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Chandler

[11] **3,720,258**

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[54] **AIR CONDITIONING SYSTEM WITH VARIABLE PRIMARY AIR VOLUME TERMINAL AND METHOD OF OPERATION THEREFOR**

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[73] Assignee: **Kilpatrick & Company,** Alhambra, Calif.

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[21] Appl. No.: **54,782**

[52] **U.S. Cl.** **165/2,** 165/16, 165/22, 98/38, 236/49

[51] **Int. Cl.** **F24f 3/00**

[58] **Field of Search** .....165/123, 22, 16; 98/40 DL, 98/38 E; 236/13, 49

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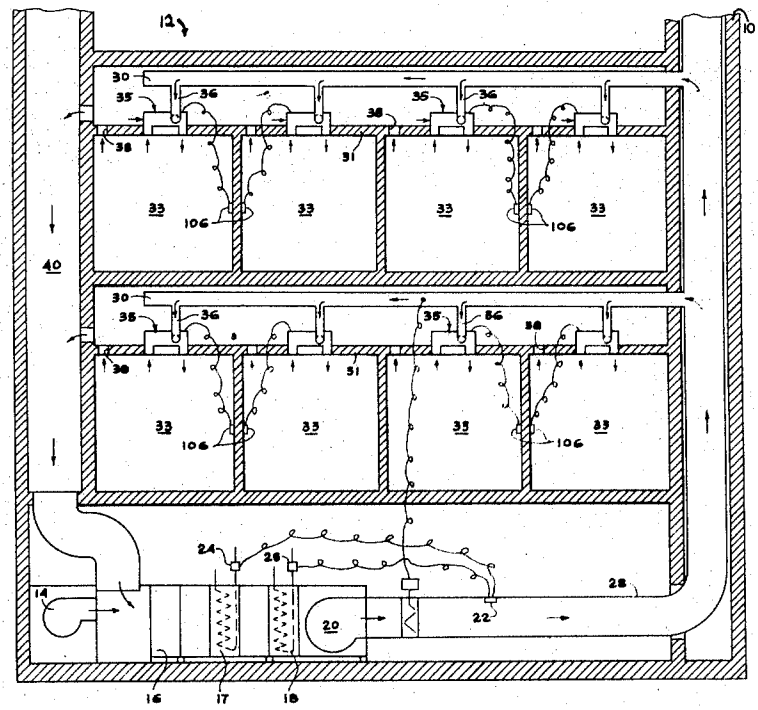
Primary Examiner—Albert W. Davis, Jr.
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[57] **ABSTRACT**

An air conditioning system and method of operating an air conditioning system wherein conditioned primary air is transmitted to a plenum chamber in a terminal unit, which terminal unit may be positioned for example, directly within a space to be conditioned or supported above a suspended ceiling in a space to be conditioned. A portion of the primary air is utilized to pass through nozzles and establish primary air flow in a mixing duct, which flow may induce and mix with a flow of secondary air to constitute supply air for discharge into a space to be conditioned. The supply air may comprise solely primary air or selectively variable volumes of primary air and secondary air, which secondary air may include selectively variable volumes of air recirculated from the space being conditioned and, if appropriate, air from the plenum chamber formed by a suspended ceiling in the space to be conditioned.

Additionally, an air handling or terminal unit according to the invention may include a casing connected to a source of primary air for providing a constant flow of primary air and a selectively variable flow of primary air, means for selectively introducing and mixing a flow of secondary air with the constant flow of primary air, the secondary air comprising selectively volumes of recirculated air from the space and, if appropriate, volumes of air drawn from the plenum chamber defined by a suspended ceiling in the space to be conditioned and a control means for controlling the thermal capacity of supply air for the space, the supply air including the primary air from the constant flow and, selectively, volumes of additional or by-pass primary air and secondary air.

9 Claims, 14 Drawing Figures



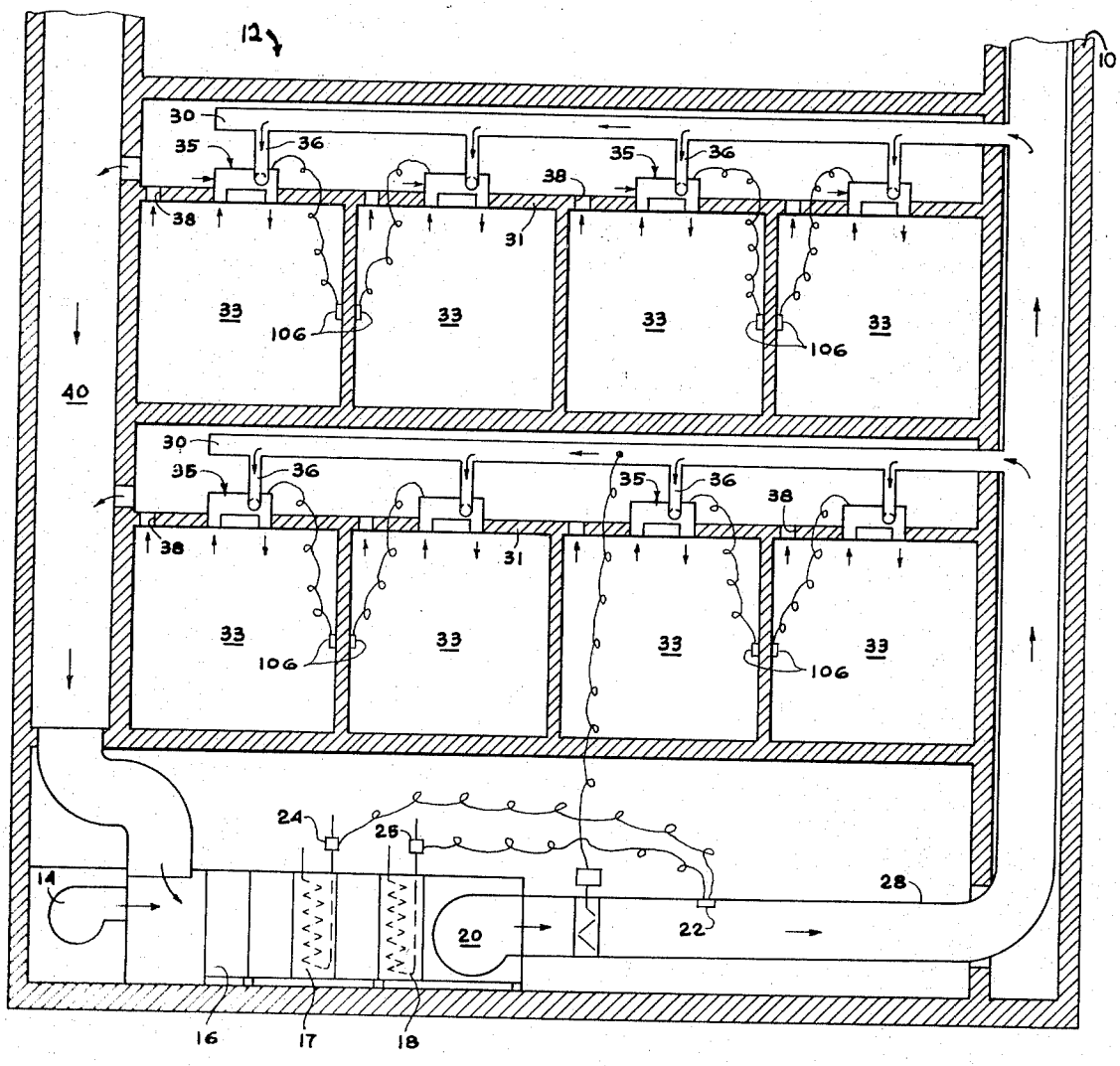


FIG. 1

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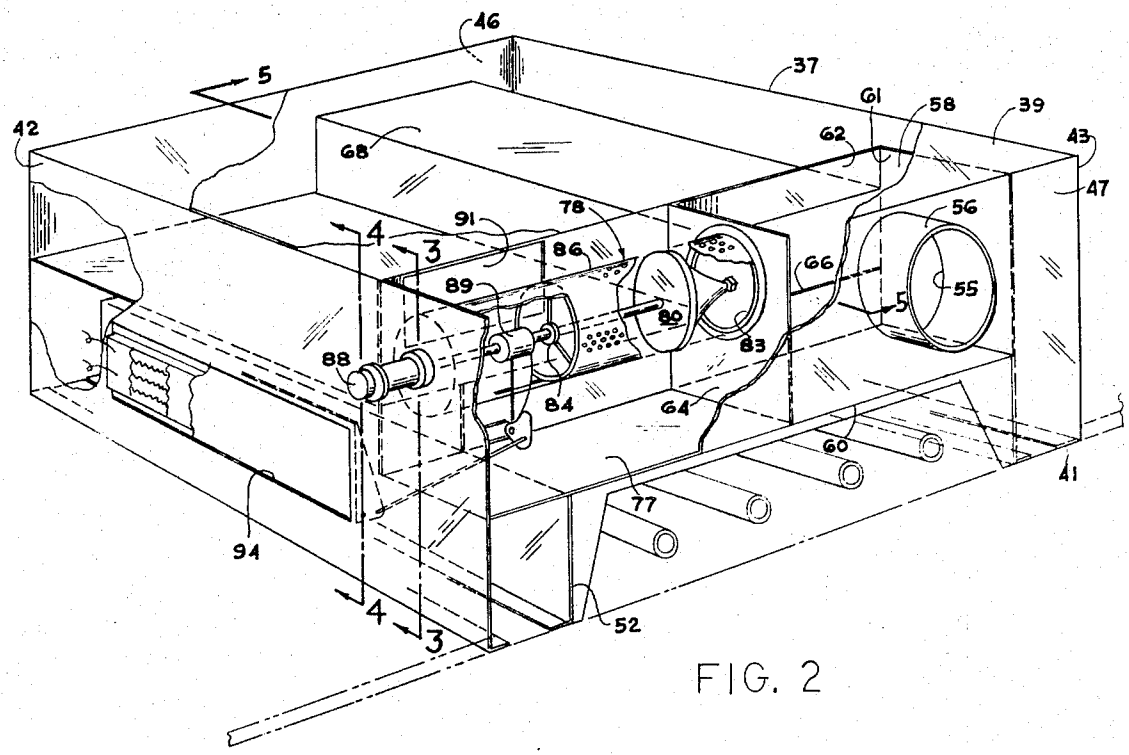


