Nov. 20, 1934. W. H. CARRIER 1,981,164

METHOD AND SYSTEM FOR VENTILATING AND CONDITIONING AUDITORIUMS AND THE LIKE

Original Filed June 22, 1927 2 Sheets-Sheet 1

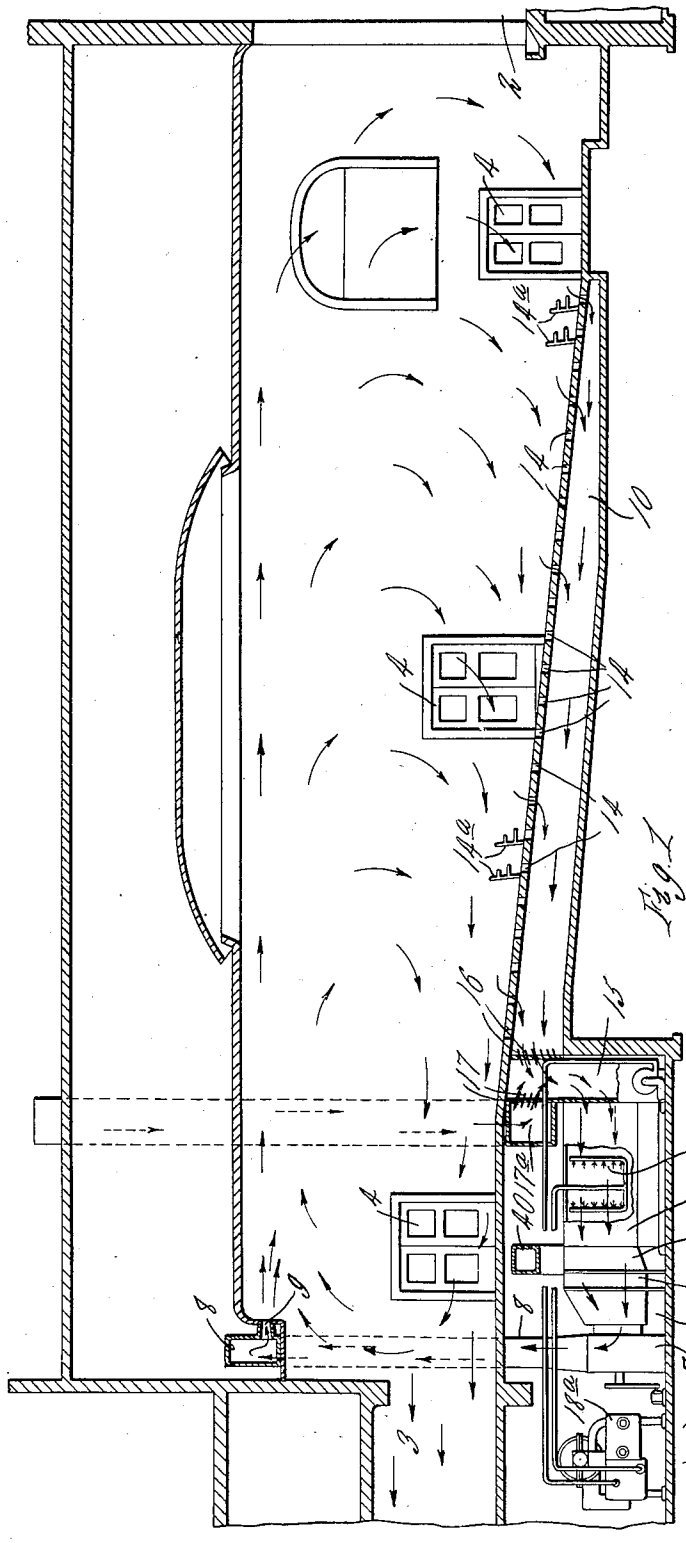


Fig. 1

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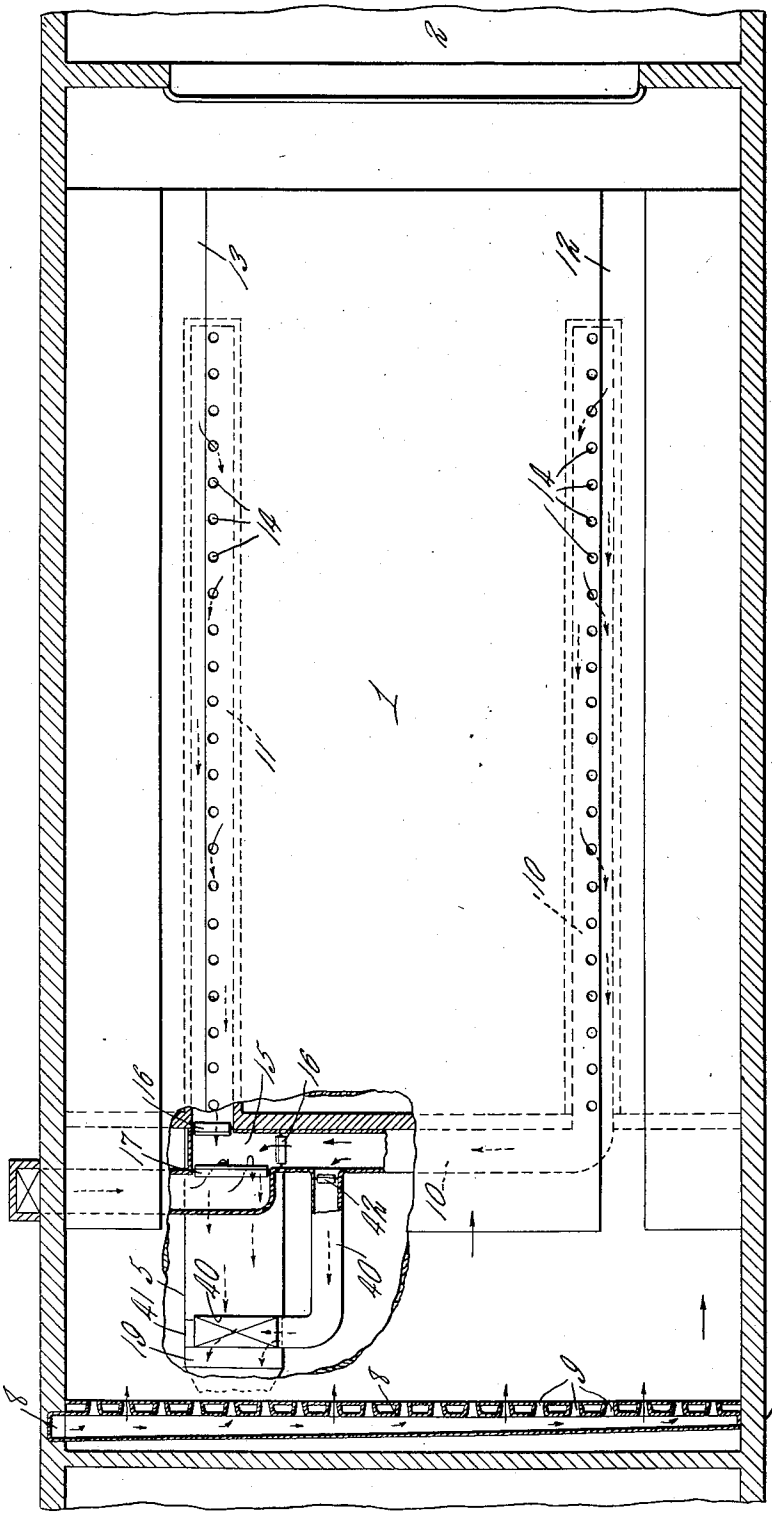


Fig. 8.

