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VENTILATION CONTROL

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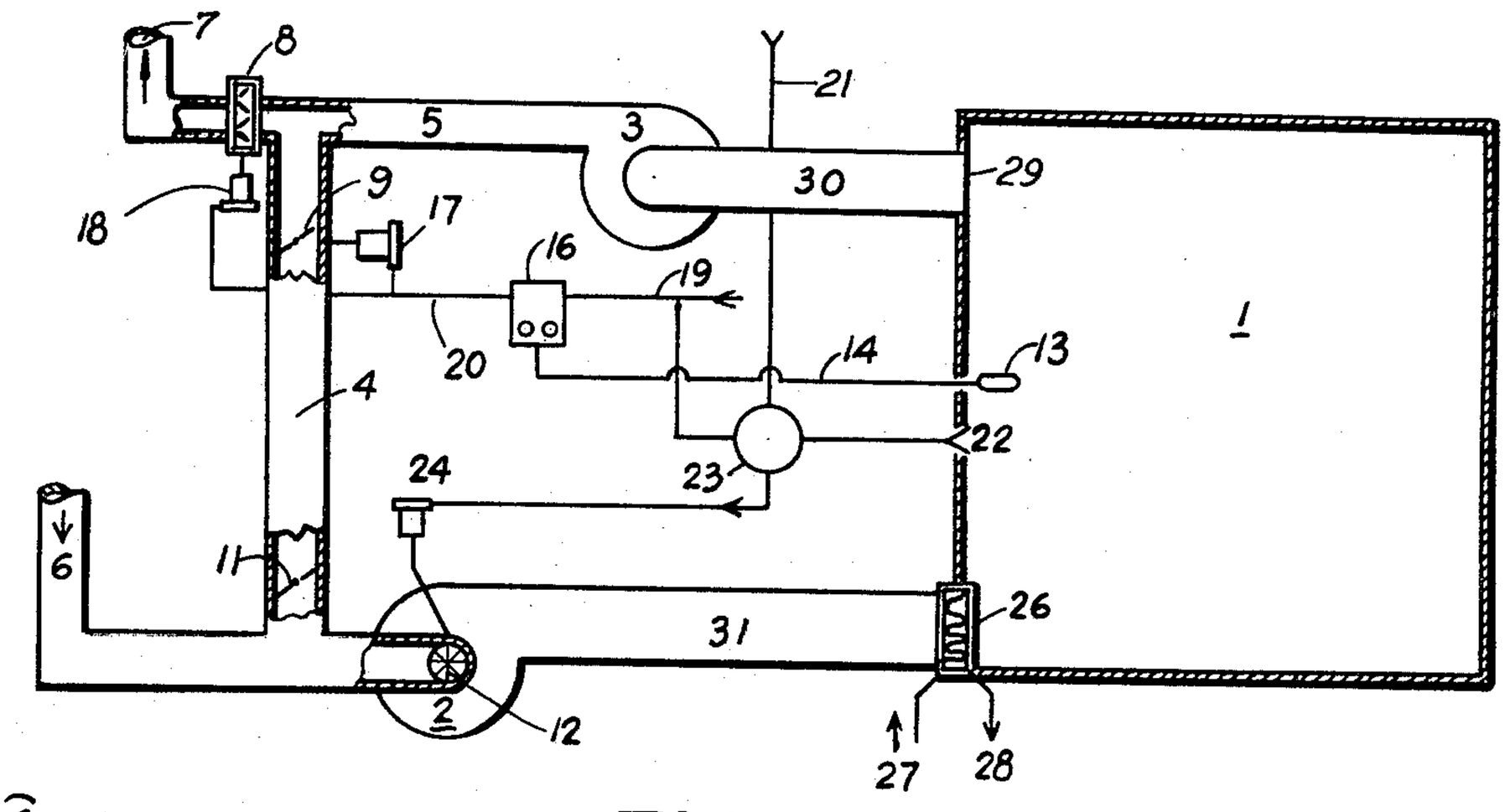