FIG. 2

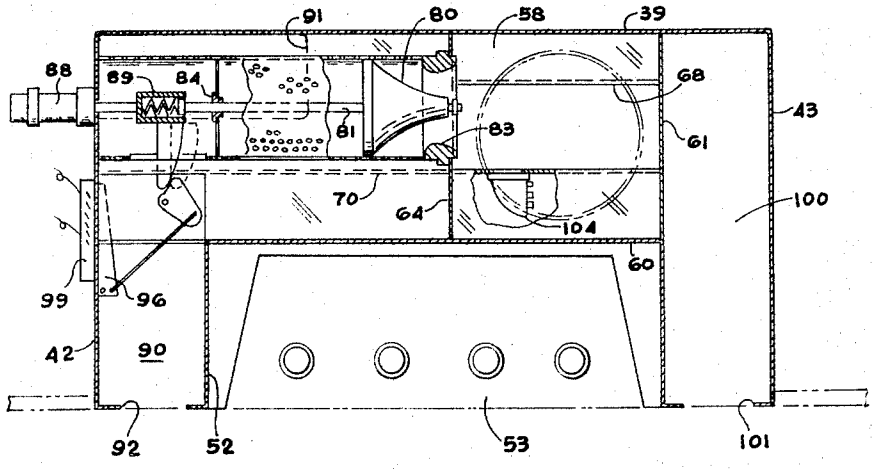


FIG. 3

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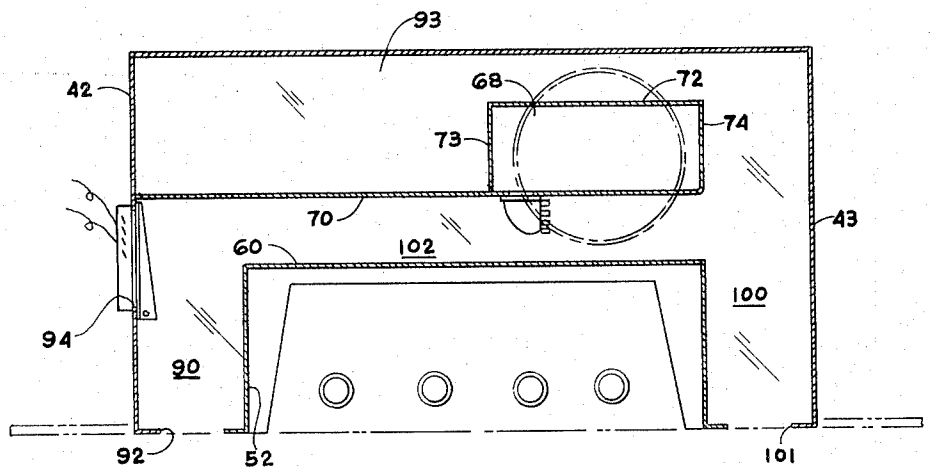


FIG. 4

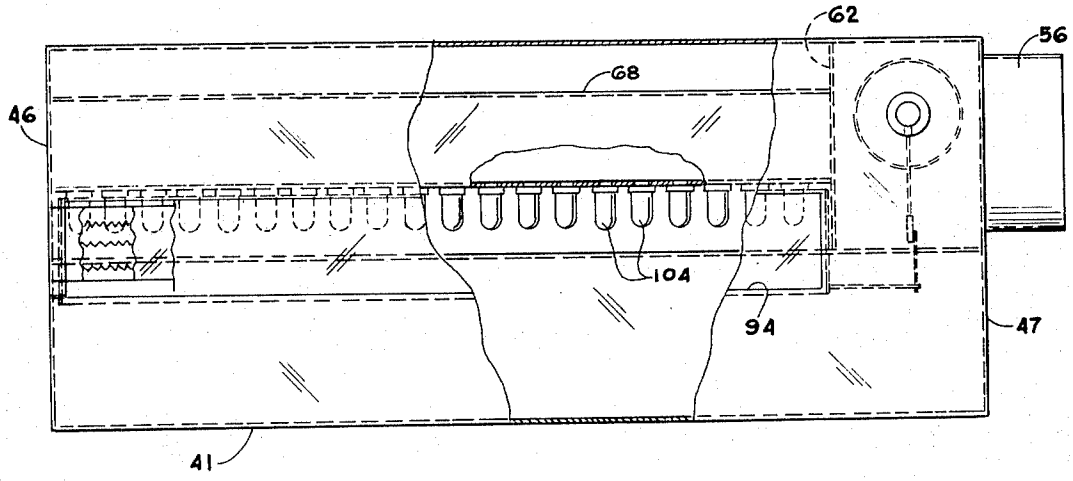


FIG. 5

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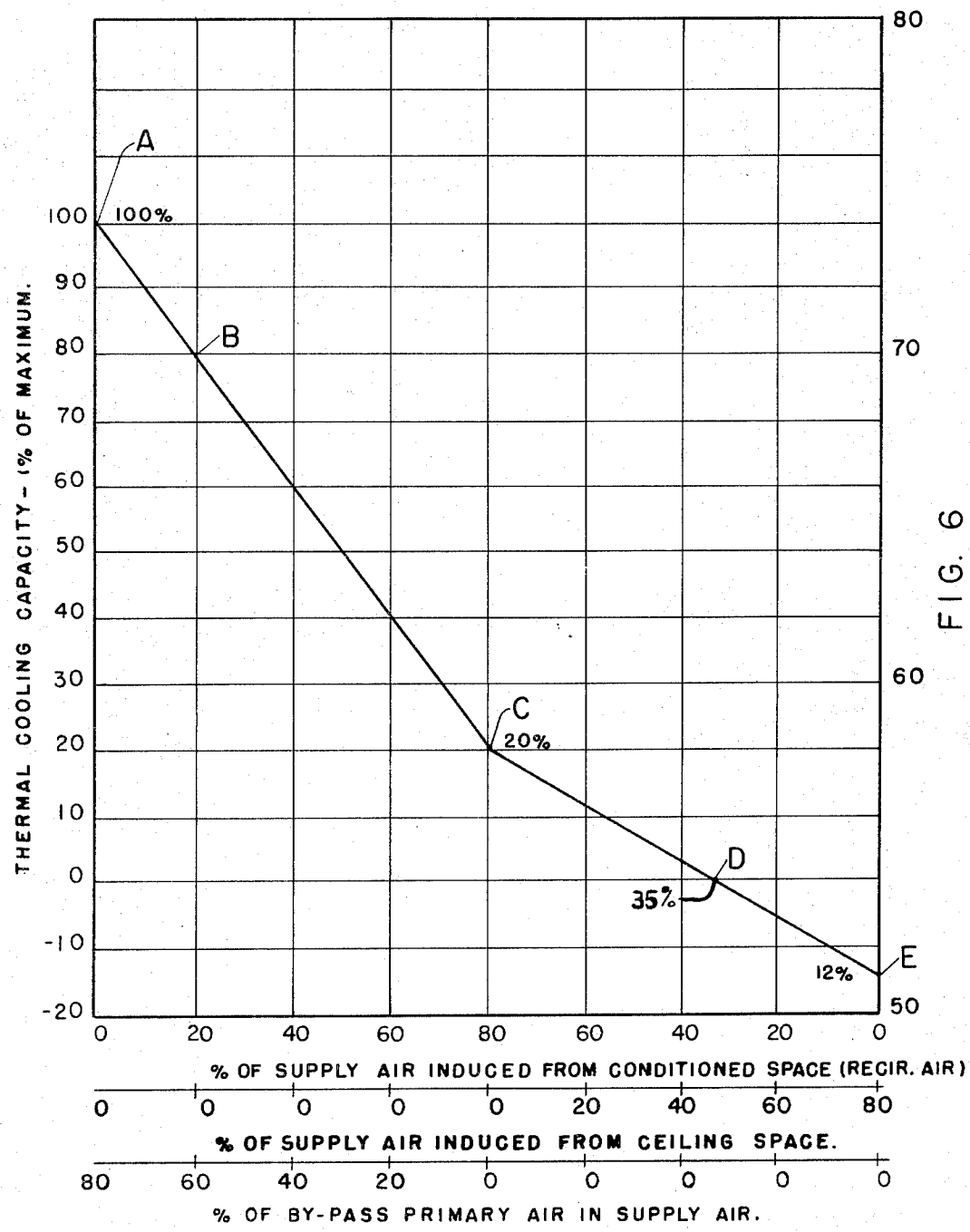