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METHOD AND SYSTEM FOR VENTILATING AND CONDITIONING AUDITORIUMS AND THE LIKE

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Original application June 22, 1927, Serial No. 200,665. Divided and this application August 12, 1930, Serial No. 474,772

10 Claims. (Cl. 98—33)

This invention relates to the heating, cooling and ventilation of auditoriums or theaters and other places of assembly which are analogous to theaters as regards the requirements and equipment for the ventilation and air conditioning thereof. The word "auditorium" as hereinafter employed is intended to designate such places or rooms.

This application is a division of my copending application Serial No. 200,665, filed June 22, 1927, which has matured into Patent 1,775,749, patented Sept. 16, 1930, and reissued Aug. 7, 1934 as Re. 19,263.

It is desirable that the air supplied to such places for ventilation purposes be conditioned so as to provide the greatest comfort for the people assembled therein, and the temperature and humidity of the conditioned air necessary to provide this comfort will vary with exterior atmospheric conditions and the number of people assembled.

Heretofore, various systems have been devised for heating, ventilating and cooling such places, but such systems have been designed with a view to carefully avoiding noticeable movements of air in the auditorium in order to avoid the possibility of any drafts striking the people congregated, and prevent the people from being sensible to pronounced atmospheric changes. It is also a matter of common knowledge that people object to drafts against the back of their heads or persons while a slight movement of the air against their faces is enjoyed, and that drafts of cold air around the feet are objectionable.

In the systems heretofore employed for ventilating, heating and cooling such places, it has been the practice to withdraw air from the room through suitable ducts or passages, mix it, if desired, with outside air, and return the mixed air to the auditorium, the relatively large volumes of air which are withdrawn and returned to the auditorium or admitted from the outside, or both, being conditioned prior to admission to the auditorium. In order to avoid drafts in the auditorium, the tempering of dehumidified air during the conditioning operation was accomplished by mixing it with the other air exteriorly of the auditorium, and then admitting the tempered mixture at a very low velocity to the auditorium by means of numerous ducts placed so as to distribute the air as evenly as possible throughout the auditorium.

In those prior systems, the relatively large amount of tempered air which must be handled at a low velocity requires the provision of relatively large blowers or fans and operating motors, and an extensive system of large supply and return conduits that are expensive and difficult to install and conceal in the building structure, especially in buildings such as theaters which are usually of elaborate architectural design and ornamentation.

With the positive circulation created by the ejector nozzles of this invention, it becomes unnecessary to provide an elaborate distribution of the points at which air is returned to the air conditioning apparatus or removed from the auditorium, to avoid "dead corners" or "dead spots" and therefore, the return system can be greatly simplified, and a great saving effected in the cost of the return or recirculation system.

An object of this invention is to provide an improved, practical and efficient method and system for cooling, ventilating and heating auditoriums and the like in which people congregate in considerable and varying numbers; with which desirable temperature and relative humidity conditions may be maintained in the enclosure regardless of the number of people therein or external atmospheric conditions; and with which there will be no discomfort to the people assembled in such places due to the operation of the improved method and system of heating, cooling and ventilation.

A further object of this invention is to provide an improved method and system for ventilating auditoriums and the like in which the size of apparatus required for conditioning the air and circulating the same will be relatively small and compact, in which the total number and size of the air ducts may be considerably reduced and the ducts more readily concealed within the structure.

When properly introduced, the small volume of air handled by the apparatus of this application will induce a secondary circulation amounting to three or four times the volume of the primary circulation, so that for an equal effect in the auditorium, air conditioning apparatus and ducts of from one fourth to one fifth normal size can be used. Furthermore, the mixture of from three to four parts of room air with one part of cooled air warms the dehumidified air, so that before coming in contact with any of the people in the audience, its temperature is raised to an amount equal to three fourths or four fifths of its original depression below the theater temperature.

A still further object of the invention is to provide an improved system or apparatus for

heating, cooling and ventilating auditoriums and the like which is relatively simple and inexpensive in both construction and operation, one of the important features of this improved system being the creation of a definite controlled circulation of air in the theater or auditorium.

Various other objects and advantages will be apparent from the following description of two embodiments of the invention, and the novel features will be particularly pointed out hereinafter in connection with the appended claims.

