

July 28, 1942.

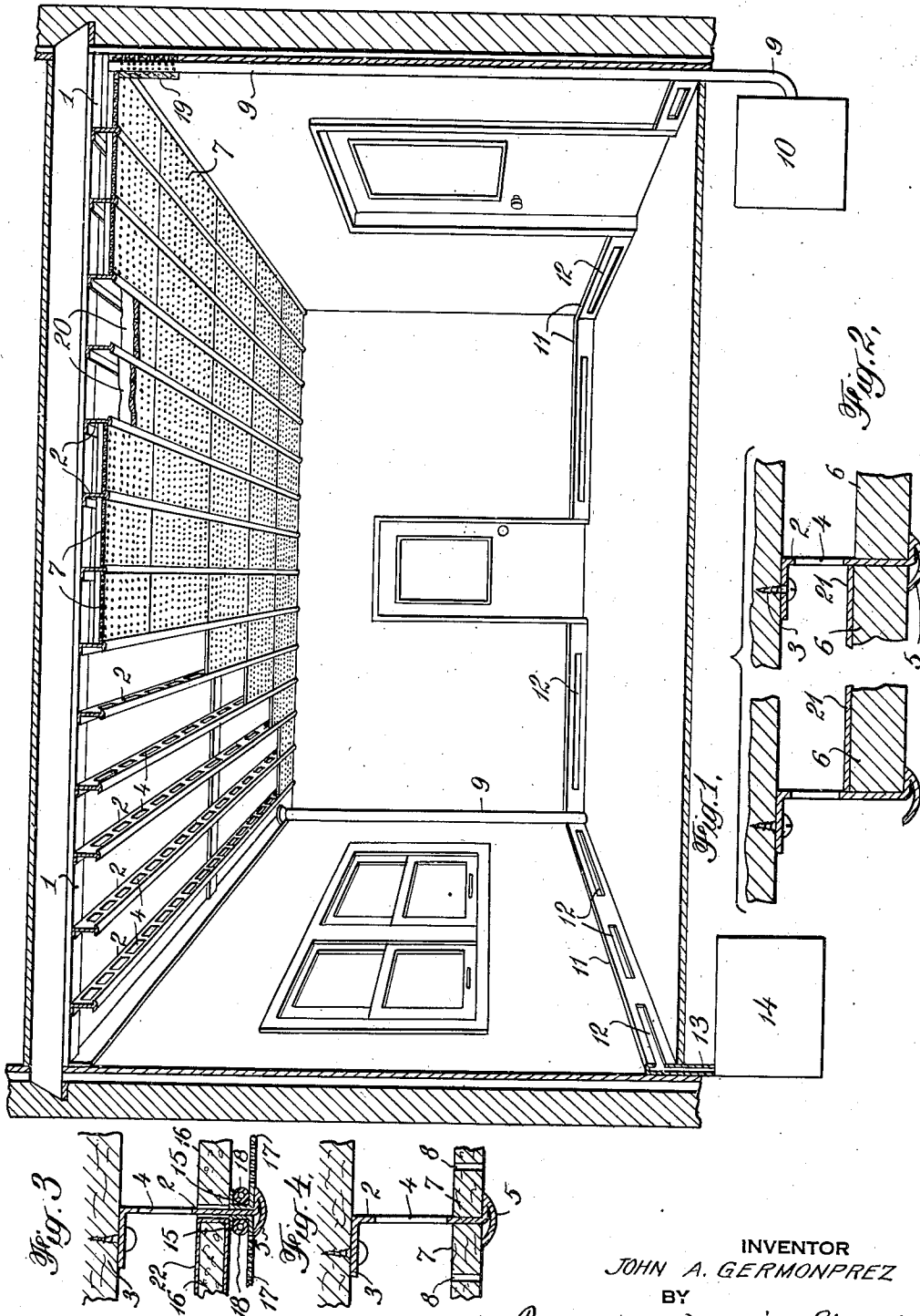
J. A. GERMONPREZ

2,291,220

VENTILATING SYSTEM

Filed Jan. 13, 1938

2 Sheets-Sheet 1



INVENTOR
JOHN A. GERMONPREZ
BY
Penne, Davis, Morris & Edwards
ATTORNEYS

