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(54) **Pressurizing buildings to improve drying**

(57) A method of drying a building (3) includes closing all openings in the building such that air movement out of the building is restricted, drawing air from outside the building, heating the outside air, and directing a stream of the heated outside air into the building through an input duct (17). The building air pressure of air inside the building is measured and compared to a desired

building air pressure that is less than the input pressure. Where the measured building air pressure is greater than the desired building air pressure, a substantially controlled flow of air is allowed to exit the building at an exhaust location and the flow of air from the building is controlled to maintain the building air pressure at the desired air pressure.

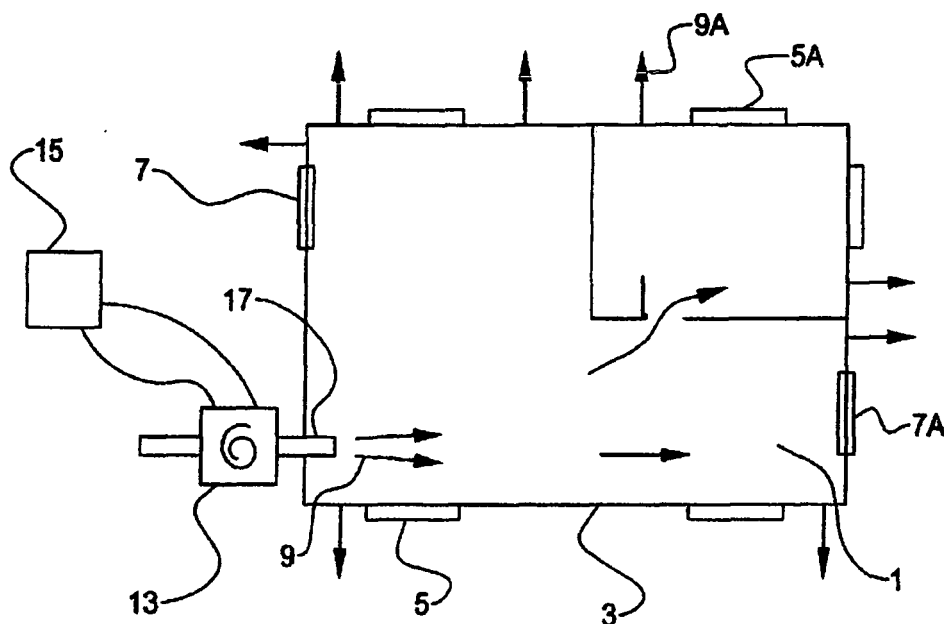


FIG 1

Description

[0001] This invention is in the field of drying building interiors that have excessive moisture accumulated therein, and in particular with drying building interiors with a pressurized flow of dry air.

BACKGROUND

[0002] It is well known that excessive moisture in buildings causes considerable problems. Drywall and flooring absorb moisture and are readily damaged if the excessive moisture condition persists for any length of time. Interior elements such as insulation, studs, and joists can eventually be affected as well. Furthermore, mold begins to form on the damp building materials, and can remain in the structure even after it has dried, causing breathing problems for persons occupying the building.

[0003] At the extreme, such excessive moisture conditions are exemplified by a flooded building. United States Patent Number 6,457,258 to Cressy et al., "Drying Assembly and Method of Drying for a Flooded Enclosed Space", discloses an apparatus for drying flooded buildings that overcomes problems in the prior art. Such prior art is said to require stripping wall and floor coverings and using portable dryers to circulate air to dry out the exposed floor boards, joists and studs. The methods were slow and allowed mold to form on the interior framing, which could then go unnoticed and be covered up and then later present a health hazard to occupants.

[0004] The solution proposed by Cressy is to introduce very hot and dry air into the building, indicated as being at 125 °F (51.67°C) and 5% relative humidity, in order to dry the building very quickly to prevent mold growth and allow an early return to occupants. In the apparatus of Cressy et al., outside air is heated by a furnace and the dry heated air is blown through a dry air duct into a location in the building. An input end of an exhaust duct is positioned in another part of the building such that the dry air moves out of the dry air duct, picks up moisture from the building and then moves into the input end of the exhaust vent and out of the building. In Cressy the warmer exhaust air is directed through a heat exchanger such that heat therefrom is transferred to the cooler outside air prior to heating by the furnace, thereby increasing the efficiency of the system.