In the accompanying drawings:

Fig. 1 is a sectional elevation of an auditorium without a balcony, in which the ventilation, heating and cooling is accomplished in accordance with this invention.

Fig. 2 is a sectional plan of the same.

In the illustrated embodiment of the invention, the building has an auditorium or room 1 in which the people assemble, with a proscenium arch 2 at one end leading to the stage. Such an auditorium has a relatively high ceiling with a deep space between the ceiling and the section occupied by the audience. The entrance to the auditorium may be through one or more passages or doorways 3 at the end opposite from the stage, and the auditorium may also be provided with the usual emergency exit doors 4.

Air conditioning apparatus 5 may be located in any suitable, available space 6 in the building, such as in the basement under the rear of the auditorium, as shown in Fig. 1, or on the roof, or in the upper rooms, or partially in the upper room or on the roof and partially in the basement, the exact place selected depending upon expediency and the particular details of the structure or building in which the auditorium is provided.

A blower or fan 7 for causing the circulation of air in and through the room 1 is preferably connected at its inlet side to the outlet side of the air conditioning apparatus 5, and at its outlet side is connected to a duct 8 which extends to a point adjacent the ceiling of the auditorium and then transversely across the room at a point adjacent the ceiling. A plurality of nozzles 9 are provided on the transverse stretch of the duct 8 through which the air is delivered into the room so as to direct the air from the duct 8 at a high velocity into the room in the relatively deep space just below the ceiling, that is, at a point well above the lower section of the room which the people occupy.

The duct 8 equipped with the discharge nozzles is preferably encased in the cornice or other part of the wall or ceiling of the room so as to be hidden from view. The nozzles can project from the duct and terminate substantially flush with the inner surface of the cornice or wall, as shown in Fig. 1, where sufficient space is afforded in the wall for this construction. The nozzles can be of sufficient length to give the required directional control of the discharging air jets.

While the ducts with the nozzle 9 may be arranged at different points spaced apart in the direction in which they open for larger rooms, they preferably, particularly for rooms of smaller or moderate size, are arranged in a row extending substantially entirely across one lateral wall of the room, as shown in Fig. 2, so that a plurality of high velocity jets of air will be directed in the same direction across the room in the upper or unoccupied part thereof. These high velocity jets of conditioned air will be discharged in such directions as to avoid directly striking the lower section of the room occupied by the people, and when the ceiling is substantially horizontal, as shown in Fig. 1, these jets of conditioned air may be directed approximately parallel and near the ceiling, so that the circulation of air caused by the jets will be along or adjacent the ceiling.

The jets act as injectors and cause a circulation of the relatively larger volume of air of the room therewith through the upper relatively deep, unoccupied space in the room, and during and by reason of such circulation the injected conditioned air is intimately mixed with and tempered by the room air which is drawn into the circulation. The mixture is then carried through the upper or unoccupied space of the room by the circulation caused by the high velocity injected air, and will descend into the lower or occupied section of the room as the circulating air loses its velocity or approaches the side of the room opposite from that where the conditioned air is injected. Some of the mixture of air moving adjacent the ceiling will descend into the lower section of the room as the mixture moves across the room, and all of the air reaching the lower or occupied section of the room will move at a relatively low velocity toward the side of the room where the conditioned air was injected, so as to complete the circulation, as shown by the arrows in Fig. 1.

Air may be withdrawn from the room and conducted to the air conditioning apparatus 5, conditioned and returned to the room through nozzles 9. When the volume of air injected into the room is greater than that withdrawn, the air displaced by the injected air may escape from the room through any suitable relief outlet, such as through the entrance passage 3, and the windows, doors and other places of leakage, since obviously auditoriums are never entirely air tight. Furthermore, the toilet and rest rooms that are provided adjacent the auditorium will usually have some ventilating means for removing to some extent the air of those rooms, and part of the air of the auditorium which is displaced may escape through those auxiliary rooms.