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J. A. GERMONPREZ

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2 Sheets-Sheet 2

Fig. 5,

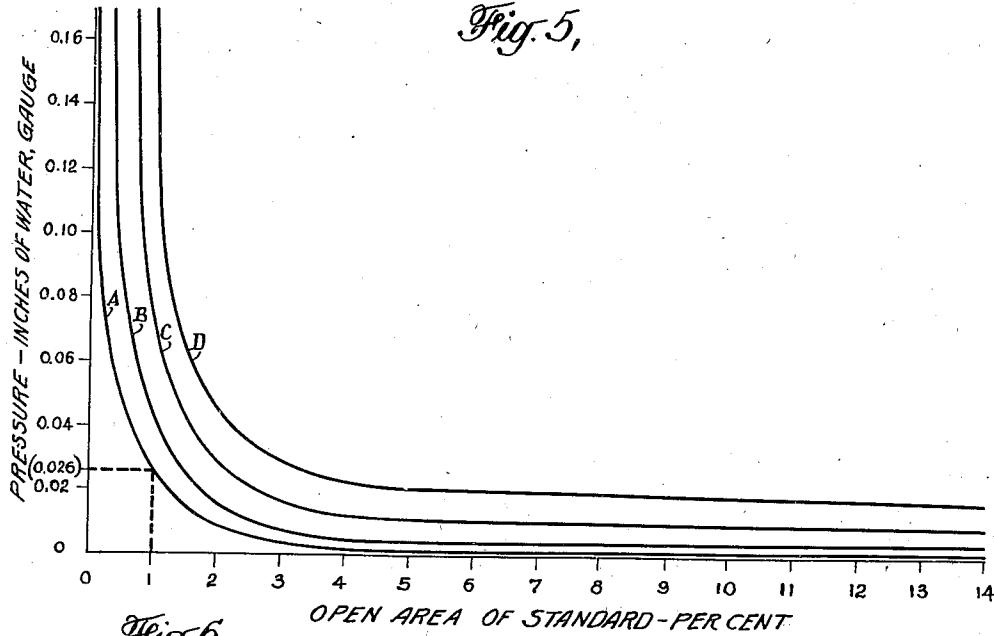
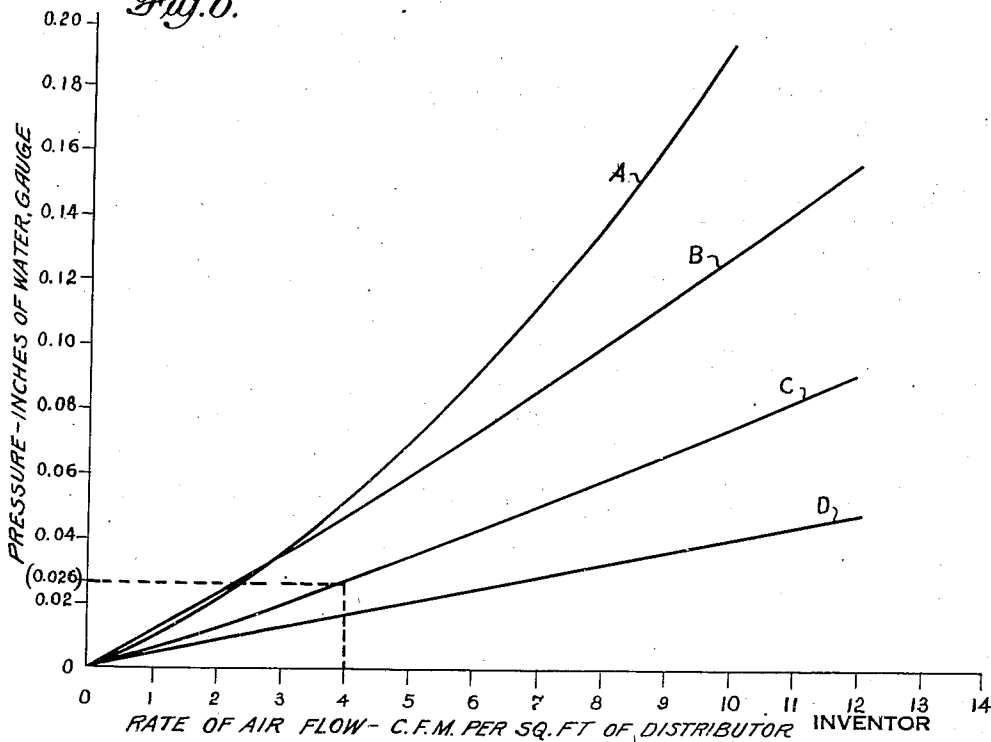


Fig. 6.



