

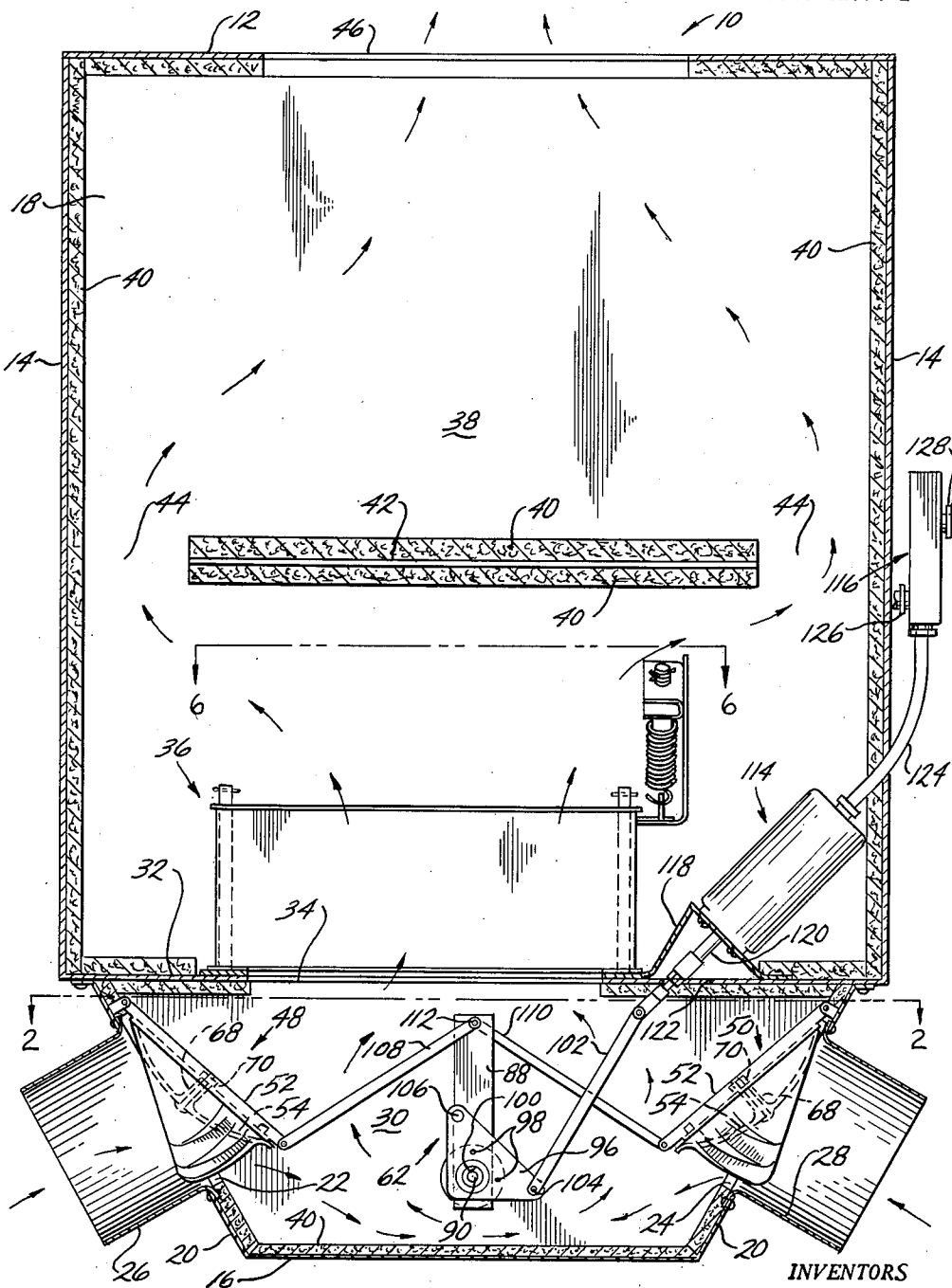
April 9, 1963

L. R. PHILLIPS ET AL
AIR DISTRIBUTION APPARATUS

3,084,711

Filed Jan. 27, 1960

4 Sheets-Sheet 1



INVENTORS
LEONARD R. PHILLIPS, WILLIAM J. WAELDNER
FIG. 1. CARL W. PALMQUIST, RAYMOND S. BARLOW
BY Teller & McCormick
ATTORNEYS

April 9, 1963

L. R. PHILLIPS ET AL

3,084,711

AIR DISTRIBUTION APPARATUS

Filed Jan. 27, 1960

4 Sheets-Sheet 2

FIG. 2.

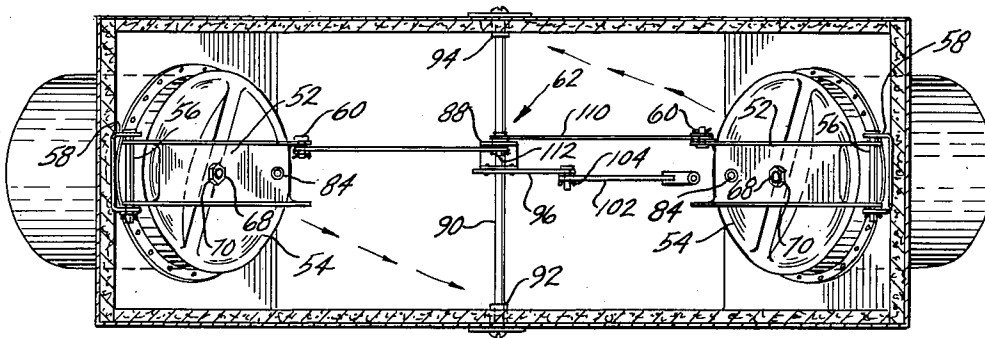


FIG. 3.

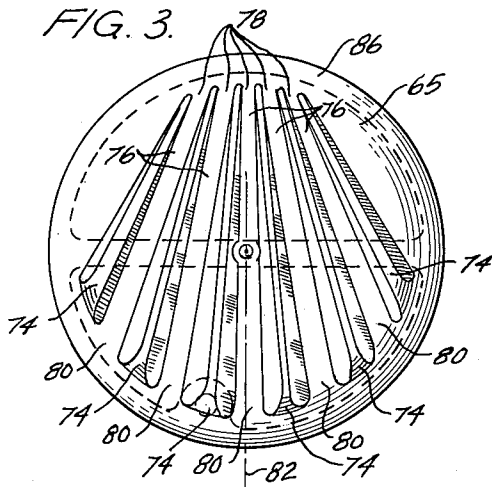


FIG. 4.

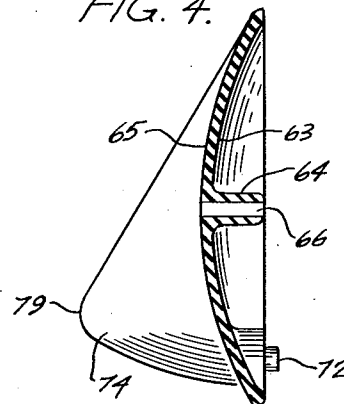
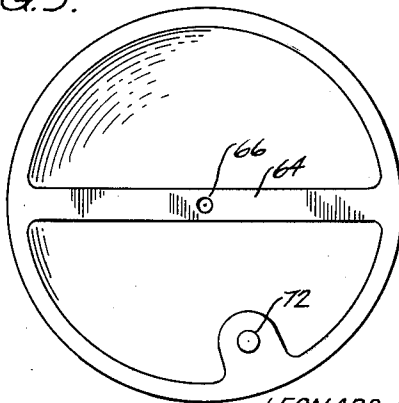


FIG. 5.