FIG. 1

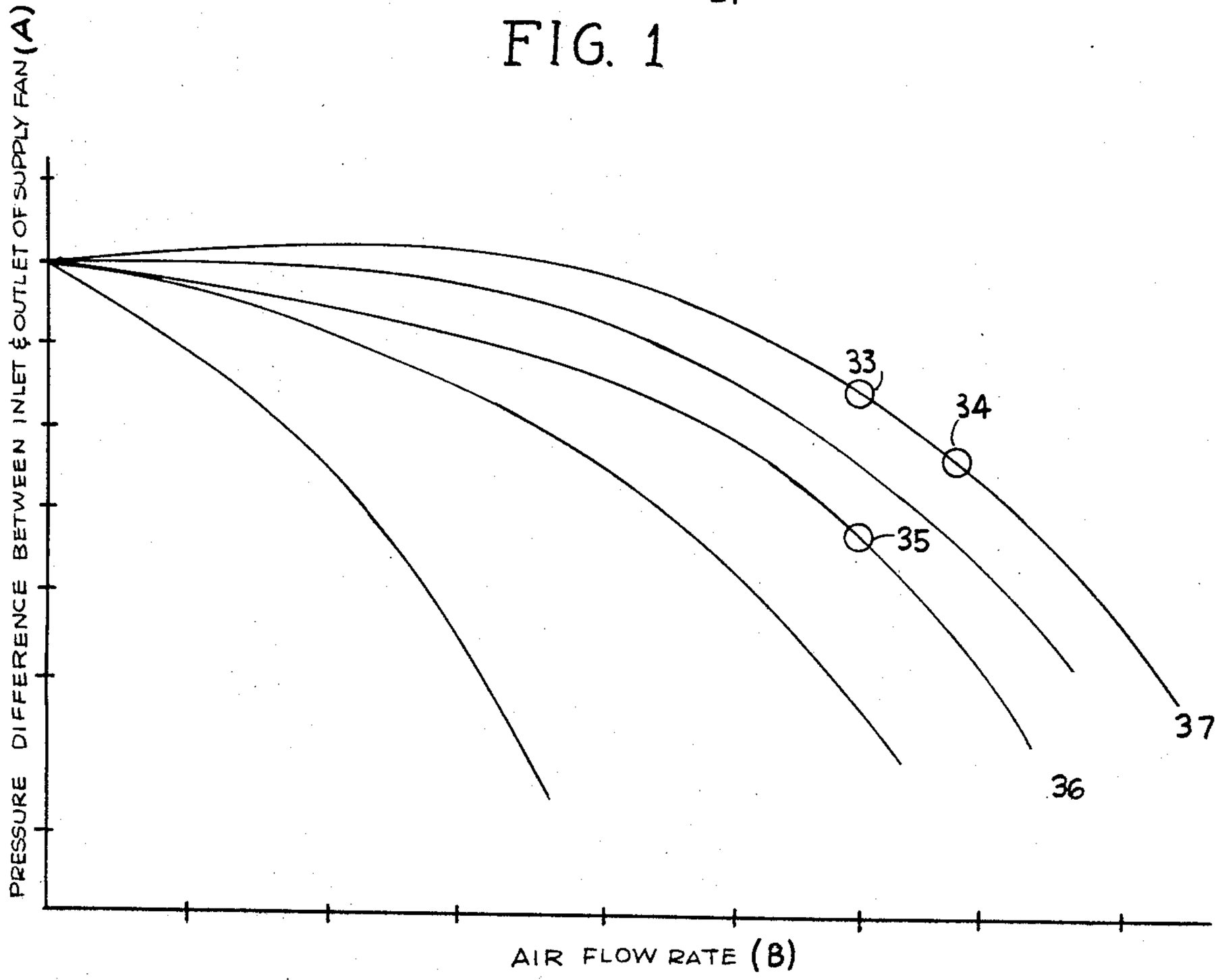


FIG. 2

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VENTILATION CONTROL

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ABSTRACT OF THE DISCLOSURE

A ventilating arrangement for a plenum chamber which includes air supply means to provide air to the chamber, means to exhaust a portion of the air emitted from the plenum chamber and recirculate a portion of the air emitted from the chamber to the air supply means in accordance with the temperature in the chamber and flow control means responsive to the pressure in the chamber to control the flow of air through the air supply means to modulate the pressure in the chamber.

