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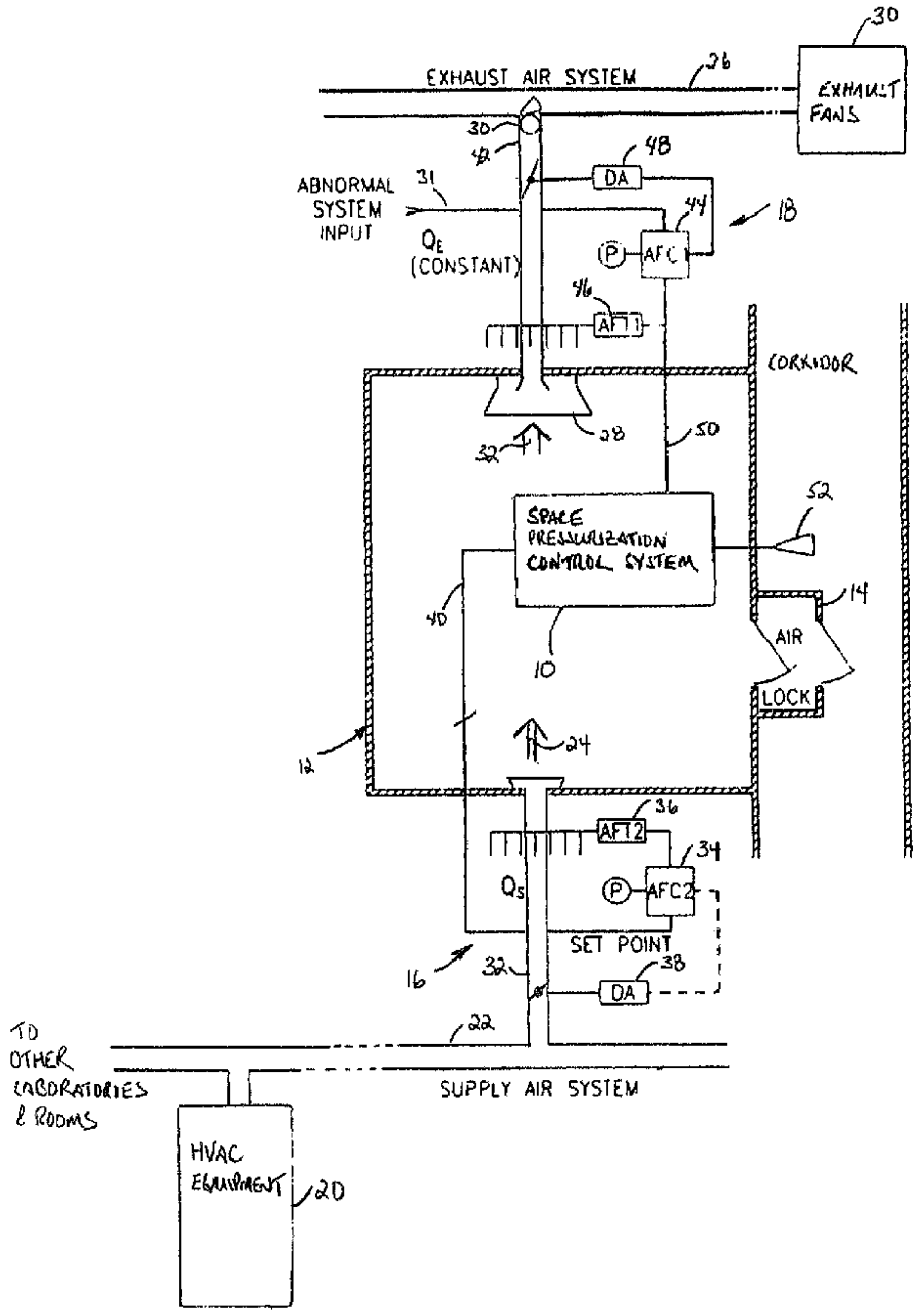
(72) **Inventeur/Inventor**:
Belusa, Manfred L., CA

(73) **Propriétaire/Owner**:
BELNOR HOLDINGS, INC., CA

(74) **Agent**: RIDOUT & MAYBEE LLP

(54) **Titre** : SYSTEME DE REGULATION DE LA PRESSURISATION POUR LES LABORATOIRES A NIVEAU CONFINEMENT ELEVE

(54) **Title**: SPACE PRESSURIZATION CONTROL SYSTEM FOR HIGH CONTAINMENT LABORATORIES



(57) **Abrégé/Abstract**:

An apparatus and method for space pressure control in high containment laboratories. The system comprises a volumetric air flow controller and a differential pressure controller. The differential pressure controller couples to the volumetric air flow

(57) **Abrégé(suite)/Abstract(continued):**

controller. To establish negative space pressurization in the laboratory, the differential pressure controller generates a variable offset signal for volumetric operation. In response to the offset signal, the volumetric air controller controls the ducted supply air to the laboratory at a set shortfall compared to the ducted exhaust air flow. The shortfall of ducted supply air creates a negative pressure which is also sensed by the differential pressure controller. The differential pressure controller reduces the variable offset signal to zero once the desired negative pressure level is attained. To maintain the negative pressure level, the supply and exhaust air flow rates must remain equal. Any change in the negative pressure level is detected by the differential pressure controller which will generate the offset signal required to restore the negative pressure level. Furthermore, if the negative pressure level is completely lost, either by breach of the laboratory containment barrier or by equipment failure, then system 10 will generate the offset signal for volumetric operation.

ABSTRACT OF THE DISCLOSURE

An apparatus and method for space pressure control in high containment laboratories. The system comprises a volumetric air flow controller and a differential pressure controller. The differential pressure controller couples to the volumetric air flow controller. To establish negative space pressurization in the laboratory, the differential pressure controller generates a variable offset signal for volumetric operation. In response to the offset signal, the volumetric air controller controls the ducted supply air to the laboratory at a set shortfall compared to the ducted exhaust air flow. The shortfall of ducted supply air creates a negative pressure which is also sensed by the differential pressure controller. The differential pressure controller reduces the variable offset signal to zero once the desired negative pressure level is attained. To maintain the negative pressure level, the supply and exhaust air flow rates must remain equal. Any change in the negative pressure level is detected by the differential pressure controller which will generate the offset signal required to restore the negative pressure level. Furthermore, if the negative pressure level is completely lost, either by breach of the laboratory containment barrier or by equipment failure, then system 10 will generate the offset signal for volumetric operation.

Title: **Space Pressurization Control System for High Containment Laboratories**

Field of Invention

This invention relates to laboratory air control systems. More particularly, it provides a space pressurization control system which is suitable for high containment laboratories.

Background of the Invention

Research laboratories are classified according to the type of activity which will be conducted. The type of laboratory activity dictates the degree of "containment" which is required. For example, the degree of "containment" to which a laboratory for biomedical research purposes should be built, is classified from Level 1 to Level 4 by guidelines issued by the National Institute of Health in the United States, and the Medical Research Council of Canada in Canada.

A Level 1 containment biomedical laboratory, is a general purpose laboratory with minimal risk to the researcher, whereas a Level 4 facility is classified to handle the most deadly substances known to mankind. To put a Level 4 facility into perspective, it has been suggested, that, if the biological agents in a Level 4 facility are ever allowed to escape to the outside world untreated, they could wipe out whole civilizations.