INVENTORS

LEONARD R. PHILLIPS, WILLIAM J. WAELDNER
CARL W. PALMQUIST, RAYMOND S. BARLOW
BY Teller & McCormick ATTORNEYS

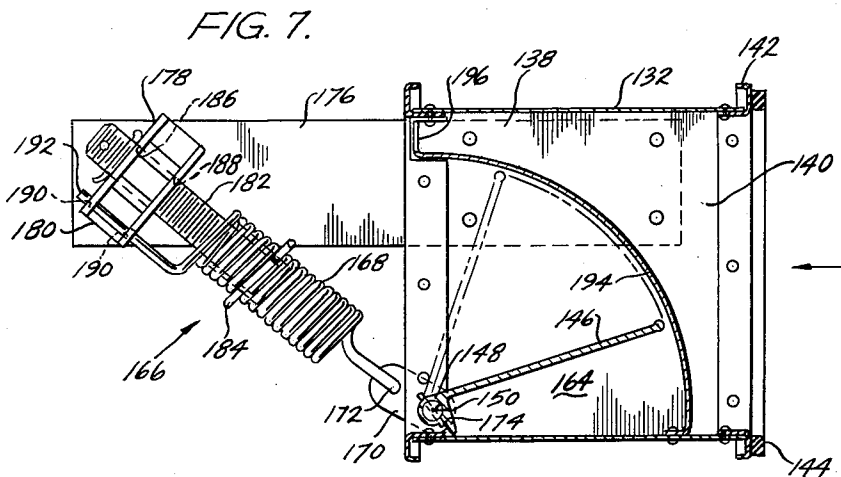
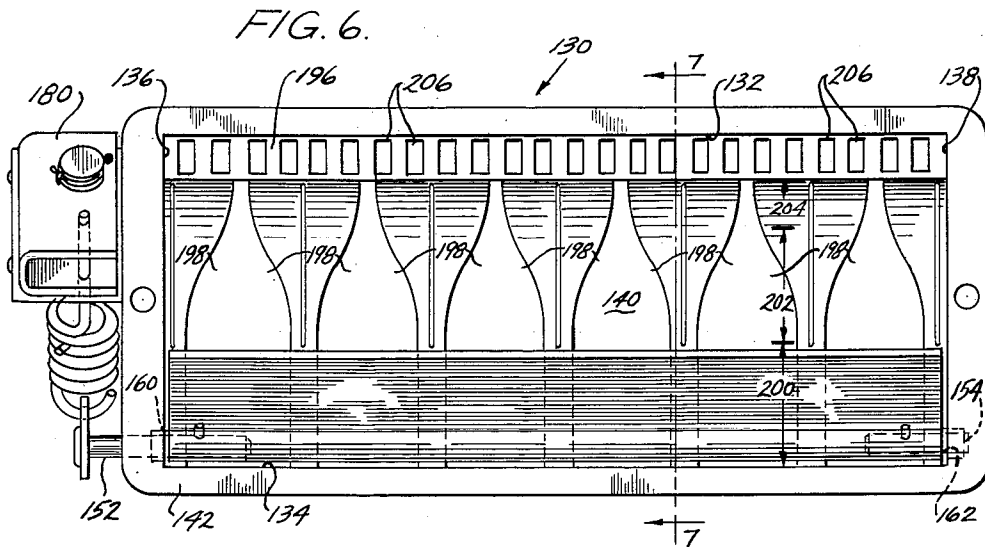
April 9, 1963

L. R. PHILLIPS ET AL
AIR DISTRIBUTION APPARATUS

3,084,711

Filed Jan. 27, 1960

4 Sheets-Sheet 3



INVENTORS

LEONARD R. PHILLIPS, WILLIAM J. WAELDNER
CARL W. PALMQUIST, RAYMOND S. BARLOW
BY Teller & McCormick ATTORNEYS

April 9, 1963

L. R. PHILLIPS ET AL
AIR DISTRIBUTION APPARATUS

3,084,711

Filed Jan. 27, 1960

4 Sheets-Sheet 4

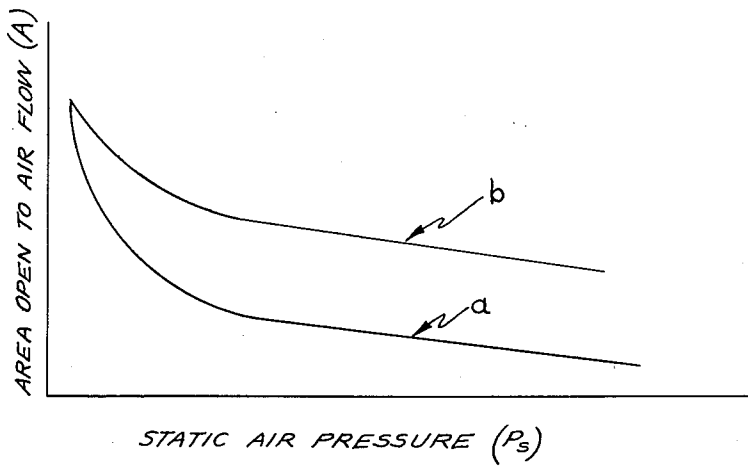


FIG. 8.

INVENTORS

LEONARD R. PHILLIPS, WILLIAM J. WAELDNER
CARL W. PALMQUIST, RAYMOND S. BARLOW

BY Teller & McCormick ATTORNEYS

1

3,084,711

AIR DISTRIBUTION APPARATUS

Leonard R. Phillips, West Hartford, William J. Waeldner, Farmington, Carl W. Palmquist, Newington, and Raymond S. Barlow, Vernon, Conn., assignors to Anemostat Corporation of America, New York, N.Y., a corporation of Delaware

Filed Jan. 27, 1960, Ser. No. 5,028
11 Claims. (Cl. 137—521)

This invention relates to air conditioning systems and, more particularly, to apparatus adapted for use in high pressure or high velocity air distribution systems of the type currently utilized in increasing numbers with central air conditioning units.

High pressure or high velocity air distribution systems are characterized by air ducts of comparatively small size and have, to a large extent, solved space problems encountered with the older and more conventional low pressure or low velocity air distribution systems which are characterized by relatively large air ducts. The use of high pressure or high velocity distribution systems has, however, introduced a number of new problems which have not been fully overcome heretofore. Since conditioned air discharged directly to a room or other enclosure at a high velocity may tend to create drafts which are objectionable or even harmful to occupants, it is desirable, and in some instances essential, that a reduction in air velocity be effected prior to discharge. Such reduction in air velocity may be accompanied by audible and even distracting noise and it is therefore advantageous to provide for velocity reduction at as low a noise level as possible and, in addition, to provide means for attenuating the low level noise that is encountered.

Further, where the distribution system comprises both hot and cold air ducts and supplies a number of rooms or other enclosures with conditioned air from these ducts at selected and possibly different temperatures, the conditioned air emerging at each discharge point must be drawn in selected proportions from the hot and cold air ducts and thoroughly mixed prior to discharge. Thorough mixing of the hot and cold air is essential in avoiding extreme temperature differentials in adjacent air zones or streams in a room or enclosure and may obviously be somewhat more difficult of accomplishment under conditions of comparatively high pressure and velocity than in the aforementioned older distribution systems where air pressures and velocities are generally lower.

In any air distribution system, it may be desirable to provide for substantially constant flows of conditioned air at the various points of discharge from the system in order to permit control of the air flow through the various distribution system ducts and to permit balancing of the temperatures in the various rooms or enclosures supplied by the system. The establishment and maintenance of substantially constant discharge air flows in a high pressure or high velocity distribution system where relatively large pressure and velocity variations may occur in the ducts may obviously be somewhat more difficult of accomplishment than in the case of a low pressure or low velocity system.

The present invention has as its general object the provision of apparatus usable in a high pressure or high velocity air distribution system, the said apparatus being adapted to effect the necessary reduction of air velocity prior to discharge of the air to a room or other enclosure with a minimum of audible noise, to regulate the relative amounts of hot and cold air admitted to the room or enclosure, to thoroughly mix such hot and cold

2

air, and to establish and maintain a substantially constant flow of air to the room or enclosure.

A more specific object of the present invention is to provide air proportioning valves adapted to regulate the relative amounts of hot and cold air discharged to a room or other enclosure, to effect a low noise level reduction in the velocity and pressure of the hot and cold air admitted to the apparatus from the distribution system ducts, and to provide for more efficient mixing of the hot and cold air than has heretofore been achieved.

