FIG. **6** and for this reason are designated **17***a'* and **17***b'* instead. Thus, whereas Pitot tubes **17***a* and **17***b* scoop up a small amount of air that may be flowing in outlet channels **11***a* and **11***b* to produce or apply positive pressures via control channels **16***a* and **16***b*, Pitot tubes **17***a'* and **17***b'*, by virtue of the fact that they point downstream, have partial vacuums or negative pressures created in them instead that are then applied through control channels **16***a'* and **16***b'*. What this means is that instead of the air stream being switched from outlet channel **15***a* to **15***b*, or vice versa, by a pushing action, it is switched instead by a pulling action and it is for this reason that it was necessary to reverse the coupling of the control channels, as abovesaid. However, aside from these two variations, the rest of the structure is arranged the same and functions the same as heretofore described and, therefore, its use in the FIG. **2** system should be apparent. Accordingly, no

further description of the FIG. 6 species is deemed necessary.

An embodiment of the invention similar to those shown in FIGS. 1 and 6 but somewhat simpler in its construction and operation is shown in FIG. 3 to which reference is now made. As shown, the fluidic device therein, as before, includes an inlet channel 10 by means of which the stream of air enters the device from the air-conditioning system's supply duct (element 26 in FIG. 2), a pair of outlet channels 11*a* and 11*b* respectively leading to the room or zone to be conditioned and to the air-conditioning system's return duct (element 27 in FIG. 2), a pair of control channels 12*a* and 12*b*, a chamber 13 disposed between the inlet and outlet channels and to which the control channels are coupled so that pressures can be exerted on opposite sides of the air stream flowing therethrough, a pair of Pitot tubes 17*a* and 17*b* respectively mounted in outlet channels 11*a* and 11*b* and respectively coupled to control channels 12*a* and 12*b*, and, finally, thermostatic apparatus 18 of the kind schematically shown in FIG. 1 and previously described in connection therewith. As is illustrated in the figure, this thermostatic apparatus (specifically the valves 18*a* and 18*b* therein) is coupled to the junctions of control channels 12*a* and 12*b* with Pitot tubes 17*a* and 17*b*.

In its operation it will again be assumed initially that the air stream is passing through outlet channel 11*a* to the room or zone to be conditioned and that the switch to this outlet channel has just occurred. It will also be assumed that thermostatic valve 18*a* is substantially fully open and thermostatic valve 18*b* closed. As a result, the air picked up by Pitot tube 17*a* passes mostly out through open valve 18*a* and, therefore, insufficient pressure is exerted through control channel 12*a* to cause the stream to switch back to outlet channel 11*b*. However, as the room or zone is cooled (or heated), the valve 18*a* is gradually closed in the manner previously explained. As a result, less of the air from the Pitot tube now escapes through valve 18*a* and, correspondingly, more of the air enters the control channel. As a further result, the pressure in control channel 12*a* and against the main air stream flowing through chamber 13 gradually increases until, at the desired temperature level in the room or zone, the pressure is sufficiently great to cause the air stream to flip over to the other side of the chamber and begin its flow through outlet channel 11*b* which, it will be remembered, carries the air to the return duct.

As will be readily be recognized, a similar operation occurs while the air is flowing through outlet channel 11*b* and thermostatic valves 18*a* and 18*b* are respectively closed and open. In this instance, as the temperature in the room or zone to be conditioned changes, valve 18*b* gradually closes and this continues until the air pressure in control channel 12*b* is sufficiently great so that when exerted against the air stream in chamber 13, it causes the stream to once again flip or switch over, this time to outlet channel 11*a*.

In the third situation, namely, when thermostatic valves 18*a* and 18*b* are both closed, the fluidic device will oscillate with equal pulse periods, that is to say, the air stream will flip back and forth between outlet channels 11*a* and 11*b* and the duration of the air stream in each channel will be substantially the same.