The air withdrawn from the room for conditioning and return to the room is taken from the room at such point or points with reference to the occupied section of the room so as to insure a circulation of the tempered mixture into this occupied section. The occupied section being along the floor, the air withdrawn for conditioning and return will preferably be taken from the room at a point or points in or near the floor. For example, a pair of return ducts 10 and 11 may be provided under the floor of the room so as to extend in a direction from front to rear, and located preferably along the aisle spaces 12 and 13. Openings 14 to the ducts 10 and 11 are provided through the floor of the room at the edges of the aisle sections, and these openings may conveniently be provided under the seats 14a in the center seat section, just at the edge of the aisles, as shown clearly in Fig. 2. The return openings may be of the mushroom or aisle-hood type, or they may be registers or grilles placed either in the floor or in the walls of the room, near the floor line, and the return ducts may be arranged as required, to suit the particular arrangement of the return openings.

The ducts 10 and 11 connect with a mixing chamber or main passage 15 opening into the inlet side of the air conditioning apparatus 5. The connection between the ducts 10 and 11 and the passage 15 leading to the air conditioning apparatus may be provided with dampers or shutters 16

which control the amount of air withdrawn through the ducts 10 and 11 from the room and conducted to the air conditioning apparatus. Dampers or shutters 17 control the passage of fresh air through a fresh air inlet 17a into the mixing chamber or passage 15. By suitably adjusting the dampers or shutters 16 and 17, the relative proportions of fresh air and return air which are conveyed through the chamber or passage 15 to the air conditioning apparatus may be varied as desired. The shutters and dampers 16 and 17 may be regulated by suitable hygrometric or temperature responsive instruments common to the art and disposed at suitable points.

The air conditioning apparatus preferably includes a dehumidifying device 18, such as a spray dehumidifier through which the air to be conditioned is passed and cooled, and its excess moisture removed. The liquid for the spray of the dehumidifier may be cooled by a refrigerating device 18a as usual. When necessary, on account of low relative humidities of the outside air in cold weather, unrefrigerated or warm water may be supplied to the spray device 18, or the necessary heat otherwise supplied to the conditioning apparatus for raising the humidity of the air to the required dew point. The cooled and dehumidified air is conducted through a heater 19, preferably located between the dehumidifier and the blower or circulating fan 7, so that when desired, the temperature of the conditioned air from the device 18 may be raised to the desired extent. In winter time it may be desirable to operate the heater so as to increase the temperature of the injected air, especially when the room is being initially heated, prior to or at the beginning of occupancy of the room by the people. By such air conditioning apparatus, the air injected into the room through the nozzles 9 may be given any desired temperature and humidity, the particular temperature and humidity being regulated so as to provide the maximum comfort to the occupants of the room.

The nozzles 9 are disposed at the rear of the assembly room, so that the circulation through the upper part of the room will be forwardly therein, with the result that the circulation in the lower or occupied section of the room will be rearwardly. Therefore, the air moving in the reverse direction in the occupied section of the room will strike the occupants from the front, which is not objectionable to them while it would be an objection to have the air current strike them from the rear. The air which moves downwardly to the floor by the circulation in the occupied section will be heated by and receive moisture from the people in the occupied section, with the result that the air striking the feet of the congregated people will be the warmest of any in the room with which the people may come in contact, and therefore, there will not be any discomfort to the occupants of the room due to cold feet.

In such an installation the air will be delivered at high velocities through the nozzles forwardly into the auditorium adjacent the ceiling thereof, so that the maximum circulation in the room will be along or near the ceiling and toward the stage. These jets of conditioned air moving at high velocities, act like injectors and cause circulation of the air in the room and a mixture of the injected air and the air of the room. The tempered mixture of air then descends and moves slowly in a direction from front to rear in the lower or occupied section of the room and will be gradually withdrawn through the outlets in the floor of the room.