Another more specific object of the invention is to provide apparatus of the type mentioned which includes a flow control device of desirably simple and compact construction, but which exhibits a high degree of accuracy and durability in operation and effectively maintains a substantially constant discharge flow of hot and cold air under the conditions of varying air velocity and pressure encountered in high pressure or high velocity air distribution systems.

The drawing show a preferred embodiment of the invention and such embodiment will be described, but it will be understood that various changes may be made from the construction disclosed, and that the drawings and description are not to be construed as defining or limiting the scope of the invention, the claims forming a part of this specification being relied upon for that purpose.

Of the drawings:

FIG. 1 is a front elevational view of the apparatus of the present invention in a unitary assembly with the front wall or cover plate of the assembly housing removed.

FIG. 2 is a horizontal sectional view taken as indicated by the line 2—2 in FIG. 1 and showing hot and cold air proportioning valves and a linkage system associated therewith.

FIG. 3 is an enlarged front elevational view of one of the proportioning valves of FIG. 2.

FIG. 4 is an enlarged view of the valve in side elevation.

FIG. 5 is an enlarged view of the valve in back elevation.

FIG. 6 is an enlarged elevational view of the flow control device of the apparatus seen from the discharge side thereof as indicated by the line 6—6 in FIG. 1.

FIG. 7 is a vertical sectional view through the flow control device of FIG. 6 taken as indicated by the line 7—7 in FIG. 6.

FIG. 8 is a graphical representation of area and pressure relationships and includes two area-pressure curves.

Referring particularly to FIG. 1 of the drawings, it will be observed that in the illustrative embodiment of the invention shown the distribution apparatus takes the form of a unitary assembly comprising a thin-walled housing indicated generally by the reference numeral 10. The housing 10 may be constructed of sheet metal or other relatively thin members and includes a top wall 12, similar oppositely facing side walls 14, 14, a bottom wall 16, and similar front and back walls 18, 18, the front wall being removed in FIG. 1 to show the elements of the apparatus which are located within the housing. Lower portions 20, 20 of each of the side walls 14, 14 are angularly disposed with respect to the upper portions thereof and with respect to each other and said portions are shown as diverging upwardly. This specific construction and arrangement of the side walls 14, 14 is not an essential feature of the invention but is preferred for reasons to be set forth hereinafter.

Similar first and second inlet openings 22 and 24, preferably of circular configuration, are provided respectively in the lower portions 20, 20 of the opposing side walls 14, 14 and said openings are connectible respectively with

3

hot and cold air supply ducts of a high pressure or high velocity air distribution system incorporating the distribution apparatus. Tubular flanges or collars 26 and 28 are provided adjacent the first and second or hot and cold air inlet openings 22 and 24 respectively for convenient attachment of such hot and cold air supply ducts. As shown, the axes of the inlet openings 22 and 24 and their tubular flanges or collars intersect at a point within the housing 10. Thus, streams of hot and cold air introduced to the interior of the housing through the said inlet openings will tend to collide and cause turbulent air flow therein. The provision of inlet openings which tend to cause collision of inflowing hot and cold air streams is optional as will be seen hereinafter.

The lower portion of the interior of the housing 10 into which the hot and cold air flows from the inlet openings 22 and 24 serves as an inlet or mixing chamber 30, hot and cold air being thoroughly comingled therein. Said chamber has a bottom wall formed by the housing bottom wall 16, opposing side walls formed by the upwardly diverging lower portions 20, 20 of the housing side walls 14, 14, front and rear walls formed by the lower portions of the housing front and rear walls 18, 18, and a top wall formed by a partition 32 extending across the interior of the housing. The partition 32 is provided with an air passageway or air opening 34 through which mixed hot and cold air is discharged from the inlet or mixing chamber 30. Associated with said air passageway or discharge opening 34 is a flow control device indicated generally at 36 and which operates to maintain a substantially constant flow of air through said passageway or opening and through the distribution apparatus.

Mixed hot and cold air discharged from the flow control device 36 enters a chamber 38 defined by and within the housing 10 and by and above the partition 32. The chamber 38 is substantially larger than the aforementioned mixing chamber 30 and the walls thereof are lined with pads or sheets 40, 40 of suitable sound absorbing or sound deadening material such as felted or matted glass fiber. Thus, substantial sound attenuation is accomplished therein and the chamber 38 may appropriately be termed an "attenuation chamber." Further provision for sound attenuation is made in the said chamber in the form of a baffle plate 42 which extends transversely in the path of incoming air from the flow control device 36 and which is also provided with pads or sheets 40, 40 of sound absorbing or sound deadening material. Preferably and as shown, the aforementioned walls of the inlet or mixing chamber 30 are also lined with pads or sheets 40, 40 of sound absorbing or sound deadening material.

From the foregoing, it will be apparent that noise accompanying the flow of hot and cold air into and through the mixing chamber 30 and the flow control device 36 will be attenuated in both the mixing chamber 30 and the attenuation chamber 38. The mixed hot and cold air entering the attenuation chamber 38 from the flow control device 36 will be directed transversely in the said chamber in two branch streams toward the opposite side walls thereof by the baffle plate 42. Said two streams of air flow respectively through two openings 44, 44 adjacent the ends of said plate. Discharge of the air from the attenuation chamber may be provided for as by a suitable discharge opening 46 formed in the aforementioned top wall 12 of the housing 10. By reason of the substantial size of the attenuation chamber with respect to the mixing chamber 30, a substantial reduction in air velocity is also effected in said attenuation chamber. In addition, there may obviously be substantial additional mixing and comingling of the hot and cold air in the said chamber.

In accordance with conventional practice, the air which emerges from the distribution apparatus through the discharge opening 46 may be passed through a diffuser prior to delivery to a room or other enclosure requiring conditioned air. Such a diffuser may include provisions for

4

the induction of room or enclosure air, as is well known in the art, and may be disposed immediately adjacent the discharge opening 46 so as to receive air directly therefrom or, in the alternative, a remote location of the diffuser may be provided for by means of suitable ducts. The provision of means for diffusing conditioned air delivered to a room or other enclosure, as well as the provision of air induction means and associated air ducts and the like, is only incidental to the present invention and therefore no showing or detailed description of such means is deemed necessary.

In accordance with the present invention and in fulfillment of its first above-mentioned specific object, air proportioning valves are provided for regulating the relative amounts of hot and cold air discharged to a room or other enclosure. In the distribution apparatus shown and described above, the inlet or mixing chamber 30 serves also as a valve chamber and has disposed therein first and second air proportioning valves indicated generally by the reference numerals 48 and 50 respectively. The valves 48 and 50 are operatively associated respectively with the first or hot air inlet opening 22 and the second or cold air inlet opening 24 and said valves are adapted to regulate the relative amounts of hot and cold air flowing through said inlet openings into the mixing chamber 30. As will be explained more fully hereinbelow, the valves 48 and 50 effect a low noise level reduction in the velocity of hot and cold air entering the mixing chamber from the inlet openings 22 and 24 and provide for highly efficient mixing of hot and cold air streams in the said chamber.

Preferably and as shown, the valves 48 and 50 are of like construction and each comprises a valve support member 52 and a valve member 54 adapted to be mounted thereon. The valve support members 52, 52 are pivotally supported at their upper end portions respectively adjacent the inlet openings 22 and 24 by suitable pivot pins 56, 56. Supporting brackets 58, 58 for the pivot pins 56, 56 are secured to the lower portions 20, 20 of the housing side walls 14, 14 adjacent the inlet openings 22 and 24. At its lower end portion each of the valve support members 52, 52 is provided with a pivot pin 60. Thus, said members are each adapted to be pivotally connected with a linkage means indicated generally at 62. It will be seen that the valve support members 52, 52 may be swung about their respective pivot pins 56, 56, as by the linkage means 62, whereby to be moved toward and away from their respective inlet openings and to impart similar movements to valve members 54, 54 mounted thereon for closing and opening said inlet openings and regulating air flow therethrough.