To protect the researchers working in research laboratories and to protect the community and environment outside the laboratory building, the guidelines outline the requirements for these type of facilities.

To prevent the release of bacteriological agents from one laboratory into another, or to the outside environment, it is usually a requirement to maintain the laboratory space at a negative pressure with respect to some reference point, such as a corridor in the laboratory building. The higher containment laboratories in a building are normally surrounded by lower containment facilities. Since the higher containment facility requires the greatest degree of safety (i.e. containment), the highest containment level is maintained at the greatest negative pressure. This establishes a requirement for several levels of negative pressurization.

Laboratories typically contain exhaust elements to allow handling of harmful materials. The exhaust elements include fume hoods, biological safety cabinets, or laminar flow hoods. The fume hood, for example, is a ventilated enclosure where harmful materials can be handled safely. The hood captures contaminants and prevents them from escaping into the laboratory by using an exhaust blower to draw air and contaminants in and around the hood's opening away from the operator so that inhalation and contact with the contaminants are minimized.

To provide protection to the researcher from harm in case of a spill, certain minimum ventilation rates are suggested. These ventilation rates, usually expressed in terms of Air Changes per Hour (ACH). They are the minimum rates at which the laboratory space must be ventilated to provide desired dilution in case of a spill of the agent, or to keep the exposure levels to bacteriological agents below certain specified levels.

Therefore, space pressurization is important to control containment in a laboratory. Space pressurization is controlled by varying the supply and exhaust air flows in a laboratory. The exhaust air flow rate is dependent on the flow rate of the ventilation ducts in addition to safety devices such as fume hoods, laminar flow cabinets, biological safety cabinets and the like located inside the laboratory. In most facilities, the air exhausted from a laboratory is supplied by the heating, ventilation, and air conditioning (HVAC) system. There will be negative pressurization if the supply air flow rate is at a shortfall compared to the total exhaust air flow rate. To maintain the negative pressure level, the volume of make-up air supplied by the HVAC system must vary as the exhaust air levels vary through the operation of the fume hoods and other safety devices.

There are two known methods for establishing and controlling negative pressure in a laboratory. They are differential pressure control and the volumetric offset method. These methods are designed for low containment or "leaky" laboratories, and are not suited to high containment or bottle-tight laboratories. High containment or bottle-tight facilities have special structural features and operating conditions, which do not easily lend them to conventional negative pressurization systems.

Unlike a low containment facility, a high containment laboratory is an air-tight chamber. The laboratory is air-tight or sealed to ensure containment of any spills within the laboratory space. A typical high containment facility features air lock entrances, sealed air ducts and sealed wall construction. The laboratory space in a high containment facility must also be maintained at a negative pressure to prevent hazardous materials from escaping into adjoining areas in the building or outside environment. Lastly, the air control system must have a fast speed of response to provide a degree of containment for catastrophic occurrences, such as a structural breach of the laboratory.

For the volumetric offset method for space pressurization, there is an initial requirement for an offset between the supply and exhaust air flows to establish a negative pressure. Once the negative space pressure is established, the supply and exhaust air flows must be equal to maintain the negative pressure. Since there is no infiltration in a bottle-tight laboratory, the air control system must keep the supply and exhaust air flows exactly equal to maintain the negative space pressure. Any difference between the supply and exhaust air flow rates will cause a cumulative pressure change inside the laboratory space. Even if known volumetric air control systems could be made to work with the required degree of accuracy, they would be very expensive for practical use. Therefore, while the volumetric offset method can provide a fast speed of response, the required air flow control accuracy makes it unsuitable for a high containment facility.

In the differential pressure control technique, negative pressurization is achieved by sensing the pressure difference between the laboratory and a reference space and using the pressure difference to control the supply air flow. The supply air flow is ducted into the laboratory space and controlled by a differential pressure controller which includes a pressure sensor. The differential pressure controller senses the pressure differential and produces a shortfall of supply air flow compared to the total exhaust air flow rate, where the exhaust flow is the sum of flow rates of the ventilation ducts, fume hoods, laminar flow cabinets and the like.

While state-of-the art differential pressure control systems can be made to work exceptionally well for "leaky" or low containment laboratories, there are limitations with the differential pressure control method when applied to a high containment facility. In a leaky facility the shortfall of supply air is made up by air which leaks into the laboratory space through cracks around the doors, cracks where ducts and pipes penetrate the wall, and through other cracks in the laboratory structure. High containment facilities by their very nature do not permit any infiltration.

Another problem in air-tight enclosures involves pressure fluctuations in the supply or exhaust air systems. The pressure fluctuations in the supply or exhaust air systems can cause oscillations of pressure in the laboratory space. If these oscillations are the same as the natural frequency of the laboratory space, then a resonant condition can occur resulting in unacceptably large pressure variations. Under these conditions, the air control system cannot achieve stability and there is the possibility of structural damage to the facility. While damping in the control loop can provide stability, it will slow the speed of response thereby preventing the control system from rapidly responding to disturbances or catastrophic events. Time delays of up to 90 seconds are typical in known pneumatically actuated systems and of up to 270 seconds are encountered in electrically actuated digital systems. If there is a breach in a bottle-tight system, the air control system must have an almost instantaneous response to increase the offset between the supply and exhaust air flows to maintain containment of any highly toxic substances.

BRIEF SUMMARY OF THE INVENTION

The present invention provides a system for controlling the space pressurization of a high containment laboratory, said system comprising: (a) volumetric air flow control means; (b) differential pressure control means, said differential pressure control means being coupled to said volumetric air flow control means, and said differential pressure control means including means for generating an adjustable offset; and (d) said volumetric air flow control means including means responsive to said adjustable offset.

In another aspect, the present invention provides a method for controlling space pressure in a room, said method comprising: (a) establishing a space pressure value for the room by controlling air volume flow; and (b) maintaining the established space pressure value in relation to a reference pressure.

BRIEF DESCRIPTION OF THE DRAWINGS

For a better understanding of the present invention, and to show more clearly how it may be carried into effect, reference will now be made, by way of example, to the accompanying drawings, in which:

Figure 1 shows a high containment laboratory with a space pressurization control system according to the present invention;

Figure 2 shows the respective supply air and exhaust air flow rates in response to the variable offset generated by the space pressurization control system of Figure 1;

Figure 3 shows in schematic form the space pressurization control system according to the present invention; and

Figure 4 shows another implementation of a space pressurization control system for a high containment laboratory.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Reference is first made to Figure 1 which shows a space pressurization system 10 according to the present invention coupled to the air control system of a high containment laboratory 12.

The high containment laboratory 12 is typically used for processing highly toxic and dangerous substances. The laboratory 12 is sealed to limit the spread of dangerous substances in case of accidental spillage or for periodic decontamination or sterilization. To provide a "bottle-tight" environment, access to the laboratory 12 is usually through an air-lock chamber 14 (or "submarine type" door).