JOHN A. GERMONPREZ

BY

Pennie, Davis, Marvin & Edwards.
ATTORNEYS

UNITED STATES PATENT OFFICE

2,291,220

VENTILATING SYSTEM

John A. Germonprez, Grosse Pointe Park, Mich.,
assignor, by mesne assignments, to Burgess
Battery Company, Chicago, Ill., a corporation
of Delaware

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14 Claims. (Cl. 98—33)

This invention relates to means for distributing air and specifically to a ventilating system whereby the air is distributed evenly and without draft at low velocity in the room or space to be ventilated. It relates to ventilating systems for rooms and enclosures of all kinds including offices, stores, restaurants, churches, auditoriums, schools, airplane cabins, railway cars, automobiles or other public conveyances, rooms of dwellings, etc. This application is a continuation in part of my copending application Serial No. 54,803, filed December 17, 1935.

The invention, as herein disclosed, is embodied for purposes of illustration in a structure of the character to be utilized in stationary enclosures, such as office buildings, stores, residences, etc. Although the structure may differ in detail when used in other enclosed spaces such as, for example, automobile bodies and railway cars, the principle or method of obtaining uniform air distribution and temperature remains the same.

The objects of this invention are to provide means for introducing ventilating air over a wide area in an enclosure whereby drafts, such as are created by ventilating air entering a room from ordinary registers and grilles, are absent; to combine acoustical correction means for said room therewith whereby a material economy in cost is effected, and to combine air filtering means with the air distribution means.

Other objects and advantages of the invention will become apparent from the following specification. In the drawings, which embody certain specific forms of my invention:

Fig. 1 is a perspective view, partly in section, showing a room interior at the top of which is provided my improved means of distributing ventilating air and showing a section of the foraminous surface blanked off to the passage of air;

Fig. 2 is an enlarged section showing the means for supporting the aspirating ceiling and a section of a hard surfaced material which is porous, or other self-sustaining porous material;

Fig. 3 is a section similar to Fig. 2 showing a somewhat different arrangement and incorporating a lighting arrangement combined with the aspirating ceiling;

Fig. 4 is an enlarged, sectional view through the perforated ceiling plate of Fig. 1;

Fig. 5 is a chart showing the relationship between air flow through a distributor, pressure differential across the distributor and percent open area of the distributing construction; and

Fig. 6 is a chart showing the performance of certain representative air-distributing materials.

In Fig. 1, nailing strips 1 are provided across the top of the room ceiling for supporting sheet metal beams 2 which are secured to these nailing strips by means of screws 3. These sheet metal supports are provided with apertures 4 throughout their length and at their lower edges they are provided with flanged portions 5 extending on opposite sides of these supports. Resting on the flanged portions 5 are a series of foraminous sheet-like members or panels 6 or 7 shown in Figs. 1, 2 and 4. These panels may be any of a number of different substances which are sufficiently porous, perforated or otherwise apertured as to allow air to move therethrough especially when a predetermined slight pressure is applied to the air. A suitable material is a porous strawboard, porous cane fiberboard or other fibrous or porous material which acts as a filter and allows air under low pressure to pass therethrough. Such a material also may have sound-absorbing qualities. These ceilings may also be made of a harder material which is provided with a multiplicity of apertures 8 through which the air passes. In the form of the device shown in Figs. 1 and 4, perforated hard fiberboard or asbestos-cement panels or perforated sheet metal panels may be used with good results, provided the open area is limited as hereinafter more fully described. The hard panels and the construction for mounting such panels may be that shown in Norris United States Patent 1,726,500 granted August 27, 1929, or that shown in Sullivan Patent 1,918,149 issued July 11, 1933. The furring strips used for supporting the hard panels may be that described and claimed in Weiss Patent 1,738,469, issued December 3, 1929, or in Norris Patent 1,833,174 issued November 24, 1931. The furring strips of these patents are attached to the nailing strips 1 as shown or hung by support means such as are described in Sullivan United States Patent 1,776,092 issued September 16, 1930, whereby the furring strips are suspended directly from the normal ceiling. When perforated sheet metal or similar self-sustaining and hard-surfaced panels are used a sound absorbing material such as hair felt, glass wool, mineral wool, pop-corn slag, shredded celulosic fibers and the like may be mounted thereon whereby the air passing through the apertured sheet is filtered and simultaneously sound in the space to be ventilated is absorbed. When such material is used as a backing for a perforated, self-sustaining facing, the open area of the facing may be greater since the restriction to air flow through the combined member would be the

