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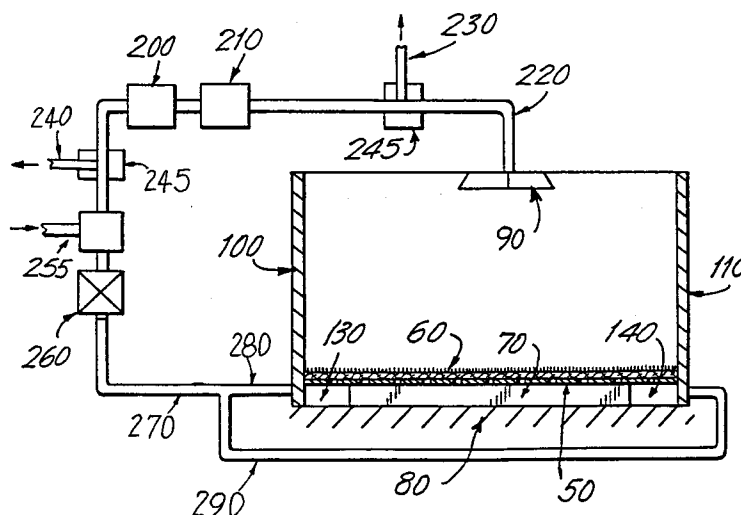
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**AT BE CH DE DK ES FR GB GR IT LI LU MC  
NL PT SE**(71) Applicant: **Philip Morris Products Inc.**  
**3601 Commerce Road**  
**Richmond Virginia 23234(US)**(72) Inventor: **Lephardt, John O.**  
**Route 10, Box 192**  
**Mechanicsville, VA 23111(US)**  
Inventor: **Tamol, Ronald A.**  
**2018 Timbers Hill Road, Apt. E.**  
**Richmond, VA 23235(US)**(74) Representative: **Marlow, Nicholas Simon et al**  
**Reddie & Grose 16, Theobalds Road**  
**London WC1X 8PL(GB)**(54) **Air ventilation system.**

(57) An air ventilation system that employs a perforated floor 50 supported on a plurality of floor joists 70, an air permeable carpet 60, which is not perforated, that is placed on top of the perforated floor, at least one air exhaust vent 90 that is located at or near the ceiling 30 of the space 5 being ventilated, a

duct 220 for conducting the exhaust air from the exhaust vent(s) to a pump 260, and a second duct 150 for transporting air from the pump to the space being ventilated, introducing air into channels 130, 140 formed by the floor joists.

**FIG. 5****EP 0 511 736 A2**

## Background Of The Invention

The present invention relates generally to an air ventilation system for ventilating, heating, cooling or purifying areas such as rooms, houses, theaters, offices or any partitioned spaces and more particularly to an air ventilation system comprising an air permeable carpet material placed over perforated flooring that is supported by a below-floor air distribution system, and further comprising an in-ceiling air exhaust vent system.

A number of different schemes have been used to provide ventilation or air conditioning in enclosed areas. Generally these schemes make use of some combination of ceiling, wall or floor vents. Various sizes and shapes of vents are known. Typically vents have a square or rectangular footprint and a minimal depth. Their footprints typically are between two and ten square feet. There are numerous other less widely used vents that are known. Illustrative examples include long side-wall diffusers and vertical pole diffusers.

Each of the vents used in typical ventilation schemes may be used either for blowing air into the enclosed area or for exhausting air, or both. For example, in one commonly used scheme, a house or office suite has one or more ceiling vents through which air that is blown through ducts enters the space to be ventilated. In addition, there are one or more ceiling exhaust vents through which air is withdrawn from the ventilated space. In this scheme, the exhaust air may be filtered or purified with an electrostatic precipitator (of the types widely used) or with a foam, glass fiber or carbon filter (also widely used) and then recirculated. More commonly, all or a portion of the exhaust air is recirculated without being purified.

These schemes for providing ventilation possess a number of known disadvantages. One such disadvantage is mixing of odorants. Mixing occurs when air from one portion of a ventilated space is intermingled with that from another portion of the ventilated space. Thus, for example, if nail polish, or some other odorant, is being used in one area, its odor can be detected in other locations in the ventilated area. Other odorants transmitted by mixing include cigarette smoke, hair and other aerosol sprays and household insecticides. Although mixing may be viewed as only a minor problem in large and uncrowded spaces, such as large offices, it can be more noticeable in enclosed spaces such as airplanes, trains, other public conveyances, restaurants, theaters, smoking lounges and meeting rooms.

Drafts are another disadvantage of the known ventilation schemes. High velocity air that is blown out of vents results in drafts that can be detected by people. Such detectable drafts typically occur

when the air velocity is over 9-12m/minute (30-40 feet/minute). If a space requires a given amount of ventilation, then the velocity of the air blown into the space must increase as the surface area of the vents used decreases. In a typical system, drafts can be felt by people located near the vents. Such drafts are undesirable because they can be uncomfortable for people exposed to the drafts and they may disturb papers or other items that are exposed or loose. The drafts also are frequently associated with perceptible noise due to high velocity of the air moving through the vents.