FIG. 6

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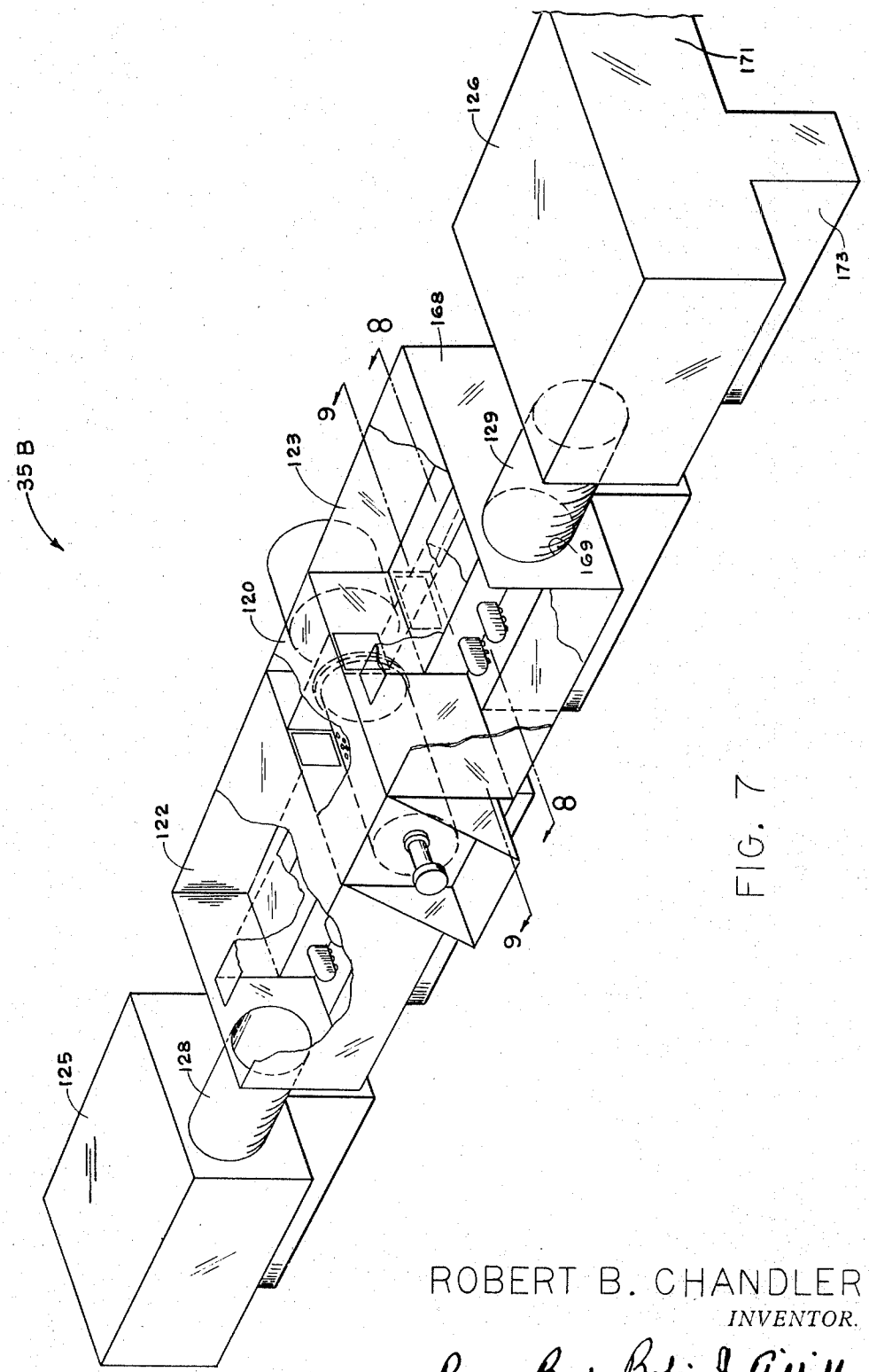


FIG. 7

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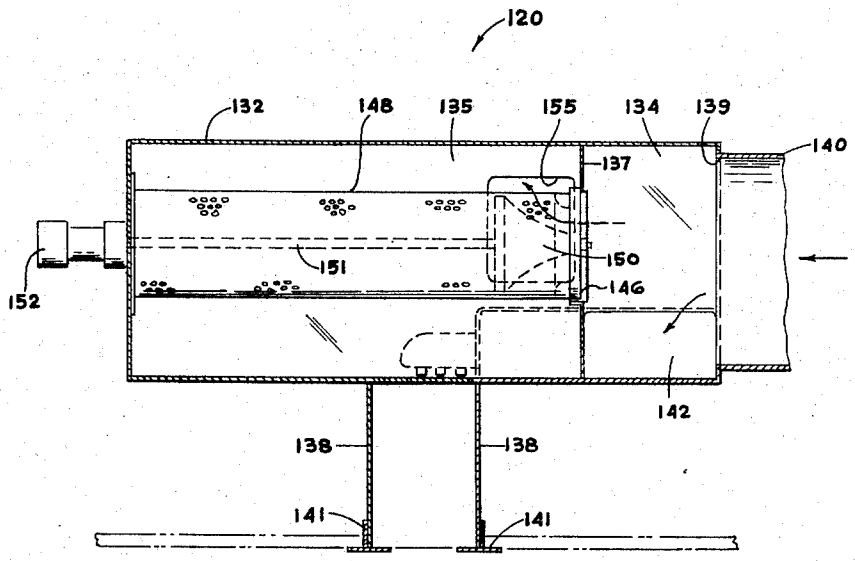


FIG. 8

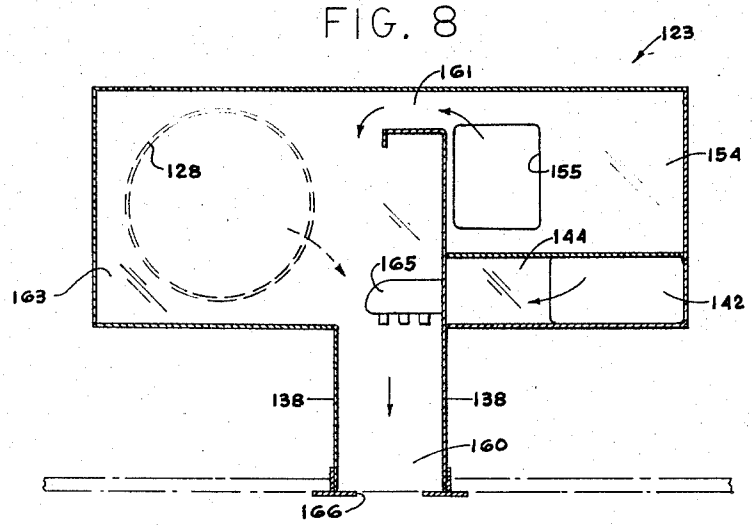


FIG. 9

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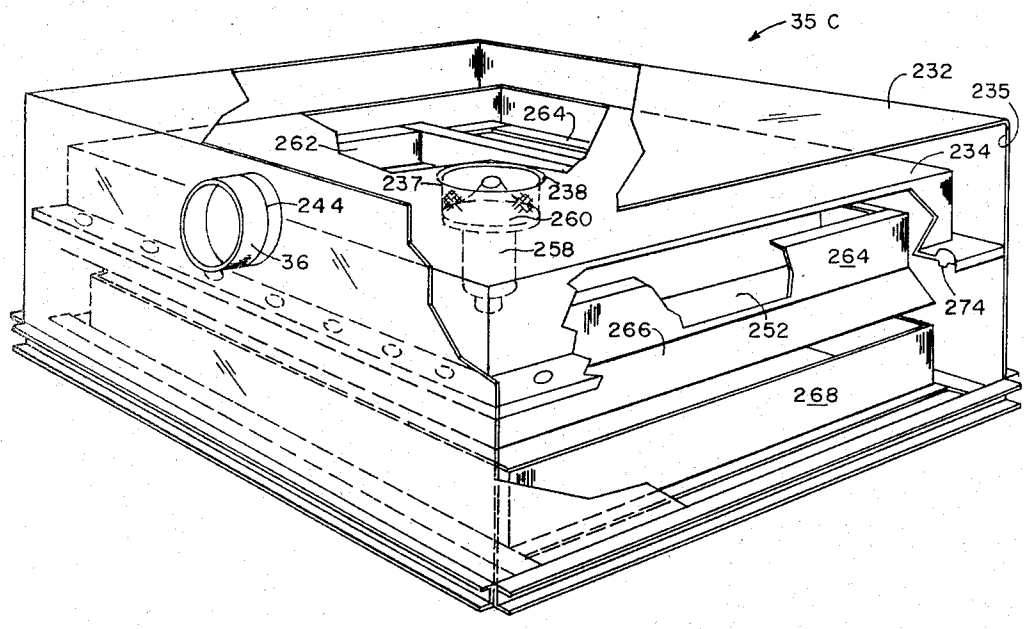