It will be observed that the tempering of the conditioned air is obtained entirely or principally within the room itself while occupied by the people and not exteriorly thereof, as has been heretofore the case. Consequently, it is only necessary to handle by the mechanical apparatus the relatively small volume of injected, dehumidified, cooled or conditioned air and not the large volume of air circulating in the room and with which it is mixed and by which it is tempered. The volume of air to be handled for any given size of room is therefore materially less with this improved system of ventilation, heating and cooling than with prior systems in which the mixing or tempering occurred principally or entirely outside of the auditorium.

With this improved system it will be observed that the total lengths of pipe or conduits required to handle the air for any given room is very considerably reduced in comparison with that required for previous systems, as it is not necessary to provide numerous supply openings disposed about the room in order to distribute the air uniformly to various parts of the room. Since a smaller volume of air is handled by mechanical apparatus in this improved system, and since the air is handled at a high velocity, the ducts for handling the air may also be made very much smaller than heretofore, and the blower and operating motor may likewise be made very much smaller, so that a considerable saving is obtained, not only in the space occupied by the apparatus and conduits, but also in the original and maintenance costs of the smaller apparatus and conduits required.

Prior systems supplied air to the room at such low velocities, 200 to 400 feet per minute, as to necessitate the handling of greatly increased volumes of air, or else create a ventilating condition amounting nearly to one of stagnation, owing to the fear of drafts upon the occupants of the room. Where the cooled air was introduced into the lower part of the room, it caused great discomfort to the feet of the occupants assembled in the lower part of the room, particularly if there was any movement of the air. My improved system, in contrast to prior systems, discharges air from the injector nozzles into the room at velocities usually averaging 2000 feet or more per minute, and is designed to create a certain amount of circulation in the occupied section of the room, so as to cause the movement of air over each and every person in the audience of such a velocity, temperature and humidity condition that the sensation is pleasing rather than disturbing. The air supplied to the room through the injector nozzles is conditioned, before admission to the room, to a dew point and temperature such that when it is mixed with the air in the room, the mixed circulating air, when it reaches the occupants of the room will have the required temperature and relative humidity to afford the maximum comfort to the people. By reason of the vigorous circulation in the upper part of the room and the uniformity of circulation in the lower part of the room, I am able to perfect uniformity of temperature and humidity in all of the air which comes in contact with the audience so that there will be no discomfort of the audience, due to cold feet or chilling drafts.

An important feature of my hereindescribed injector circulating system is that by it the tem-

perature of the air injected through the nozzles into the room is raised by mixing it in the upper portion of the room with the relatively large volume of warmer air in the room before any part of the mixed air comes in contact with the people.

The following example affords an illustration of the operation of the system under practical conditions. In order to maintain the auditorium temperature at 75 degrees with a desirable relative humidity, air at about 51 degrees would ordinarily be introduced into the room through the injector nozzles. But experience has shown that it was entirely impractical to distribute air at 51 degrees by prior systems in a place such as an auditorium occupied by people. If, however, as in the present system, a secondary circulation in the room is introduced by the injected air in the ratio of one part of injected air to four parts of room air, the 51 degree injected air is mixed with 75 degree air of the room, and the temperature of the mixture is 69 degrees. This mixed air at 69 degrees can be, and by this system is, distributed so as to reach people without causing objectionable drafts or atmospheric changes. This mixing and temperating of the air is done in the free upper space of the room itself so that the air capacity of the fan and ducts in this injector system under the operating conditions just above described is one-third that of the fan and duct capacity of systems such as heretofore used, in which the mixing of the low temperature air and the air from the room is done outside of the room in the air recirculating apparatus.

It will be noted that the auditorium or space as illustrated in the drawings tapers or gradually increases in depth from one end toward the other end thereof so that the volume of air in the room per unit of room length gradually increases from the end having the least height toward the end having the greatest height, and since the conditioned air is injected into the upper portion of a part of the room of lesser depth and in a direction toward the part of the room having greater depth, the resistance to the flow of the injected air currents progressively decreases commensurately with the increasing distance which the currents travel from the injector nozzles, and the relatively small volumes of injected air which are delivered at relatively high velocity are adapted to travel and move and mix with the strata of air in the upper part of the room substantially throughout the length of a comparatively long room and cause the whole body of air in the room to roll downwardly and backwardly through the lower portions of the room.