Background of the invention

In previous forced circulation and ventilation systems where temperature and pressure in a plenum chamber have been controlled by mixing proportioned amounts of recirculated air with fresh air, expensive and intricate control apparatus has been required. In most such systems, temperature and pressure controls have not been directly interrelated and as a result, operation of the control equipment has been difficult and a coordinated response has not been attained. Moreover, pressure control in some such previous systems has been attained by increasing the pressure of the supply air to an arbitrary value well in excess of the pressure desired in the chamber and selectively reducing the pressure to the desired level. Such systems have been inefficient and have required oversize air moving equipment.

Summary of the invention

In accordance with the present invention, an inexpensive and straightforward arrangement has been devised to simultaneously, effectively, and efficiently control the pressure at a selected location in the system wherein the pressure of the supply air is not reduced downstream of the air supply means so the efficiency of the air supply means is improved. Furthermore, in accordance with the present invention, the quantity of air circulating in the system is controlled and it has been found that such an arrangement provides stable control and operation of the ventilation system.

Various other features of the present invention will become obvious to one skilled in the art upon reading the disclosure set forth hereinafter.

More particularly, the present invention provides a temperature and pressure control arrangement for ventilating a plenum chamber comprising: air supply means having an air inlet communicating with a source of air, an outlet communicating with the plenum chamber, and an air flow control means in the air inlet to the supply means; air exhaust means including an air inlet means communicating with the plenum chamber and exhaust air outlet means; an air recirculation conduit having a first end communicating with the exhaust air outlet means and a second end communicating with the air supply means inlet; damper means to selectively control exhaust air flow through the recirculation conduit to the air supply means inlet in accordance with temperature at selected locations; and, means to regulate the air flow control means in the air supply means inlet in response to changes in pressure in the plenum chamber.

It is to be understood that various changes can be made in the arrangement, form, and construction of the ventilation system as disclosed herein without departing from the scope or spirit of the present invention.

FIGURE 1 is a plan view, partly in section, of a circulation and ventilation system to ventilate a plenum chamber in accordance with the present invention; and

FIGURE 2 is a diagram illustrating operating characteristics of a supply air fan in accordance with the present invention.

Referring to the example of the present invention shown in FIG. 1, air is introduced to the ventilation system through conduit **6** which has an inlet end communicating with a source of ventilating air, and a second end communicating with the inlet to supply air fan **2**. Fan **2** is provided to supply air to plenum chamber **1** served by the ventilation system. Exhaust air is emitted from chamber **1** through opening **29** and flows through conduit **30** to exhaust fan **3**. Fan **3** pumps exhausted air through conduit **5** to exhaust air outlet **7** and to recirculation duct **4** downstream of fan **3** to return a portion of the exhaust air from conduit **5** to air inlet conduit **6** in a manner hereinafter described.

In accordance with the present invention, the temperature is controlled at a selected location in the ventilating system, for example chamber **1**, by recirculating controlled quantity of air from exhaust conduit **5** through recirculation duct **4**. The combined fresh and recirculated air is mixed in duct **6** and is pumped to chamber **1** by fan **2**.

To control the quantity of air recirculated through duct **4**, air damper **8** is provided in conduit **5** downstream of conduit **4** to regulate the quantity of air exhausted from the ventilation system through outlet **7**. A second cooperative damper **9** is located in the recirculation duct **4** to control the amount of air passing through duct **4** to inlet duct **6**.