When the inlet openings 22 and 24 are of circular configuration as shown, the valve members 54, 54 are preferably circular or, more specifically, disc shaped as illustrated in FIGS. 3, 4 and 5 wherein a single valve member 54 is shown in detail. As best shown in FIGS. 4 and 5, an inner or concave face 63 of each valve member 54 is provided with an integral rib 64 which extends across said face and projects outwardly to the plane of the peripheral portion thereof. An axial bore 66 at the center of each valve member 54 and its integral rib extends through the member and is adapted to receive a bolt 68 (FIGS. 1 and 2) which can be entered in a suitable bore in a valve support member 52 and engaged with a nut 70 to securely mount the valve member on the support member. There is also provided on the inner or concave face 63 of each valve member 54, an integral locating pin 72 which is disposed adjacent the aforesaid peripheral portion thereof and which projects beyond the plane of said portion. The function of the pin 72 will be set forth hereinbelow.

Referring now to an outer or convex face 65 of the valve member 54, it will be observed that a plurality of similar fins 74, 74 are formed integrally thereon. The face 65 of the valve member is engaged at an angle by the stream of air flowing into the mixing chamber 30 when

5

the valve member is mounted on its support member 52 and is disposed in an open position and the fins 74, 74 provided thereon serve to direct and otherwise treat the said air stream in a desired manner. That is, the fins 74, 74 serve to broaden and flatten the air stream flowing thereby so that it assumes a fan pattern and they also serve to direct the fan pattern along a selected path. As shown, the outer or convex valve member face 65 is provided with six similar fins 74, 74 arranged in a fan pattern and which define five air channels 76, 76 also arranged in a fan pattern. The air channels 76, 76 have air inlet ends 78, 78 relatively closely spaced with respect to each other and air outlet or discharge ends 80, 80 spaced substantially farther apart. The fins 74, 74 are generally triangular in shape and their outer edges slope gradually outwardly from the outer or convex face of the valve member adjacent the inlet ends 78, 78 of the air channels 76, 76. From rounded apexes 79, 79 the said edges of the fins slope sharply inwardly to the outlet or discharge ends 80, 80 of said channels. Thus, the depth of the air channels 76, 76 increases gradually and then decreases sharply in the direction of air flow there-through.

From the foregoing, it will be apparent that a stream of air angularly engaging and passing over the outer or convex face of a valve member 54 will enter the air channels 76, 76 and will be broadened and flattened on discharge from said channels and will enter the mixing chamber in a fan pattern. It will be further apparent that the air discharged from the valve member in a fan pattern will have a general direction of flow determined by a center line 82 of the fan pattern formed by the fins 74, 74.

In further accord with the present invention, provision is made for directing streams of hot and cold air into the mixing chamber 30 in such manner that said streams of air whirl within the chamber in side-by-side relationship but in opposite directions, it being found that superior mixing of the hot and cold air is thus achieved. The desired whirling air flow patterns may obviously be obtained with various constructions and arrangements of hot and cold air inlet openings and associated proportioning valves, and such constructions and arrangements of valves and inlet openings fall within the scope of the invention. It is presently the preferred practice, however, to provide inlet openings with intersecting axes as shown and to effect a change in direction in the air streams flowing there-through by means of the associated proportioning valves whereby to avoid collision of the air streams and to instead achieve the desired whirling air flow pattern. With the valve member construction shown, the required changes in the direction of air flow may be effected by angular adjustments of the valve members and the center lines 82, 82 of the fins 74, 74 thereon as will be presently described.

In mounting the valve members 54, 54 on their respective support members 52, 52, the aforementioned locating pins 72, 72 on the said members are entered in locating holes 84, 84 (FIG. 2) formed in said valve support members to effect the angular adjustments of the valve member center lines 82, 82 required to achieve the desired whirling air flow pattern in the mixing chamber 30. Referring again to FIG. 5, it will be observed that the locating pin 72 on the valve member 54 shown therein is offset with respect to the center line 82 of the fins 74, 74. On the other hand, and as best illustrated in FIG. 2, the locating holes 84, 84 in the valve support members 52, 52 are disposed directly beneath the bores in said members which receive the securing bolts 68, 68 and said holes would fall on the valve center lines if the valve members were secured to the support members in the attitudes shown in FIG. 3. Thus the valve members 54, 54 must be rotated through a selected angle (in a counterclockwise direction as viewed from outside the inlet openings 22 and 24) in mounting the said members on their respective support

6

members 52, 52. Such rotation of the valve members effects angular adjustments of the center lines 82, 82 of the fan patterns formed by their fins 74, 74 whereby the fins on one of said valve members is angularly related with respect to the corresponding fins on the other valve member so as to provide for the desired side-by-side whirling air streams in the mixing chamber 30.

In FIGS. 1 and 2, wherein the valve members 54, 54 are shown mounted on their respective support members 52, 52 and wherein said valve members are in partially open positions, the air flow pattern in the mixing chamber 30 is illustrated generally by arrows representing the center lines of the fan pattern formed by the air on discharge from the valve members. Thus, it will be seen that the hot air stream is directed in a fan pattern by the fins 74, 74 on the valve member 54 associated with the hot air inlet opening 22 downwardly and rearwardly in the mixing chamber 30. The corresponding cold air stream is directed in a fan pattern downwardly and forwardly in said chamber by the fins 74, 74 on the valve member 54 associated with the cold air inlet opening 24. Thus, the hot air stream whirls in a vertical path in a rear portion of the mixing chamber and in a clockwise direction as viewed in FIG. 1, while the cold air stream whirls similarly and adjacent the hot air stream but in a counterclockwise direction in a front portion of said chamber. The aforementioned preference for mixing chamber side walls which diverge upwardly, such as the walls 20, 20, can now be appreciated, it being apparent that the said walls are conducive to the desired side-by-side vertically whirling air flow pattern.

From the foregoing, it will be apparent that side-by-side whirling hot and cold air streams will be present in the mixing chamber 30 with resulting thorough mixing of hot and cold air whenever both valve members 54, 54 are in open positions with respect to their associated inlet openings. Discharge of the air from the air channels 76, 76 on the valve members 54, 54 in a fan pattern serves to enhance mixing of the air in the mixing chamber. That is, the broadening and flattening of the air streams passing the valve members into fan patterns entails a loss of forward energy and a reduction in the velocity of the air and this is of course conducive to thorough mixing in the chamber. Further, it is to be noted that the localized impingement of high velocity air streams or jets on the bottom or front and back walls of the mixing chamber is avoided. This results in a substantial reduction in the tendency of the air to generate noise in the mixing chamber and air velocity reduction is accomplished at a desirably low noise level.

Each of the valve members 54, 54 is movable from a fully open to a fully closed position and to a number of discrete positions therebetween by appropriate swinging movements of their supporting members 52, 52 as will be described hereinbelow. In their fully closed positions, the valve members 54, 54 are adapted for substantially airtight sealing engagement with the portions of the mixing chamber side walls 20, 20 adjacent the hot and cold air inlet openings 22 and 24, and such sealing is preferably accomplished without the use of separate sealing elements. That is, each valve member 54 is preferably formed of a rubberlike or plastic compound having characteristics suitable for substantially airtight sealing and a relatively smooth peripheral portion 86 (FIG. 3) of the outer or convex face thereof lying beyond the ends of the fins 74, 74 is adapted to tightly engage the portion of the mixing chamber side wall adjacent the inlet opening whereby to provide a substantially airtight seal.

The aforementioned linkage means 62 is adapted to effect swinging movements of the valve support members 52, 52 about their respective pivots toward and away from their associated inlet openings whereby to respectively effect closing and opening movements of the valve members 54, 54, said valve movements being in unison but in opposite directions. As best illustrated in FIGS. 1 and

2, the linkage means 62 comprises, in presently preferred form, an input member in the form of a two-part bell crank which may be moved in one and an opposite direction or, more specifically, which may be rotated in opposite directions to actuate the linkage means, the valve support members 52, 52, and the valve members 54, 54. A first part 88 of the bell crank is shown as being generally U-shaped with arms of unequal length which are provided near their connected ends with aligned circular openings which receive a pivot pin 90. The pin 90 is journaled at opposite ends in suitable bearings 92 and 94 which are mounted respectively on the front and back housing walls 18, 18. A second part of the bell crank comprises a flat generally triangular plate 96 which is fixedly secured to the shorter arm of the first part 88 of the crank as by suitable rivets 98, 98. The pivot pin 90 is received in a suitable opening 100 in the plate 96 and said plate is pivotally connected adjacent one corner thereof with one end of a driving link 102 by means of a suitable pivot pin 104. An opening 106 formed in a corner of the plate 96 diagonally opposite the aforementioned corner may be utilized in pivotally connecting the driving link 102 with the said plate in an alternative manner and for a purpose to be set forth hereinafter.