From this relatively brief description of the FIG. 3 embodiment it will be recognized that although this embodiment is more simply constructed than the FIGS. 1 and 6 embodiments heretofore described in detail, it nevertheless provides a pulse-modulation type of air-conditioning system in which the conditioned air, always at full force, enters the room or zone as needed. As before, the pulse periods will depend on the state of the thermostatic valves, that is to say, on whether they are closed or open and if one is open, the degree or extent to which it is open. This has all been described and explained before and since the substance of the prior description and explanation is applicable here in connection with the FIG. 3 embodiment, much of the specific detail has been omitted at this point to avoid being overly redundant.

It will also be recognized from the earlier discussion herein that by reversing both the orientation of the Pitot tubes 17*a* and 17*b* and the coupling of control channels 12*a* and 12*b* with chamber 13, the device can be modified to operate on the basis of a partial vacuum or negative pressure, as in the case of the FIG. 6 arrangement.

A third embodiment of a fluidic device adapted for air-conditioning purposes is illustrated in FIG. 5 and, as shown therein, includes the usual inlet channel 10, outlet channels 11*a* and 11*b*, control channels 12*a* and 12*b*, Pitot tubes 17*a* and 17*b*, and thermostatic apparatus 18 comprising the air escape valves 18*a* and 18*b* and the bi-metallic bar 18*c*. However, this third embodiment also includes a supply chamber, generally designated 30, which tapers down to and connects with inlet channel 10, the air from the supply duct first entering this supply chamber. On opposite sides of this chamber 30 are a pair of openings or ports respectively designated 31*a* and 31*b*, and a corresponding pair of hinged doors or closure devices 32*a* and 32*b* by means of which the ports can be opened or closed. In the present instance, the hinges for these devices are shown located at 33*a* and 33*b*. Further included in this third embodiment are a pair of variablevolume or variably-sized chambers generally designated 34 and 35, the variable nature of these chambers being made possible because each includes, as a wall or as part of a wall thereof, a membrane capable of expanding and contracting according to the above-ambient pressure therein. These membranes are respectively designated 34*a* and 34*b* and, as shown in the figure, are coupled to closure devices 32*a* and 32*b* by means of mechanical linkages 35*a* and 35*b*. As will be seen later, under the influence of membranes 34*a* and 34*b*, closure devices 32*a* and 32*b* are respectively opened and closed with the aid of these linkages 35*a* and 35*b*.

Finally, the FIG. 5 embodiment includes a pair of intermediate chambers, generally designated 36 and 37, that respectively couple, first, to opposite sides of chamber 13 and, second, to opposite sides of chamber 30. In the latter instance, the coupling is achieved via ports 31*a* and 31*b* and, for this reason, chambers 36 and 37 respectively have a pair of openings 36*a* and 37*a* to provide a clear passageway to these ports, as is shown in the FIGURE. Pitot tubes 17*a* and 17*b* are respectively intercoupled with variable chambers 34 and 35 as well as with thermostatic valves 18*a* and 18*b*, so that air from the Pitot tubes will either enter the chambers or escape through the valves.

Considering now the operation of this embodiment, it will be assumed at the outset that air is flowing in outlet channel 11*a* and, therefore, that some of this air is

being channeled back to the vicinity of chamber **34** via Pitot tube **17***a*. However, assuming that thermostatic valve **18***a* is closed, or substantially closed, this air that is channeled back therefore enters chamber **34** and causes membrane **34***a* to expand. With this expansion, closure device **32***a* is forced to swing open, thereby exposing port **31***a* to the air entering supply chamber **30.** As a result, a portion of the incoming air, as determined by the extent that port **31***a* is exposed, passes through port **31***a* and opening **36***a* into chamber **36** and from there into control channel **12***a* wherein it is directed against the main air stream flowing through the chamber of this device. As more and more air is fed back into chamber **34,** membrane **34***a* expands more and more and closure device **32***a* also opens more and more, with the result that more and more air is directed into control channel **12***a* and against the mainstream. Accordingly, as the pressure builds up, a point is reached when the mainstream switches from outlet channel **11***a* to outlet channel **11***b* and back to the return duct. This point is reached when the room or zone is at the desired level of conditioning.