The temperature in chamber **1** is sensed by thermal element **13** and is transmitted to controller **16** through conduit **14**. Controller **16** controls an output response in accordance with an input signal and can, for example, be a pneumatic operator, as manufactured by Johnson Service Company, which regulates an output pressure in accordance with changes in a selected condition. In the example of FIG. 1 pneumatic output from controller **16** is fed to damper actuators **18** and **17**, respectively, to control the operation of dampers **8** and **9** in response to the temperature in chamber **1**. Damper actuators **17** and **18** are cooperatively linked for operation by controller **16** so in the example of FIG. 1 damper actuators **17** and **18** are pneumatically driven. Pneumatic actuators **17** and **18** operate in response to the output air pressure supplied from controller **16** through conduit **20** where compressed air is supplied to controller **16** from a convenient source (not shown) by means of conduit **19**. Controller **16** provides the pneumatic output signal by reducing the pressure of the compressed air in accordance with the temperature in space **1** to operate actuators **17** and **18** and dampers **8** and **9** to selectively control the quantity of air recirculated through duct **4**. Operation of dampers **8** and **9** can be interrelated to accomplish a coordinated effect. In the example of FIG. 1 actuators **17** and **18** advantageously operate dampers **8** and **9** in an inverse fashion so that at selected high temperatures damper **9** is closed and damper **8** is fully open so there is no recirculated air provided through duct **4** to chamber **1**. Accordingly, only fresh air is provided to chamber **1**. On the other hand, as the temperature in chamber **1** decreases, damper **8** is progressively closed and damper **9** is progressively opened so increasing amounts of warm recirculated air are provided to chamber **1** to prevent undesirable low temperatures. Normally both

dampers 8 and 9 will be partially open so that a controlled quantity of fresh ambient air will be continuously introduced into chamber 1.

The arrangement in accordance with the present invention can be used to control the temperature in a plenum chamber whether the chamber is to be heated or cooled. In the example of FIG. 1, heat is added to the air stream to control the temperature of chamber 1. Furthermore, the control system in accordance with the present invention can, for example, be used to control temperature within selected limits or to maintain a temperature in a selected location, for example, chamber 1. In the example of FIG. 1, heat can be provided to the air emitted from fan 12 by heat exchanger 26 adapted to receive a suitable tempering medium from an inlet 27 where the tempering medium is exhausted from the heat exchanger through outlet 28.

In some situations, the air flowing through the system will gain heat rejected from equipment (not shown) such as fans, motors, and waste heat from air conditioning condensers and other sources so additional heat sources may not be necessary to maintain desired temperatures in chamber 1. Without recirculation, the rejected heat would normally be exhausted through outlet 7, but by diverting a controlled portion of the warm exhaust air through recirculation duct 4 and mixing such heated air with ambient air drawn into the ventilation system through conduit 6, temperature control can be maintained in chamber 1.

In accordance with the present invention, temperature and pressure control are improved by controlling the total quantity of air passed through the system regardless of the relative quantities of fresh air and warm recirculated air supplied to fan 2. In accordance with the present invention as shown in the example of the FIG. 1, the total quantity of air flowing through the system is controlled by controlling the flow of air to inlet 12 of fan 2 to maintain a constant difference in pressure between chamber 1 and a reference pressure, for example atmospheric pressure. As an example of the operation of the arrangement shown in FIG. 1, increased air flow, assuming a constant outlet flow resistance from fan 3, increases the pressure in chamber 1 to increase the differential in pressure between chamber 1 and atmospheric pressure. In response to such pressure increase in chamber 1, controller 23, which regulates the operation of inlet damper 12 of supply fan 2 to maintain a constant differential pressure, adjusts damper 12 to restrict the flow of air to fan 2 to decrease air flow and the pressure in chamber 1.