The linkage means 62 also includes first and second connecting links 108 and 110 each of which is pivotally connected with and driven by the first part 88 of the bell crank. That is, the longer arm of the crank part 88 is pivotally connected adjacent its free end with one end of each of the connecting links 108 and 110 by a suitable pivot pin 112. The opposite ends of said connecting links are pivotally connected respectively with the aforementioned pivot pins 60, 60 adjacent the lower end portions of the valve support members 52, 52.

From the foregoing, it will be apparent that reciprocable or push-pull movements of the driving link 102 may be effected generally along the longitudinal center line of said link to respectively impart clockwise and counterclockwise rotative movements to the bell crank comprising the parts 88 and 96. Clockwise rotation of the bell crank resulting from a pushing movement of the link 102 will obviously effect an opening movement of the valve member 54 associated with the hot air inlet opening 22 and a simultaneous and equal closing movement of the valve member 54 associated with the cold air inlet opening 24. Pulling movement or retraction of the driving link 102 and resulting counterclockwise rotation of the bell crank will have a similar effect but linkage and valve member movements will of course be in an opposite direction. Thus, it will be seen that the relative amounts of hot and cold air introduced to the mixing chamber 30 and the temperature of the air discharged by the distribution apparatus may be regulated by appropriate push-pull actuation of the driving link 102.

The function and purpose of the aforementioned opening 106 in the bell crank plate 96 may now be more readily understood. With the driving link 102 pivotally connected to the said plate by insertion of the pivot pin 104 in the opening 106, and the said driving link actuated as indicated above, the valve members 54, 54 will be moved in unison but in opposite directions as described above but the operation of the linkage means will be reversed. That is, a pushing movement or a partial forward stroke of the driving link 102 will result in a closing movement of the valve member 54 associated with the hot air inlet opening 22 and in a simultaneous and equal opening movement of the valve member 54 associated with the cold air inlet opening 24. A pulling or retracting movement of the driving link will of course result in movement of the respective valve members in opposite directions. Obviously, the flexibility of the linkage means is enhanced in providing for two alternative modes of valve operation and the incorporation of the distribution apparatus in various air distribution systems is facilitated. For example, it may be desirable in one distribution sys-

tem to have the hot air inlet opening 22 closed and the cold air inlet opening 24 open when the system is inoperative and the driving link 102 is at rest. In another distribution system, reverse conditions of the inlet openings may be desirable when the system is inoperative. Either set of conditions may be conveniently provided for with the linkage means 62 described above.

Automatic control of the temperature of the air discharged by the distribution apparatus is preferably provided for and, in the illustrative embodiment of the invention shown, automatic temperature responsive operation of the linkage means 62 and the valve members 54, 54 is accomplished by means of an actuator indicated generally at 114 and a thermostat indicated generally at 116. Any number of commercially available types of actuators may be utilized, the actuator 114 which is shown being of the well known pneumatically operable type and requiring no detailed description. The said actuator is supported in the attenuation chamber 38 by means of a suitable bracket 118 and has a reciprocable output member or piston rod 120 which extends through an opening 122 in the partition 32 and which is pivotally connected with the aforementioned driving link 102. It will be apparent that the actuator may be reciprocally operated so that its piston rod 120 will actuate the driving link 102 by regulating air pressure in a control conduit 124 connected with the actuator.

The thermostat 116, also connected with the control conduit 124, is adapted to vary a control pressure responsive to air temperature change and is or may be of a well known type not requiring detailed description. Air from a pressurized source is introduced to the thermostat 116 through a supply conduit 126 and pressurized air may be discharged therefrom and from the control conduit 124 through an appropriate vent conduit 128. It will be apparent that the thermostat may be rendered responsive to the temperature of air discharged by the distribution apparatus as by locating the same in a room or other enclosure served by the apparatus, and it will be further apparent that the respective positions of the valve members 54, 54 may be controlled thereby through operation of the actuator 114 and the linkage means 62 whereby to regulate the temperature of the apparatus discharge air or the temperature of the air in the room or other enclosure in a desired manner.

It is believed that the characteristics of the aforementioned flow control device 36 which maintains a substantially constant flow of air through the distribution apparatus can best be understood with reference to the air pressure, flow and velocity conditions in the apparatus and the associated supply ducts. In a high pressure or high velocity air distribution system, air pressures and velocities in hot and cold air supply ducts connected with the distribution apparatus may be expected to vary over relatively wide ranges and to vary in diverse manners in the hot and cold air ducts. Further, the positions of the valve members 54, 54 relative to their respective inlet openings will vary in the course of the above-described temperature controlling operation thereof. Under these conditions, there will obviously be substantial variation in air flow through the distribution apparatus in the absence of an appropriate flow control device.

In controlling fluid flow, it is a conventional practice to provide a variable area device whereby the area open to fluid flow may be varied in accordance with a predetermined schedule to control the flow of fluid in a desired manner. This practice is followed in the design of the flow control device 36 and an area open to air flow is varied in accordance with a predetermined schedule so as to maintain a substantially constant air flow. The manner in which an area open to air flow must be varied or scheduled in relation to static air pressure in order to provide for a substantially constant air flow is illustrated graphically in FIG. 8 and, more specifically, by curve *a* in said figure.

From an examination of curve *a* FIG. 8, it will be apparent that a constant air flow condition will be obtained when area open to air flow is varied or scheduled with static air pressure so that a given static pressure change at a relatively low pressure effects a relatively large offsetting area change and so that an equal static pressure change at a relatively high pressure effects a relatively small offsetting area change. Stated differently, it may be said that the maintenance of substantially constant flow conditions requires that the area open to air flow be decreased quite sharply with increasing static air pressure at relatively low pressures and that such area be decreased more gradually with increasing static pressures as the pressures rise to intermediate and relatively high levels.

Constant flow devices adapted to provide for the required nonlinear relationship between area open to air flow and static air pressure shown by curve *a* have been used heretofore but have not been found completely satisfactory. In general, it may be said that such prior art constant flow devices fall into two categories. A first category includes constant flow devices wherein there is defined an air passageway through which flow is maintained substantially constant. A valve in the air passageway is adapted for movement responsive to static air pressure therein and serves to vary the passageway area open to air flow in the required nonlinear manner with respect to static air pressure change. There may or may not be an orifice plate or other similar means in the passageway, but in any event, area variation is wholly dependent on the nature of valve movement. That is, valve movement is nonlinear with respect to static air pressure in a particular way, or in accordance with a specific predetermined schedule which is formulated to provide for area change with pressure change in keeping with the schedule of curve *a* FIG. 8. Thus, it will be apparent that a biasing means must be provided to oppose valve movement induced by static air pressure change, and it will be further apparent that such biasing means must provide for a specific and somewhat complicated nonlinear relationship between valve movement and static air pressure change. In consequence, constant flow devices of the type referred to ordinarily include a plurality of stacked biasing springs and/or rather complicated linkage systems for providing the required nonlinear relationship. Devices such as stacked springs, complicated linkage systems and the like are undesirable from the standpoint of operational accuracy, frictional characteristics, durability and other factors and are to be avoided where possible, this being particularly true in the design of air distribution apparatus of the type under consideration where simplicity of construction, accuracy of operation, and durability are highly desirable.