Drafts are more likely to occur when an area is subjected to high density use or high thermal loads. High density use and high thermal loading occur when an area is occupied by a large number of people (for example, over one person per ten square feet is a high density use). High density use and high thermal loading also occur when machinery that requires cooling or air exchange is used in an area being ventilated. Drafts are likely to occur in areas subject to high density use loading because in order to keep the air fresh (i.e., free of atmospheric contaminants such as carbon dioxide and particulate matter) a relatively large amount of fresh air or purified air must be delivered into the area. Similarly, drafts are likely to occur in areas subject to high thermal loading because in order to maintain a comfortable air temperature, a relatively large amount of fresh or purified air at a subambient temperature must be delivered into the area.

A further disadvantage of the known ventilation schemes becomes evident in partitioned office space. Partitioned office space generally comprises a space that is subdivided by barriers known as partitions, which typically are between four and six feet high. The partitions do not contact the ceiling. Each of the subdivided areas (commonly called "cubicles") typically is used as an office for one or more persons. However, there typically is not a vent in each cubicle. Thus cubicles near a vent will receive a better ventilation than cubicles far from a vent. One solution to providing ventilation to distant cubicles is to increase the velocity of air blown through the vents so that distant cubicles receive adequate ventilation. However, the increased air velocity may be perceived as an undesirable draft in cubicles near to the vent. Also, papers may be disturbed by the resulting drafts. Mixing of odorants also is a problem with ventilating partitioned areas.

It is also known to ventilate rooms by introducing air through perforations in the floor. French Patent No. 698.707 discloses a system for distribution of air in a room using large porous or perforated parts of the floor as a diffusion surface. The floor is formed of a lining of metal wires that are wound helically and interlaced with each other and

are reinforced by rods. This lining is covered with a permeable carpet. The air is blown into and circulates within the spaces kept free by the coils of metal wires. The air enters the room being ventilated by diffusing through the carpet.

French Patent No. 828.779 discloses a perforated floor that is covered by a covering, which may be formed of a material with closely spaced slits and orifices through which the air diffuses.

In addition, a perforated computer floor ventilation system is offered commercially by Goldbach GMBH (Bahnhofstrasse 5C, P.O. Box 1240, Goldbach, Germany) as the Type L600x600 Access Floor System. In that system, air is vented into an area through a perforated floor that has a carpeted surface. The perforations in that system extend through both the carpet material and the floor support material, thus making the carpet material aesthetically unattractive.

It has been desired to provide a ventilation system that can minimize drafts typically involved in air ventilation systems, both in moderate and high density applications.

It has also been desired to provide a ventilation system that minimizes mixing, which typically occurs in ventilating enclosed areas.

It has also been desired to provide a ventilation system which provides adequate ventilation of partitioned spaces, while minimizing drafts and mixing of odorants between partitioned areas.

#### Summary Of The Invention

The present invention provides an air ventilation system that employs: (a) a perforated floor that is supported on a plurality of floor joists; (b) an air permeable carpet, which is not perforated, that is placed on top of the perforated floor; (c) at least one air exhaust vent that is located at or near the ceiling of the area being ventilated; (d) a duct means for conducting the exhaust air from the exhaust vent(s) to a pumping means; and (e) a second duct means for transporting air from the pumping means to the space being ventilated, which introduces air into both ends of channels formed by the floor joists. Employing the present invention, drafts that occur in areas having conventional ventilation systems, especially in areas having high density uses, are substantially eliminated. In addition, mixing is also reduced and partitioned spaces are adequately ventilated.

In a preferred embodiment, the perforated floor/permeable carpet displacement air ventilation system of the present invention also comprises: an apparatus for purifying or screening the exhaust air; an apparatus for drawing in fresh air from the atmosphere outside the space being ventilated; an apparatus for conducting exhaust air to the at-

mosphere outside the space being ventilated; and an apparatus for mixing exhaust air and fresh air.

In the present invention, air is introduced in a room or other area at the floor level and is removed at, or near, the ceiling level. This offers advantages in air quality and occupant comfort over conventional mixed air systems. The advantages arise because air contaminants and impurities are carried upwards with minimal mixing through the zone occupied by people in the room. This zone is called the "breathing zone" or the "occupied zone". Heat generated by the occupants is also displaced upwards to the ceiling. Thus a comfortable condition can be maintained in the occupied zone.

Conventional ventilation systems which introduce air at or near the floor level through vents tend to produce drafts that are uncomfortable to people. This problem is overcome because use of a perforated floor enables reduction in the velocity of the air being introduced. The same amount of air can be introduced as with a conventional system, but at lower velocities, because the surface area available for sending air into the ventilated area is generally larger in the floor than in standard vents.