FIG. 10

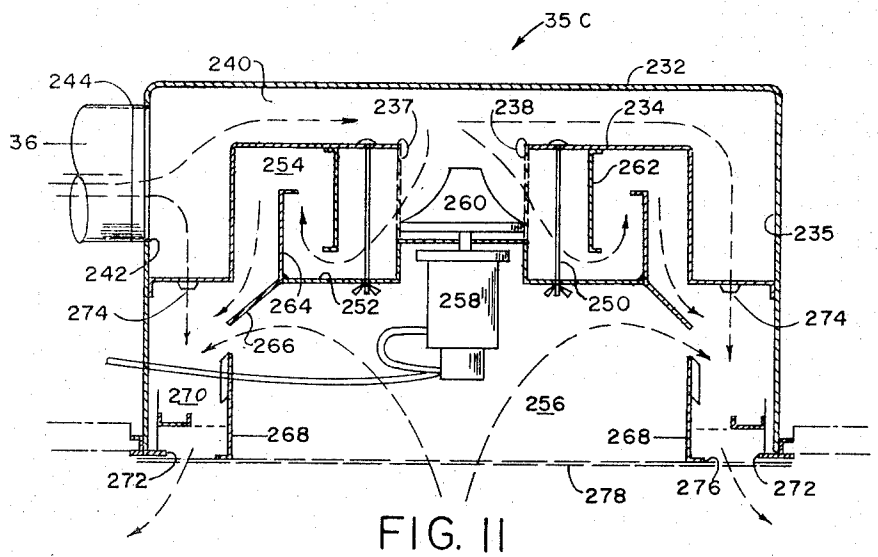


FIG. 11

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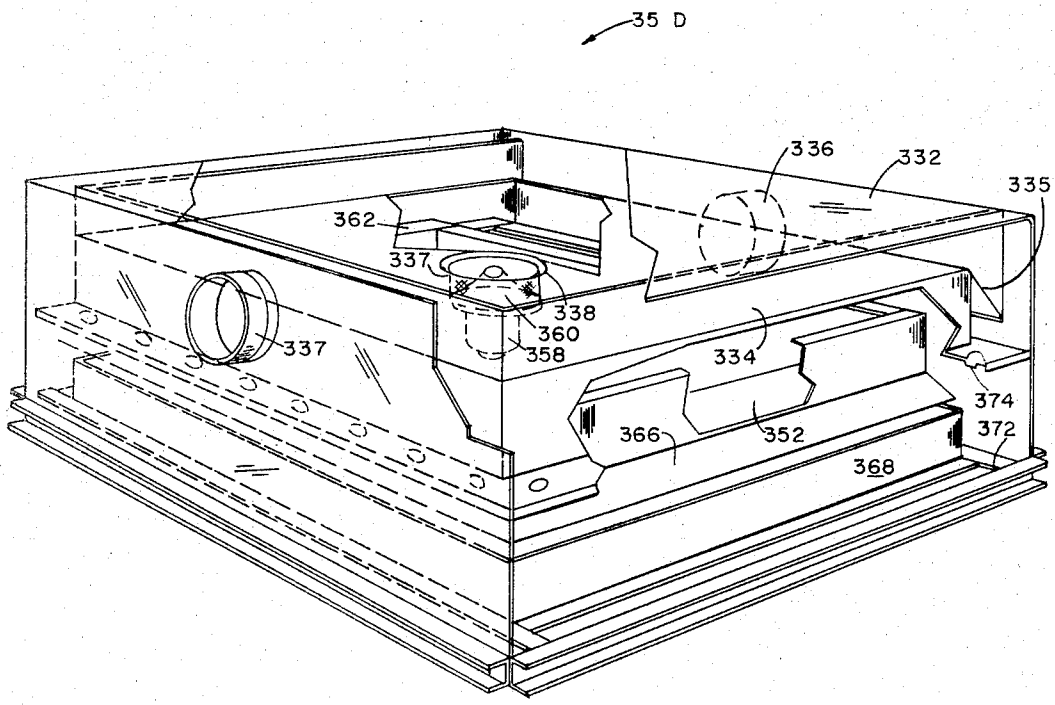


FIG. 12

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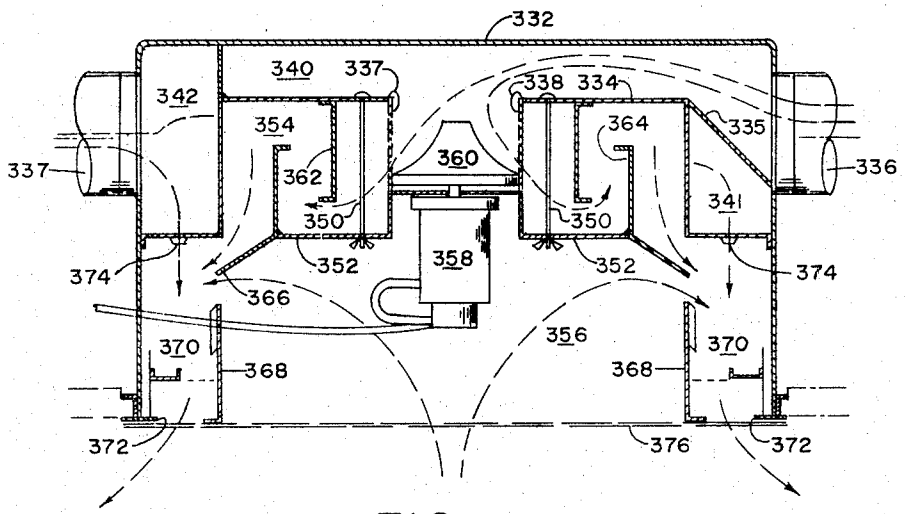


FIG. 13

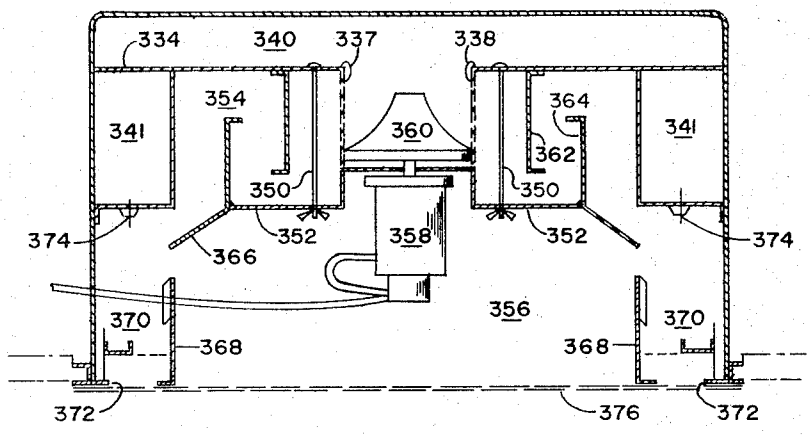


FIG. 14

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AIR CONDITIONING SYSTEM WITH VARIABLE PRIMARY AIR VOLUME TERMINAL AND METHOD OF OPERATION THEREFOR

BACKGROUND OF THE INVENTION

This invention relates generally to air conditioning systems and methods for their operation. In particular, this invention relates generally to air conditioning systems of the type wherein conditioned primary air is transmitted to a terminal unit and a flow of secondary air is induced and mixed with the primary air to provide supply air to a space to be air conditioned.

Satisfactory air conditioning of a space requires that the effective temperature of air in the space be maintained within a small range. As thermal loads in the space vary, the thermal capacity of the air supplied to the space by the system must be varied in order to maintain the air temperature in the space within the allowable range. Variation in the thermal capacity of supply air can be accomplished either by delivering constant volume of air to the space at a varying temperature, or be delivering a variable volume of air to the space at a constant temperature.

Delivery of a variable volume of air to a space is often unsatisfactory because the ordinarily used fixed air diffusers do not compensate for variations in the volume of supply air and as such, proper circulation of supply air in the space is seldom achieved. Diffusers which are capable of compensating for variations in volume of air flow are relatively expensive and often difficult to maintain. From the room circulation standpoint, therefore, it is desirable to provide a relatively constant volume of conditioned air to a space.

Among the various approaches to providing such a relatively constant volume of supply air to a space is the induced air method of air conditioning wherein a flow of primary air is utilized within an air handling unit to induce a flow of secondary air which combines with the primary air to provide a flow of supply air to the space to be conditioned. Thermal capacity of the supply air is ordinarily varied by causing the secondary air to pass over a heat exchanger containing an exchange medium which exchanges heat with the secondary air in response to the sensed thermal load in the space to be conditioned. The use of such a heat exchanger in such known induction type units, however, has caused the units to be relatively expensive. Further, their use requires the provision of a heat exchange medium at the unit which often necessitates connecting air handling units with central conditioning equipment through a system of pipes. Units not having such heat exchange equipment are known in the art, however, they have been limited in their capability to compensate for variations in thermal load and for other reasons often have been operationally unsatisfactory.

SUMMARY OF THE INVENTION

It is the principal object of the invention, therefore, to provide an air conditioning system wherein a primary air system with induction type terminal units can be utilized, without the necessity for providing heat exchangers in the units or for providing a source of heat exchange medium to each unit from a central source, while maintaining a broad range of thermal capacity of supply air for conditioning a space.

This object and others not enumerated are achieved by the air conditioning system of the present invention which may include apparatus for conditioning and distributing a volume of primary air to a space to be conditioned, a terminal unit in the space wherein at least a portion of the primary air is passed through nozzles to establish a flow of primary air in a mixing duct in the unit, which portion of primary air may induce a flow of secondary air in the unit and mixes with selectively variable volumes of the secondary air or by-pass primary air to constitute supply air for the space to be conditioned, and a by-pass means, independent of the nozzles, for accommodating the passage of the by-pass primary air into the mixing duct, the selective volumes of by-pass primary air and secondary air being variable in response to changes in the temperature of air in the space being conditioned.

The invention also includes a novel terminal unit, one embodiment of which may include a casing connected to a source of primary air for providing constant flow of primary air and selectively variable flow of primary air, means for selectively introducing and mixing a flow of secondary air with the constant flow of primary air, the secondary air comprising selectively volumes of recirculated air from the space and, if appropriate, volumes of air drawn from the plenum chamber defined by a suspended ceiling in the space to be conditioned, and a control means responsive to variations in the temperature of air in the space for controlling the thermal capacity of supply air for the space, the supply air including the primary air from the constant flow and, selectively, volumes of additional or by-pass primary air and secondary air.

The invention also includes a method of operating an air conditioning system for air conditioning a space which may include the steps of conditioning primary air, transmitting the conditioned primary air to a terminal unit, passing a portion of the conditioned primary air through nozzle means to establish a flow of supply air into the space, mixing an additional volume of air with the portion of the conditioned primary air to constitute the supply air, the additional volume of air selectively comprising volumes of secondary air and by-pass primary air, the ratio of which volumes is selectively variable in response to changes in the thermal load conditions of the space.

BRIEF DESCRIPTION OF THE DRAWING

A more complete understanding of the present invention may be had from the following detailed description, particularly when read in the light of the accompanying drawings wherein:

FIG. 1 is a front cross-sectional elevational view of a building having therein an air conditioning system according to the invention;

FIG. 2 is a perspective view, having portions cut away, of one embodiment of a terminal unit according to the present invention;

FIG. 3 is a cross-sectional view through the plane 3—3 of FIG. 2;

FIG. 4 is a cross-sectional view through the plane 4—4 of FIG. 2;

FIG. 5 is a cross-sectional view through the plane 5—5 of FIG. 2;

FIG. 6 is a graphical presentation of the operation of the embodiment of the terminal unit shown in FIGS. 2–5;

FIG. 7 is a perspective view, partially cut away, of another embodiment of a terminal unit according to the present invention;

FIG. 8 is a cross-sectional view through the plane 8—8 of FIG. 7;

FIG. 9 is a cross-sectional view through the plane 9—9 of FIG. 7;

FIG. 10 is a perspective view, partially cut away, of yet another embodiment of a terminal unit according to the present invention;

FIG. 11 is a cross-sectional view through the plane 11—11 of FIG. 10;

FIG. 12 is a perspective view, partially cut away of still another embodiment of a terminal unit according to the present invention;

FIG. 13 is a cross-sectional view through the plane 13—13 of FIG. 12; and

FIG. 14 is a cross-sectional view through the plane 14—14 of FIG. 12.