In constant flow devices falling within the second of the above-mentioned categories, a valve adapted for static pressure responsive movement is provided in an air passageway. In these devices, however, valve movement is linear with respect to static air pressure and the required passageway area variation is provided for wholly by means of an orifice plate or the like having orifices therein which are progressively closed by the valve and which are of particular size, shape and number. The size, shape and number of the orifices are such that linear valve movement results in passageway area change which is nonlinear with respect to valve movement and which is in accordance with the desired predetermined area-pressure schedule of curve *a* FIG. 8. Obviously, a simple biasing means comprising a single constant rate spring may be operatively connected with the valve in this type of device to provide for linear valve movement responsive to static air pressure change and the above-mentioned undesirable complication of stacked springs, linkages and the like may be avoided. There is, however, another problem which arises with this type of constant flow device and this involves the construction of the orifice plate or

the like which is associated with the valve. Considerable difficulty is encountered in providing for the required schedule of area variation wherein area decreases quite sharply and then more gradually with increasing static air pressure. More specifically, the initial sharp change in area, irrespective of the specific size, shape, and number of orifices in the orifice plate, dictates a plate having a rather large dimension in one direction. The subsequent gradual change in area dictates a plate having a substantial dimension in a direction normal to said one direction. Thus, a relatively large orifice plate may be needed in order to provide the area variation needed for substantially constant flow conditions. This may be highly undesirable particularly where size considerations are important as in the design of high velocity air distribution systems and apparatus.

The flow control device 36 included in the distribution apparatus of the present invention avoids the inherent disadvantages of each of the types of constant flow devices discussed above and is of a desirably simple and compact construction particularly well suited to high pressure or high velocity air distribution apparatus. As will be seen, the curve *a* area-pressure relationship is achieved partially by means of movement of a valve in a slightly nonlinear manner and in accordance with a specific predetermined schedule and partially by means of a specific orifice plate construction which provides for area variation in a nonlinear manner with respect to valve movement and in accordance with a predetermined schedule which is complementary to the said schedule of valve movement. The slight nonlinear valve movement is obtained by means of a desirably simple and yet efficient and durable biasing means comprising a constant rate spring and a single connecting link and a desirably small and compact orifice plate construction is permitted by reason of the fact that a part of the task of nonlinear area variation is accomplished through nonlinear valve movement.

Referring now to FIGS. 6 and 7 particularly, it will be observed that the flow control device 36 comprises a thin-walled housing indicated generally at 130 and shown as having similar generally rectangular top and bottom walls 132 and 134 and similar but smaller generally rectangular opposing side walls 136 and 138. The said top, bottom and side walls collectively define an air passageway 140 which is of generally rectangular cross section and through which mixed hot and cold air may flow from the aforementioned air passageway 34 and the mixing chamber 30 when the housing 130 is attached to the partition 32 as shown in FIG. 1. For attaching the housing 130 to said partition, an appropriate mounting flange 142 is provided on the housing adjacent the inlet or upstream end of the air passageway 140 extending therethrough. A suitable gasket 144 may be utilized to prevent air leakage between the housing and the partition in the area adjacent the partition air passageway 34. Sheet metal is used in the construction of the housing 130 shown, but it will be obvious that a number of other suitable materials may be utilized. Further, it is within the scope of the invention to provide housings and air passageways of a variety of shapes and sizes other than those shown in order to meet the needs of a particular air distribution apparatus.

In accordance with the invention, there is disposed in the air passageway 140 and within the housing 130 a valve which is movable from one position to another in said passageway responsive to the static air pressure therein. In preferred form said valve comprises a flat imperforate substantially rectangular member 146 which extends between the side walls 136 and 138 of the housing 130 and which is supported for pivotal movement between first and second angular positions in the air passageway 140. The valve member 146 is inclined upwardly in the upstream direction or toward the inlet end of the said air passageway as best illustrated in FIG. 7 and its lower

11

edge portion at 148 is formed to provide a cylindrical opening 150 extending from one side edge portion thereof to the other. Suitable first and second pivot pins 152 and 154 are partially entered respectively in opposite ends of the opening 150 and are fixedly secured to the valve member by means not shown. The projecting end portions of the pivot pins 152 and 154 are rotatably received respectively in aligned circular openings 160 and 162 formed respectively in the housing side walls 136 and 138 adjacent the housing bottom wall 134.

From the foregoing, it will be apparent that the valve member 146 cooperates with the housing bottom and side walls 134, 136 and 138 to define an open air chamber or air pocket 164 which is disposed generally beneath the said member as shown in FIG. 7 and which is in free communication with upstream or inlet air. Said chamber or pocket also communicates with passageway 140 downstream or discharge air but only through small clearance spaces adjacent the side and/or lower edges of the said valve member. Air at substantially upstream or inlet static pressure thus acts on the lower or upstream face of the valve member 146 and tends to pivot the same through an arc in a downstream direction from a first angular position shown wherein its upper edge portion is disposed above and upstream of its lower edge portion to a second substantially vertical angular position wherein its said upper edge portion is disposed above and upstream of said first position. Such pivotal movement of the valve member 146 induced by static air pressure is opposed by a resilient biasing means indicated generally at 166 and which will be described presently.

The resilient biasing means 166, in further accord with the present invention, is operatively connected with the valve member 146 and opposes the effect of the aforementioned air pressure forces thereon in such manner that increase in upstream or inlet static air pressure at a constant rate will effect pivotal movement of the valve member from its first to its second position at a decreasing rate of movement. Stated differently, it may be said that the biasing means opposes pressure induced valve movement in accordance with a predetermined schedule whereby a given static air pressure change at a relatively low static pressure will result in a comparatively large increment of valve movement and an equal pressure change at a relatively high static pressure will result in a comparatively small increment of valve movement. Since the area of the air passageway 140 which is open to air flow varies in keeping with valve movement, it will be apparent that an area-pressure relationship such as that shown by curve *b* FIG. 8 may be obtained. Examination of curve *b* with reference to curve *a* will illustrate that the necessary area variation for constant flow conditions may be at least partially provided for through nonlinear valve movement.

While the resilient biasing means 166 may take a variety of forms within the scope of the invention, said means preferably comprises a single constant rate spring 168 of the conventional coil type and a linkage means or crank arm 170. The spring 168 is supported for operation in tension and its free end is pivotally connected at 172 with one end of the crank arm 170. The crank arm 170 is rigidly connected at its opposite end with a projecting end portion of the aforementioned pivot pin 152. The axis of the spring and the longitudinal center line of the crank arm are angularly related to each other and to the plane of the valve member 146 so as to provide for the desired schedule of valve movement set out above. That is, the angular relation of these elements is such that spring deflections or elongations and the accompanying changes in spring induced biasing force are smaller in magnitude for given increments of valve member movement when said member is at or near the position shown during low static pressure conditions than when the member is positioned upwardly from such position as shown in phantom during higher pressure conditions. As

12

a result, given increments of pressure change at low and high pressures respectively produce comparatively large and comparatively small valve member movements and passageway area is changed as desired.

In further accord with the present invention, there is provided a manually operable means for adjusting both the rate and the initial tension of the resilient biasing means 166 whereby to permit adjustment of the level at which air flow is maintained substantially constant by the flow control device 36. It will be observed that the valve member 146 is provided adjacent its lower edge portion 148 and on its lower or downstream face with a flange or lug 174. The said flange or lug serves to limit downward or upstream pivotal movement of the valve member and thus establishes the aforesaid first angular position thereof. In addition, it will be noted that the stop flange or lug 174 indirectly prevents pivotal movement of the crank arm 170 to a position wherein its longitudinal center line is in exact alignment with the axis of the coil spring 168. With the valve member 146, the crank arm 170, and the spring 168 positioned as shown in FIG. 7, the said spring is under nominal tension.