Use of a perforated plate as a flooring material is not aesthetically pleasing. In addition, it is difficult to achieve a uniform air distribution because of the low pressure differential across the perforated plate. Therefore, an air permeable carpeting is applied over the perforated plate. This increases the pressure drop between the area below the plate and the space above the plate and thereby achieves a uniform air distribution throughout the space being ventilated. In addition, the use of a permeable carpet material, rather than solely a perforated plate, provides an aesthetically pleasing appearance and conceals the air ventilating apparatus from the occupants.

The perforated floor/permeable carpet system of the present invention can be used for ventilating any type of space, including offices, houses, theaters, conference rooms, designated smoking areas, buses, passenger railway cars, and airplanes. Partitions may be supported on top of the air permeable carpet to divide the ventilated area into convenient work areas.

#### Brief Description Of The Drawings

The above and other objects and advantages of the invention will be apparent upon consideration of the following detailed description, taken in conjunction with the accompanying drawings, in which like reference characters refer to the like parts throughout and in which:

FIG. 1 is a vertical cross-sectional view of a room having a perforated floor/permeable carpet

ventilation system according to the invention;

FIG. 2 is an enlarged vertical cross-sectional view of the floor portion of the room of FIG. 1;

FIG. 3 is a vertical cross-sectional view of the floor portion of FIG. 2, taken from line 3-3 of FIG. 2;

FIG. 4 is a vertical cross-sectional view of the floor portion of an alternative embodiment of the present invention;

FIG. 5 is a diagram showing each of the components of the preferred embodiment of the perforated floor/permeable carpet ventilation system of the present invention;

FIG. 6 is a graphic illustration of the air velocity distribution in a room having a ventilation system as in FIG. 3, in which there is no carpet and air is blown into the room from the left side; and FIG. 7 is a graphic illustration of the air velocity distribution in a room having a ventilation system as in FIG. 3, in which there is no carpet and air is blown in to the room at relatively equal velocities from both the left and right sides; and FIG. 8 is a graphic illustration of the air velocity distribution in a room having a perforated floor/permeable carpet ventilation system, taken from the same viewpoint as FIG. 3.

#### Detailed Description Of The Invention

Referring now to FIG. 1, an area 5 having two side walls 10, 20, front and rear walls (not shown in FIG. 1), a ceiling 30 and a floor 40 is ventilated, heated or cooled by means of the perforated floor/permeable carpet ventilating system of the present invention. The floor 40 comprises a perforated plate 50 and a carpet 60 that is permeable to air. The plate 50 is supported by a plurality of elongated roughly parallel floor joists 70. The plate 50 is placed on the top side of the floor joists 70. The bottom side of each floor joist 70 is on a surface 80 (hereafter "ground") that is relatively impermeable to air, such as the ground, a concrete foundation, or the ceiling of a lower floor in a multi-floor structure. Two exhaust vents 90 are shown.

The perforated plate 50 can be made of any material, such as wood (with holes or slits) or, preferably, perforated steel sheet. The plate 50 must be strong enough to support a load comprising people, furniture, machinery or other objects that may occupy the area 5 to be ventilated. It is preferable to maximize the density of perforations. However, since perforations tend to decrease the strength of the plate, the density of perforations is constrained by the expected load and the strength of the material used. Preferably, each of the perforations is sufficiently small such that pointed objects that typically contact floors, such as a pointed or spiked shoe heels, will not enter the perforations

by mistake.

It has been found that the best results are achieved if the air velocity through the carpet 60 is approximately 3 m/minute (10 feet/minute). At that velocity, mixing is avoided in the occupied zone because air moves upwards before sideways diffusion can occur. Also that velocity is below the velocity of 9-12 m/minute (30-40 feet/minute) at which people normally notice drafts.

Carpet 60 can be made of any material which is relatively permeable to air. Preferably, the carpet 60 is sufficiently permeable so as to permit an air flow rate of at least 3 m/minute (10 feet/minute) without any noticeable lifting or buckling. Typical commercial carpets are not adequate because they generally incorporate relatively impermeable backing materials, such as adhesives or other film forming agents, or the strands of the carpet are too tightly packed or woven. It has been found that one suitable carpet is Design VI carpet, made by Lees Carpet, which has been modified by incorporating a latex backing with a reduced filler and a reduced film forming agent, rather than the relatively impermeable backing that generally is used. Using this modified backing makes the carpet sufficiently permeable because the tiny openings which naturally occur in the carpet when it is manufactured are not blocked.

The carpet 60 may be installed on the perforated plate 50 in any manner which will not significantly impair the carpet's permeability and will sufficiently anchor the carpet such that it will not become detached under normal use and will not bow or buckle. One means of installing the carpet 60 is to attach it to the plate 50 with tack strips. Another installation means is to glue the carpet 60 to the plate 50 with 50 mm (two inch) wide strip of glue along its perimeter.

In the preferred embodiment, more than one exhaust vent 60 is used. Mixing is reduced by uniformly distributing the exhaust vents 60 throughout the ceiling area, rather than placing the vents at or near the walls. If only one exhaust vent 60 is used, it would be preferable to locate it at the center of the ceiling so as to minimize mixing.