[0005] Prior art systems for drying flooded buildings also include desiccant dehumidifiers that use a desiccant material with a high affinity to water to absorb water from the air, and refrigerant dehumidifiers that condense water out of the air by cooling it. In both of these systems, the water must be disposed of in some manner. The water absorbed by the desiccant material is removed by subsequently drying the material. The water condensed by the refrigerant system is collected in a reservoir that must be emptied from time to time or piped to a disposal area. Such systems are relatively costly to manufacture and operate, and are relatively slow to remove moisture from

the subject building.

[0006] United States Patent Number 6,647,639 to Storrer, "Moisture Removal System", addresses the problem of extracting water from interior portions of a structure such as inside walls and from hardwood floors. Storrer discloses using a blower to blow (or draw) dry air through a hose and manifolds that can be directed through injectors into the interior of walls.

[0007] Similarly, United States Patent Numbers 5,960,556 to Jansen, "Method for Drying Sheathing in Structures", is directed to drying walls with warm, low humidity air. United States Patent Numbers 5,893, 216 to Smith et al., 5,555,643 to Guasch, and 5,408,759 to Bass disclose systems for drying walls by directing pressurized air into the inside of the wall.

SUMMARY OF THE INVENTION

[0008] It is an object of the present invention to provide a system for drying buildings that overcomes problems in the prior art.

[0009] Co-pending United States Patent Application 2005/0145109 of the present inventors Dancy et al. discloses a controlled system for maintaining a desired humidity level in buildings and for drying buildings. Portable heat exchanger units comprise a temperature adjusting element, illustrated for example as comprising a fluid coil and a fan drawing air from an inlet through the coil and out an outlet. The coil is connected by conduits to a fluid heater or fluid cooler such that the air passing through the coil can be either heated or cooled. By drawing in outside air and heating it, the relative humidity of the air is reduced, and the drier air is directed into the building. A vent is provided, typically somewhere opposite the intake, so that the drier air moves through the building and picks up moisture from building and carries it out through the vents.

[0010] The relative humidity of the air is an indicator of how much water the air is holding, and thus how much more water it can hold. The amount of water air can hold increases with the temperature of the air, and the relative humidity thus decreases as the temperature increases. By way of illustration, in a closed room with standing water on the floor, the relative humidity of the air in the room would approach 100% (i.e. the air would become saturated with water) and so no more water would evaporate off the floor. Raising the air temp 10°C will reduce the relative humidity by 50% to a 50% relative humidity, resulting in a moisture gradient between the water and the air, and thus more water will evaporate off the floor and the relative humidity will again rise to 100%, provided no air moves in or out of the room.

[0011] By bringing in a dry air stream at a first location in the room and opening an exhaust vent, such as a window, door, at a second location in the room, air entering at the first location pushes the air in the room toward the second location and out the vent. As the dry air moves through the room it picks up moisture and takes the mois-

ture out through the vent. Over time the water will eventually evaporate and be carried out of the room.

[0012] A heat controller can be operated to supply heat at the proper rate to achieve a desired relative humidity in the air stream, and thus in the enclosed space. On a wet day for example if the outside air has a relative humidity of 100%, raising the temperature of the outside air by 20 °C will reduce the relative humidity of the air stream to 25%. Alternatively raising the temperature of the outside air by 40 °C will reduce the relative humidity of the air stream to about 6% and provide fast drying in a flooded building, where damage to sensitive materials is not an issue.

[0013] The present invention provides, in a first embodiment, a method of drying a building. The method comprises closing substantially all openings in the building such that air movement out of the building is restricted; drawing air from outside the building, heating the outside air, and directing a stream of the heated outside air into the building through at least one input duct at an input pressure; measuring a building air pressure of air inside the building; comparing the measured building air pressure to a desired building air pressure that is less than the input pressure; and where the measured building air pressure is greater than the desired building air pressure, allowing a substantially controlled flow of air to exit the building at an exhaust location and controlling the flow of air from the building to maintain the building air pressure substantially at the desired air pressure.

[0014] A significant proportion of buildings that require drying due to floods or mishaps will be fairly poorly sealed against the elements. For example in many areas, especially those in warmer climates, vapor barriers are not commonly installed. Thus it is possible to pressurize the interior of these buildings with heated dry air using a fan similar to a furnace fan, or like available fan, to a level of about 0.2 to 0.5 water column inches ("WC, or 0.498 to 1.245 mbar) and force air through the walls and ceilings of the building. The method also provides improved drying of buildings that are better sealed against air movement.