resultant of that of the backing and that of the facing. Porous materials other than those hereinbefore mentioned and which may have excellent sound absorbing properties are baked porous clay or similar ceramic products, the porous ceramic acoustic tile of the Kliefoth Patents 1,966,069 issued July 10, 1934, and 1,976,946 issued October 16, 1934. It is also possible to use the metal coated acoustic tile of the Kliefoth Patent 1,959,057, issued May 15, 1934.

A chamber is formed between the aspirating ceiling and the normal room ceiling. Air is blown into this chamber by means of the blower-duct 9 from any convenient type of blower as suggested by the blower casing 10 shown in Fig. 1. Blower 10 may be any air-conditioning unit of the type now being marketed extensively. One or several blower ducts may be provided in each room, and, if desired, the blower ducts may be built into the walls of the room as is normally done in ventilating systems. At the lower part of the room at the floor level is a pipe 11 which has the appearance of a baseboard and is provided with air exhaust slots 12 therein thereby also distributing the exhaust air outlets. This pipe extends completely around the room at the floor level and is connected by one or more ducts 13 to an exhaust fan housing 14.

In operation, air from blower 10 passes through the ducts 9 into the chamber between the aspirating ceiling and the normal room ceiling. The apertures 4 in supports 2 are large enough so that the air may pass readily through the entire chamber above the aspirating ceiling. The air flows evenly through the panels over the entire ceiling area provided that a slight pressure is built up between the aspirating ceiling and the normal ceiling. The blower or blowers supplying air to the chamber therefore should be capable of building up this slight pressure thereby forming a plenum chamber above the foraminous member. Air passing through the aspirating ceiling moves downwardly evenly through the room in a blanket-like manner.

Since the air is exhausted evenly about the four walls of the room at the floor level through the slots 12 the air moves downwardly in a vertical direction to below the normal breathing level and then spreads outwardly gradually to the exhaust duct 11. Ordinary grilles or outlet screens also may be used whereby the air leaves the room at one side of a wall or at one side of the floor. When such grilles are used uniformity of air distribution near the floor is not as good as that obtained with the construction shown in Fig. 1. In the room below the foraminous ceiling a pressure is not built up since the air is constantly exhausted from the room or lower chamber by the exhaust duct 11. The uniform flow of air may be increased or decreased by increasing or decreasing the pressure in the plenum chamber within the limits hereinafter defined, as by increasing or decreasing the volume of air blown into the chamber.

An advantage obtained with this system of ventilating is that the dust or smoke which normally tends to rise within the room is carried downwardly by the incoming clean air and is exhausted at the floor level where the dust accumulates. The dust is thereby prevented from rising to the discomfort of the occupants of the room and discolor the ceiling or walls of the room. The dust, smoke, etc., are constantly discharged at the floor-level so that the room atmosphere above the normal breathing level is free from it.

It is obvious that the air entering the room through the foraminous ceiling may have been heated, cooled, dried, humidified, etc. This type of construction is especially desirable with cool conditioned air which produces uncomfortable drafts when introduced into the room at high velocities through the ordinary grilles. The rushing noise produced by the air entering the room through such grilles also is eliminated by the foraminous ceiling comprising sound-absorbing material.

In Fig. 3 a porous panel and a perforated plate is shown. The edges of the perforated plate 17 are turned up to provide flanges 15 on each side of the supporting member 2 and the porous or foraminous panels 16 are mounted on these flanges. The perforated sheet metal or other hard-surfaced or self-sustaining panels 17 are supported on opposite sides of the flanged member 5. Neon tubes 18 may be inserted as shown longitudinally of the support flange between the porous panel 16 and the perforated panel 17. This produces a unique lighting effect, in that the room is lighted through the multiplicity of apertures provided in the perforated plate 17, and, at the same time, the air flow will operate in the same manner as in the other forms of the invention. If the sound-absorbing material is of fire-resistant fibers or other materials such as mineral wool, pumice, and the like, a fireproof construction is obtained provided that the perforated plate also is made of metal or other fire-resisting material such as an asbestos-cement mixture.