In a system such as hereindescribed, in which a relatively small volume of conditioned air is injected at a relatively high velocity into the auditorium for conditioning a relatively much larger volume of air in the room, it is desirable to maintain a substantially constant volume of the air supplied to the injector nozzles in order to obtain a substantially constant discharge velocity from the nozzles, and therefore a uniform circulation and mixture of the air in the room. When, however, the auditorium is sparsely occupied, the heat and moisture produced in the auditorium by the people is of course much less, and consequently a smaller volume of conditioned air would be sufficient to give comfort to the few people in the audience. But, if the same volume of dehumidified air is discharged into the room as when it is filled with people, heating means would be necessary to bring the dehumidified air up to the desired temperature for delivery to the room. When, therefore, the auditorium is empty or only sparsely occupied, it may be desirable to recirculate more or less of the air withdrawn from the room and return it to the room without passing it through the air conditioning device, mixing this recirculated air with the conditioned or dehumidified air coming from the air conditioner and discharging the mixture into the room, thereby utilizing the recirculated air to heat or temper the conditioned air, and to this extent, saving fuel for heating the air delivered to the room.

To make this possible, a by-pass or branch duct may be provided, for instance as shown at 40, connecting the air circulating fan with the return duct 10 around or outside of the air dehumidifying or conditioning device. The by-pass duct 40, as shown connects with a mixing chamber 41 between the dehumidifier 18 and the heater 19, and is controlled by a damper 42 so that the proportions of return air passed through or bypassed around the dehumidifier can be controlled by the operation of the dampers 16 and 42 in accordance with the requirements for the auditorium. All or any required proportion of the return air can thus be directed through or around the air conditioning or dehumidifying device.

It will be obvious that various changes in the details, which have been hereindescribed and illustrated in order to explain the nature of the invention, may be made by those skilled in the art within the principle and scope of the invention as expressed in the appended claims.

I claim as my invention:

1. The method of ventilating and attemperating a room in which people congregate and which is so designed with seats that the people normally face the front or stage portion of the room, which comprises injecting air at a high velocity into the room well above the occupied section and people and in a direction toward the front or stage portion of the room so as to avoid direct blasts into the said occupied section, and removing air from the lower or occupied section of the room at a plurality of points spaced in a direction forwardly and rearwardly of the room, whereby the injected air will be mixed with and tempered by the warm air of the room while passing through the upper section thereof, and the tempered air mixture then circulated rearwardly at a lower velocity in the lower occupied section of the room.

2. A ventilating and attemperating system for a room in which people congregate, which comprises air conditioning apparatus, means for injecting conditioned air from said apparatus at a high velocity into the upper space of said room and above the portion thereof occupied by the people, said injected air moving in a direction to avoid direct blasts into the portion of the room occupied by the people, whereby the injected conditioned air will be first mixed with and tempered by the warm air of the room and circulated therewith in the space above the occupied portion, means for removing portions of the circulated mixed air from the occupied portion of the room at a plurality of points spaced lengthwise of the room with respect to the direction in which the conditioned air is injected into the room and in such manner that strong drafts in the occupied portion of the room will be avoided, and means for guiding desired proportions of the air withdrawn from the room

to said air conditioning apparatus for reconditioning and return to the room.

3. A ventilating and attemperating system for a room having a relatively deep space below the ceiling and above the lower section in which people congregate, which comprises a plurality of air outlets along the length of the room and from said lower section, said outlets arranged at different distances from one lateral wall of the room, a blower having its suction side connected to said outlets for withdrawing air from the room through said outlets, means connected to the outlet side of the blower for conducting the withdrawn air to said room space and discharging it thereinto in jets adjacent the ceiling in a manner to cause an intimate mixture of the injected air with the air in said room space and a movement of the mixture through the room, and means for dehumidifying and cooling the withdrawn air before its return to the room.