DETAILED DESCRIPTION

Referring to FIG. 1, there is shown installed in a building 10 an air conditioning system according to the invention and designated generally by the reference numeral 12.

Air conditioning system 12 comprises a main primary air handling unit having an outside air fan 14 for providing ventilation air to the system, a filter section 16 which may be any of the filter sections known to those having skill in the art, a cooling coil 17, a heating coil 18 and a main supply fan 20 which establishes a flow of primary air through the system.

The dry bulb and wet bulb temperatures of primary air leaving the air handling unit are controlled by a suitable thermostat 22 which controls the operation of control valves 24 and 25 and thereby the flow of heat exchange media through the cooling and heating coils 17 and 18 respectively. In this regard, the temperature controls for system 12 may be suitable controls of any of the types generally known in the art.

Primary air is transmitted from the primary air handling unit to spaces to be air conditioned through a main primary air duct 28 and floor run-out ducts 30 which are shown mounted above the ceiling 31 of spaces 33 to be air conditioned. For run-out ducts 30, primary air is supplied to terminal units, designated generally by the reference numeral 35, through air pipes 36.

Primary air in terminal units 35 may be mixed with secondary air, as is discussed below in detail, and supplied to spaces 33 so as to effect proper air-conditioning and circulation. Air leaving spaces 33 and not recirculated as secondary air as is discussed below, passes through suitable openings 38 in ceiling 31 to the space thereabove, and thereafter, downwardly through return air shaft 40 to be re-conditioned in the primary air handling unit.

It can be seen, therefore, that system 12 functions by conditioning primary air at a main air handling unit, transmitting the primary air to terminal units at the spaces to be conditioned, selectively mixing the primary air with secondary air as discussed below to provide supply air to spaces 33 at a thermal capacity proper for the prevailing thermal load, and returning air from the spaces to the main air handling unit through a return air shaft.

Considering now the structure and operation of terminal units 35, one embodiment of such a terminal unit according to the invention is shown in FIGS. 2–5 and designated generally by the reference numeral 35A. Terminal unit 35A includes a casing 37 having upper and transverse extending walls 39 and 41 longitudinally extending vertical side walls 42 and 43, and transversely extending vertical end walls 46 and 47. Formed in the lower portion of casing 37 is a recessed channel 52 which is suitable for receiving a light fixture 53 therein.

Formed in end wall 47 is an opening 55 having a collar 56 to which may be secured air pipe 36 (FIG. 1) for providing unit 35A with primary air from run out duct 30. Opening 55 communicates with a primary air plenum chamber 58 formed in casing 37 by the cooperation of upper wall 39, a vertically longitudinally extending side wall 61, and wall 47, a transversely extending plate 60 which defines the upper wall of recess 52, a transversely vertically extending wall 62, and a longitudinally vertically wall 64.

An opening 66 is formed in transverse wall 62 to communicate primary air plenum chamber 58 with a longitudinally extending duct 68 best seen in FIG. 4 defined by a transverse plate 70 which extends from side wall 42 across the major portion of casing 37 to a point generally above the vertical wall of recess 52, an upper duct wall 72 and side duct walls 73 and 74. Plate 70 extends longitudinally from transverse wall 62 to end wall 46 in a plane which is parallel to and spaced above transverse plate 60.

As is evident from FIG. 4, the transverse dimension of plate 60 corresponds to the width of recess 52. Between end wall 47 and transverse wall 62, however, plate 60 extends beyond recess 52 to side wall 42 (FIGS. 2 and 3), thereby to cooperate with side wall 42, upper wall 39, vertical walls 62 and 64 and end wall 47 to define a primary air by-pass plenum chamber 77.

Mounted in primary air by-pass plenum chamber 77 is a closure means which acts as a throttling device, designated generally by reference numeral 78. Throttling device 78 comprises a generally conical damper 80 which is mounted on a shaft 81 for reciprocation into and out of sealing engagement with the surface of a grommet mounted in an opening 83 formed in vertical wall 64. Shaft 81 is supported for longitudinal reciprocation by a suitable bearing 84 mounted centrally of a perforated cylindrical cage 86 which extends coaxially with shaft 81 from side wall 42 to opening 83. Shaft 81 is operably connected to a damper operator 88, which may be a pneumatic motor or the like, through a spring coupling 89 so as to permit continued operation of damper operator 88 after the engagement of damper 80 with opening 83 as is discussed below.

Formed in vertical wall 62 is an opening 91 which communicates primary air by-pass plenum 77 with a primary air space 93 above transverse plate 70. As is discussed below in detail, a flow of primary air is established through space 93 to the space to be conditioned under high cooling load conditions. The space 90 defined by side wall 42, transverse plate 70 and the side wall of recess 52 (FIG. 4) defines a passage

through which a flow of air can be induced either from the conditioned space through an inlet opening **92** or through a dampered orifice **94** formed in side wall **42** of casing **37**. Orifice **94** is selectively opened and closed by a pivoted damper **96**, of conventional construction, which is operated between open and closed position by a cam-linkage operator **98** (FIG. 3) actuated by damper operator **88** through spring coupling **89**. Damper **96** also operates to close passage **90** when it is in the fully open position (not shown) with respect to orifice **94**.

Depending upon the range of thermal capacity of air to be supplied to a space to be conditioned, it may be desirable to provide a heating means such as strip heater **99** over orifice **94** so that additional heat may be added to air entering the unit through orifice **94**. It is to be recognized, however, that such a heater may not be required, particularly in installations wherein terminal unit **35** is recessed within a suspended ceiling and the ceiling contains air heated as a result of light load conditions and the like.

The space **100** bounded by side wall **43**, upper casing wall **39**, side duct wall **74** and the side of recess **52** (FIG. 4) defines a passage through which a flow of air can pass from terminal unit **37** through outlet opening **101** to the space to be conditioned.

The flow path comprising space **90**, the space **102** between plates **60** and **70**, and space **100** defines a mixing duct wherein a flow of primary air induces and mixes with a flow of secondary air to form supply air for discharge through outlet opening **101** into a space to be conditioned.

A relatively constant flow of primary air for inducing a flow of secondary air through passage **90** is introduced to the mixing duct through a plurality of nozzles **104** (FIGS. 3 and 5) which are mounted in transverse plate **70** and communicate primary air duct **68** with the space **102** between plates **60** and **70**. In this regard, nozzles **104** operate in the conventional manner by discharging primary air into space **102** at such a velocity as to induce a flow of secondary air to be carried along therewith.

Considering, therefore, the operation of terminal unit **35A**, primary air is introduced to primary air plenum chamber **58** from air pipe **36** (FIG. 1) through opening **55**. A constant flow of the primary air passes unrestrictedly from plenum chamber **58** through opening **66** into air duct **68** and thereafter through air nozzles **104** into the mixing duct. Under certain operating conditions, the passage of primary air through nozzles **104** may induce and mix with a flow of secondary air from passage **90** which mixture is discharged through outlet opening **101** into a space to be conditioned, e.g. space **33** of FIG. 1.

The volumetric make-up of supply air being discharged through outlet opening **101** at any time is determined by the thermal requirements of the space being conditioned. Thus the supply air can be made-up of substantially all primary air during periods of maximum cooling requirements, i.e. the volume of constantly flowing primary air plus a volume of by-pass primary air, and during periods of lesser cooling load, can be made up of the constant volume of primary air flowing through nozzles **104** and the secondary air from passage **90** which is induced by the flowing primary air from either the conditioned space as recirculated air or from the space above ceiling **31**. As was noted above, however, it is desirable for purposes of maintaining proper circulation, to provide a relatively constant volume of supply air to the space being conditioned, notwithstanding variations in the make-up of the supply air.

The thermal load requirements of the air in the space to be conditioned may be sensed by a thermostat such as thermostat **106** in FIG. 1. Changes in air temperature are sensed in the space to be conditioned and a resulting signal is sent to damper motor **88** to adjust make-up of supply air to accommodate for the change occurring in the thermal load of the room. Thus, when thermostat **106** senses such a rise in space temperature as to call for full cooling, damper operator **88** is actuated to fully withdraw conical damper **80** from opening **83** to allow conditioned by-pass primary air to flow from primary air plenum chamber **58** into by-pass plenum **77** through opening **91**. Thereafter, the by-pass primary air flows over duct **68** and into space **100** where it is mixed with the constantly flowing primary air from nozzles **104** and discharges as supply air through outlet opening **101**. The relatively unrestricted flow of by-pass primary air into passage **100** during full cooling causes the air pressure in passage **100** to be such as to virtually eliminate the induction of any secondary air from passage **90** by the flow of primary air through nozzles **104**.

As less cooling in the space is required, however, conical damper **80** is modulated toward opening **83** by damper operator **88** so as to reduce the flow of by-pass primary air into plenum chamber **77** and ultimately passage **100**. The throttling effect of damper **80** also introduces a pressure drop into the by-pass primary air system thereby reducing the pressure of air in passage **100** so as to allow the flow of primary air through nozzles **104** to commence inducing a flow of secondary air from passage **90**. At this stage of the operation, damper **96** is in the closed position thereby providing that all secondary air induced by the flow of primary air through nozzles **104**, is recirculated air, i.e. air from the conditioned space entering passage **90** through inlet opening **92**.

The amount of secondary air induced by the flowing primary air at any time should be substantially equal to the reduction in flow of primary air from the full flow condition so as to maintain the volume of supply air substantially constant. The thermal effect of such a volume of unconditioned air which is induced from the space is to reduce the thermal cooling capacity of the supply air to the space. Thus a reduction in space cooling load is compensated for by reducing the volume of by-pass primary air being supplied and correspondingly increasing the volume of return air being recirculated by induction so that the thermal cooling capacity of the supply air can be reduced without any substantial change in volume of the supplied air.