It also is possible to utilize this construction for the introduction of different gases into the room. For example, in hospitals chlorine gas may be introduced into the air used for ventilating purposes for the treatment of certain respiratory diseases. It is also possible to use chemicals in the porous panel to kill bacteria and other undesirable organisms in the air as it is filtered through the porous panel. As previously stated, this construction may be used with air conditioning equipment. When used in connection with ventilating systems in which the air passes through the supply pipe 9, at high velocities it is desirable to line at least a portion of the supply line 9 especially that portion near its outlet end, with a sound-absorbing material, as at 19. This sound-absorbing material is preferably faced with a perforated metal sheet such as is described in the Norris Patent 1,726,500 to reduce the resistance to air-flow to a minimum.

In this invention the entire ceiling arrangement, or a substantial portion thereof, acts as a grille. It is possible to produce complete air changes in the room as fast as one change per minute without any noticeable draft in the room where the foraminous distribution means is substantially co-extensive with the floor. Due to the continuous downward flow of air in the room this movement overcomes the normal tendency of the warm air to rise and thus the air in all parts of the room is at the same temperature without warm or cold areas. With this type of air distribution system small size ducts may be used to distribute the air at high velocity to the plenum chamber, the rate of air-flow possible being in excess of 3,500 to 4,000 feet per minute without any noticeable noise apparent to the occupants of the room especially where the foraminous facing is a sound-absorbing material and where the interior of the outlet portion of the entering duct is lined with sound-absorbing material. About 1,500 feet per minute is the

maximum allowable air speed in present-day ventilating ducts. Such small ducts together with the elimination of grilles effect a substantial saving in building costs which may be applied to the original cost of the sound-absorbing foraminous ceiling. Because of the large ceiling area the air may be distributed through the foraminous material with slight resistance.

When a stiff perforated panel such as 17 of Fig. 3 is used the sound-absorbing material is usually placed above this in the form of small pads which usually are wrapped with cheese-cloth, paper and the like to prevent the fibers of the sound-absorbing material from sifting through the openings in the facing member. The paper wrapping 22 which is transparent to sound usually is practically impervious to the passage of the ventilating air. It is possible therefore to blank off certain areas of the ceiling to the passage of the air as at 20, if this is desirable. If the sound-absorbing material is an unwrapped loose fiber or other porous material, an impervious sheet of paper or other convenient material 21 may be laid on top of the loose absorber to blank off the desired area. With the perforated facing 7 of Fig. 1 this may be accomplished likewise by laying a sheet of paper or other material on top of the areas which are to be blanked off, or by using material in which the perforations do not extend entirely through the thickness thereof.

In Fig. 3 the sound-absorbent or filtering material 16 is spaced from perforated sheet 17 and the air is introduced back of this porous material. Openings 4 in the furring strips allow the air to pass over the entire porous material so that it enters the room uniformly throughout the entire ceiling. If porous material 16 is a sound-absorbing material whereby the room also is acoustically corrected, it may be desirable to glue or otherwise fasten it to the normal ceiling so that the air does not pass through it. This construction may be used where the volume of air supplied to the plenum chamber per unit of air distributing area is comparatively large so that the restriction of the facing required to maintain a static pressure in the plenum chamber is not so great as to also restrict the passage of sound waves from the room to the sound-absorbing material. Spacing the absorbent material from the facing does not interfere with its sound-absorbing properties. The air then circulates through openings 4 over the entire ceiling above the perforated plate 17 and passes downwardly over the entire area of the foraminous ceiling. As pointed out in the Norris United States Patent 1,726,500, small openings in a perforated facing for the sound absorbent may be so spaced apart so that only a small percentage of the facing is open without interfering with the passage of the sound to the absorbent backing, the sound absorption actually increasing under certain conditions by the use of such a perforated facing. Such a construction therefore provides an improved combination comprising the acoustical correction of the room and an air distribution facing which permits the air to be distributed evenly throughout the area of the room. Perforated sheet 17 may be replaced by any suitable foraminous membrane or sheet-like material.