[0015] For example, a portable heat exchanger unit comprising a fluid coil connected to a fluid heater and a fan drawing air from an inlet through the coil and out an outlet can be used to draw in outside air, heat it to reduce the relative humidity thereof, and direct a stream of the dry heated outside air into the building through an input duct at an input pressure of about 0.6 - 0.7 "WC (or 1.495-1.744 mbar). With all openings in the building closed, such as windows, doors, vents, or the like, air movement out of the building is restricted to the extent possible. When the air stream is directed into the closed building, the building air pressure inside the building will rise. As the building air pressure rises, air inside the building will seek to flow to the lower pressure ambient air outside the building, and will thus flow out through cracks and the like in the walls and ceiling. The dry air picks up moisture from inside the building, and from inside wall

areas to a certain extent as well, and carries it out as it exits the building.

[0016] The input pressure developed by the fan is a pressure differential between the air exiting the input duct and the ambient outside air. Where the doors and windows of the building are open a very low pressure will develop in most buildings, depending on the number and location of the doors and windows. The fan will thus be drawing air in and blowing it out against negligible pressure. The volume of air in the air stream for any given fan at those conditions will be known, and the fluid heater can be adjusted to provide the desired temperature rise to that volume of air flow.

[0017] When drying a building by directing a heated and dried air stream through the building the amount of time air remains in the building will depend on the volume of the interior of the building. For example where the air stream has a volume of 5000 cubic feet (or 141.58 cubic meters) of air entering the building every minute (cfm), and the building has a volume of 25,000 cubic feet (or 707.92 cubic meters), the air inside the building will essentially change every five minutes. At this rate of air movement, the amount of moisture carried out by the air stream will depend on the degree of moisture in the building, and the relative humidity of the entering air stream. The lower the relative humidity of the air stream, the higher the moisture gradient between the air inside the building and the wet building surfaces, and the faster moisture will be absorbed by the air. When the air is in the building, it absorbs moisture and the relative humidity thereof rises. The longer the air remains in the building then, the more moisture it will absorb, and thus the longer the air remains in the building, the lower the rate of moisture absorption and drying.

[0018] Basically then, for any given relative humidity of the air stream, the faster the air moves through the building the faster the building will be dried. The operator thus is typically attempting to push the air through the building as quickly as possible, and thus opens such windows and doors as are available in order to reduce the pressure inside the building to a minimum and maximize the volume of the air stream flowing through the building.

[0019] With the method of the present invention however, the operator will determine that at a building air pressure of 0.25 "WC (or 0.623 mbar), where the inside pressure will be such that the air will try to force its way through wall openings, the fan will only create an air stream volume of perhaps 3500 cfm (or 99.11 cubic meters/ min) instead of the 5000 cfm (or 141.58 cubic meters/ min) available where building air pressure is negligible. The operator then will start the fan with all building openings closed. As the air stream enters the building, the building air pressure will rise, and the operator will monitor the building air pressure with a manometer or the like, with a view to attaining the desired building air pressure of 0.25 "WC (or 0.623 mbar), and input air volume of 3500 cfm (or 99.11 cubic meters/ min).

[0020] With the doors, windows, and whatever other

openings might be present closed, the building air pressure will rise to an equilibrium point where the amount of air in the air stream will equal the amount of air leaking out of the building through door seals, window seals, cracks and the like. Where the building is poorly sealed, the building air pressure at this equilibrium point may be less than the desired building air pressure of 0.25 "WC (or 0.623 mbar). In this situation the operator may choose to simply allow the air to flow through the building at whatever the building air pressure is at equilibrium, and then adjust the heat to raise the temp of the air stream to the desired level. Where obvious large air leakage is occurring the operator may attempt to seal these leaks.

[0021] Alternatively the operator may increase the volume of air flowing into the building by adding a second fan to boost air flow through the coil, or by adding a second portable heat exchanger unit, or by like means such that the building air pressure rises above the desired pressure of 0.25 "WC (or 0.623 mbar).

[0022] Where the building is relatively well sealed, the building air pressure will rise, and could approach the input pressure developed by the fan. At that state very little air would be moving into the building.

[0023] In any event, when the building air pressure exceeds the desired pressure of, in the present example, 0.25 "WC (or 0.623 mbar), the operator allows a substantially controlled flow of air to exit the building at an exhaust location and controls the flow of air from the building to maintain the desired air pressure. Typically the operator will accomplish this end by partially opening a door or window in the building at a location opposite the input location where the air stream is entering the building.