As shown in Figure 1, the air control system comprises a supply air control system 16 and an exhaust air control system 18. The supply air control system 16 is coupled to heating cooling and air conditioning equipment 20 through supply air ducting 22. The supply air system 16 pumps make-up air indicated by arrow 24 into the laboratory space 12. The exhaust air system 18 couples ventilation outlets 28 and safety devices, such as fume hoods and laminar flow hoods, (indicated by reference 29) to exhaust air ducting 26 in the facility. Through the action of exhaust fans 30, the exhaust air system 18 draws or removes an exhaust air volume 32 from the laboratory 12 according to safety regulations for the particular facility.

The function of the supply air control system 16 is to provide the laboratory space 12 with fresh supply or make-up air 24. The supply air control system 16 comprises a supply duct 32, a supply air flow controller 34, an air flow transmitter 36 (or other type of known flow sensor) and a difference amplifier 38. The flow of make-up air 24 from the HVAC equipment 20 through the supply duct 32 is controlled in known manner by the air flow controller 34 which is coupled to the duct 32 by the air flow transmitter 36 and the difference amplifier 38. The air flow controller 34 is connected to the space pressurization control system 10 through a control line 40.

As will be explained in detail below, the space pressurization control unit generates a flow control signal on control line 40 which is applied to the supply air flow controller or actuator 34. The supply air flow controller 34 can be a device such as a variable speed controller, a controllable air flow venturi (venturi valve) or a damper. The air flow controller 34 varies the supply air flow 24. The flow of the supply or make-up air 24 is sensed by the air flow transmitter 36, which produces a feedback signal (not shown) for the air flow controller 34. In known manner, the supply air flow controller 34 can be a proportional controller, a proportional controller with integral action, or a proportional with integral and derivative action controller. The supply air flow controller 34 can be implemented as an analog, digital, stand alone system or as part of a larger distributed digital control system.

It will be appreciated by those skilled in the art that for safe system operation, the sum of all time delays of the supply air flow controller 34, including sampling rates, control loop delays, actuator delays, and the delay in accelerating or decelerating the column of air being moved, must be of the order of less than 2 to 3 seconds. This is a value that research has determined to be the maximum speed of response of a fume hood face velocity control system in order for it to maintain containment. Since the principles are the same, this limiting value would also apply to space pressurization systems.

The function of the exhaust air control system 18 is to remove the exhaust air volume 32 in order to maintain the required ventilation rates for the laboratory 12. These ventilation rates are usually expressed in terms of air changes per hour (ACH). They represent the minimum rates at which the laboratory space 12 must be ventilated to provide desired dilution in the case of a spill or to keep the exposure levels of the subject substances below certain specified levels.

The exhaust air control system 18 comprises, as will be understood by one skilled in the art, an exhaust air duct 42, an exhaust air flow controller 44, an air flow transmitter (sensor) 46, and a difference amplifier 48. The exhaust duct 42 couples the ventilation outlets 28 and fume hoods 29 to the exhaust air ducting 26 so that the exhaust fans 30 can draw the exhaust air volume 32 from the laboratory space 12.

The exhaust air control system 18 can also be used in conjunction with the space pressurization system 10 to establish and maintain negative pressurization in the laboratory space 12. The exhaust air control system 18 is coupled to the space pressure control system 10 through an exhaust control line 50, the operation of which will be explained below.

As shown in Figure 1, the space pressurization control system 10 includes a reference pressure sensor 52. The pressure sensor 52 detects the pressure level in a reference space 54 and produces a reference pressure signal (not shown). The control system 10 uses the reading from the pressure sensor 52 to establish the negative pressurization in the laboratory 12. In some facilities, the high containment laboratory 12 may be surrounded by a number of low containment facilities (not shown). Since the high containment laboratory requires the greatest degree of safety, i.e. containment, the high containment laboratory 12 is maintained at the greatest negative pressure. For the purposes of Figure 1, the reference space 54 is chosen as the corridor adjacent to the laboratory 12.

The space pressurization control system 10 according to the present invention provides a hybrid system that maintains the fast speed of response of the volumetric offset method, combined with the benefits of the differential pressure control method to produce containment in laboratory spaces that are air tight or close to being air tight.

The operation of the space pressurization control system 10 according to the present invention can be explained briefly as follows. When first activated, the system 10 operates as a volumetric offset air flow controller in a "leaky" room application. Negative pressurization is quickly achieved by operating the supply air control system 16 at a shortfall flow rate, i.e. a flow rate which is less than the flow rate of the exhaust air control system 18. The shortfall rate is dependent on the flow control signal which is generated by the control system 10 and received on control line 40. This method of operation quickly achieves the desired initial negative space pressurization to ensure containment, but as the desired negative space pressurization level is reached, the control system 10 reduces the shortfall rate (through the flow control signal), until at the desired level of negative pressure, the air flows of the exhaust and supply control systems 16,18 will be exactly matched. This is illustrated in Figure 2.

If the air flows of the supply or exhaust systems 16 or 18 do vary for whatever reason, this will impact on the negative pressure level inside the laboratory space 12. The control system 10 detects this pressure variation and in response generates a feedback control signal which will vary the supply air flow to maintain the desired negative pressure level in the laboratory space 12. The feedback signal compensates for inaccuracies in the air flow measurement and control loops as well as any system disturbances.

Reference is next made to Figure 3 which shows in schematic form the space pressurization control system 10 according to the present invention. The control system 10 achieves and maintains negative space pressure in the laboratory by generating a variable offset signal 54 which varies over a predefined schedule or range. The space pressurization system 10, in its simplest form, comprises a differential pressure transmitter 56, a pressure controller 58, a signal limiter 60 (optional), and a difference amplifier 62. For the purposes of this explanation, the pressure transmitter 56 (and sensor 52) and pressure controller 58 (and signal limiter 60, if included) will be termed as a secondary control loop 63.

The differential pressure transmitter 56 includes a space pressure sensor 66. The space pressure sensor 66 detects the space pressure level in the laboratory 12 and produces a space pressure level signal (not shown) for the pressure transmitter 56. The pressure transmitter 56 compares the space pressure signal to the reference pressure signal and produces a difference signal which is fed to the pressure controller 58. The pressure controller 58 produces a feedback signal 68 that is inputted by the difference amplifier 62. The difference amplifier 62 generates a flow control signal 64 (i.e. set point) for operating the supply air flow controller 34 by subtracting the feedback signal 68 from a signal 70 on control line 50 which is indicative of the exhaust air flow rate.

Alternately, the differential pressure transmitter 56 can be replaced by a network of absolute pressure sensors (not shown). As will be appreciated by one skilled in the art, this arrangement allows one absolute (barometric) sensor to be located outdoors or in some other reference location and absolute pressure sensors to be located in each room in building. The differential pressure for each space or room can be obtained from a local difference amplifier circuit (not shown). The resulting signal can then be applied to the pressure controller 58 (shown in Figure 3) in lieu of the single differential pressure transmitter 56. Such an approach has the advantage of providing several levels of negative or positive or mixed pressure levels in the building, all referenced to the reference pressure, without providing a path for leakage of the containments through the sensing tubes that penetrate the barrier wall of the high containment space. This can allow the relative pressure levels to be maintained inside the building, while allowing the building as a whole to be either slightly negative or positive with respect to the reference space. If the reference pressure sensor (e.g. sensor 52 in Figure 1) is located outside the building, allowances for the seasonal pressure variations of the outside air density and the effect of this change on the differential pressure across the building walls, can thus be made automatically, as will be within the capability of one skilled in the art.