In order to elucidate the above general description, the considerations involved in the designing of a suitable air-distributing ceiling are here set forth, and specifications of operative

embodiments of the various forms of the invention are given. As stated above, it is necessary to maintain a positive static pressure in the plenum chamber in order to produce movement of air from the plenum chamber into the room at all points of the distributor at a uniform velocity. With a predetermined volume of air to be introduced into the space to be ventilated, the distributing ceiling must be designed with a maximum open area calculated to maintain the static pressure in the plenum chamber. It has been found that the lower limit of pressure for satisfactory performance is approximately 0.01 inch of water. Systems operating at plenum pressures lower than this value are unstable in that air may be caused to flow from the room into the plenum chamber when a door or window is opened, or when a strong wind blowing against an exposed wall of the room having poorly fitting windows causes an atmospheric disturbance within the room. Although there is theoretically no upper limit to plenum chamber pressures, it has been found to be impractical in practically all instances to use pressures greater than approximately 0.5 inch of water. Excessive power consumption and size of blower, air noises due to high velocity air jets and leakage of air from the plenum chamber other than through the distributing ceiling, are among the practical considerations determining this upper limit. The preferable operating range is from 0.02 inch to 0.15 inch of water.

It is impossible to specify the proportion of actual open area of an aspirating ceiling which will operate to distribute the air as described because of the large number of variable quantities other than the actual open area of the panel. For example, with a given pressure differential, more than twice the volume of air will pass through a round hole of a certain area than will pass through a similar hole of one-half its area; a greater volume of air will pass through a round edged orifice than will pass through a sharp-edged orifice; the greater the thickness of the perforated material used as a distributing panel, the greater will be the friction losses in passing through each opening and thus the less will be the air flow through the member; the restriction of a foraminous material depends upon its density. For these reasons, it is convenient to use the expression "effective open area" as a quantitative measure of the ability of an apertured panel to permit flow of air therethrough under differential pressure with respect to the opposed sides of the panel. In any particular installation the open area of the air distributor must be specified since the plenum chamber pressure is a function of effective open area of this member. A standard must be adopted, and for this purpose 20 (U. S.) gauge sheet metal (0.0375" thick) perforated with $\frac{1}{8}$ " holes was used. The "effective open area" of this material was taken to be 100% of the actual open area. All other materials were compared with this standard.

It will be seen by an inspection of the chart of Fig. 5 that the effective open area of a distributing member must be only a very small proportion of the area of the member and that this proportion is fairly critical. For the highest air volumes per unit area of distributor delivered in practice, the maximum effective open area giving satisfactory air distribution is approximately 4% of the total area of the distributing member. Where substantially the entire ceiling area of a room is used to distribute the air at a specified

volume of 4 c. f. m. per square foot of ceiling, the percent effective open area may be as great as 1.8%, the preferred maximum being about 1.2%.

The relationship between the plenum chamber pressures and the proportion of open area of the standard material for particular rates of flow of air through the distributing element is shown in Fig. 5. In this chart curve A is drawn for the condition in which 4 cubic feet of air per minute is supplied per square foot of distributor, curve B for 6 c. f. m. per square foot of distributor, curve C for 10 c. f. m. per square foot of distributor and curve D for 15 c. f. m. per square foot of distributor. Fig. 6 shows the performance curves of certain representative materials as follows:

A—20 gauge sheet metal having ninety-six $\frac{3}{32}$ " holes per square foot, being 0.46% open.

B—100% jute felt 1" thick, 108 oz. per square yard, used as backing for 20 gauge sheet metal having fifteen $\frac{3}{32}$ " holes per square inch, the sheet metal being 10% open.

C—50% jute, 50% hair felt 1" thick, 99 oz. per square yard, used as backing for 20 gauge sheet metal having fifteen $\frac{3}{32}$ " holes per square inch, the sheet metal being 10% open.

D— $\frac{1}{2}$ " Celotex fibreboard having 290 one-eighth inch holes per square foot, being 2.5 open.

To determine the effective open area of the perforated metal having a 50% hair, 50% jute felt backing, the plenum pressure produced by, say, 4 cubic feet of air per minute per square foot of area is determined from the curve of Fig. 6. The dotted lines indicate the path followed in this determination. The pressure is found to be 0.026" of water. Reading over on curve A of Fig. 5, drawn for the condition in which 4 cubic feet of air per minute per square foot of standard material is supplied to the plenum chamber, as indicated by the dotted lines, it is seen that the equivalent or effective open area is 1.0%. Similarly, the effective open area of the Celotex fibreboard, 2.5% open (curve D), will be found to be approximately 1.35%.