With the switching of the stream, if valve **18***b* is closed, the air tapped off by Pitot tube **17***b* enters chamber **35** and the process, as previously described, is repeated. More particularly, membrane **34***b* expands and thereby forces closure device **32***b* to swing open which, in turn, exposes port **31***b* to the air in chamber **30.** As previously explained, an ever increasing amount of air enters control channel **12***b* and, therefore, an ever increasing amount of pressure is brought to bear against the mainstream At substantially the right moment, the main air stream once again switches to outlet channel **11***a* and flows to the room or zone to be conditioned.

Following this last switch and in the manner previously described, chamber **35** will return to its normal or unexpanded state and chamber **34** will once again enlarge to respectively close and open ports **31***b* and **31***a*. A complete cycle of operation when thermostatic valves **18***a* and **18***b* are both closed has thus been described. However, enough of an understanding of the operation has been provided to permit anyone skilled in the art to realize that the overall operation of this embodiment is basically the same as those previously described. Accordingly, it is not deemed necessary to again describe the operation with one thermostatic valve open and the other one closed.

A last embodiment of the present invention is illustrated in FIG. **4** and involves a fluidic oscillator of the monostable type. More particularly, in this embodiment, the first fluidic element is of the bistable type, but the second fluidic element is biased so that the air flowing in its inlet channel **14** will normally flow into its outlet channel **15***a* and from there to control channel **12***a*. As a result, the main air stream will normally flow through outlet channel **11***b*. Assuming that outlet channel **11***b* leads to a return duct, when the conditions are right, the conditions being among those already described, the air entering Pitot tube **17***b* also enters control channel **16***b* which has the effect of switching the stream in that fluidic element from outlet channel **15***a* to outlet channel **15***b*. When this happens, the air in outlet channel **15***b* enters and passes through control channel **12***b* of the larger fluidic element to chamber **13** where it impinges against the mainstream therein to cause it to switch to outlet channel **11***a*. As has already been mentioned, the air in outlet channel **11***a* is directed to the room or zone to be conditioned.

Under the control of the thermostat and the valves therein, the air will continue to flow in outlet channel **11***a* until the room or zone is conditioned to the desired level, at which point the pressure in control channel **16***b* will drop sufficiently to permit the air stream in outlet channel **15***b* to return to outlet channel **15***a*. When this occurs, the main air stream will likewise be returned to outlet channel **11***b* until the conditions again exist for the process to again be initiated.

In connection with this FIG. **4** embodiment, it will be recognized that it may be modified in the same manner as that in FIG. **1,** namely, by reversing the orientation of the Pitot tube and reversing the point of connection of the control channel to employ vacuum or negative pressure rather than positive pressure to switch the air stream from one to the other of the outlet channels.

Although a number of particular arrangements of the invention have been illustrated above by way of example, it is not intended that the invention be limited thereto. Accordingly, the invention should be considered to include any and all modifications, alterations or equivalent arrangements falling within the scope of the annexed claims.

Accordingly, having thus described the invention, what is claimed is:

1. A method of conditioning the air in an open space comprising: providing a source of continuously flowing conditioned air under pressure; directing a plurality of pulses of said conditioned air from said source to said space; and varying the duration of said pulses if the ambient air temperature of the space differs from a predetermined reference temperature.

2. A method as set forth in claim **1,** wherein said directing step includes keeping the duration of said pulses substantially uniform when said ambient temperature is substantially the same as said reference temperature.

3. A method as set forth in claim **1,** wherein said varying step includes decreasing the duration of said pulse as said ambient temperature approaches said reference temperature.

4. A method of conditioning the air in a space comprising: directing a flow of conditioned air under pressure from a source along a first path toward said space; directing a plurality of pulses of said conditioned air from said continuous flow into the space; varying the duration of said pulses if the ambient air temperature of the space differs from a predetermined reference temperature; and directing the conditioned air of said flow along a path to the source in bypassing relationship to said space during the intervals between said pulses.

5. A method of conditioning the air in a room comprising: providing a source of conditioned air under pressure; directing a flow of said conditioned air along a first path from said source to said room; sensing the flow of said conditioned air into said room; returning the flow of conditioned air along a second path to said source in bypassing relationship to said room in response to the sensed flow into said room and when the ambient air temperature of the room is within a predetermined range of values relative to a preselected reference temperature; detecting the flow of said conditioned air returned to said source; redirecting said flow of conditioned air to said room in response to said de-

tected flow; and repeating said directing, sensing, returning and detecting steps a plurality of times to cause a plurality of pulses of conditioned air to be delivered to said room.