[0024] The operator will adjust the heat supplied by the fluid heater to a setting where the fluid coil will raise the temperature of the air stream by the desired amount.

[0025] The invention further provides the opportunity to control the direction of the flow of air through the building by positioning the exhaust location. For example where one room or area is wetter than the rest of the building the exhaust location can be positioned such that the wetter area is between the input location and the exhaust location. Air flow will be greatest between the input and output location as the air stream seeks to exit the building to the lower pressure outside. Interior fans will typically be provided at locations throughout the building to agitate the air and circulate same along the walls to improve drying, however by moving the air stream directly through the wetter areas of the building, drying times will typically be reduced. Where there are two wetter areas in a building, two exhaust locations could be provided to split the air flow and direct a portion of the air flow through each wetter area. Similarly where a plurality of air streams are available, the input locations could be positioned to direct the air flow as desired as well.

[0026] It is also contemplated that pressurizing the building interior will improve the circulation of air through the building by pushing air into all corners and like areas that are somewhat removed from the main air flow path.

It is also contemplated that the pressurized air will also push against the wet surfaces improving moisture transfer from the surfaces to the air.

5 DESCRIPTION OF THE DRAWINGS

[0027] While the invention is claimed in the concluding portions hereof, preferred embodiments are provided in the accompanying detailed description which may be best understood in conjunction with the accompanying diagrams where like parts in each of the several diagrams are labeled with like numbers, and where:

Fig. 1 is a schematic top view of a building interior showing all openings in the building closed such that the building air pressure rises and at least some air exits the building interior through the building structure;

Fig. 2 is a schematic top view of the building interior of Fig. 1 showing a window opened to allow a controlled flow of air to exit the building interior;

Fig. 3 is a schematic top view of the building interior of Fig. 1 showing a window and a door opened to allow a controlled flow of air to exit the building interior through two locations;

Fig. 4 is a schematic top view of the building interior of Fig. 1 showing a window and a door opened to allow a controlled flow of air to exit the building interior through two locations, and showing an increased amount of air being drawn into the building interior.

35 DETAILED DESCRIPTION OF THE ILLUSTRATED EMBODIMENTS

[0028] Figs. 1 - 4 schematically illustrate a method of drying an interior 1 of a building 3. The method comprises closing substantially all openings in the building, such as windows 5 and doors 7, such that air movement out of the building is restricted, as illustrated in Fig. 1. Outside air is drawn from outside the building 1 and heated, and a stream 9 of the heated outside air is directed into the building 1 through an input duct 11 at an input pressure.

[0029] While it is contemplated that other apparatuses could be used, in the illustrated embodiment, the air stream 9 is conveniently provided by a portable heat exchanger unit 13 comprising a fan and a coil heating element. The air is heated by hot fluid circulating through the coil from a boiler 15, or like fluid heater. As the air stream is forced into the building through the input duct 17 at the input pressure developed by the fan, the air pressure in the building interior 1 rises, since the windows 5 and doors 7 have been closed. The input duct 17 is substantially sealed to the building 3 to prevent escape of air.

[0030] Using a manometer or like instrument, the build-

ing air pressure of the air inside the building 3 is measured, and compared to a desired building air pressure that is less than the input pressure. Typically the input pressure will be about 0.6 - 0.7 "WC (or 1.495-1.744 mbar) compared to the air pressure outside the building 3, and the desired building air pressure in the interior 1 of the building 3 will be about 0.25 - 0.40 "WC (or 0.623-0.996 mbar), creating a pressure gradient between the building interior 1 and the air outside of the building 3 such that air inside the building will seek to pass through the structure to the lower pressure outside the building.

[0031] At least some air will flow through cracks or the like in the walls and roof, especially in buildings with no vapor barrier, as indicated by arrows 9A showing portions of the air stream 9 passing through the walls of the building 3. For example, air will enter a crack in the interior wall surface, and flow along the inside of the wall until it comes to a crack or the like in the outside wall surface through which the air will flow to the lower pressure outside. In this way, some air circulation will be developed inside the walls that will help to dry the inside of the wall.