In the example of FIG. 1, atmospheric pressure is sensed by element 21 which communicates with controller 23 and the pressure in chamber 1 is determined by sensing element 22 which also communicates with controller 23. Controller 23, like controller 16, operates a pneumatic damper actuator 24 and is supplied with a suitable driving force, for example, compressed air by means of conduit 19 (as hereinbefore described with reference to controller 16) to operate damper actuator 24 to adjust damper 12 of supply fan 2 in accordance with the difference in pressure between the atmosphere and chamber 1. Advantageously, damper 12 of fan 2 of the example of FIG. 1 can be a variable area flow control damper, as is known in the art, designed to change the operating characteristics of fan 2 in a manner hereinafter described.

In accordance with the present invention, a constant quantity of air is circulated through chamber 1 so as the amount of air recirculated through duct 4 is increased, to increase the temperature of the air supplied to chamber 1, it is necessary to decrease the amount of air drawn from the exterior ambient air source through duct 6 by an equal amount. Since the recirculated air is provided to duct 6 at a slightly higher pressure than air drawn from the ambient source because the pressure in duct 4 and at outlet 7 is greater than atmospheric, the absolute pressure at the inlet to fan 2 is increased for increasing amounts of recirculated air. If the operating characteristics of fan 2 are not altered, the increased absolute pressure at the inlet accordingly increases the quantity of air moved by fan 2 or increases the discharge pressure at fan 2 and in either case the pressure in chamber 1 is increased. To compensate for the increased pressure at the inlet and to maintain a constant pressure in chamber 1 at a constant air flow rate through the system, the operating characteristics of fan 2 are changed to decrease the capacity of fan 2. In the example of FIG. 1, reduction in fan capacity is advantageously accomplished by damper 12, which can be a vortex type damper, as known in the art having a variable flow area at the inlet to supply fan 2 where the vortex damper is adjusted by pneumatic motor 24 operated by controller 23. To adjust the capacity of fan 2 to provide constant flow through the system while maintaining a constant pressure in chamber 1 regardless of pressure at the inlet to fan 2, damper 12 causes fan operation to adjust to a new supply curve in response to change in pressure in chamber 1. Changing fan operation to a new flow supply curve in response to change in pressure at the inlet to fan 2 changes the flow capacity and assures a constant discharge pressure at a constant volumetric flow of air through the system.

The effect of the operation of vortex damper 12 and the change of capacity of fan 2 is illustrated in FIG. 2 of the drawing which shows a series of curves representing the operation of the fan. In FIG. 2 the vertical axis A represents the increase in pressure experienced by air flowing through supply fan 2 while the horizontal axis (B) represents the flow rate of air through the fan. The curved lines including lines 36 and 37 represent operation at different relative settings of damper 12. Point 33 for example, illustrates fan operation without recirculation of air through duct 4. When the inlet pressure at the fan is increased (more recirculated air is introduced to the supply duct 4 to increase the absolute pressure at the inlet to the fan) the system would normally rebalance at point 34, giving a higher flow rate for a lower differential pressure across the fan. Upon consideration, it will be realized the decreased differential pressure at higher flow occurs without adjusting the operating characteristics of fan 2 because increased pressure at the inlet to fan 2 increases flow and if the flow resistance at the outlet from chamber 1 is not changed the pressure in chamber 1 is increased but the pressure increase in chamber 1 (and the discharge of fan 2) is not as great as the increased pressure at the inlet to fan 2 so the new result is increased air flow, a small pressure increase in chamber 1, and, a decreased differential pressure across fan 2. When damper actuator 24 adjusts vortex damper 12 in response to the small increase in pressure in chamber 1 the quantity of air entering fan 2 is reduced and fan operation as shown in FIG. 2 is shifted from fan performance curve 37 to a lower fan performance curve 36 at point 35. The lower fan performance curve gives the original quantity of air at an even lower fan differential pressure to restore the original pressure at the outlet from fan 2 and in chamber 1. It will be realized that when the temperature in chamber 1 increases, a reverse sequence of operations occurs.