Referring back to Figure 3, the pressure controller 58 in conjunction with the signal limiter 60 produces the variable offset signal 55. The variable offset signal 55 can have a defined range. The range of the variable offset signal 55 can be defined by high and low limits which are set on the signal limiter 60. As shown in Figure 3, the high and low limits of the range can be defined using a pair of potentiometers 68.

The purpose of the variable offset signal 55 is to produce an offset flow rate when the system 10 is turned on (see Figure 2) and to compensate variations in the components or other inaccuracies. For example, if the negative space pressure in the laboratory 12 increases above the reference pressure level (e.g. additional fume hoods are turned on), then the differential pressure transmitter 56 and pressure controller 58 will generate the negative feedback signal 68 for the difference amplifier 62. The difference amplifier 62 subtracts the feedback signal 68 from the exhaust air flow signal 70 (on line 50), and produce the flow control signal 64 (on line 40) which, in this case, reduces the set point of the supply air controller 34. The resultant reduction in supply air flow causes a reduction in the negative space pressurization, until the desired pressure level is attained. At this point, the differential pressure transmitter 56 and the pressure controller 58 will be produce a lower level feedback signal 68. This means that the difference amplifier 62 subtracts less from the exhaust air flow signal 70 (on line 50), thereby increasing the set point and allowing the supply air flow controller 34 to increase the make-up air volume 24 towards the exhaust air volume 32. When the desired negative space pressure level has been attained, the feedback signal 68 produced by the pressure controller 58 will be zero, and the make-up or supply air 24 will once again equal the exhausted air 32.

In addition to the signal limiter 60 with the separate high and low potentiometers 67, other variations of the space pressurization controller 10 are possible. For example, electronic signal filters 72 (shown in broken outline) in both or either of between the output of the signal limiter 60 and the difference amplifier 62, between the differential pressure transmitter 56 and the pressure controller 58, and mechanical filters in the sensing lines 52,56 to introduce signal averaging and system stability.

The system 10 depicted in Figure 3 was described using discrete circuit elements such as operational amplifiers. The space pressurization control system 10 can also be implemented by means of a digital computer, used in a distributed controller hierarchy such as commonly found in the control of modern buildings.

The space pressurization control system 10 according to the present invention has the major advantage, of allowing the supply air control system 16 and the exhaust air control system 18 to quickly establish negative pressurization by operating in the volumetric offset mode. The volumetric control mode allows the exhaust and supply air control systems 16,18 to be operated at high flow rates thereby providing a fast speed of response which can be in the order of one second. Once negative pressurization is achieved in the laboratory space, the control system 10 will use the pressure controller 58 to correct any variations in pressure or in exhaust and supply flow rates. Because the volumetric mode is used to establish the negative pressurization of the laboratory, the secondary loop 63 comprising the sensors 52,66, the pressure transmitter 56 and the pressure controller 58 can have a relatively low speed of response which ensures accuracy and stability of operation.

Once the desired negative pressurization level is established, the secondary control loop 63 need not have a fast response time, since it must only correct for loss of accuracy of the flow measurement (e.g. air flow transmitter 36) and control devices (e.g. air flow controller 34), component drift, and other such parameters in the devices. Since these errors vary slowly with time, their correction is not time critical. By providing system damping, filtering, averaging, or other similar methods (known to those skilled in the art) to eliminate transient conditions, the secondary control loop 63 can be made to be accurate and stable. This is a desirable result for high containment facilities, Even if the containment barrier wall of the laboratory 12 is penetrated, say, from an explosion or earthquake, as long as the control system 10 (and supply and air control systems 16,18) have motive power, the control system 10 will continue to work. For example, if a breach in the wall of the laboratory 12 causes the differential pressure to drop to zero (i.e. negative pressure is lost), then the control system 10 will revert to the volumetric offset method because the pressure controller will produce a high level feedback signal 68. In the volumetric mode, the re-pressurization of the laboratory 12 will result in minimal disturbance to the pressurization systems of the other rooms or laboratories in the facility. In this example, the secondary control loop 63 will slowly increase the offset, until such time as it has reached its limit setting, and then the exhaust and supply air flow rates are made equal (see Figure 2).

Another advantage of the control system 10 according to the present invention appears in the case of supply air or exhaust air system 16,18 failure. In most high containment laboratories, the supply air control system 16 and exhaust air control system 18 will have two or more supply fans and exhaust fans operating in parallel.

If, for example, one of the exhaust fans fails, or must be shut down for maintenance, a serious room over pressurization condition will occur unless something is done to reduce the supply air to the labs affected by the reduced exhaust air flow. In the operation of the control system 10 only the supply air 24 need be reduced, so that the reduced air flow is allowed in those rooms which can tolerate it, leaving the critical rooms with the same ventilation levels.

Referring back to Figure 1, the loss of an exhaust fan 30 can be detected by means of a current relay in the motor circuit of the fan which allows the loss of the fan 30 to be determined almost instantaneously. The system 10 can then determine the reduced total exhaust values, and reduce the air flow through those exhaust devices which can tolerate the loss with minimal impact on safety (this is shown as the abnormal system input 31 in Figure 1). This will then result in a new volume of exhaust air 32, and the control system 10 will function to maintain the negative pressurization level as before, except under the new lower exhaust air volume.

In the previous discussion, the control system established and maintained negative pressurization in the laboratory by controlling the set point of the supply air controller 34. The control system 10 can be modified to vary the exhaust air flow rate by controlling the exhaust air supply system 18 and keeping the supply air flow rates independently controlled, using the same principles of operation for the secondary control loop 63 as explained above.

In another aspect of the present invention, the control system 10 can modified for use in a high containment laboratory where the supply air flow 24 is variable and where the exhaust air flow 32 is varied to maintain negative space pressure in the laboratory 12, but where the ventilation rates in the laboratory may be changed, say for night or unoccupied time periods of time. In this case, the previously fixed air flow may be changed, and the floating air flows will follow, can be applied to rooms where two or more separate air flow rates are required. This is usually a requirement in high containment applications in case of partial failure of either the supply or exhaust air flow system. The exhaust air system may consist of multiple exhaust sources, some of which may be individual exhaust fans, or the main exhaust fan system may consist of two or more exhaust fans operating at the same time, and some may be on standby duty. If any of these exhaust fans fail, due to a motor burn out or for some other reason, the exhaust air volume from the room may be affected. If no provision is made to reduce the ventilation level, then in those rooms closest to the exhaust fan, the fan will continue to draw the same amount of air as with all fans operating, and the other rooms attached to the same duct, may be starved. It is a requirement to predetermine how the reduction in air will affect each lab. Therefore, it is a requirement to be able to vary the ventilation levels in all laboratory rooms.