[0032] Typically in a relatively sound building after the fan has been running for a period of time and equilibrium has been reached, the measured building air pressure will be greater than the desired building air pressure. The operator will then select an exhaust location, typically an available window 5 or door 7, although an exhaust could be provided of any kind, and a substantially controlled flow of air will be allowed to exit the building at the exhaust location to maintain the desired air pressure. Typically the exhaust will be opened a small amount, and when equilibrium is reached the building air pressure will be measured again. If it is still above the desired pressure, the exhaust will be opened further, and this process will be repeated until the desired building air pressure is attained, at which time the exhaust will be fixed in place, the amount of heat supplied to the air stream will be adjusted to provide the desired temperature rise, and drying will proceed. Fig. 2 illustrates the window 5A being used to provide the exhaust.

[0033] The method of the invention also provides for directing the flow of the air stream 9 through the building such that the air flow is increased through wetter areas or other desired areas of the building interior 1 by configuring the input location of the input duct 17 and the exhaust location such that an air flow is created from the input location through a desired area of the building to the exhaust location. For example Fig. 2 illustrates a desirable configuration of the input duct 17 and exhaust location at window 5A where it is desired to increase air-flow through the room 19 in the building interior 1, such as where the room 19 may be wetter than the rest of the building interior 3. Thus a portion of the air stream 9A will continue to exit through the structure, and a portion 9B will exit through the window 5A. While circulation fans, not shown, will typically be used in the building interior 1 to circulate air in the building against the walls, air flow

through the room 19 will be greater than through the balance of the building interior 1.

[0034] Fig. 3 illustrates a configuration where a substantially controlled flow of air is allowed to exit the building interior 1 at two exhaust locations, the window 5A and door 7A, such that in addition to the air flow 9A through the structure, a first air flow 9B is created from the input duct 17 through a first desired area of the building, the room 19, to the first exhaust location at window 5A, and a second air flow 9C is created from the input duct 17 through a second desired area 21 of the building to the second exhaust location at door 7A. With the door 7A opened, the window 5A will be closed somewhat compared to its position in Fig. 2, since it will be desired to maintain about the same area of opening that was provided by the window 5A alone in Fig. 2 using the window 5A and the door 7A in Fig. 3.

[0035] Where the building interior 3 is about equally wet throughout, the configuration of Fig. 3 allows the room 19 to experience sufficient air flow for drying that may not be available without an exhaust location in the room 19.

[0036] In some less well sealed buildings, such as older or damaged buildings, the air stream provided by a single portable heat exchanger unit may not be sufficient to raise the building air pressure to the desired level because is leaking out as fast as it is coming in. It may be that the operator will choose to simply let the air flow out of the building through the structure, or he could draw an increased volume of outside air into the building interior 1 by adding a second portable heat exchanger unit 13A as illustrated in Fig. 4 directing a second air stream 9' into the building interior through a second input duct 17A. The steps set out above would typically be followed to maintain the desired building air pressure.

[0037] The foregoing is considered as illustrative only of the principles of the invention. Further, since numerous changes and modifications will readily occur to those skilled in the art, it is not desired to limit the invention to the exact construction and operation shown and described, and accordingly, all such suitable changes or modifications in structure or operation which may be resorted to are intended to fall within the scope of the claimed invention.

Claims

1. A method of drying an interior (1) of a building (3), the method comprising:

closing substantially all openings in the building such that air movement out of the building is restricted;

drawing outside air from outside the building, heating the outside air, and directing a stream of the heated outside air into the building through at least one input duct (17) at an input pressure;

measuring a building air pressure of air inside the building;

comparing the measured building air pressure to a desired building air pressure that is less than the input pressure; and

where the measured building air pressure is greater than the desired building air pressure, allowing a substantially controlled flow of air to exit the building at an exhaust location and controlling the flow of air from the building to maintain the building air pressure substantially at the desired air pressure.

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2. The method of Claim 1 further comprising, where the measured building air pressure is less than the desired building air pressure, drawing an increased volume of outside air into the building (3).
3. The method of Claim 2 further comprising increasing the amount of air drawn into the building (3) until the desired building air pressure is substantially maintained.
4. The method of Claim 1 comprising configuring an input location of the at least one input duct (17) and the exhaust location such that an air flow is created from the input location through a desired area of the building (3) to the exhaust location.
5. The method of Claim 4 comprising allowing a substantially controlled flow of air to exit the building (3) at first and second exhaust locations configured such that a first air flow is created from the input location through a first desired area of the building to the first exhaust location and such that a second air flow is created from the input location through a second desired area of the building to the second exhaust location.
6. The method of Claim 1 comprising directing a stream of the heated outside air into the building (3) through a plurality of input ducts (17) located at a plurality of input locations.
7. The method of any one of Claims 1 - 6 wherein the desired building air pressure is between 0.25 "WC and 0.70 "WC (or between 0.623 and 1.744 mbar) compared to an ambient pressure of the outside air.
8. The method of any one of Claims 1 - 7 wherein the outside air is heated with a heating element (13), and wherein the amount of heat supplied to the air stream (9) is adjusted.