6. A method as set forth in claim **5,** wherein said sensing step includes generating a positive air pressure signal, said returning step including directing said signal toward a location adjacent to one of said paths and against the flow therethrough to cause said flow to be switched from said first path to said second path.

7. A method as set forth in claim **5,** wherein said sensing step includes generating a negative air pressure signal, said returning step including directing said signal away from a location adjacent to one of said paths and away from the flow therethrough to cause said flow to be switch from said first path to said second path.

8. A method as set forth in claim **5,** wherein said detecting step includes generating a positive air pressure signal, said redirecting step including directing said signal toward a location adjacent to one of said paths and against the flow therethrough to cause said flow to be switch from said second path to said first path.

9. A method as set forth in claim **5,** wherein said detecting step includes generating a negative air pressure signal, said redirecting step including directing said signal away from a location adjacent to one of said paths and away from the flow therethrough to cause said flow to be switched from said second path to said first path.

10. A method as set forth in claim **5,** wherein said sensing and detecting steps include generating first and second positive air pressure signals, respectively, said returning step including directing said first signal toward a location adjacent to one of said paths and against the flow therethrough to cause said flow to be switched from said first path to said second path, said redirecting step including directing said second signal toward a location adjacent to the other of said paths and against the flow therethrough to cause the last-mentioned flow to be switched from said second path to said first path.

11. A method as set forth in claim **5,** wherein said sensing and directing steps include generating first and second negative air pressure signals, respectively, said returning step including directing said first signal away from a location adjacent to one of said paths away from the flow therethrough to cause said flow to be switched from said first path to said second path, said redirecting step including directing said second signal away from a location adjacent to the other of said paths and away from the flow therethrough to cause the last-mentioned flow to be switched from said second path to said first path.

12. A method as set forth in claim **5,** wherein said sensing step includes generating a positive air pressure signal, said returning step including directing said signal along a channel having an orifice capable of being changed in size, and changing the size of the orifice as a function of the difference between said ambient air temperature and said reference temperature.

13. A method as set forth in claim **12,** wherein said changing step includes decreasing the size of said orifice as the ambient air temperature approaches said reference temperature.

14. A method as set forth in claim **5,** wherein said sensing step includes generating a negative air pressure signal, said returning step including directing said signal along a channel having an orifice capable of being varied in size, and changing the size of the orifice as a function of the difference between said ambient air temperature and said reference temperature.

15. A method as set forth in claim **14,** wherein said changing step includes decreasing the size of the orifice as the ambient air temperature approaches said reference temperature.

16. A method as set forth in claim **5,** wherein said sensing step includes generating a first positive air pressure signal, said returning step including directing said signal along a first channel having a first orifice to the atmosphere with the first orifice capable of being changed in size, said detecting step including generating a second positive air pressure signal, said redirecting step including directing said second signal along a second channel having a second orifice to the atmosphere with the second orifice capable of being changed in size, and including the step of changing the size of each orifice as a function of the difference between said ambient air temperature and said reference temperature when the ambient air temperature is on a respective side of said reference temperature.

17. A method as set forth in claim **16,** wherein said first orifice is open when the ambient air temperature differs from and is on one side of said reference temperature, said second orifice being closed when first orifice is open, said second orifice being open when the ambient air temperature differs from and is on the opposite side of said reference temperature, said first orifice being closed when said second orifice is open, said first and second orifices being closed when said ambient air temperature is substantially the same as said reference temperature.

18. A method of conditioning a fluid in an open space comprising: providing a source of said fluid under pressure with said fluid flowing continuously and being conditioned at said source; directing a plurality of pulse of said conditioned fluid from said source to said space; and varying the duration of said pulses if a parameter of the fluid in the space has a value which differs from a predetermined reference value.