Within the scope of the present invention, other suitable means can be used to restrict or regulate the flow of air through fan 2. In the example hown in the figures, it has been found that the use of a damper at the inlet to supply fan 2, as hereinbefore described, advantageously provides enhanced control and reduced power requirements for the fan motor.

It has been further realized that control of the quantity of air flowing through a system is improved if flow resistance is the same through alternate flow paths in the system. In arrangements as in the example of FIG. 1, the flow resistance encountered by air emitted from fan 3, and therefore the quantity of air emitted, can be affected by the flow path followed by the air leaving the fan. If flow resistance incurred in one flow path is greater than flow

resistance incurred in a second flow path, the quantity of air flowing through the system will vary accordingly. Assuming stable fan operation, operation of the arrangement of FIG. 1 is improved by making certain the flow resistance encountered by air emitted from fan 3 is not affected by a change in flow path regardless whether the air is exhausted through outlet 7 or is recirculated through duct 4. For example, in FIG. 1 assume the flow resistance incurred by air passing through damper 8 and exhaust 7 is greater than the flow resistance incurred by air recirculated through damper 9 and duct 4. In accordance with the present invention, to equalize flow resistance in the recirculation air flow path through duct 4, a manually adjusted damper 11 is provided and is located in recirculation duct 4. Damper 11 can be adjusted manually to provide additional flow resistance as required so flow resistance through recirculation duct 4 is equivalent to flow resistance through damper 8 and exhaust air outlet 7 and the discharge pressure outlet of fan 3 is uniform regardless of the flow path.

In the example of FIG. 1, exhaust fan 3 is provided to pump exhausted air from chamber 1 to outlet 7 or recirculation duct 4 to assure a controlled rate of air flow at selected pressure in chamber 1. It will be noted that in circumstances where the pressure in chamber 1 is maintained at a value sufficiently in excess of atmospheric, it is not always necessary to provide an exhaust fan such as exhaust fan 3. If the pressure maintained in chamber 1 is sufficiently in excess of atmospheric, exhaust fan 3 can be eliminated and the system can be operated by regulating the rate of flow of air exhausted from chamber 1 by damper systems which control the difference in pressure between chamber 1 and atmospheric pressure.

A secondary advantage of the system is to provide room pressure control in spite of changes in specific volume of the air as it enters the room and is heated (as in the case where heat is emitted by equipment in the room to provided heat for the air). For example, air entering the room from supply fan 2 is heated from the heat sources in the room. As the specific volume (volume occupied by specific weight) increases, there is a greater volume of air that must be exhausted by fan 3 and the pressure in chamber 1 increases accordingly. The room pressure control system including inlet damper 12 as hereinbefore described, adjusts supply fan inlet damper to maintain the desired room temperature and dampers 8 and 9 cooperated to adjust room temperature as desired.

The invention claimed is:

1. A temperature and pressure control arrangement for ventilating a plenum chamber comprising: air supply means including a ventilating air inlet communicating with a source of ventilated air, an air outlet communicating with said plenum chamber; air exhaust means including an exhaust air conduit means having an inlet communicating with said plenum chamber and an exhaust air outlet; an air recirculating conduit having one end communicating with said exhaust air conduit and a second end communicating with said air supply means; damper means cooperatively disposed to control air flow from said exhaust conduit through said recirculation conduit in accordance with the temperature at selected locations so a selected portion of the air exhausted from the plenum is recirculated thereto; and, plenum chamber pressure control means including damper means disposed in said air supply means downstream of said ventilating air inlet and said second end of said recirculation conduit to regulate air flow through said air supply means to said chamber in response to change in pressure in said plenum chamber.