The floor 40 and floor joists 70 arrangement is shown in detail in FIGS. 2 and 3. The floor joists 70 are preferably spaced in roughly parallel alignment with each other and runs between front wall 100 and rear wall 110. The spaces between floor joists are channels 120 which extend unimpeded from the area of the front wall 100 to the area of the rear wall 110. There also may be channels formed between the wall 10 and the adjacent floor joist and between wall 20 and the adjacent floor joists. Although it is preferred that the floor joists 70 be roughly parallel to each other, other arrangements are possible. For example, some of the floor joists

may contact each other to provide additional support for the floor 40 but still allow air to flow in the channels. In general, however, it is preferred that, at minimum, the floor joists be oriented with respect to each other such that they form unobstructed channels, which can be used for air distribution. In some areas to be ventilated, as few as two floor joists, forming just one air distribution channel, may be used.

Any type of floor joist may be used. Typical floor joists have a rectangular or "I"-shaped cross section and are made of wood or steel. The floor joists 70 should be constructed such that are strong enough to support a load comprising people, furniture, machinery or other objects that may occupy the area 5 to be ventilated without sagging.

In one embodiment, ends of the floor joists do not contact either the front wall 100 or the rear wall 110, thus forming two feeder ducts 130, 140.

The front feeder duct 130 runs parallel to the front wall 100 between the front wall 100 and the front ends of the floor joists 70. Rear feeder duct 140 runs parallel to the rear wall 110 between the rear wall 110 and the rear ends of the floor joists 70. The air flow rates through the feeder ducts can be varied in accordance with the flow rate desired through the permeable carpet 60. Generally it will be desirable to maintain approximately the same air flow rates in each of the feeder ducts in order to promote a uniform air velocity distribution through the permeable carpet 60. However, other desirable air velocity distributions may be achieved by using different air flow rates in the feeder ducts.

In an alternative embodiment, illustrated in FIG. 4, the floor joists 70 run all the way from the front to the rear walls 100, 110 and the front and rear ends of the floor joists contact the walls. Front and rear feeder ducts 143, 145 are formed in this embodiment by two ducts, one that runs the entire length of the front wall 100, at a level below the floor 40 and above the ground 80 and the second that runs the entire length of the rear wall 110, also at a level below the floor 40 and above the ground 80. In another alternative embodiment, there is only one feeder duct.

As shown in FIG. 5, air is conducted through ducts 280, 290 to the front and rear feeder ducts 130, 140. Air then enters the channels 120 from both the front and rear ends of the channels through front and rear feeder ducts 130, 140. Because of a pressure differential between the channels 120 and the area 5 above the floor 40, air diffuses from the channels 120 through the perforated floor 50 and the permeable carpet 60. It has been found that a pressure differential that can achieve a desirable air velocity through the floor 40 of 3 m/minute (10 feet/minute) is about 0.63 mm (0.025 inches) of water, in a system using the

modified Lees carpet described above. Other pressure differentials may be used, but generally the best results are achieved in the range of from about 0.3 mm (0.01 inches) of water to about 6.3 mm (0.25 inches) of water.

A benefit of the present invention in which air is fed into the channels 120 simultaneously from both the front and rear ends through the front and rear feeder ducts 130, 140 and in which a permeable carpet, rather than a perforated carpet is used as a covering is a relatively even air flow. This benefit is illustrated in FIGS. 6-8. FIG. 6 shows the air velocity distribution in a system having no carpet and only one feeder duct. The air flows in from the left hand side). As shown, the velocity through the perforated floor closest to the feeder duct is low in comparison to the velocity at the far wall (at right). FIG. 7 shows the air velocity distribution in a system having no carpet and two feeder ducts (one on the right side and one on the left side). The air velocity in this case is higher in the middle than at the edges. FIG. 8 shows that if a permeable carpet, and front and rear feeder ducts are used, as in the present invention, then the air velocity approximately is the same at the edges as in the interior. This flat velocity distribution helps eliminate drafts and mixing.

As shown in FIG. 5, the ventilation system of the present invention optionally may include either an electrostatic precipitator 200 or a carbon filter 210, or both. It also may include other air filtering or purifying apparatus, as well as air heating and cooling systems. Air is exhausted from the ventilated area 5 through any of the exhaust vents 90 and into exhaust duct 220. The exhaust air optionally may be completely or partially exhausted to the atmosphere either through exhaust duct 230 or exhaust duct 240 or both. A shunt or valve-type apparatus 245 is used to control the amount of air that is vented to the atmosphere. Exhaust duct 240 is positioned after the air purifying apparatus such as the carbon filter 200 and the electrostatic precipitator 210. The energy use and wear and tear on machinery can be reduced if duct 230 is used instead because the exhaust air that is not recirculated is not subjected to purification. On the other hand, in certain circumstances it may be desirable to purify the exhaust air before venting to the atmosphere in order to prevent the release of pollutants to the atmosphere. Air is taken in from the atmosphere through intake duct 250 and a shunt or valve-type apparatus 255 is used to control the amount of fresh air that is drawn in. A pumping means 260, such as a fan or compressor, propels air in the conventional fashion into duct 270. Duct 270 branches into two ducts 280, 290 which lead to the feeder ducts 130, 140. In alternative embodiments, pumps or fans may be in-

cluded in the system in other locations, as needed.