Continued reduction in the cooling requirement of the space causes a further modulation of conical damper **80** toward the closed position thereby progressively reducing the amount of conditioned primary air in the supply air, and increasing the amount of recirculated air, thus reducing the thermal cooling capacity of the supply air. It should be recognized, however, that

the supply of primary air to the space is never completely stopped because at all times during the operation of the system, primary air flows through nozzles **104**.

During approximately the last 10 percent of the advance of conical damper **80** toward opening **83**, pivoted damper **96** commences to uncover orifice **94** thereby resulting in the air being induced in passage **90** both through inlet opening **92** and orifice **94**. This operation is of particular importance where terminal unit **35A** is mounted in a ceiling space which contains warmer air than the environmental air in the space because of the mounting of lights or other heat generating equipment in the ceiling space. Specifically, by using this heated air, the thermal cooling capacity of the supply air can be further reduced, and, depending upon the temperature of air in the ceiling space, a heating capability can even be achieved without a necessity for utilizing a supplemental source of heat.

A further reduction in the cooling requirement of the space causes damper operator **88** to further displace damper **96** in the clockwise direction so as to continue to open orifice **94** and to progessively cover space **90** until, at some point, all secondary air is being drawn into terminal unit **35A** through orifice **94**. If further heating of the secondary air is required after space **90** is completely closed, the use of a heating means such as strip heater **99** becomes necessary. It has been found, however, that most commercial and domestic installations do not require the provision of this additional heating means.

It was noted above that even after the engagement of conical damper **80** with opening **83**, damper operator **88** continues to operate damper **96** between partially and fully open positions. This is accomplished by attaching cam linkage operator **98** to the output shaft of damper operator **88** on the operator side of spring coupling **89**. Thus, although shaft **81** is restrained against further displacement to the right as seen in FIG. **3** once conical damper **80** is engaged with opening **83**, further operation of damper operator **88** causes the spring of spring coupling **89** to be compressed thereby allowing further displacement of cam-linkage operator **98**.

The operation of terminal unit **35A** may better be understood from a consideration of FIG. **6** which graphically depicts the relative thermal capacity of air supplied to a space to be conditioned in terms of the volumetric make-up of the supply air. Thus, it can be seen from the graph of FIG. **6**, that at point A maximum cooling is required and the total volume of supply air is made up of 80 percent by-pass primary air in addition to the 20 percent constant flow of primary air. As the cooling load in the space decreases, damper **80** modulates as discussed above to restrict the flow of by-pass primary air thereby permitting the commencement of induction of secondary air as discussed above. Thus, at point B on FIG. **6**, the thermal cooling capacity of the supply air is 79 percent of the maximum thermal cooling capacity. In order to accommodate this load, the supply air volumetrically comprises 20 percent constant flow of primary air, 60 percent by-pass primary air and 20 percent secondary air which is induced as recirculated air from the space being conditioned. Continued reduction in the required thermal cooling capacity of the supply air to 20 percent of the maximum thermal cooling capacity (point C on FIG. **6**,) is sensed by the thermostat in the space being conditioned and causes damper **80** to modulate to restrict totally the flow of by-pass primary air. Thus, at this stage of the operation, the volumetric make-up of the supply air is 20 percent constant flow or primary air and 80 percent secondary air which is induced as recirculated air from the space being conditioned.

As the cooling load in the space is reduced to the point where no cooling is required to maintain comfort conditions, (D on FIG. **6**), damper **80** is maintained in total flow restricting position with respect to by-pass primary air and damper **96** commences modulation to cause the make-up of secondary air to include both recirculated air from the space being conditioned and air drawn from the plenum above suspended ceiling **31**. Thus, at this stage of the operation, it can be seen from FIG. **6** that in addition to the 20 percent constant flow of primary air, the remaining volume of secondary air comprises 35 percent recirculated from the conditioned space and 45 percent air drawn from the space above the suspended ceiling.

Finally, as the cooling load in the conditioned space passes to a negative load or heating load, e.g. .E on FIG. **6**, damper **96** continues to be operated to restrict the flow of secondary air drawn as recirculated air from the conditioned space and to further permit the induction of secondary air from the space above the suspended ceiling. Thus, at .E where the heating load is 12 percent of the relative thermal capacity of the system, the total volume of supply air to the system includes in addition to the **20%** constant flow of primary air, 80 percent secondary air induced from the space above the suspended ceiling.

If it is desired to provide additional heating capacity, thereby extending the thermal capacity line beyond .E on FIG. **6**, strip heater **99** can be incorporated as discussed above.

It can be seen, therefore, that the terminal unit **35A** of FIGS. **2–5** embodies an air missing device which combines variable volumes of primary and secondary air to provide a substantially constant volume of supply air to a space at a desired thermal capacity, which capacity is variable in response to variations in the thermal load sensed in the space. Additionally, the terminal unit **35A** when mounted in a space above a suspended ceiling wherein heated air is available, can accommodate not only cooling loads but also, heating loads to the extent noted above.

Another embodiment of a terminal unit according to the invention is shown in FIGS. **7–9** and designated generally by reference numeral **35B**. Unit **35B** is similar in basic operation to the embodiment **35A** of FIGS. **2–5** with the exception that there is not provision of inducing a flow of air other than as return air from the space being conditioned.

Referring to FIG. **7**, terminal unit **35B** comprises a primary air inlet section **120** which is disposed between two induction and mixing sections **122, 123**. Induction and mixing sections **122, 123** are in communication with recirculated air plenums **125, 126** through connector pipes **128, 129**, respectively. The structure and operation of induction and mixing sections **122, 123** and recirculated air plenums **125, 126** are identical.

Accordingly, the terminal unit **35B** is described below in terms of primary air inlet section **120**, induction and mixing section **123** and recirculated air plenum **126** with the understanding that the structure and operation of sections **122** and **125** are identical.

Referring therefore to FIG. **7**, primary air inlet section **120** is shown to comprise a casing **132** the internal volume of which is divided into a primary air plenum chamber **134** and a primary air by-pass plenum chamber **135** by a vertically extending partition **137**. Depending from casing **132** are mounting strips **138** which support casing **132** above the Tee bars **141** of a suspended ceiling.

Plenum chamber **134** is provided with an opening **139** having a collar **140** suitable for attachment to primary air supply pipe such as air pipe **36** in FIG. **1**. A further opening **142** is formed in the lower side wall of plenum chamber **134** to place plenum chamber **134** in unrestricted communication with a primary air duct **144** which is formed in induction and mixing section **123**. Additionally, partition **137** is provided with a grommeted opening **146** which communicates plenum chamber **134** with by-pass plenum chamber **135**. Opening **146** is selectively opened and closed by a throttling device **148** which is identical in structure to the throttling device **78** of the terminal of FIGS. **2–5** except that the conical damper **150** of device **148** is coupled directly to the output shaft **151** of damper operator **152** and not indirectly through a spring coupling such as coupling **89**. Finally, by-pass plenum chamber **135** is in communication with a primary air space **154** in induction and mixing section **123** through an opening **155** in the casing **132**.

Induction and mixing section **123** is best seen in FIG. **8** and comprises a casing **158** which is supported above Tee bars **141** by mounting strips **138**. The space between mounting strips **138** defines a passage **160** which is in communication with the interior of section **123**. In this regard, one of the mounting strips **138** extends into the internal volume of section **123** and is flanged at its top to define a passage **161** which communicates primary air space **154** with a mixing chamber **163**.

Mixing chamber **163** and primary air duct **144** are in communication through a plurality of nozzles **165** which are oriented to direct air flowing from duct **144** downwardly into passage **160** so as to establish a flow of air through passage **160** and into a space to be conditioned through an outlet opening **166**. Additionally, the end wall **168** of casing **158** is provided with an opening **169** which places mixing chamber **163** in communication with return air plenum **126** through connector pipe **129**.

Recirculated air plenum **126** comprises a casing **171** which is supported above Tee bars **141** by mounting strips **173** which cooperate to define a passage (not shown) through which air from the condition spice may be induced for recirculation as secondary air during the operation of terminal unit **35B**.

The operation of terminal unit **35B** is substantially the same as the operation of terminal unit **35A**. Specifically, primary air is introduced to primary air plenum chamber **134** from a source of primary air such as air pipe **36**. A constant volume of the primary air passes unrestrictedly from plenum chamber **134** through opening **142** into air duct **144** and thereafter through nozzles **165** into mixing chamber **163**. As noted above, the passage of primary air through nozzles **165** establishes a flow of air through passage **160** and outlet opening **166** into a space to be conditioned. In passage **160** which defines a mixing duct, the primary air from nozzles **165** is mixed with a volume of additional air from mixing chamber **163** to define the supply air for the space to be conditioned. The additional air is supplied from two sources, viz. by-pass primary air from primary air space **154** through passage **161**, and secondary air which in this embodiment comprises recirculated space air from recirculated air plenum **126** through air pipe **129**. The relative amounts of additional air from the two sources are established in response to the thermal load in the space to be conditioned as is sensed by a thermostat mounted in the space, which controls the operation of damper operator **152**. Thus, when a thermostat, e.g. thermostat **106** of FIG. **1** senses such a rise in space temperature as to call for full cooling, damper operator **152** is actuated to withdraw conical damper **150** from opening **146** to allow conditioned primary air to flow from plenum chamber **134** into by-pass plenum chamber **135** through opening **146**. Thereafter the primary air flows from by-pass plenum **135** to air space **154** through opening **155** and into mixing chamber **163** through passage **161**. The amount of by-pass primary air flowing into mixing chamber **163** under full cooling conditions is such when combined with the primary air from nozzles **165**, as to fully satisfy the volumetric requirements of the space to be conditioned. Thus, under full cooling conditions, no air from the space is induced from recirculated air plenum **126** through air pipe **129**.