Ventilating specifications generally call for a particular air supply per square foot of floor area of the space to be ventilated. The area of the proposed aspirating ceiling is specified and a desirable working plenum chamber pressure is selected. The air distributing construction is then designed with the aid of experimental information, such as that represented by the curves of Fig. 5 and 6.

The average rate of flow of air through an aspirating ceiling may vary, in practice, from 2 to 15 cubic feet per minute per square foot of air distributing ceiling, depending upon the air requirements of a particular installation and the proportion of the entire ceiling used to distribute the air. The following specifications of suitable air-distributing materials are given by way of example:

Where an average air supply of 4 cubic feet per minute per square foot of air distributing ceiling is desired, $\frac{1}{2}$ " Celotex having 290 one-eighth inch holes per square foot, or 1" standard hair felt (50% hair, 50% jute, 99 oz. per square yard) having a facing of 20 gauge metal perforated with fifteen $\frac{3}{32}$ " holes per square inch, is suitable. If less than the total ceiling area is used for air distributing purposes, the proportion of open area per unit area of air distributing ceiling must be increased accordingly in order to maintain approximately the same pressure in the

plenum chamber. For example, if only one-half of the entire ceiling is used, the proportion of effective open area per unit area of air distributing ceiling must be approximately doubled by increasing the number and/or size of holes or decreasing the thickness or density of felt where it is used.

Although my improved construction provides the means for introducing the air uniformly into the room from a ceiling or other wall surface it also provides a means for exhausting the air uniformly from the room if it is desirable to do so since the air may be exhausted through such a foraminous ceiling or wall. Under some conditions it may be desirable to use one part of the ceiling or wall surface for introducing the ventilating air into the room and another part of the ceiling or wall surface for exhausting the air.

Various modifications of the invention other than those described and illustrated herein may be made without departing from the invention as defined by the appended claims.

I claim:

1. In a ventilating system, the combination of a wall or ceiling surface, sheet-like foraminous means spaced therefrom and comprising sound-absorbing material, and means for introducing air continuously into said space between said surface and said foraminous means, the area of the totality of openings in said foraminous means bearing such relation to the total area of said foraminous means, that said air introduced into said space builds up a low but appreciable pressure whereby to cause said air to pass through said foraminous means at a velocity substantially uniform over the entire area thereof.

2. In a ventilating system, the combination of a wall or ceiling surface, sheet-like foraminous means substantially co-extensive therewith and spaced therefrom, and means for introducing air continuously into said space between said surface and said foraminous means, said foraminous means comprising a perforated self-sustaining and hard-surfaced sheet in combination with a backing of sound-absorbing material.

3. In a ventilating system, the combination of a room to be ventilated and acoustical correction means for distributing air without drafts in the room comprising a layer of air-pervious and sound-absorbing material spaced from a wall or ceiling surface thereof, means for introducing air continuously into the space between said sound-absorbing material and said wall or ceiling surface, the sound-absorbing material being of sufficient area so that the ventilating air passes therethrough into said room at low velocity and of substantial sound-absorbing quality so that the desired acoustical correction is obtained with reference to the room to be ventilated.

4. In a room having a wall or ceiling surface and a floor, the combination therewith of a ventilating system comprising a sheet-like foraminous means spaced from said wall or ceiling surface and comprising sound-absorbing material, means for introducing air continuously into said space between said wall or ceiling surface and said foraminous means, said foraminous means being of such area that said air passes therethrough at low velocity, means for exhausting the air from said room near the floor level, said arrangement and construction being such that at least a slight air pressure compared with that in said room is maintained in said space between said wall or ceiling surface and said foraminous means.

5. In a ventilating system, the combination of a wall or ceiling surface, sheet-like foraminous means spaced therefrom, a secondary sheet-like foraminous means comprising sound absorbing material spaced between said wall or ceiling surface and said first foraminous means to thereby form two chambers one on either side of said secondary foraminous means, and means for introducing air continuously into the chamber between said wall or ceiling surface and said secondary foraminous means, said first foraminous means being of such area that said air passes therethrough at low velocity.