At the end portion thereof opposite the crank arm 170, the spring is supported and held by means of a bracket 176, a U-shaped retaining member 178, a nut 180, a retaining rod 182, and a retaining pin 184, the latter three of these elements constituting the aforesaid manually operable rate and tension adjusting means. The bracket 176 is fixedly connected to the side wall 136 of the housing 130 by suitable means not shown and carries the U-shaped member 178 angularly disposed thereon so that aligned openings 186 and 188 in said member are coaxial with the spring 168. The retaining rod 182 extends through the said openings 186 and 188 and projects within the coils of the spring 168 with the retaining pin 184 secured transversely in and extending at each end from a suitable bore in the projecting end portion of the rod. The nut 180 is disposed between and fixedly secured to the arms of the U-shaped retaining member 178 and receives the retaining rod 182 which is provided with suitable threads over at least a portion of its length. Two aligned openings 190, 190 formed in the arms of the retaining member 178 receive and fixedly hold a free end portion 192 of the upper end coil of the spring 168.

From the foregoing, it will be apparent that the extending end portions of the retaining pin 184 may be inserted between the coils of the spring 168 so that rotation of the retaining rod 182 will cause the said end portions of the pin to move along the spaces between adjacent spring coils. With the lead of the threads on the retaining rod 182 and those in the bore of the nut 180 less than the lead of the coils of the spring 168, it will be seen that with rotation of the rod 182 and advancement of the same into the spring the pin 184 will be moved therewith and the coils above said pin will be compressed and deactivated leaving only the coils disposed between the said pin and the crank arm active for biasing operation. This will obviously result in an increased rate of the spring 168 and increased initial tension thereof. Conversely, rotation of the retaining rod 182 in an opposite direction will result in a reduction of spring rate and in a reduction in initial spring tension.

In still further accord with the present invention, an orifice plate is disposed in the air passageway 140 of the flow control device and is provided with orifices which are closed progressively by the valve member 146 in the course of movement of the latter from its first to its second angular position. Said orifices are of particular size, shape and number whereby to provide for passageway area variation with valve movement in accordance with a predetermined schedule which complements the aforementioned schedule of valve movement to provide the schedule of area variation with pressure change necessary for constant flow conditions. More specifically,

the size, shape, and number of the orifices in the orifice plate are such that valve member movement effected by increasing air pressure on said member results in a decreasing passageway area open to air flow, said decrease in area being at a rate in excess of the rate of valve member movement. Thus, that portion of the necessary area variation which is not provided for by nonlinear valve member movement (compare curves *a* and *b* in FIG. 8) may be provided for in the construction of the orifices of the orifice plate associated with the valve member.

While a number of forms of orifice plates may be utilized, it will be observed in FIGS. 6 and 7 that a generally arcuately shaped orifice plate 194 is shown in the air passageway 140 extending between the side walls 136 and 138 and the top and bottom walls 132 and 134 of the housing 130. Said orifice plate is disposed in the passageway 140 with its lower edge secured to the bottom wall 134 of the housing 130 and with its upper edge secured to the top wall 132 of said housing. A major portion of the plate extending upwardly from its lower edge is partially circular in cross section and curves in a downstream direction from its said lower edge adjacent the arcuate path of the free edge of the valve member 146. An upper edge portion 196 of the plate 194, in accordance with presently preferred practice, extends substantially normal to and downwardly from the top wall 132 of the housing to the upper extremity of said partially circular plate portion.

From the foregoing, it will be apparent that pivotal movement of the valve member 146 from its first to its second position will progressively close orifices provided in the partially circular portion of the orifice plate 194, but such valve movement will not effect orifices provided in the upper edge portion 196 thereof. The orifices in the plate 194 may obviously take various forms, but are preferably as shown and comprise a series of similar slots 198, 198 (six shown) which are spaced across the plate and each of which extends upwardly therein throughout the partially circular portion thereof. The slots 198, 198 are closed progressively by movement of the valve member from its first to its second position and each of said slots decreases in width upwardly to provide the aforementioned desired rate of decrease in area open to flow. More specifically, each of the slots 198, 198 has a lower portion 200 which is of substantially uniform width and which provides for free entry of upstream or inlet air to the chamber or pocket 164 beneath the valve member 146. An intermediate portion 202 of each slot 198 decreases in width upwardly rather sharply and assists in the provision of the necessary sharp area decrease in the first portion of the area-pressure curve *a* of FIG. 8. An upper portion 204 of each slot 198 decreases in width upwardly at a somewhat more gradual rate and assists in the provision of the area change illustrated by the latter or high pressure portion of the said area-pressure curve.

Preferably, the orifice plate 194 also includes orifices in the upper edge portion 196 thereof and such orifices may comprise a series of similar small rectangular slots 206, 206 extending across said plate portion. Said slots are separate from the slots 198, 198 and are unaffected by valve member movement as indicated above. The purpose of the slots 206, 206 is to provide a required minimum orifice area which is always open to air flow. It will be noted that the slots 198, 198 would have to be extended substantially at their upper ends in order to provide an orifice area equal to that provided by the slots 206, 206. Thus, a smaller and more compact orifice plate is provided for with the use of auxiliary orifices such as the slots 206, 206.

It is to be noted that the total area of the auxiliary slots 206, 206 must be added to the total area of the slots 198, 198 in determining the exact shape and size of the latter for constant flow conditions. Further, there may be other extraneous factors which must be considered in

determining the exact size and shape of the slots 198, 198. For example, the valve member 146 may taken on the characteristics of an airfoil under conditions of high air velocity and pressure and errors in the operation of the flow control device may result. Such errors as well as others due to extraneous factors may be compensated for by modifying slot configurations and/or sizes as indicated by appropriate calculations or test results.

The operation of the distribution apparatus of the present invention is described above with respect to its several parts and only a brief summary of operation is now deemed necessary. Hot and cold air under high pressure and high velocity conditions is introduced to the mixing chamber 30 of the apparatus through the inlet openings 22 and 24. The valves 48 and 50 are operated by their linkage means 62, the actuator 114, and the thermostat 116 to proportion the flow of hot and cold air to the mixing chamber whereby to provide a desired temperature of air discharged by the apparatus or a desired room or enclosure temperature. Reductions in air velocities and pressures are accomplished by the proportioning valves at a low noise level and some sound attenuation is obtained in the mixing chamber. Further, a thorough mixing of hot and cold air in the mixing chamber is obtained as a result of a side-by-side whirling air flow pattern created therein.

From the mixing chamber comingled hot and cold air passes through the flow control device 36 at a substantially constant rate of flow as determined by the adjustment of the rate and tension of the biasing spring. Higher constant flows may be obtained by increasing the spring rate and initial spring tension and, conversely, when constant flow at a low level is desired adjustment may be made to decrease spring rate and tension.

On discharge from the flow control device 36, the air enters the attenuation chamber 38 wherein additional sound attenuation and velocity reduction is accomplished and wherein some additional mixing of hot and cold air may also be accomplished. From the attenuation chamber the thoroughly mixed temperature and flow regulated air is discharged either directly or through a suitable diffuser for delivery to a room or other enclosure requiring air conditioning.

The invention claimed is:

1. For use in air distribution apparatus, a flow control device comprising a housing defining a substantially rectangular air passageway having top and bottom walls and oppositely facing side walls, a flat imperforate substantially rectangular valve member extending between the side walls of said air passageway and inclined upwardly in the upstream direction with its lower edge portion pivotally supported adjacent the bottom wall of the passageway so that upstream air pressure tends to pivot the same through an arc from a first angular position wherein its upper edge portion is disposed above and upstream of its said lower edge portion to a second angular position wherein said upper edge portion is disposed above and downstream of said first position, resilient biasing means operatively connected with said valve member and opposing the force exerted thereon by upstream air pressure so as to provide for movement of said valve member in accordance with a predetermined schedule whereby a constant rate of increase in upstream air pressure effects pivotal movement of said valve member from said first to said second angular position at a decreasing rate of movement, and a generally arcuately shaped orifice plate extending across said passageway with its upper edge portion disposed above and downstream of its lower edge portion and having orifices therein which are closed progressively by said valve member during movement of the latter from said first to said second position, the size and shape of said orifices being such that valve movement effected by increasing air pressure decreases the total orifice area open to air flow at a rate in excess of the rate of valve movement and in accordance with a predeter-

15

mined schedule whereby to provide for a schedule of decreasing orifice area with increasing air pressure which results in a substantially constant flow of air through the device.