As less cooling in the space is required, conical damper **150** is modulated toward opening **146** by damper operator **152** thus reducing the flow of by-pass primary air. As the flow of by-pass primary air is throttled by displacement of conical damper **150**, and in order to maintain a substantially constant volumetric flow of supply air into the space to be conditioned, a flow of recirculated air is induced from recirculated air plenum **126** in an amount substantially equal to the amount by which the flow of by-pass primary air is reduced. Continued reduction in the cooling load is sensed by the thermostat and conical damper **150** continues to be modulated by damper control **152** until damper **150** is in sealing engagement with opening **146**. At this stage of the operation, primary air is flowing through nozzles **165** and the flowing air is inducing a flow of secondary air from the conditioned space through recirculated air plenum **126** and air pipe **129**.

It can be seen from the foregoing, therefore, that terminal unit **35B** enables the provision of a substantially constant volume of supply air to a space to be conditioned, the thermal capacity of which supply air can be varied over a relatively wide range without the necessity for auxiliary heat exchangers, the provision of supplementary heat exchange media, or other heat exchange equipment as is ordinarily used in known equipment.

A further embodiment of a terminal unit according to the invention is shown in FIGS. **10** and **11** and designated generally by the referenced numeral **35C**. Unit **35C** operates in the same manner as the unit **35B**

of FIGS. 6–8, and is similar in the basic operation to the embodiment 35A of FIGS. 2–5 with the exception that there is no provision for inducing a flow of air other than as return air from the space being conditioned. In this regard, the general operation of the embodiment of FIGS. 10 and 11 is to provide supply air to the space to be conditioned from a peripheral outlet opening and to induce recirculated air from the space being conditioned through a central opening in the terminal unit.

Referring therefore to FIGS. 10 and 11, terminal unit 35C can be seen to include a generally square casing 232 having vertically extending walls and a top wall for closing the upper end of the casing. The volume defined by casing 232 is divided into an upper portion and a lower portion by a partition 234 which is secured to the vertically extending walls of casing 232 and extends generally transversely thereacross. Partition 234 is provided with a vertically upwardly extending stepped portion which cooperates with the inner surface of the vertical walls of casing 232 to define a generally annular channel 235.

Formed generally centrally in partition 234 is a substantially circular opening 237 which is provided with a grommet 238 around the inner edge thereof.

The upper portion of the inner volume of casing 232 defines a primary air plenum chamber 240 which is in communication with a source of primary air to an opening 242 in a vertical wall of the casing 232 which is provided with a collar 244 which may be secured to a suitable air pipe, e.g. air pipe 36 (FIG. 1).

Suspended from the central portion of partition 234 by suitable bolts 250 is a baffle plate 252. Baffle plate 252 separates the lower central portion of the inner volume of casing 232 into a by-pass primary air plenum 254 and a secondary air plenum 256. Additionally, the central portion of baffle plate 252 is raised to define a mounting surface from which is dependently supported a damper motor 258 which reciprocably operates a generally conical damper 260 into and out of engagement with the grommet 238 of opening 237 so as to selectively permit and interrupt a flow of primary air from primary air plenum chamber 240 through opening 237 into by-pass primary air plenum chamber 254.

The flow of by-pass primary air through by-pass primary air plenum chamber 254 is restricted by a first baffle plate 262 which depends from the under-surface of partition 234, and a second baffle plate 264 which is disposed outwardly of first baffle plate 262 and extends upwardly from the upper surface of plate 252. The outer edge of plate 252 is provided with an angularly downwardly extending flange 266 which directs the flow of by-pass primary air from by-pass plenum chamber 254 outwardly against the surfaces of the vertical walls of casing 232.

Disposed inwardly of the vertical walls of casing 232 is a vertically extending divider 268 which cooperates with the vertically extending walls of casing 232 to define an annular mixing duct 270 which is in communication with a space to be conditioned through an outlet opening 272.

Disposed above mixing duct 270 and mounted in transverse partition 234 adjacent the vertically extending walls of casing 232 are a plurality of nozzles 274 which accommodate therethrough a substantially constant flow of primary air from primary air plenum chamber 240 into mixing duct 270.

Secondary air plenum chamber 256 is in communication with the space being conditioned through an opening 276 which may be covered by a suitable ornamental screen or the like.

The operation of terminal unit 35C is substantially the same as the operation of terminal unit 35B. Specifically, primary air is introduced to primary air plenum chamber 240 from a source of primary air such as air pipe 36. The constant volume of the primary air passes unrestrictedly from plenum chamber 240 through nozzles 274 into mixing duct 270. As was discussed above with respect to the other embodiment, the passage of primary air through nozzles 274 establishes a flow of air through mixing duct 270 and outlet opening 272 into a space to be conditioned. In mixing duct 270, the primary air from nozzle 274 is mixed with a volume of additional air to define the supply air for the space to be conditioned. The additional air is supplied selectively from two sources, viz. by-passed primary air from primary air plenum chamber 240 through opening 237 and by-pass primary air plenum chamber 254, and secondary air which, in this embodiment, comprises recirculated space air from secondary air plenum 256.

The relative amounts of additional air from the two sources are established in response to the thermal load in the space to be conditioned as is sensed by a thermostat mounted in the space which controls the operation of damper motor 258. Thus, when a thermostat, e.g. thermostat 106 of FIG. 1, senses such a rise in space temperature as to call for full cooling, damper motor 258 is actuated to withdraw conical damper 260 from opening 237 to allow conditioned primary air to flow from plenum chamber 240 into by-pass plenum chamber 254. Thereafter, the by-pass primary air flows from by-pass plenum 254 over flange 266 and into mixing duct 270 to augment the flow of primary air from nozzles 274 and to define supply air to the space to be conditioned. As was the case with respect to the embodiment of FIGS. 6–8 above, no air from the space is induced for recirculation from secondary air plenum 256 under full cooling conditions.

As less cooling in the space is required, conical damper 260 is modulated toward opening 237 by damper motor 258, thus reducing the flow of by-pass primary air. As the flow of by-pass primary air is throttled by the displacement of conical damper 260, and in order to maintain a substantially constant volumetric flow of supply air into the space to be conditioned, a flow of recirculated air is induced from secondary air plenum 256 is an amount substantially equal to the amount by which the flow of by-pass primary air is reduced. Continued reduction in the cooling load is sensed by the thermostat and conical damper 260 continues to be modulated by damper motor 258 until damper 260 is in sealing engagement with grommet 238 of opening 237. At this stage of the operation, primary air is flowing through nozzles 274 and the flowing air is inducing a flow of secondary air which comprises recirculated air drawn from the conditioned space through secondary air plenum 256.

Terminal unit 35C, therefore, defines an air terminal unit wherein supply air is discharged into a space through an annular peripheral outlet opening and air to be recirculated through the unit as secondary air is drawn into the space through a central opening 276. Thus, this embodiment provides for desirable air circulation conditions.

Still another embodiment of terminal unit according to the invention is shown in FIGS. 12–14 and designated generally by reference numeral 35D. This embodiment is very similar in structure to that disclosed in FIGS. 10 and 11. However, it is adapted for use in an air conditioning system wherein independent supplies of primary air are supplied to each terminal unit. One supply which shall be designated "interior" primary air for purposes of this description is provided at constant temperature from a central conditioning unit. The second supply, which shall be designated "-perimeter" primary air, is provided at variable temperature from a central conditioning unit. In this regard, the primary air for both the interior and perimeter systems may be conditioned at the same central conditioning unit thereafter separated so that the air for the perimeter system may be subjected to further temperature central either by reheating at the central conditioning unit or by reheating at the individual terminal units to accomplish individual room control.

Considering terminal unit 35D in detail, and referring particularly to the figure a generally square casing 332 can be seen to include four vertically extending walls and a top wall for closing in the upper end of the casing. The volume defined by casing 332 is divided into an upper portion for defining an interior primary air plenum chamber 340, an annular perimeter primary air plenum chamber 341, a by-pass primary air plenum 354, a secondary air plenum 356 and an annular mixing duct 370.

Interior primary air is supplied to interior primary air plenum chamber 340 through an air pipe 336 which is connected to a suitable source of interior primary air (not shown). Similarly, annular perimeter primary air plenum 341 communicates with air pipe 337 through a perimeter primary air inlet chamber 342. Air pipe 337 is connected to a suitable source of perimeter primary air (not shown).

Perimeter primary air plenum 341 and by-pass primary air plenum 354 are separated from interior primary air plenum chamber 340 by a partition 334 which extends transversely of casing 332 except for an inclined portion 335 on the end thereof adjacent air pipe 336. Formed generally centrally in partition 334 is a substantially circular opening 337 which is provided with a grommet 338 around the inner edge thereof.

Secondary air plenum 356 is separated from by-pass primary air plenum 354 by a baffle plate 352 which is suspended below partition 334 by suitable bolts 350. Additionally, in the same manner as discussed above with respect to terminal unit 35C, the central portion of baffle plate 352 is raised to define a mounting surface from which is dependently supported a damper motor 358 which reciprocably operates a generally conical damper 360 into and out of engagement with the grommet 338 of opening 337 so as to selectively permit and interrupt a flow of interior primary air from plenum chamber 340 into by-pass primary air plenum 354. In this regard, the interior primary air flowing from plenum 340 to plenum 354 functions as by-pass primary air in the context of the term as used with respect to the description of terminal units 35A, 35B and 35C.

The flow of by-pass (interior) primary air through by-pass primary air plenum chamber 354 is restricted by a first baffle plate 362 which depends from the under-surface of partition 334, and a second baffle plate 364 which is disposed outwardly of first baffle plate 362 and extends upwardly from the upper surface of baffle plate 352. The outer edge of baffle plate 352 is provided with an angularly downwardly extending flange 366 which directs the flow of by-pass (interior) primary air from by-pass plenum 354 outwardly against the surfaces of the vertical walls of casing 332.

Disposed inwardly of the vertical walls of casing 332 is a vertically extending divider 368 which cooperates with the vertically extending walls of casing 332 to define annular mixing duct 370 which is in communication with a space to be conditioned through an outlet opening 372.