Numerous other arrangements of ducts, pumping means and purification apparatus may be used, as long as air is circulated out of the exhaust vent 90 and into the feeder ducts 130, 140. For example, the purification apparatus may be eliminated and all the exhaust air may be vented through duct 230. In such a system, all the air conducted to the feeder ducts 130, 140 would be fresh air. In another embodiment, two pumps may be used, one placed to feed air into the front feeder duct 130 and the other placed to feed air into the rear feeder duct 140. In yet another embodiment, a portion of the exhaust air is vented to the atmosphere and the remainder is mixed with fresh air from the atmosphere and then fed into the feeder ducts 130, 140.

In addition, a control system may be incorporated to control the air flow rates, intake rates and exhaust rates throughout the system.

The carbon filter 200 may be of the known type, such as the Model 3CF Glide Pack sold by Farr Air Filter Company. Various carbon filter media may be used such as acid impregnated carbon. Such carbon filters may remove gaseous materials, such as ammonia and nicotine, from the exhaust air and can be 80%, or more, efficient in removing those materials. The electrostatic precipitator 210 also may be constructed of known components. The electrostatic precipitator 210 removes particulate matter, such as dust and smoke particles, from the exhaust air. A typical electrostatic precipitator can be 80%, or more, efficient in removing these materials. Other air purification apparatus that optionally may be used include glass fiber filters and high efficiency particulate ("HEPA") filters and temperature and humidity controls.

The following example illustrates a ventilating system having the components of the present invention.

#### Example

A room was ventilated as follows. The room was fourteen feet long, fourteen feet wide and ten feet, nine inches high. The perforated plate was made of steel having round punched holes averaging 6.3mm (0.25 inches) in diameter. Open area occupied 23% of the area enclosed by the perimeter of the plate. The permeable carpet was the modified Lees carpet discussed above. Ten exhaust vents were built into the ceiling. Each exhaust vent had a square footprint covering one square foot. An electrostatic precipitator, a carbon filter and temperature control mechanism were incorporated in the ventilating system.

Air was introduced into the room at a rate of 50 m<sup>3</sup>/minute (1800 cubic feet/minute) and an average

carpet face velocity of about 3 m/minute (10 feet/minute). The air introduced into the room was comprised of a mixture of 50% fresh air and 50% recirculated room air that was purified by being passed through an electrostatic precipitator and a carbon filter. The controlled air temperature was set at 23° C (73° F) and the relative humidity was set at 50%. Twenty-four cigarettes were continuously statically burned -- sitting in ash trays. The static burning was begun one-half hour before the start of measurements in order to achieve an equilibrium within the room. The heat generated by a room full of people was simulated by lighting sixteen 100-watt light bulbs at a height of about four feet from the ground.

Air particulate levels were measured at several locations on the floor of the room and, for each location, at three different heights in relation to the floor (at floor level, about five feet above the floor and about eight and one-half feet above the floor). In the present example, the air particulate level of the air exiting the room at the exhaust vents also was 0.4 mg/m<sup>3</sup>. In a room having a conventional ventilating system, which caused mixing, there would be an air particulate level of 0.4 milligrams/cubic meter (mg/m<sup>3</sup>) throughout the room under these conditions. However, at lower heights within the breathing zone (the area normally occupied by people), the measured air particulate levels were significantly lower: 0.05 mg/m<sup>3</sup> at floor level, 0.06 mg/m<sup>3</sup> at a height of 5 feet above floor level and 0.28 mg/m<sup>3</sup> at a height of 8.5 feet above floor level. There was little mixing at the floor level and 1.5 m (5 feet) above the floor. At a height of 2.6 m (8.5 feet) above the floor, there was some mixing, but less than would be expected in a room with a conventional ventilating system.

In addition, people in the room did not feel drafts from the air entering through the carpet. The carpet face air velocity at the various locations was measured to be almost uniform throughout the room. The air velocity profile, which is shown in FIG. 8, shows that there was a uniform air velocity throughout the room with approximately 10% variation between the edges and center.

#### Claims

1. Apparatus for ventilating a space (5) defined by a ceiling (30), a front wall, a rear wall and at least one other wall (10)(20) and a relatively air impermeable base (40), comprising:
  - a plurality of floor joists (70) supported on the base; and
  - a perforate floor (50) supported by the floor joists
  - the floor joists being oriented such that together with the base and the perforate floor

they form at least one air distribution channel (120);

the apparatus further comprising:

an air permeable carpet (60) laid on top of the perforate floor;

at least one air exhaust vent (90) located substantially at the ceiling;

a first duct (230) for conducting air exhausted through the exhaust vent to the atmosphere;

a first feeder duct (130) (143) for directing air into the air distribution channels;

a second duct (270) for conducting air into the first feeder duct;

a third duct (255) for conducting air from the atmosphere into the second duct; and

a pump (260) for propelling air through the third duct means.