Reference is next made to Figure 4 which shows a practical implementation of the space pressurization system 10 according to the present invention. In Figure 4, like elements from Figure 1 are indicated by the same reference numbers. The supply air control system 16 and the exhaust air control system 18 comprise "controllable air flow venturi" (CAFV) devices 76,78 respectively. Suitable devices 76,78 include the EXV or MAV Series control valves manufactured by Phoenix Controls Corporation. The control system 10 is coupled to a make up air control panel 75 such as the MAC120 which is also available from Phoenix Controls. The installation and operation of the Phoenix Controls equipment is described in an Application and Design Guide which is available from Phoenix Controls.

The make up air control panel 75 is also shown in exploded view in Figure 4. The make up air controller 75 consists of standard circuit elements. For example, the panel includes a P/E module 80 which is a standard pressure to electric transducer to convert a pneumatic thermostat signal to an electric or electronic signal. If the thermostat output signal is electronic, then this transducer would not be required. The panel 75 also includes a scaling function module f(sc) 82, which usually comprises an operational amplifier with adjustable zero and range.

The systems shown in both Figures 1 and 2 can be further modified to include a temperature controller which in known manner can be coupled to the supply duct 32. In this aspect, the system 10 can maintain the temperature in the laboratory space as well as maintaining a minimum ventilation level in the space. In known manner, the temperature controller sequences the reheat oil valve (for heating) with additional air from the primary air supply system (for cooling). The system will not allow the supply air from dropping below the minimum desired ventilation levels. If additional heat is required, then the system will add reheat. This control system can only be used on a supply air system usually referred to as a "Reheat System". Similar systems are available for other supply air systems such as dual duct applications.

The pressure controller 58 (shown in Figure 3) may be adjusted to provide a scheduled override. Normally this override schedule is not limited to the indicated pressure valves. Rather it determines a straight line relationship, that is then allowed to continue from (theoretically) minus infinity to plus infinity. Of course, other system parameters limit the adjustment range to something more finite. If however, the override must be limited to set limits, then the circuits must be used.

As will be appreciated by one skilled in the art there are applications where several fixed adjustment ranges for the offset signal may be useful. In a high containment laboratory operating normally, one set of limits may be desirable. However, if an emergency exit door leading to another containment level space is opened, another adjustment range may be desirable. Thirdly, if an explosion or fire has been sensed, a third adjustment range may be desirable. Each one of the different adjustment ranges may be sensed by a sensor whose output is an electrical contact. This contact can then switch the desired adjustment range on the high or limit inputs of the limit circuit.

An example space pressure override schedule for illustration purposes could be as follows. Assume that the ventilation system is designed to provide ventilation rates at 500 Litres per second and that the desired (negative) space pressurization of -25 Pa has already been established. If at some point in time, the space pressure is measured at -15 Pa with respect to a reference pressure (usually the corridor), the system would increase the exhaust air flow by 25 L/sec to compensate for lack of accuracy of the measuring system or to compensate for leakage (due to a temporary opening of a door). Similarly, when the space pressure is measured at -35 Pa, the control system should reduce the exhaust air flow by 25 L/sec from the design 500 L/sec to bring the space pressure back down to the design level. Normally without the additional limiting circuits, the adjustment schedule has been set up, in this example, to provide an exhaust air flow adjustment of (+25 L/sec to -25 L/sec) 50 L/sec over a measured differential pressure range of (-15 Pa to -35 Pa) -25 Pa. Therefore the adjustment range is 2 L/sec per (negative) Pa change in space pressure. In some applications, this unlimited adjustment may be desirable; in others it may not, as will be understood by one skilled in the art.

It will be evident to those skilled in the art that other embodiments fall within the scope of the present invention as defined by the following claims.

CLAIMS:

1. A system for controlling space pressure in a room at a predetermined level with respect to a reference space, said system comprising:

(a) volumetric air flow control means for controlling air flow to and from the room and including means for setting the air flow level;

(b) said volumetric air flow means having means for generating an offset in said air flow level to produce a predetermined space pressure level in the room;

(c) differential pressure control means for sensing a change in said space pressure level and generating a control signal having a value corresponding to the change in said space pressure level, and said differential control means being coupled to said volumetric air flow control means and forming a control loop for said volumetric air flow control means; and

(d) said means for generating an offset having means responsive to said control signal for adjusting the offset in said air flow level for restoring the space pressure in the room to said predetermined level.

2. The system as claimed in claim 1, wherein said volumetric air flow control means includes means for generating an abnormal condition control signal for providing an offset level for operating said volumetric control means at an increased containment level.

3. The system as claimed in claim 1, further includes setback means for producing a setback air flow level, said means for generating an offset in said air flow level being responsive to said setback air flow level to produce a space pressure level in the room corresponding to said setback air flow level.

4. The system as claimed in claim 1, wherein said differential pressure control means includes means for producing a reference pressure signal corresponding to the space pressure in a reference space and means for producing a space pressure signal corresponding to the space pressure level in the room, and said control signal being dependent on the difference between said reference pressure signal and said space pressure signal.

5. The system as claimed in claim 4 wherein said reference space comprises a space exterior the building containing the room.

6. The system as claimed in claim 4, wherein said differential pressure control means comprises a pressure controller and a pressure transmitter having an input for said reference pressure signal and an input for said space pressure signal and means for producing an output signal corresponding to the difference between said reference pressure signal and said space pressure signal and said pressure controller having means for receiving said output signal and generating said corresponding control signal.

7. The system as claimed in claim 6, wherein said means for generating an offset in said air flow level provides a setpoint for controlling flow of supply air to the room.

8. The system as claimed in claim 6, wherein said means for generating an offset in said air flow level provides a set point for controlling flow of exhaust air from the room.

9. The system as claimed in claim 2, wherein said volumetric air flow control means includes an input for receiving an external signal indicative of an abnormal

condition and means for generating said abnormal condition control signal in response thereto.

10. A method for controlling space pressure in a room, said method comprising:

(a) providing an air flow at a selected level for the room;

(b) generating an offset in said air flow level until a predetermined space pressure is established for the room;

(c) detecting a change in said established space pressure with respect to a reference pressure;

(d) generating a variable offset which varies with said detected change in said space pressure; and

(e) applying said variable offset to said offset in said air flow level to restore said predetermined space pressure level.

11. The method for controlling space pressure as claimed in claim 10, further including the step of generating an abnormal condition offset for producing an air flow level for increased containment.

12. The method for controlling space pressure as claimed in claim 10, wherein said step (a) comprises providing an exhaust air flow at a predetermined level and a supply air flow at a level which is variable in response to said offset and said variable offset.

13. The method for controlling space pressure as claimed in claim 10, wherein step (b) comprises operating a supply air flow to said room at a level less than an exhaust air flow to said room and said level corresponding to said offset.