2. For use in air distribution apparatus, a flow control device comprising a housing defining a substantially rectangular air passageway having top and bottom walls and oppositely facing side walls, a flat imperforate substantially rectangular valve member extending between the side walls of said air passageway and inclined upwardly in the upstream direction with its lower edge portion pivotally supported adjacent the bottom wall of the passageway so that upstream air pressure tends to pivot the same through an arc from a first angular position wherein its upper edge portion is disposed above and upstream of its said lower edge portion to a second angular position wherein said upper edge portion is disposed above and downstream of said first position, resilient biasing means comprising a substantially constant rate spring and a linkage means connected between the spring and said valve member so that pivotal valve member movement from said first to said second angular position is opposed by said spring and so that such valve member movement occurs at a decreasing rate of movement for a constant rate of upstream air pressure increase, and a generally arcuately shaped orifice plate extending across said passageway with its upper edge portion disposed above and downstream of its lower edge portion and having orifices therein which are closed progressively by said valve member during movement of the latter from said first to said second position, the size and shape of said orifices being such that valve movement effected by increasing air pressure decreases the total orifice area open to air flow at a rate in excess of the rate of valve movement and in accordance with a predetermined schedule whereby to provide for a schedule of decreasing orifice area with increasing air pressure which results in a substantially constant flow of air through the device.

3. For use in air distribution apparatus, a flow control device comprising a housing defining a substantially rectangular air passageway having top and bottom walls and oppositely facing side walls, a flat imperforate substantially rectangular valve member extending between the side walls of said air passageway and inclined upwardly in the upstream direction with its lower edge portion pivotally supported adjacent the bottom wall of the passageway so that upstream air pressure tends to pivot the same through an arc from a first angular position wherein its upper edge portion is disposed above and upstream of its said lower edge portion to a second angular position wherein said upper edge portion is disposed above and downstream of said first position, resilient biasing means comprising a substantially constant rate spring and a crank arm connected at one end with said valve member for movement therewith and connected at the opposite end with said spring in such manner that spring deflection is nonlinear with respect to valve member movement so that movement of the valve member from said first to said second angular position occurs at a decreasing rate of movement in response to an increase in upstream air pressure at a constant rate, and a generally arcuately shaped orifice plate extending across said passageway with its upper edge portion disposed above and downstream of its lower edge portion and having orifices therein which are closed progressively by said valve member during movement of the latter from said first to said second position, the size and shape of said orifices being such that valve movement effected by increasing air pressure decreases the total orifice area open to air flow at a rate in excess of the rate of valve movement and in accordance with a predetermined schedule whereby to provide for a schedule of decreasing orifice area with increasing air pressure which results in a substantially constant flow of air through the device.

4. A control device as set forth in claim 3 wherein the spring included in the resilient biasing means is provided

16

with a manually operable rate adjustment device which permits selection of the level at which air flow is maintained substantially constant.

5. For use in air distribution apparatus, a flow control device comprising a housing defining a substantially rectangular air passageway having top and bottom walls and oppositely facing side walls, a flat imperforate substantially rectangular valve member extending between the side walls of said air passageway and inclined upwardly in the upstream direction with its lower edge portion pivotally supported adjacent the bottom wall of the passageway so that upstream air pressure tends to pivot the same through an arc from a first angular position wherein its upper edge portion is disposed above and upstream of its said lower edge portion to a second angular position wherein said upper edge portion is disposed above and downstream of said first position, resilient biasing means operatively connected with said valve member and opposing the force exerted thereon by upstream air pressure so as to provide for movement of said valve member in accordance with a predetermined schedule whereby a constant rate of increase in upstream air pressure effects pivotal movement of said valve member from said first to said second angular position at a decreasing rate of movement, and a generally arcuately shaped orifice plate extending across said passageway with its upper edge portion disposed above and downstream of its lower edge portion, said plate having a plurality of orifices therein which take the form of similar slots which extend from a lower to an upper portion of the plate and which have upwardly converging side edges, said slots being closed progressively by said valve member during movement of the latter from said first to said second position with increasing air pressure whereby the total slot area open to air flow is decreased at a rate in excess of the rate of valve movement so as to provide for a substantially constant flow of air through the slots and through the control device.

6. For use in air distribution apparatus, a flow control device comprising a housing defining a substantially rectangular air passageway having top and bottom walls and oppositely facing side walls, a flat imperforate substantially rectangular valve member extending between the side walls of said air passageway and inclined upwardly in the upstream direction with its lower edge portion pivotally supported adjacent the bottom wall of the passageway so that upstream air pressure tends to pivot the same through an arc from a first angular position wherein its upper edge portion is disposed above and upstream of its said lower edge portion to a second angular position wherein said upper edge portion is disposed above and downstream of said first position, resilient biasing means operatively connected with said valve member and opposing the force exerted thereon by upstream air pressure so as to provide for movement of said valve member in accordance with a predetermined schedule whereby a constant rate of increase in upstream air pressure effects pivotal movement of said valve member from said first to said second angular position at a decreasing rate of movement, and a generally arcuately shaped orifice plate extending across said passageway with its upper edge portion disposed above and downstream of its lower edge portion, said plate having a series of similar slots thereacross which extend upwardly from a lower to an upper portion of said plate and which decrease in width upwardly and said plate also having a series of orifices in an upper edge portion thereof which are adjacent to but separate from the upper ends of said slots, said orifices being unaffected by valve member movement but said slots being closed progressively by said valve member during movement of the latter from said first to said second position with increasing air pressure whereby the total slot and orifice area open to air flow is decreased at a rate in excess of the rate of valve movement so as to provide for a substantially constant flow of air through the slots and through the control device.

17

7. For use in air distribution apparatus, a flow control device comprising means defining an air passageway, a valve pivotally movable in a passageway closing direction in said air passageway between first and second positions at the urging of increasing air pressure therein, resilient biasing means operatively connected with said valve and opposing the force exerted thereon by air pressure with an increasing biasing force so as to provide for a decreasing rate of passageway closing movement of said valve in response to a constant rate of increase in passageway air pressure, and a stationary orifice plate in said passageway operatively associated with said valve and having orifices therein which are closed progressively to air flow through the passageway by said valve during closing movement of the latter, the size and shape of said orifices being such that the total orifice area decreases when the plate is viewed in the direction of passageway closing valve movement, such valve movement thus serving to decrease the total orifice area open to air flow at a rate in excess of the rate of valve movement.

8. A flow control device as set forth in claim 7 wherein said valve comprises a generally flat plate pivotally supported in said passageway at a downstream edge portion and swingable through an arc between said first and second positions at an upstream edge portion, and wherein said orifice plate is generally arcuate and disposed adjacent said upstream edge portion of said valve plate so as to generally follow the arc of movement thereof.

9. For use in air distribution apparatus, a flow control device comprising a housing defining an air passageway, a valve member pivotally supported at a downstream

18

edge portion so that an upstream edge portion thereof is swingable in a passageway closing direction through an arc at the urging of upstream air pressure, resilient biasing means operatively connected with said valve member and opposing the force exerted thereon by upstream air pressure, and a generally arcuately shaped orifice plate fixedly supported in said passageway adjacent said upstream edge portion of said valve member, said plate being arranged so as to approximately follow the arc of movement of said upstream edge portion of said valve member.

10. A flow control device as set forth in claim 9 wherein said orifice plate is characterized by orifices of such size, shape, and location that the total orifice area decreases when the plate is viewed in the direction of closing movement of said valve member.

11. A flow control device as set forth in claim 10 wherein at least some of said orifices take the form of slots extending in the direction of closing movement of said valve member and decreasing in width in said direction.

References Cited in the file of this patent

UNITED STATES PATENTS

2,111,611	Brenner	Mar. 22, 1938
2,263,980	Carlson	Nov. 25, 1941
2,706,492	Horland	Apr. 19, 1955
2,759,490	Phillips	Aug. 21, 1956
2,880,752	Kreuttner	Apr. 7, 1959
2,890,717	Werder	June 16, 1959
2,936,123	Kreuttner	May 10, 1960