19. A method as set forth in claim **18,** wherein said parameter is the temperature of the fluid in said space.

20. A method of conditioning the air in a plurality of spaces comprising: directing a flow of conditioned air under pressure along a first path toward said spaces; directing a plurality of pulses of said conditioned air from said flow into each of the spaces; varying the duration of said pulses directed into each space if the ambient air temperature of the last-mentioned space differs from a predetermined reference temperature; and directing the conditioned air of said flow along a path in bypassing relationship to each of said spaces during the intervals between the pulses directed thereto.

21. A method as set forth in claim **20,** wherein is included the step of providing a source of said conditioned air under pressure for said spaces, the first directing step including periodically placing said source in fluid communication with each space, the second directing step including returning the conditioned air to said source.

22. A method of conditioning the air in a plurality of rooms comprising: providing a source of conditioned air under pressure; directing a flow of said conditioned air along a first path from said source toward and into said rooms; sensing the flow of said conditioned air into each room; returning the flow of conditioned air di-

rected toward each room in bypassing relationship thereto along a second path to said source in response to the sensed flow into the room and when the ambient air temperature therein is within a predetermined range of values relative to a preselected reference temperature; detecting the flow of said conditioned air which bypasses each room and is returned to said source; redirecting the flow of conditioned air into each room in response to the detected flow which bypasses the same; and repeating said directing, sensing, returning and detecting steps a plurality of times for each room, respectively, to cause a plurality of pulses of conditioned air to be delivered thereto.

23. In an air conditioning system having a supply duct and a return adjacent to a space in which air is to be conditioned, apparatus comprising: a bistable fluidic amplifier device having an inlet channel adapted to be coupled to the supply duct, first and second outlet channels adapted to be coupled to said space and said return duct, respectively, a control chamber between said inlet channel and the outlet channels, and a pair of control channels coupled to said control chamber on respective sides of the airflow path therethrough; means coupled with the device for alternately directing first and second air pressure signals to said first and second control channels; and means responsive to the flow of air in at least one of said outlet channels and to a parameter of the air in said space for causing a variation in the rate at which one of the signals is applied to the respective control channel when the value of said parameter differs from a predetermined reference value.

24. In a system as set forth in claim **23,** wherein said causing means includes first structure defining a pair of feedback channels with each feedback channel being coupled to a respective outlet channel, said directing means including second structure defining a passageway for each feedback channel, respectively, each passageway placing the corresponding feedback channel in fluid communication with the corresponding control channel of said device, said causing means further including means coupled with at least one of said feedback channels for venting the same in response to said parameter.

25. In a system as set forth in claim **23,** wherein causing means includes structure defining a feedback channel coupled with one of said outlet channels and operable to generate a positive air presure signal in response to the flow of air through said one outlet channel, and means responsive to said parameter for venting said feedback channel.

26. In a system as set forth in claim **23,** wherein said causing means includes structure defining a feedback channel coupled with one of said outlet channels and operable to generate a negative air pressure signal in response to the flow of air through said one outlet channel, and means responsive to said parameter for venting said feedback channel.

27. In a system as set forth in claim **23,** wherein said directing means includes a monostable fluidic amplifier having an inlet coupled to the inlet channel of said device, a pair of outlets coupled to respective control channels of said device and a pair of control ports to effect switching of the airflow therethrough between said outlets thereof, said causing means including structure defining a feedback channel coupled to one of the outlet channels of said device and one of said control ports, and means responsive to said parameter for venting said feedback channel.

28. In a system as set forth in claim **23,** wherein said directing means includes a bistable fluidic amplifier unit having an inlet coupled to the inlet channel of said device, a pair of outlets coupled to respective control channels of said device, and a pair of control to effect switching of the airflow therethrough between said outlets thereof, said causing means including structure defining a pair of feedback channels with each feedback channel being coupled between a respective outlet channel of said device and a respective control port of said unit, and means responsive to said parameter for venting at least one of the feedback channels.

29. In a system as set forth in claim **28,** wherein said venting means includes a thermostatic valve having one portion for venting a first of said feedback channels when the temperature of said space has a value on one side of a predetermined reference temperature and a second portion for venting the second feedback channel when the temperature of said space has a value on the opposite side of said reference temperature, said valve portions having substantially no venting effect when the temperature of said space is substantially the same as said reference temperature.