RIDOUT & MAYBEE
Toronto, Canada
Patent Agents

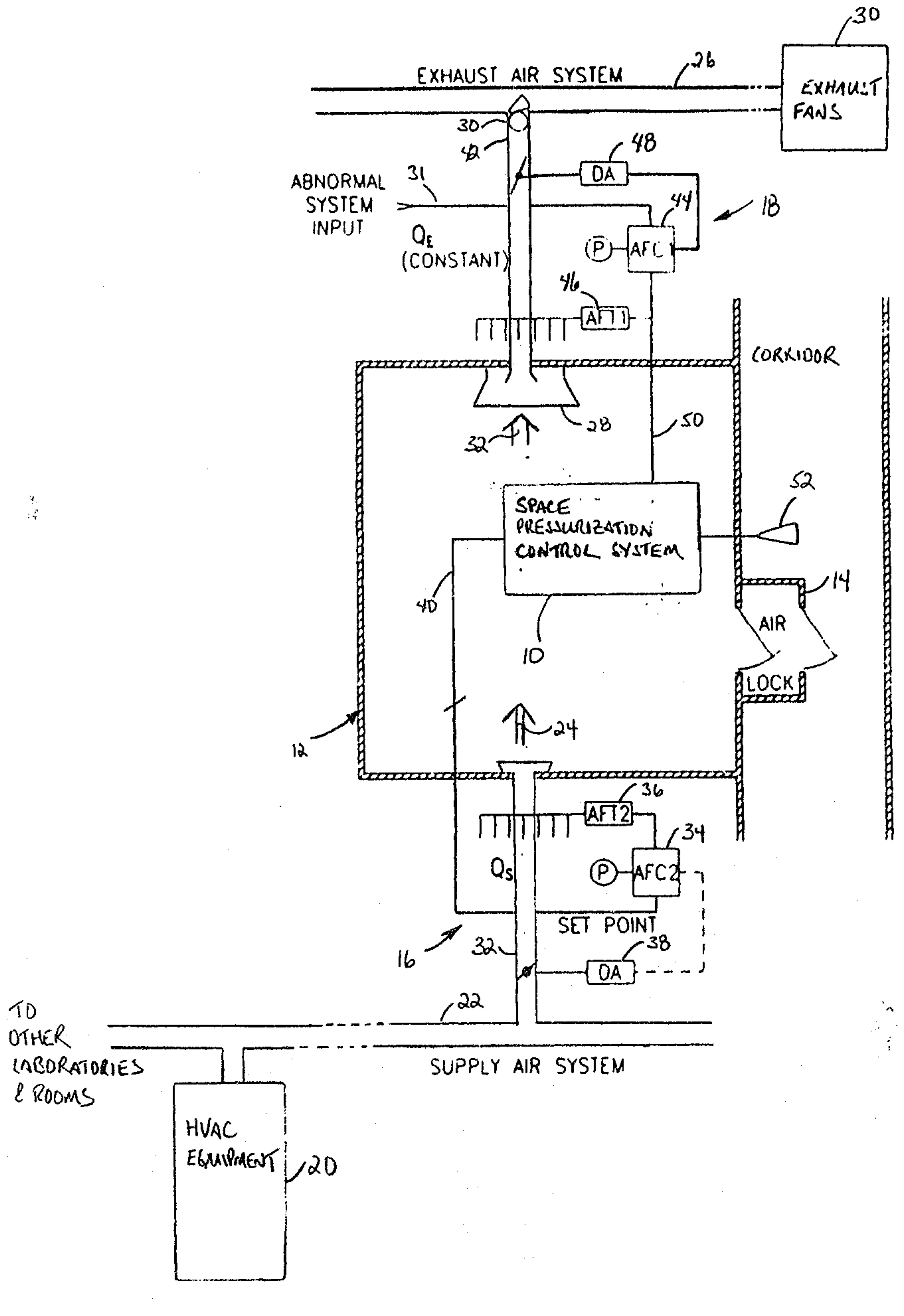

30
EXHAUST AIR SYSTEM
26
EXHAUST FANS
30
42
48
DA
ABNORMAL SYSTEM INPUT
31
44
18
Q_E (CONSTANT)
P
AFC 1
46
AFT1
CORRIDOR
28
32
50
52
SPACE PRESSURIZATION CONTROL SYSTEM
40
14
AIR
LOCK
10
24
12
36
AFT2
34
P
AFC2
Q_S
SET POINT
16
32
38
DA
22
TO OTHER LABORATORIES & ROOMS
SUPPLY AIR SYSTEM
HVAC EQUIPMENT
20

FIGURE 1

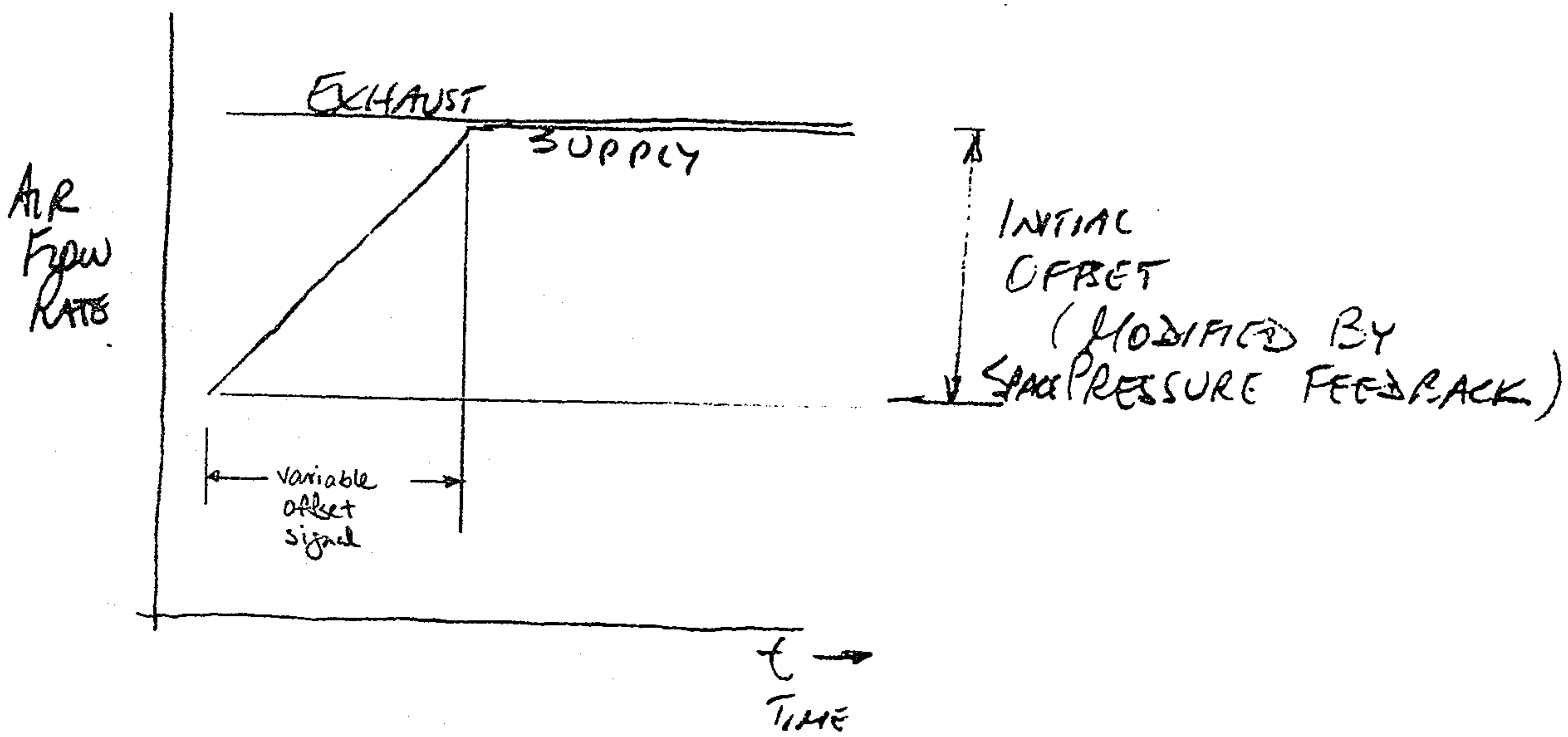

AIR FLOW RATE
EXHAUST
SUPPLY
INITIAL OFFSET (MODIFIED BY SPACE PRESSURE FEEDBACK)
variable offset signal
t
TIME