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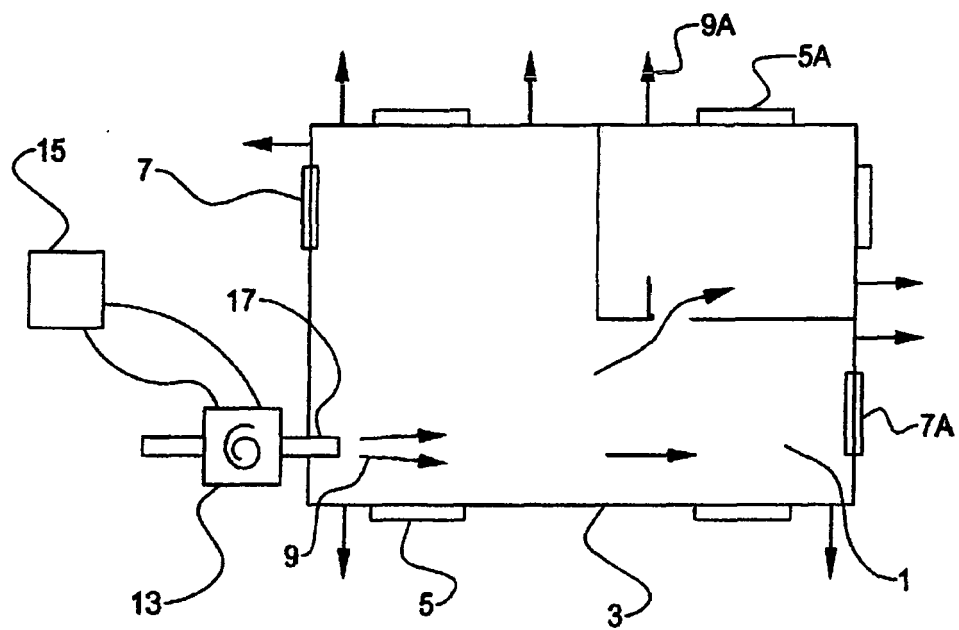