Disposed above mixing duct 370 and mounted in the lower transverse walls of perimeter primary air plenum 341 and perimeter primary air inlet chamber 342 are a plurality of nozzles 374 which accommodate therethrough a substantially constant flow of perimeter primary air into mixing duct 370.

Secondary air plenum 356 is in communication with the space being conditioned through an opening 376 which may be covered with a suitable ornamental screen or the like.

The operation of terminal unit 35D is substantially the same as the operation of terminal unit 35C with the exception that in terminal unit 35C the constant flow of primary air and by-pass primary air are supplied to the unit directly from a single air pipe source whereas in terminal unit 35D, the constant flow of primary air and the by-pass primary air are provided from separate sources, viz. the perimeter primary air system and the interior primary air system.

Thus, in operating terminal unit 35D, a constant volume of perimeter primary air is introduced into chamber 342 and plenum 341 from air pipe 337. The constant volume of primary air passes unrestrictedly from chamber 342 and plenum 341 into mixing duct 370. As was discussed above with respect to the other embodiments, the passage of primary air through nozzles 374 establishes a flow of air through mixing duct 370 and outlet opening 372 into the space to be conditioned. In mixing duct 370, the primary air from nozzle 374 is mixed with a volume of additional air to define the supply air for the space to be conditioned. The additional air is supplied selectively from two sources, viz by-passed (interior) primary air from plenum chamber 340 through opening 337 and by-pass primary air plenum chamber 354, and secondary air which, in this embodiment, comprises recirculated space air from secondary air plenum 356.

The relative amounts of additional air from the two sources are established in response to the thermal load in the space to be conditioned as is sensed by a thermostat mounted in the space which controls the operation of damper motor 358. Additionally, the thermostat in the space may be utilized to control the temperature at which perimeter air is introduced to the unit, e.g., by controlling a reheater upstream of air pipe 337. Thus, when the space thermostat senses such a rise in space temperature as to call for full cooling, no re-heat is provided to the perimeter primary air being supplied through air pipe 337, and damper motor 358 is actuated to withdraw conical damper 360 out of opening 337 to permit interior primary air to flow from plenum chamber 340 into by-pass plenum 354. Thereafter, the

interior primary air flows as by-pass primary air from pass plenum **354**, over flange **366** and into mixing duct **370** to augment the flow of primary air from nozzles **374** and to define supply air to the space to be conditioned. As was the case with respect to the above-described embodiments, no air from the conditioned space is induced for recirculation from secondary air plenum **356** under full cooling conditions.

As less cooling in the space is required, conical damper **360** is modulated toward opening **337** by damper motor **358**, thus reducing the flow of by-pass (interior) primary air. As the flow of by-pass primary air is throttled by the displacement of conical damper **360**, and in order to maintain a substantially constant volumetric flow of supply air into the space to be conditioned, a flow of recirculated air is induced from secondary air plenum **356** in an amount substantially equal to the amount by which the flow of by-pass primary air is reduced. Continued reduction in the cooling load is sensed by the thermostat and conical damper **360** continues to be modulated by damper motor **358** until damper **360** is in sealing engagement with grommet **338** of opening **337**. At this stage of the operation, perimeter primary air is flowing through nozzles **374** and the air thus flowing is inducing a flow of secondary air which comprises recirculated air drawn from the conditioned space through secondary air plenum **356**.

Continued reduction in the cooling load in the conditioned space will cause the space thermostat to actuate heating means such as a reheater coil for increasing the temperature of the perimeter primary air as required by the particular space thermal load.

It should also be recognized that the basic terminal units of the invention may be modified for wall mounting without departing from the basic teaching and without departing from the scope of the method of the invention.

It is considered to be manifest that many modifications and variations can be made to the described embodiments without departing from the scope and teaching of the present invention.

What is claimed is:

1. An air conditioning system for controlling the condition of air in a space comprising:

a. means for conditioning primary air,

b. terminal unit means in said space,

c. means for transmitting the conditioned primary air from said conditioning means to the terminal unit,

d. said terminal unit including,

1. a mixing duct having an inlet for air to be induced from said space and an outlet for conditioned supply air into said space,

2. a primary air plenum in communication with the conditioned air delivered to said terminal unit having nozzle means for introducing a constant relatively small proportion of the conditional primary air into the mixing duct to induce a flow of conditioned supply air from this mixing duct through said outlet into the space,

3. by-pass means in communication with the conditioned primary air delivered to the terminal unit and connected to the mixing duct for delivering a supply of damped conditioned primary air into the mixing duct at a point spaced from and independent of the induction air delivered by the nozzle means, and

4. means responsive to changes in the thermal requirements of the space to be conditioned to regulate the conditioned primary air to be delivered by said by-pass means into the mixing duct relative the volume of air induced from the space through the inlet to the mixing duct whereby a constant volume of conditioned supply air including a ratio of by-pass conditioned air and induced space air is delivered by the terminal unit to obtain the necessary thermal capacity for meeting the cooling requirements of the space to be conditioned.

2. In the air condition system as claimed in claim **1** wherein the by-pass means is operatively connected to the primary plenum at one end and has an outlet communicating with the mixing duct at the said spaced point and the means responsive to the condition of the air in the space includes, a normally closed damper means disposed in the by-pass means, and an actuator for moving said damper means as a function of the variations in the thermal requirements of the space to be conditioned.

3. In an air condition system as claimed in claim **1** wherein the space to be conditioned includes a suspended ceiling defining an above-ceiling plenum space and the said terminal unit further includes:

a. means forming an opening to provide communication between the above-ceiling plenum space and the mixing duct, and

b. second damper means operatively associated with the means responsive to changes in thermal conditions of the space to be conditioned and disposed to normally maintain said opening closed whenever conditioned primary air is being by-passed into the mixing duct,

c. the second damper means operable to uncover the opening from the above-ceiling space to permit delivery of varying volumes of warmer air from the above-ceiling plenum relative to the volume of air induced from the space to modulate the temperature of the air from the space and to provide a constant volume of conditioned supply air including a ratio of primary air, above-ceiling air and induced space air to obtain the necessary thermal capacity for meeting the heating requirements of the space to be conditioned.

4. In an air conditioning system as claimed in claim **3** wherein said second damper means is positioned in the terminal unit to simultaneously and selectively vary the opening of the inlet for the mixing duct and the opening for the above-ceiling space in the terminal unit.

5. In an air conditioning system as claimed in claim **3** further including:

a. means mounted adjacent said opening for further heating the warmer air in the above-ceiling plenum which passes through the opening into the mixing duct,

b. and means for controlling delivery of heating media to the heating means.

6. An air conditioning system for controlling the condition of air in a space having a suspended ceiling defining an above-ceiling plenum space comprising:

a. means for conditioning primary air,

b. terminal unit means in said space,

c. means for transmitting the conditioned primary air from said conditioning means to the terminal unit,

d. said terminal unit including,

1. a mixing duct having an inlet for air to be induced from said space and an outlet for conditioned supply air to said space,

2. a primary air plenum in communication with conditioned primary air delivered to the air delivered to the space having nozzle means for introducing a constant relatively small proportion of the conditioned primary air into the mixing duct to induce a flow of conditioned supply air from the mixing duct through said outlet into the space,

3. by-pass means in communication with the conditioned primary air delivered to the terminal unit and connected to the mixing duct for delivering a supply of damped conditioned primary air into the mixing duct at a point spaced from and independent of the induction air delivered by the nozzle means,

4. means providing an opening between said above-ceiling air plenum and said mixing duct, and

5. means responsive to the changes in the thermal requirements of the space to be conditioned to selectively and alternatively regulate the relative mixture of damped conditioned bypass air, the above-ceiling plenum air and air from said space entering the mixing duct whereby a constant volume of conditioned supply air is delivered from the mixing duct through said outlet into the space to meet the thermal requirements for selectively and alternatively cooling and heating said space as may be required.

7. In an air conditioning system as claimed in claim **6** further including:

a. means mounted adjacent the means forming the opening in the terminal unit for heating air passing therethrough, and

b. means to control the operation of said heating means.

8. In a method of operating an air conditioning system for controlling the condition of air in a space the steps of:

conditioning primary air,

transmitting the conditioned primary air to a terminal unit proximate the space to be conditioned,

discharging a constant relatively small portion of said conditioned primary air in said terminal unit to induce the flow of air from said space into the terminal unit and the flow of conditioned supply air from the terminal unit into said space,

damping the pressure and selectively by-passing varying volumes of conditioned primary air to a point in said terminal unit spaced from and independent of the induction air,

controlling the relative volumetric proportions of by-passed damped conditioned primary air and the induced air from the space entering the unit to mix with said constant relatively small volume of induction air responsive to the thermal conditions in the space to be conditioned whereby when the temperature in said space rises above a predetermined cooling temperature level said control means will gradually increase the volumetric ratio of the damped conditioned air by-passed relative the air induced from the space and when it falls below this predetermined cooling level said control means will decrease the volumetric ratio of damped conditioned air by-passed relative the air induced from the space to continuously maintain delivery of a constant volume of conditioned supply air from the terminal unit for meeting the requirements for conditioning the air in said space.

9. The method for air conditioning as claimed in claim **8** wherein space to be conditioned has a ceiling defining an above-ceiling plenum and said method further including the steps of:

selectively passing varying volumes of warmer air from the above-ceiling plenum to the terminal unit to mix with varying volumes of air induced from said space to be conditioned provided conditioned primary air is not being by-passed into the terminal unit,

controlling the relative volumetric proportions of air from the above-ceiling plenum space and the induced air from the space in the unit for mixing with said constant relatively small volume of conditioned primary air responsive to the thermal conditions in the space to be conditioned whereby as the temperature in said space drops to a predetermined heating level the control will operate to gradually increase the volume of air delivered from the above-ceiling plenum to that induced from the space and as the temperature in the space rises above the predetermined heating level the control means will operate to decrease the volume of air delivered from the above-ceiling plenum to that induced from the space so that a constant volume of conditioned supply air is delivered from the terminal unit to said space over an entire range of normal heating and cooling conditions as such space may require.

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