4. A ventilating and attemperating system for a room having a relatively deep space below the ceiling and above the lower section in which people congregate, which comprises a plurality of air outlets along the length of the room and from said lower section, said outlets arranged at different distances from one lateral wall of the room, a blower having its suction side connected to said outlets for withdrawing air from the room through said outlet connections, means connected to the outlet side of the blower for conducting the withdrawn air to said room space and discharging it thereinto adjacent the ceiling in a jet and at a relatively high velocity and in a manner to cause an intimate mixture of the injected air with the air in the room space and a movement of the mixture through the room, means for admitting fresh outside air to the air column moving from the outlets to said room space, and means for dehumidifying more or less of the air for admission into the room prior to its admission to said room space.

5. The method of ventilating and attemperating the air in a relatively deep and large enclosure in which people congregate in considerable numbers, which comprises discharging conditioned air at a high velocity into said enclosure in a direction to travel across the top of said enclosure and be mixed with the air of the enclosure while moving in the upper zone of said enclosure, and then travel in a reverse direction across and through the lower zone of the enclosure, and removing air from the enclosure at a plurality of points arranged along the direction of travel of the air in said lower zone to aid the injected air in creating said movements of air in the enclosure.

6. The method of ventilating and attemperating the air in a relatively deep and large enclosure in which people congregate in considerable numbers, which comprises withdrawing air from the lower zone of said enclosure at a plurality of points spaced apart in one direction across said zone, conditioning air and discharging it into said enclosure at a high velocity in a direction to avoid direct blasts into said lower zone and travel across the upper zone of the enclosure, whereby the high velocity conditioned air discharged into said enclosure will mix with the air of the enclosure in said upper zone and cause a movement of the upper strata of air of the enclosure across the upper part of the enclosure and then a descent of the air mixture and a gentle movement across and through the lower zone.

7. The method of ventilating and attemperating the air in a relatively deep and large enclosure in which people congregate in considerable numbers, which comprises withdrawing air from the lower zone of said enclosure at a plurality of points spaced apart in one direction across said zone, conditioning air as to its temperature, humidity and freshness, and discharging it into said enclosure at a high velocity in a direction to avoid direct blasts into said lower zone and travel across the upper zone of the enclosure, whereby the high velocity conditioned air discharged into said enclosure will mix with air of the enclosure in said upper zone and cause a movement of the upper strata of air of the enclosure across the upper part of the enclosure and then a descent of the air mixture and a gentle movement across and through the lower zone.

8. The method of ventilating and attemperating the air in an enclosure in which people congregate and of the type having an occupied section with seats arranged to face in the same direction, comprising injecting air into said enclosure in the direction in which the seats face, at a relatively high velocity and well above the occupied section, and removing displaced air from the occupied section at a plurality of points from front to rear to insure circulation of the injected air forwardly through the upper section, and then rearwardly at a lower velocity through the occupied section.

9. A ventilating and attemperating system for relatively large enclosures, in the lower zone of which people may congregate, comprising means including a nozzle for discharging air at a high velocity into the upper zone in a direction to travel across the enclosure first in said upper zone, descend and travel in a reverse direction through the occupied zone of said enclosure, and means for removing air from said occupied zone at a plurality of points arranged along the direction of travel of said injected air through the occupied zone, whereby the air of the enclosure will be kept in a state of circulation across the upper zone and in a reverse direction in the lower zone.

10. A ventilating and attemperating system for relatively large enclosures, in the lower zone of which people may congregate, comprising means for withdrawing air from the lower zone of said enclosure at a plurality of points spaced apart in one direction across said zone, means for conditioning said withdrawn air, means for discharging said conditioned air at a high velocity into the upper zone of said enclosure in a direction to travel across said enclosure opposite to said one direction and to avoid direct blasts into the lower occupied zone, whereby said discharged air will cause a circulation of the air of the enclosure in one direction across the top of the enclosure, and in the opposite direction through the occupied zone, and also cause a tempering of the said discharged air by mixture with the air of the enclosure before its descent into and movement through the occupied zone.

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