FIG 1

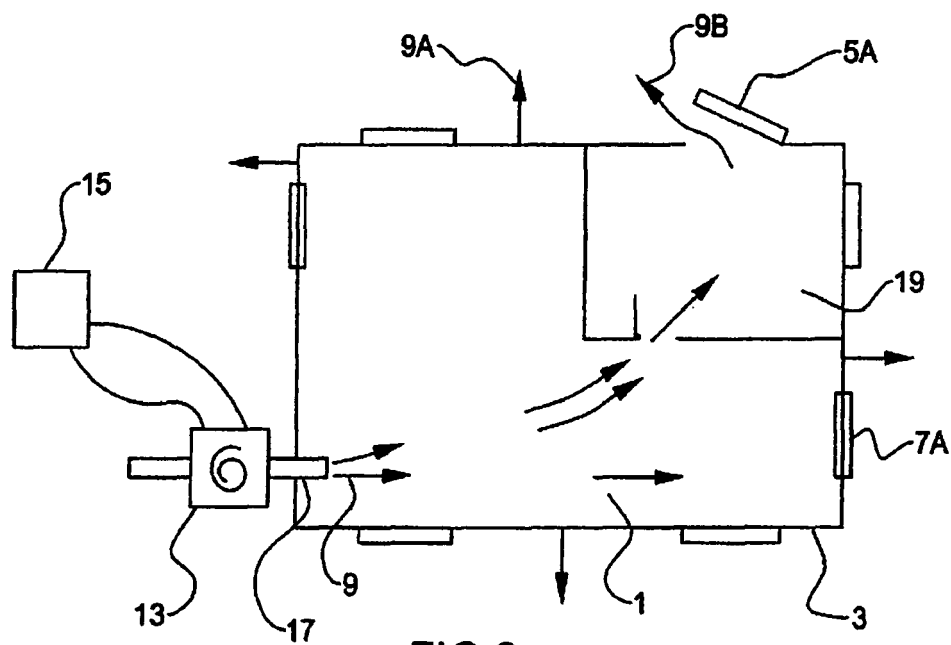


FIG 2

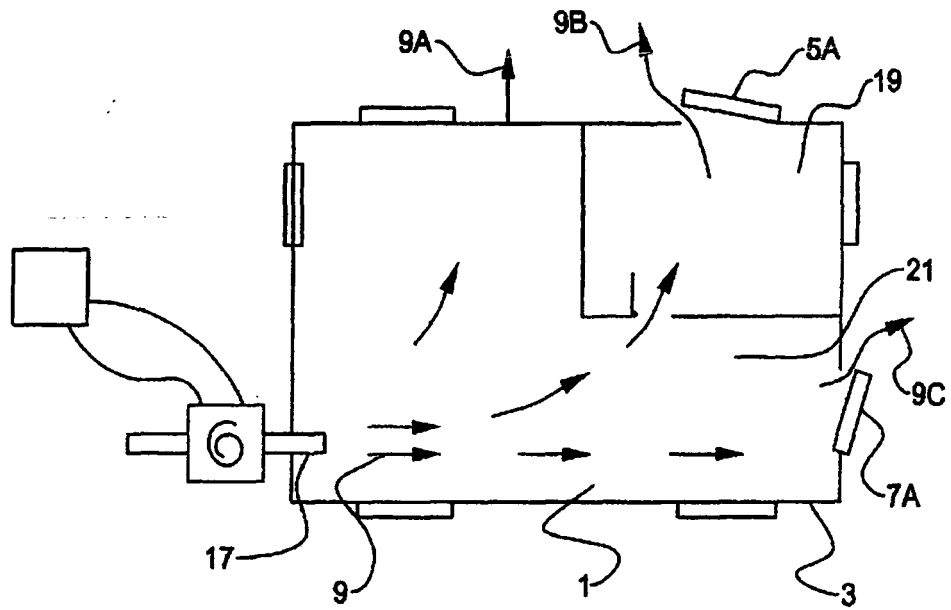


FIG 3

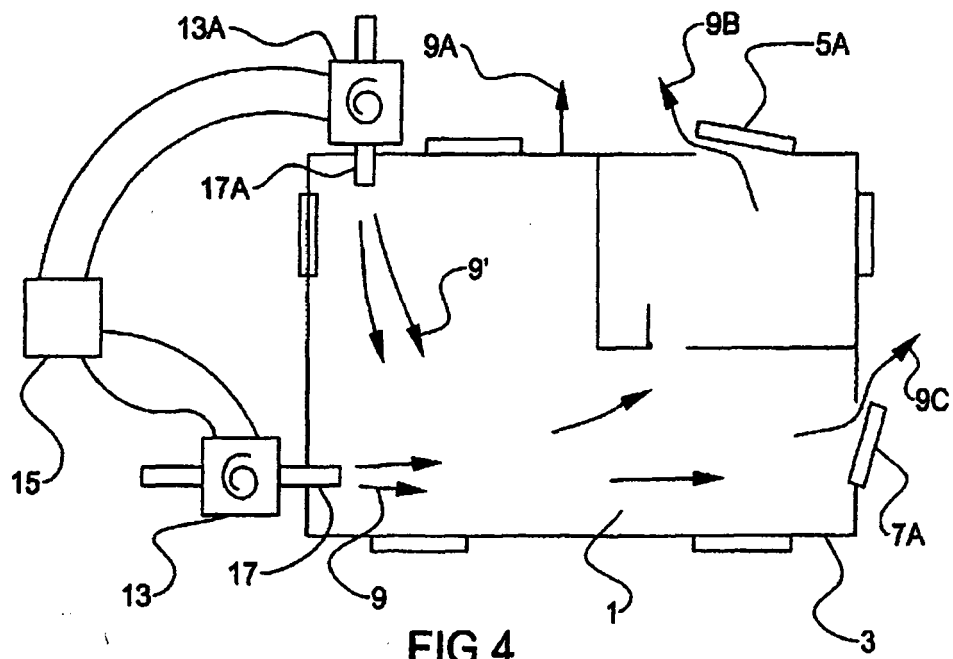


FIG 4

REFERENCES CITED IN THE DESCRIPTION

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