FIGURE 2

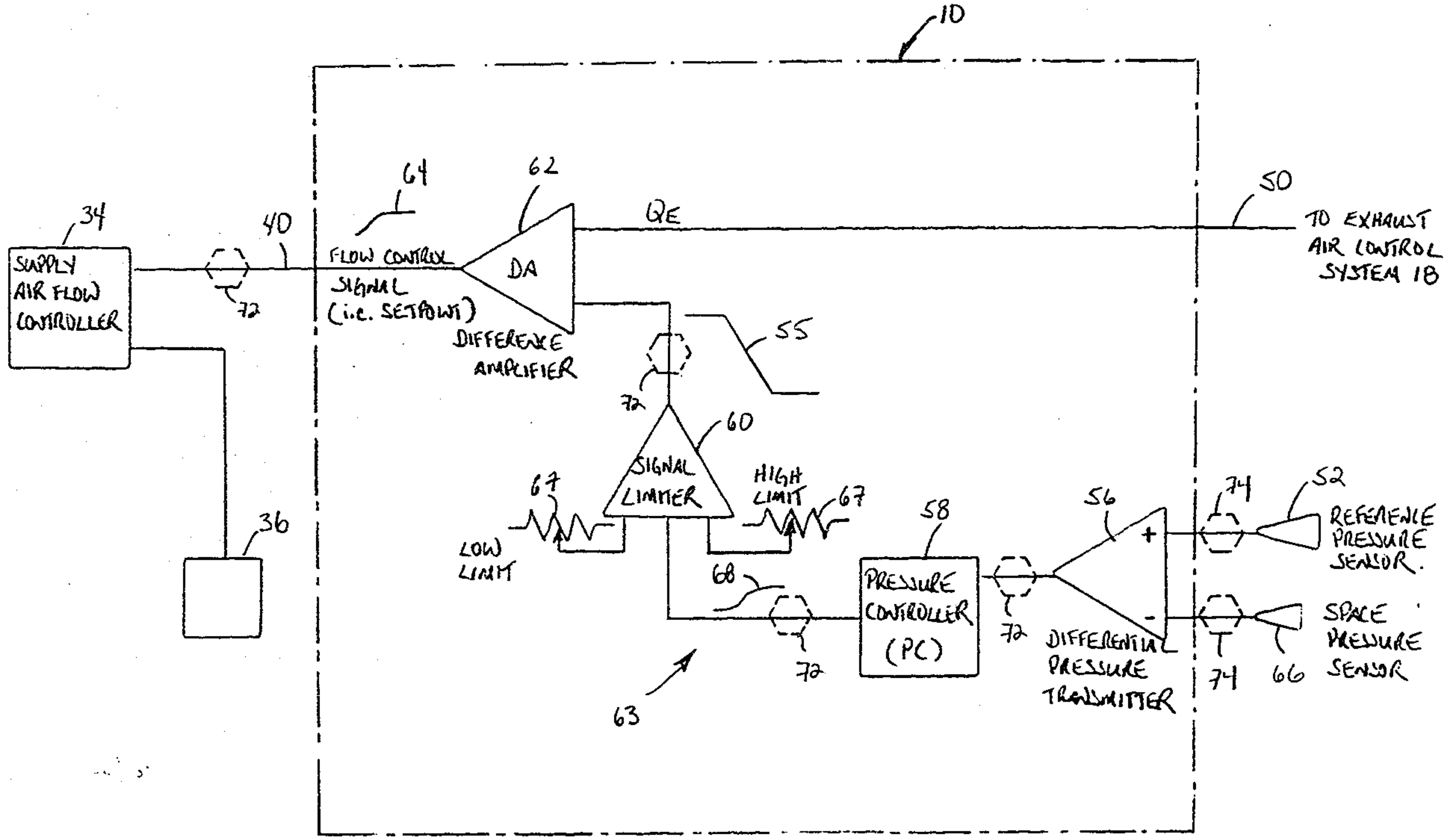

10
34
SUPPLY AIR FLOW CONTROLLER
72
40
64
FLOW CONTROL SIGNAL (i.e. SETPOINT)
62
DA
DIFFERENCE AMPLIFIER
QE
50
TO EXHAUST AIR CONTROL SYSTEM 18
55
72
60
SIGNAL LIMITER
67
LOW LIMIT
HIGH LIMIT
67
36
68
72
63
58
PRESSURE CONTROLLER (PC)
72
56
+
-
DIFFERENTIAL PRESSURE TRANSMITTER
74
52
REFERENCE PRESSURE SENSOR.
74
66
SPACE PRESSURE SENSOR