6. In a combination ventilating system and acoustical treatment, the combination of a wall or ceiling surface of a room to be ventilated, an extended sheet-like foraminous member spaced from said surface, air pervious sound-absorbing material between said member and said surface contiguous to said foraminous member and forming a plenum chamber between said sound-absorbing material and said surface, and means for introducing air continuously into said chamber, at least a portion of said sound absorbing material having a covering of substantially air-impervious sheet material being so arranged as to block off the passage of air through a portion of said sound-absorbing material, the balance of said sound-absorbing material being of such area that the ventilating air passes through said latter material into said room at low velocity.

7. In a combination ventilating system and acoustical treatment, the combination of a wall or ceiling surface of the room to be ventilated, an extended sheet-like foraminous member spaced from said surface, air pervious sound-absorbing material between said member and said surface contiguous to said foraminous member and forming a chamber between said sound-absorbing material and said surface, means for introducing air continuously into said chamber, and a layer of material having a specific resistance to the flow of air therethrough greater than that of said sound-absorbing material within said chamber on the surface of a portion of said sound-absorbing material, the balance of said sound-absorbing material being of such area that the air passes therethrough into said room at low velocity.

8. In a ventilating system, the combination with a wall or ceiling of a room to be ventilated, of acoustical correction means for said room for distributing ventilating air without drafts in said room comprising a layer of sound-absorbing material of substantial sound-absorbing quality so that the desired acoustical correction is obtained with reference to the room to be ventilated, said acoustical correction means being substantially coextensive with and spaced from said wall or ceiling, means for introducing air continuously into the space between said sound-absorbing material and said wall or ceiling, said sound-absorbing material having distributed passageways therethrough of restricted dimensions whereby a low but appreciable pressure is built up by the ventilating air introduced into said space, the construction being such that the ventilating air passes into said room at low velocity throughout the area of said acoustical correction means.

9. In a ventilating system, the combination with a wall or ceiling surface of a room to be ventilated of a foraminous, self-sustaining sheet spaced from said surface to form a plenum chamber between said surface and said sheet, means for continuously introducing ventilating air into said plenum chamber, said foraminous sheet having a contiguous backing of sound-absorbing material through which backing said air passes and forming the outlet for the air from said chamber, said foraminous sheet and said absorbing backing being sufficiently extensive in area that said air passes therethrough at a low velocity throughout the area thereof.

10. In a ventilating system, in combination, a ceiling of a room to be ventilated, sheet-like foraminous means spaced therefrom to form a plenum chamber between said ceiling and said foraminous means, and means for introducing air continuously into said plenum chamber, the effective open area of said foraminous member being less than 4% of the total area of said ceiling.

11. In a ventilating system, in combination, a ceiling of a room to be ventilated, sheet-like foraminous means spaced therefrom to form a plenum chamber between said ceiling and said foraminous means, and means for introducing air continuously into said plenum chamber, the effective open area of said foraminous member being less than 1% of the total area of said ceiling.

12. In a ventilating system, the combination of a wall or ceiling surface, sheet-like foraminous means spaced therefrom to form a plenum chamber between said surface and said foraminous member, and means for introducing air continuously into said plenum chamber, the area of the totality of openings in said foraminous means bearing such relation to the total area of said foraminous means that said air introduced into said plenum chamber builds up a pressure of 0.01 inch of water to 0.50 inch of water whereby to cause said air to pass through said foraminous means at a velocity substantially uniform over the entire area thereof.

13. In a ventilating system, the combination of a wall or ceiling surface, sheet-like foraminous means spaced therefrom to form a plenum chamber between said surface and said foraminous member, and means for introducing air continuously into said plenum chamber, the area of the totality of openings in said foraminous means bearing such relation to the total area of said foraminous material that said air introduced into said plenum chamber builds up a pressure of 0.02 inch of water to 0.15 inch of water whereby to cause said air to pass through said foraminous means at a velocity substantially uniform over the entire area thereof.

14. In a ventilating system, in combination, a ceiling of a room to be ventilated, sheet-like foraminous means spaced therefrom to form a plenum chamber between said ceiling and said foraminous means, said foraminous means being substantially co-extensive with said ceiling, and means for introducing air continuously into said plenum chamber, the effective open area of said foraminous member being less than 4% of its total area.

JOHN A. GERMONPREZ.