2. Apparatus according to claim 1 further comprising:

a fourth duct (220) connected to the exhaust vent (90) and to the third duct (255);

an air purifier (200)(210) which draws air from the fourth duct, purifies the air and returns the purified air to the fourth duct;

a control means (245) for regulating the amount of air exhausted through the exhaust vent which is directed into the atmosphere through the first duct (230) and the amount of air exhausted out of the exhaust vent which is directed through the fourth duct for purification and recirculation.

3. Apparatus according to claim 2, in which the air purification means comprises an electrostatic precipitator (200).

4. Apparatus according to claim 2 or 3, in which the air purification means comprises a carbon filter (210).

5. Apparatus according to any preceding claim, in which the first feeder duct (130) (143) runs along the front wall (100) of the ventilated space (5) and further comprising a second feeder duct (140) (145) which runs along the rear wall (110) of the ventilated space, the second feeder duct being connected to the second duct (270) such that it receives air conducted through the second duct.

6. Apparatus according to any preceding claim, in which the volume of air conducted into through the first feeder duct (130) (143) into the air distribution channels (120) is equal to the volume of air conducted through the second feeder duct (140) (145) to the air distribution chan-

nels.

7. Apparatus according to any preceding claim, in which the air velocity through the permeable carpet (60) and the perforate floor (50) from the air distribution channels (120) to the space (5) being ventilated is approximately the same near the walls (10,20, 100,110) as it is remote from the walls.

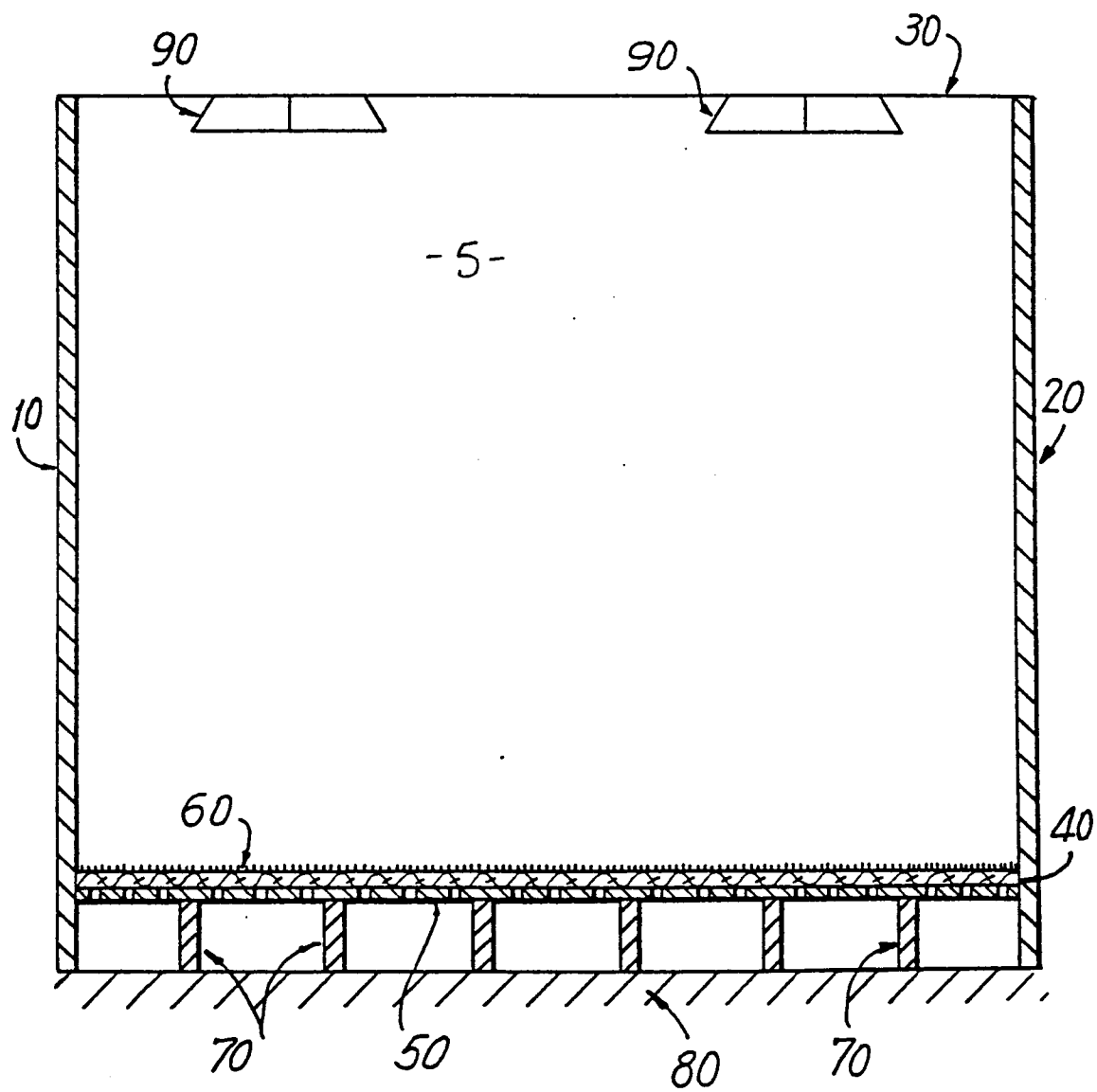
8. Apparatus according to any preceding claim further comprising means for cooling the air that is directed into the or each feeder duct (130,143) (140,145).