FIGURE 3

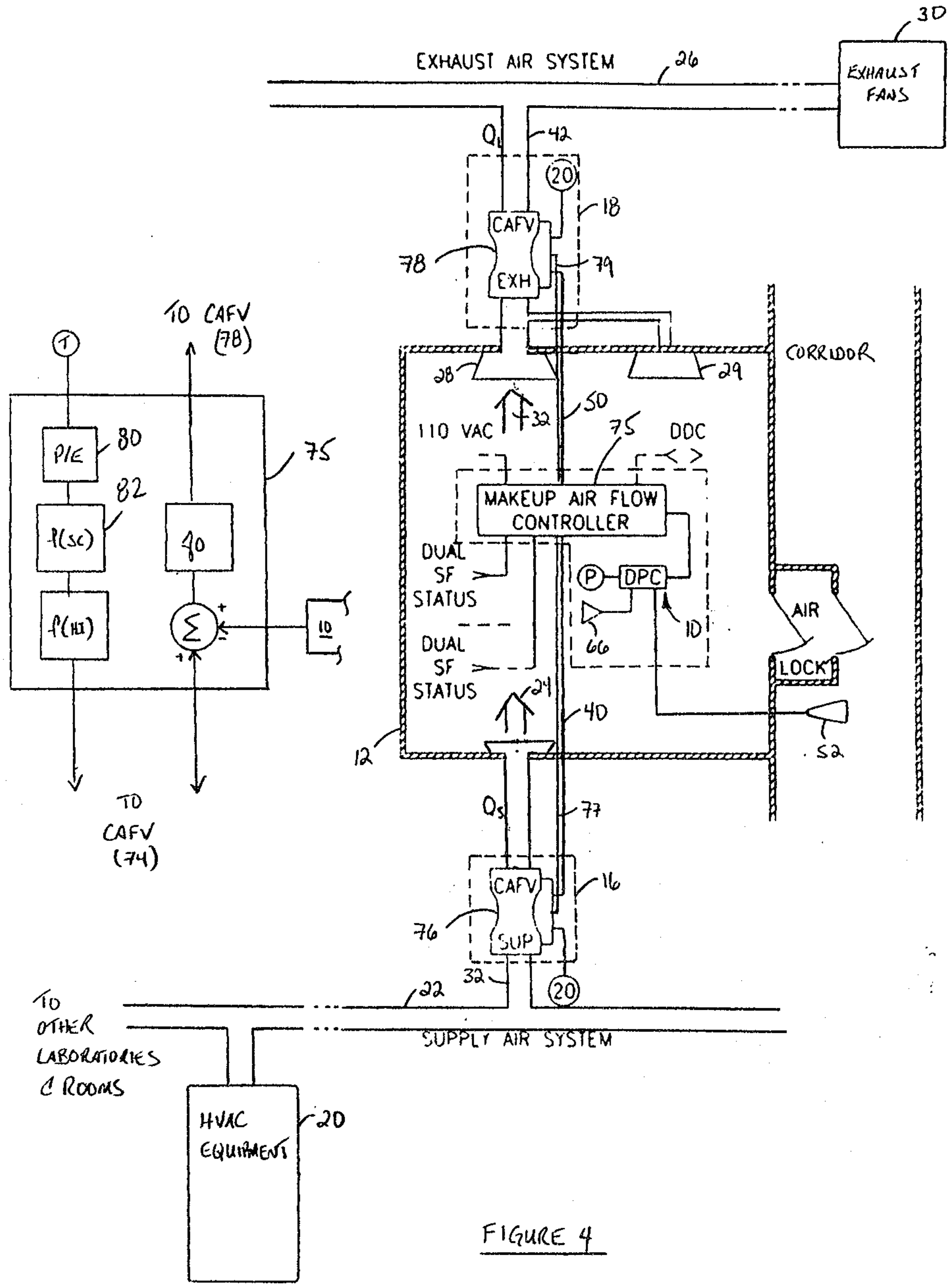
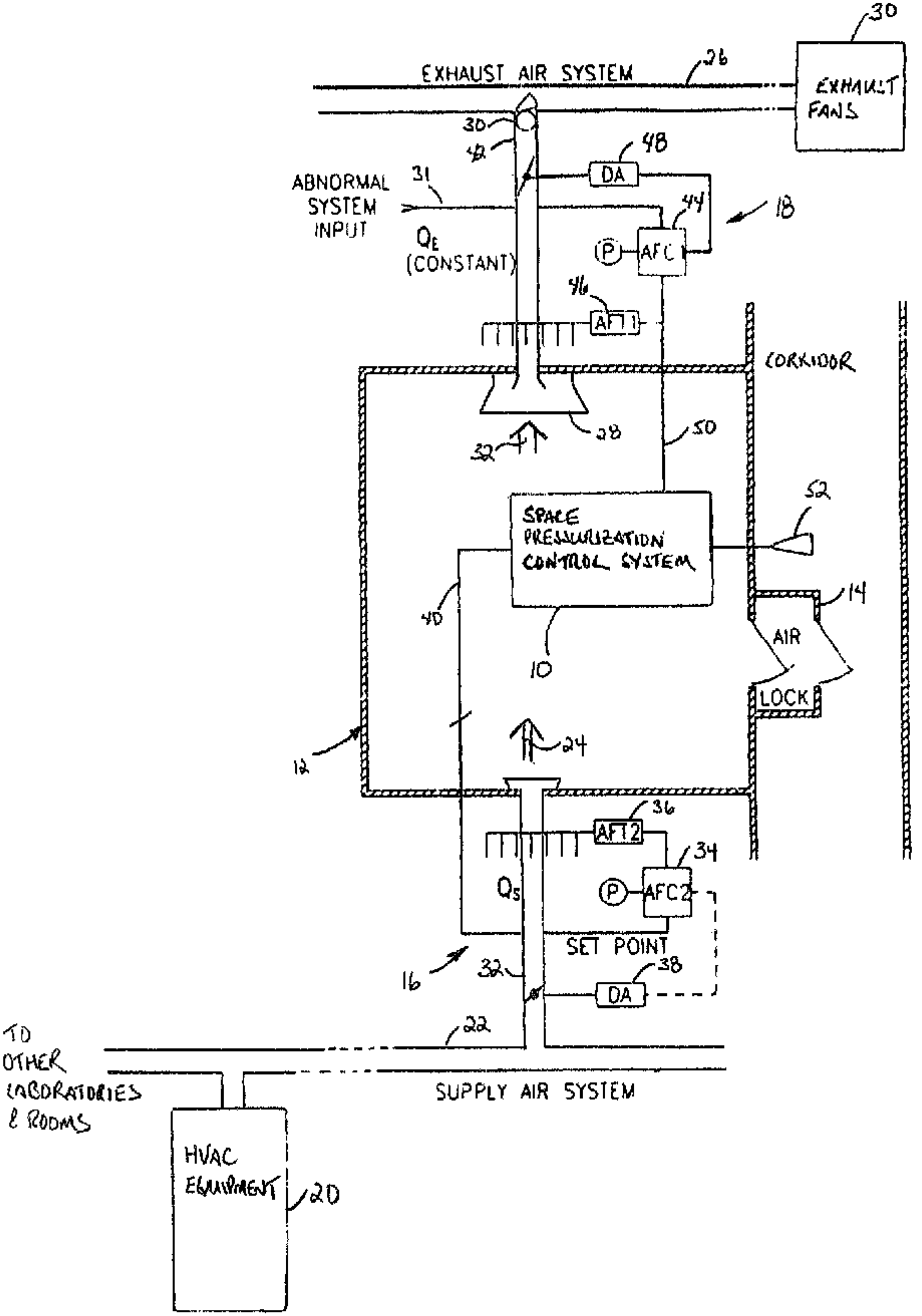

EXHAUST AIR SYSTEM
26
30
EXHAUST FANS
Q_L
42
20
18
CAFV
EXH
78
79
TO CAFV (78)
T
80
P/E
82
f(SC)
f(HI)
f0
Σ
+
−
+
ID
75
TO CAFV (74)
CORRIDOR
28
29
32
50
110 VAC
75
DDC
MAKEUP AIR FLOW CONTROLLER
DUAL SF STATUS
DUAL SF STATUS
P
DPC
66
10
AIR LOCK
52
24
40
12
Q_S
77
16
CAFV
SUP
76
32
22
20
TO OTHER LABORATORIES & ROOMS
SUPPLY AIR SYSTEM
HVAC EQUIPMENT
20

FIGURE 4


30
EXHAUST AIR SYSTEM
26
EXHAUST FANS
30
42
48
DA
ABNORMAL SYSTEM INPUT
31
44
18
P
AFC1
Q_E (CONSTANT)
46
AFT1
CORRIDOR
28
32
50
SPACE PRESSURIZATION CONTROL SYSTEM
52
40
14
AIR
LOCK
10
24
12
36
AFT2
34
Q_S
P
AFC2
SET POINT
16
32
38
DA
22
TO OTHER LABORATORIES & ROOMS
SUPPLY AIR SYSTEM
HVAC EQUIPMENT
20