30. In a system as set forth in claim **28,** wherein said structure includes means for each feedback channel, respectively, for generating a positive air pressure signal therein in response to the flow of air through the corresponding outlet channel.

31. In a system as set forth in claim **28,** wherein said structure includes means for each feedback channel, respectively, for generating a negative air pressure signal therein in response to the flow of air through the corresponding outlet channel.

32. A fluid handling apparatus comprising: a fluid amplifier having a fluid inlet, a pair of fluid outlets, and a pair of control ports upstream of the fluid outlets for causing a fluid flow through the inlet to be switched back and forth between said outlets in response to fluid signals being alternately applied to said ports; means responsive to the flow of fluid through the amplifier for alternately applying fluid signals to said ports to cause the fluid flow to switch a number of times between said fluid outlets; and means coupled with said applying means and responsive to a parameter of the fluid in a space adjacent to the amplifier for controlling the rate at which the fluid signal is applied to one of the ports.

33. Apparatus as set forth in claim **32,** wherein said applying means includes a bistable fluidic amplifier unit having an inlet coupled to the fluid inlet of said amplifier, a pair of outlets coupled to respective control ports of the amplifier. and a pair of control channels to effect switching of the airflow therethrough between the outlets thereof, and structure defining a feedback channel for each fluid outlet of said amplifier, respectively, each feedback channel being coupled between a respective fluid outlet of the amplifier and a respective control channel of said unit, said controlling means being operable to vent at least one of said feedback channels.

34. Apparatus as set forth in claim **32,** wherein said applying means includes structure defining a feedback channel between each fluid outlet, respectively, and a respective control port, there being an opening in the feedback channel corresponding to said one port, said

controlling means including a device responsive to said parameter for varying the size of said opening.

35. Apparatus as set forth in claim **34,** wherein said device includes a thermostatic element responsive to the ambient temperature.

36. Apparatus as set forth in claim **34,** wherein said applying means includes structure responsive to the flow through each fluid outlet, respectively, and operble to generate a positive air pressure signal in the respective feedback channel.

37. Apparatus as set forth in claim **34,** wherein said applying means includes structure responsive to the flow through each fluid outlet, respectively, and operable to generate a positive air pressure signal in the respective feedback channel.

38. Fluid-handling apparatus comprising: a pair of fluidic amplifiers, each amplifier having a fluid inlet, a pair of fluid outlets, and a pair of control ports for receiving respective fluid pressure signals to cause a fluid flowing through the amplifier to switch back and forth between the outlets thereof, the inlet of each amplifier adapted to be coupled to a source of fluid under pressure, the fluid outlets of one of the amplifiers being coupled to respective ports of the other amplifier; and means responsive to the flow of fluid through said other amplifier for applying a fluid pressure signal to at least one of the ports of said one amplifier.

39. Apparatus as set forth in claim **38,** wherein the inlet of said one amplifier is coupled to the inlet of the other amplifier to receive a portion of the fluid flow therethrough.

40. Apparatus as set forth in claim **38,** wherein said one amplifier is a monostable device, the other amplifier being a bistable device.

41. Apparatus as set forth in claim **38,** wherein each of the amplifiers comprises a bistable device, said applying means including structure for directing a fluid pressure signal to each port, respectively, of said one amplifier.

42. Apparatus as set forth in claim **38,** wherein said applying means includes structure coupled with said other amplifier for developing a positive fluid pressure signal in response to the flow of fluid through one of the outlets thereof.

43. Apparatus as set forth in claim **38,** wherein said applying means includes structure coupled with said one amplifier for developing a negative fluid pressure signal in response to the flow of fluid through one outlet thereof.

44. Apparatus as set forth in claim **38,** wherein said applying means includes structure for each port of said one amplifier, respectively, the structures being coupled with respective outlets of said other amplifier for developing respective fluid pressure signals in response to the flow of fluid through the corresponding outlets of said other amplifier.

45. Apparatus as set forth in claim **45,** wherein each structure is coupled to the corresponding outlet of said other amplifier at a position to cause a positive fluid pressure signal to be developed.

46. Apparatus as set forth in claim **44,** wherein each structure is coupled to the corresponding outlet of said other amplifier at a position to cause a negative fluid pressure signal to be developed.

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