2. An improved temperature and pressure control arrangement for ventilating a plenum chamber comprising: air supply fan means including an air inlet having air inlet damper means in adjacent cooperative relation with said air inlet to selectively control flow of air to said fan means, and an air outlet communicating with said chamber; air supply conduit means having one end communicating with said supply fan air inlet, a second end communicating with a source of ventilating air; exhaust conduit means for emission of air from said chamber including an inlet communicating with said chamber and exhaust air outlet; air recirculation conduit means having one end communicating with said exhaust conduit means and a second end communicating with said air inlet conduit; temperature responsive damper means cooperatively disposed to selectively control air flow through said recirculation air conduit in response to temperature at a selected location; and, chamber pressure control means including pressure sensing means in said chamber and damper actuator means to operate said supply air fan inlet damper to control flow of air to said supply fan in response to change in pressure in said chamber.

3. The apparatus of claim 2 including manual damper means in said recirculation air conduit means, said manual damper means being disposed downstream of said recirculation air damper means to regulate air flow resistance through said recirculation conduit means.

4. The apparatus of claim 2 including heat exchange means in said supply fan outlet end to receive tempering means and transfer effect of said tempering means to air passing through said supply air fan outlet means.

5. The apparatus of claim 2 wherein said exhaust means includes: exhaust fan means having an air inlet communicating with said chamber and an outlet; and, exhaust air conduit means having a first end communicating with said outlet of said exhaust fan and an exhaust air outlet communicating with atmosphere where said recirculation conduit communicates with said exhaust air conduit downstream of said exhaust fan means.

6. The apparatus of claim 5 wherein said temperature responsive damper means includes exhaust damper means disposed in said exhaust air conduit downstream of said air recirculation conduit means to selectively control flow of air emitted from said exhaust conduit; and, recirculation air damper means in said recirculation conduit to control flow of air through said recirculation conduit.

7. The apparatus of claim 6 wherein said temperature responsive damper means includes: temperature sensing means in said chamber; temperature controller means communicating with said temperature sensing means and including power output means to furnish power in response to changes in temperature sensed by said temperature sensing means; and damper actuator means cooperatively operated by power from said power output means to selectively operate said exhaust damper and recirculation damper in accordance with change in temperature in said chamber.

8. The apparatus of claim 7 wherein said damper actuator means operate said exhaust damper means and said recirculation damper means and controls air flow through said recirculation conduit means to maintain minimum temperature in said chamber.

9. The ventilation control system of claim 7 wherein said temperature controller means regulates said exhaust air damper and said recirculation air damper in response to change of temperature in said chamber to control temperature in said chamber within selected limits.

10. The apparatus of claim 7 wherein said damper actuator means moves said exhaust damper and said recirculation damper in reverse relative direction in response to power furnished by said temperature controller to change exhaust air flow through said recirculation duct in response to change in temperature in said chamber.

11. The apparatus of claim 5 wherein said pressure control means includes: first pressure sensing means in said selected space; second pressure sensing means in a reference space; differential pressure control means communicating with said first and second pressure sensing means and including power output means to furnish power in response to changes in differential in pressure sensed by said first and second pressure sensing means; and, damper

actuator means operated by power supply means to selectively operate said inlet damper and control flow of air to said supply fan.

12. The apparatus of claim **10** wherein said air inlet damper control means includes movable inlet vanes to be opened and closed by said damper actuator means to change rate of flow of air through said fan and progressive closing of said vanes directs inlet air flow more and more in direction of rotation of said fan.

13. A method of controlling air temperature and pressure in a ventilated plenum chamber comprising: moving air by a prime mover to said chamber through an inlet conduit communicating with said chamber; controlling the quantity of air supplied to the chamber in accordance with the pressure in said chamber; exhausting air from said chamber; recirculating a portion of the exhausted

air to said air inlet conduit; and, controlling the quantity of air recirculated to said inlet conduit in accordance with temperature in said chamber.

14. The method of claim **13** including: controlling the quantity of air pumped to said chamber by restricting flow of air to said prime mover in accordance with air pressure in said chamber.

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