9. Apparatus according to any preceding claim further comprising means for heating the air that is directed into the or each feeder duct (130,143) (140,145).

10. Apparatus according to any preceding claim, in which the pressure difference between the pressure in the air distribution channels (120) and the pressure in the area above the carpet (60) is between 0.3mm and 6.3mm (0.01 and 0.25 inches) of water.

11. Apparatus according to any preceding claim, in which the air exhaust vents (90) are uniformly spaced apart in the ceiling (30).

12. Apparatus according to any preceding claim, in which the perforate floor (50) supports a plurality of room partitions on top of the air permeable carpet (60).



**FIG. 1**



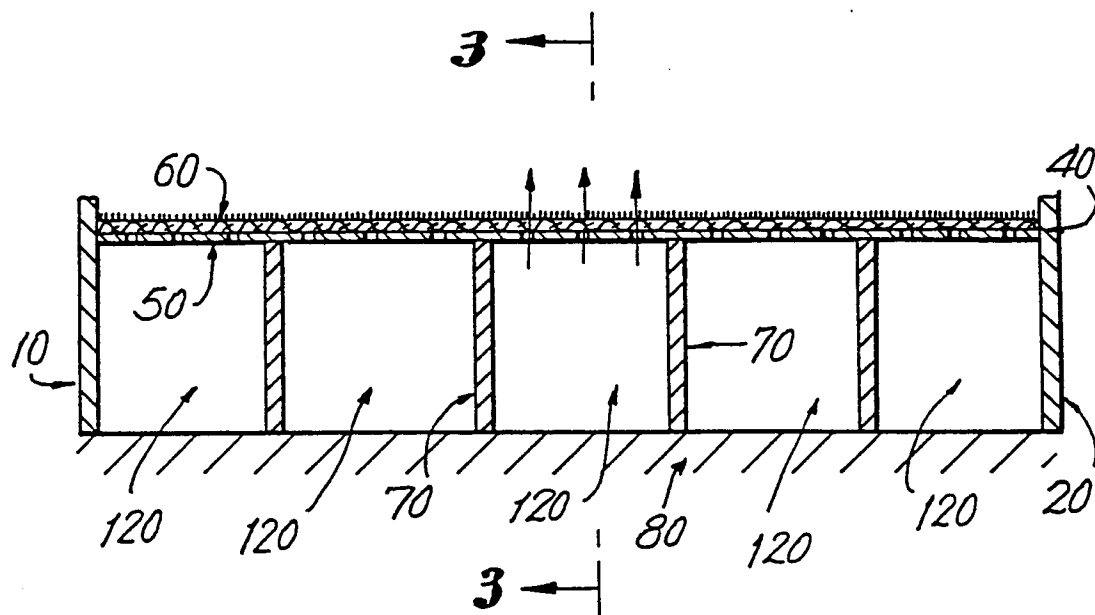


FIG. 2

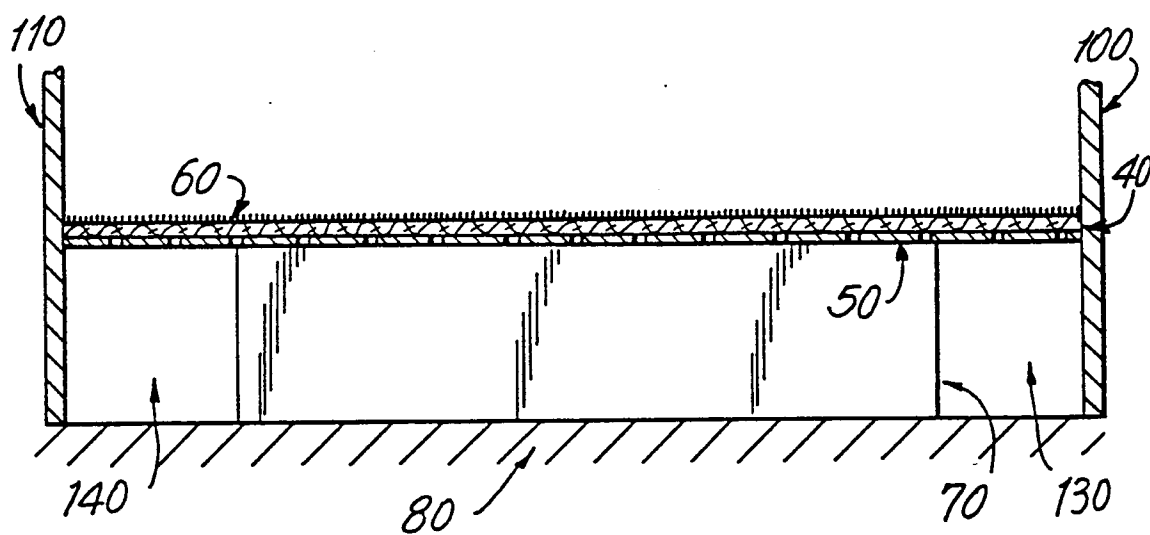
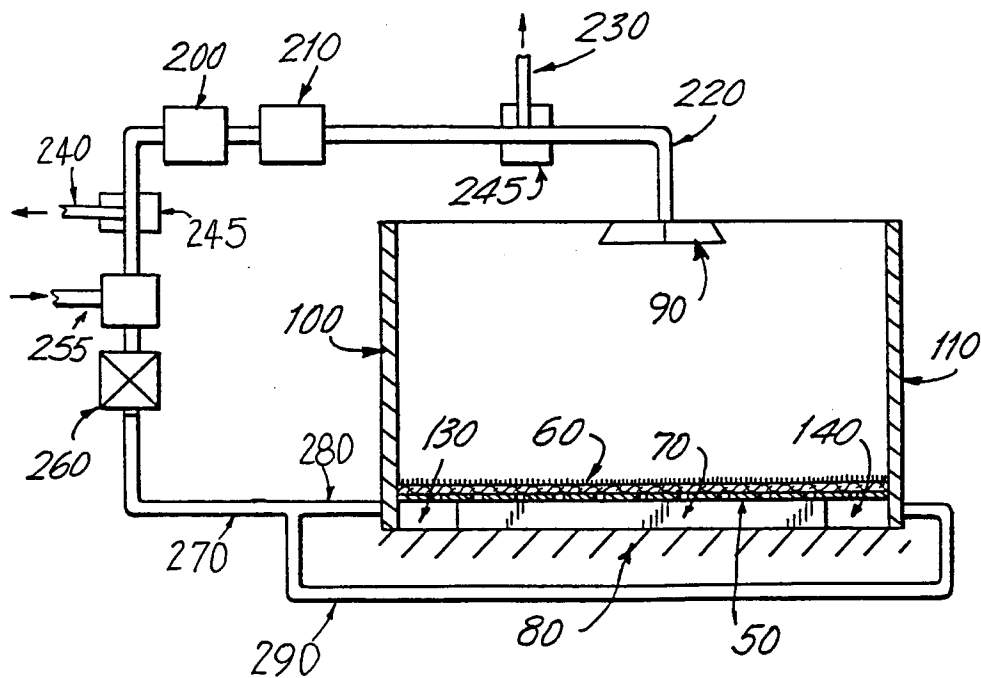
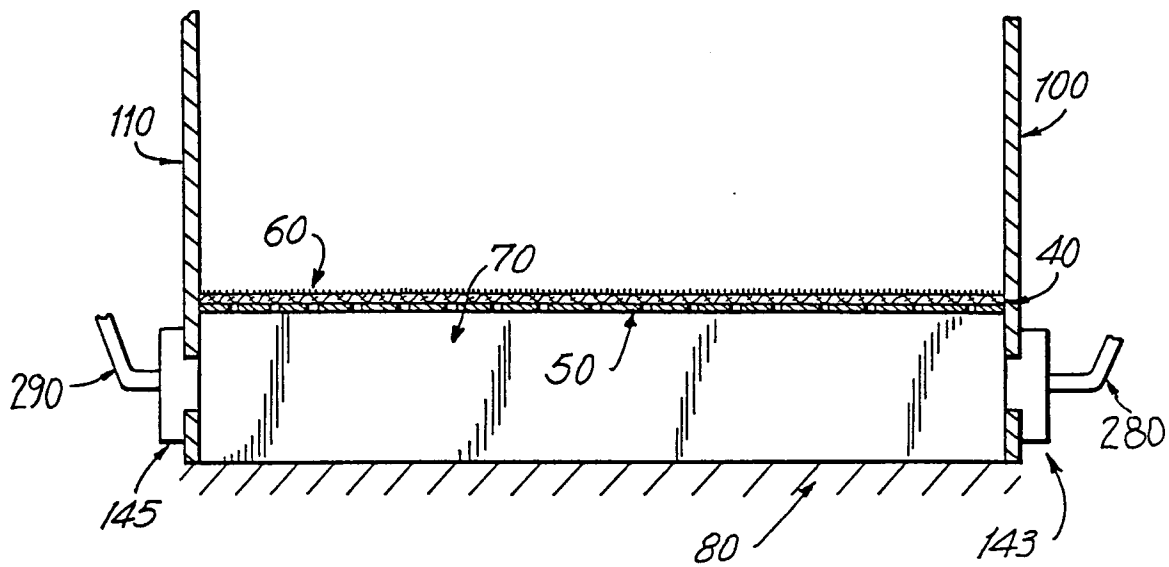


FIG. 3

**FIG. 4**



**FIG. 5**

