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(54) Title: SYSTEM AND METHOD FOR COOLING ELECTRONIC EQUIPMENT

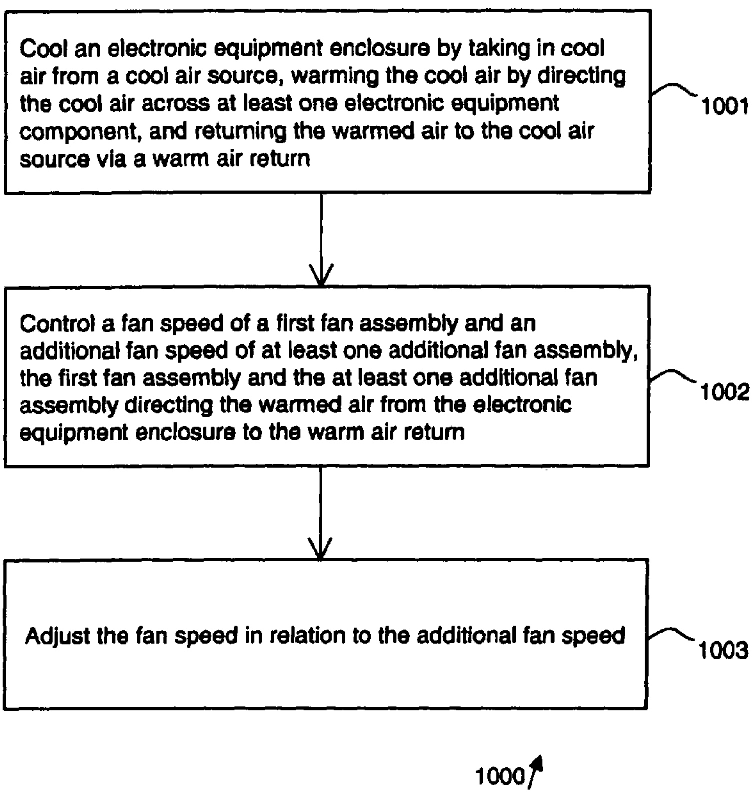

FIGURE 10

(57) Abstract: A system for cooling electronic equipment includes one or more electronic equipment enclosures that receive cool air from one or more cool air sources and return warmed air utilizing a plurality of fan assemblies. The plurality of fan assemblies include a fan speed controlled to maintain a temperature and/or pressure. The plurality of fan assemblies are capable of independent operation, but adjust the fan speed in relation to the fan speed of the one or more other fan assemblies. In an alternative embodiment, one or more cool air sources determine the airflow for one or more electronics equipment enclosures based on fan speed and fan model type communicated by one or more fan assemblies and adjust the amount of cool air provided based on the airflow.

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SYSTEM AND METHOD FOR COOLING ELECTRONIC EQUIPMENT

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The present application claims priority under 35 U.S.C. § 120 to United States Patent Application Serial Number 11/897,304, filed August 30, 2007, entitled "System and Method for Cooling Electronic Equipment." The present application claims priority under 35 U.S.C. $120 to United States Patent Application Serial Number 12/228,494, filed August 13, 2008, entitled "System and Method for Cooling Electronic Equipment." United States Patent Application Serial Number 11/897,304 and United States Patent Application Serial Number 12/228,494 are incorporated herein by reference in their entirety.

TECHNICAL FIELD

[0002] The present disclosure generally relates to the field of electronic equipment, and more particularly to a system and method for cooling electronic equipment.

BACKGROUND

[0003] Information handling system installations, such as data centers, server farms, and telecommunications switching systems (generically referred to as data centers) generate a great deal of waste heat. This waste heat may need to be dissipated in order for the systems to continue operation. The capacity of such data centers continues to grow at a rapid pace to meet the demands of increasingly computerized societies. In addition to the increase in these installations of computing capacity and overall volume, power density increases as well. Increased size and density leads to increased cooling requirements.

SUMMARY

[0004] A system for cooling electronic equipment may include one or more electronic equipment enclosures and one or more cool air sources. The one or more electronic equipment enclosures may receive cool air provided by the one or more cool air sources and direct the cool air across one or more electronic equipment components before returning warmed air to the one or more cool air sources utilizing a plurality of fan assemblies. The one or more cool air sources may re-cool the warmed air and re-circulate the cool air.

[0005] The plurality of fan assemblies may each include a fan speed controlled to anywhere between 0% and 100% of the plurality of fan assemblies' rated capacity. A fan speed may be based on a temperature of the one or more electronic equipment enclosures, a temperature of the one or more warm air returns, a differential temperature between the one or more electronic equipment enclosures and the one or more warm air returns, a pressure of the one or more electronic equipment enclosures, a pressure of the one or more warm air returns, and/or a differential pressure between the one or more electronic equipment enclosures and an exterior of the one or more electronic equipment enclosures. The fan speed of the plurality of fan assemblies may be controlled to maintain a specific temperature, maintain a negative pressure, maintain a slightly negative pressure, maintain a neutral pressure, maintain a positive pressure, and/or maintain a slightly positive pressure. Maintaining a temperature or pressure may require the fan speed to increase or decrease revolutions per minute (RPM) to accommodate changes in airflow rates. The plurality of fan assemblies may be communicatively coupled. Each of the plurality of fan assemblies may be capable of independent operation but may receive the fan speed of the one or more other fan assemblies and adjust the fan speed in relation to the fan speed of the one or more other fan assemblies. Further, the plurality of fan assemblies may determine that the one or more other fan assemblies have failed or are operating improperly and may compensate for the one or more failed or improperly operating fan assemblies.

[0006] In an alternative embodiment, a system for cooling electronic equipment may include one or more electronic equipment enclosures that may receive cool air provided by one or more cool air sources via one or more cool air supplies and direct the cool air across one or more electronic equipment components before returning warmed air to the one or more cool air sources via one or more warm air returns utilizing one or more fan assemblies. The one or more cool air sources may re-cool the warmed air and re-circulate the cool air. The one or more fan assemblies may each include a fan speed operable between 0% and 100% of the fan assembly's rated capacity based on a detected temperature and/or pressure. The fan speed of each fan of the plurality of fan assemblies may be controlled to maintain a specific temperature, maintain a negative pressure, maintain a slightly negative pressure, maintain a neutral pressure, maintain a positive pressure, and/or maintain a slightly positive pressure.

[0007] The one or more cool air sources may determine the airflow for the one or more electronics equipment enclosures based on fan speed (which may be measured utilizing one or more tachometers of the one or more fan assemblies based upon a model type of the fan assembly) communicated by the one or more fan assemblies and may adjust the amount of cool air provided based on the airflow. Thus, the one or more cool air sources may provide a substantially sufficient amount of cool air required by the one or more electronics equipment enclosures, resulting in more efficient utilization of the one or more cool air sources.

[0008] It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory only and are not necessarily restrictive of the present disclosure. The accompanying drawings, which are incorporated in and constitute a part of the specification, illustrate subject matter of the disclosure. Together, the descriptions and the drawings serve to explain the principles of the disclosure.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] The numerous advantages of the disclosure may be better understood by those skilled in the art by reference to the accompanying figures in which:

FIG. 1A is a diagram illustrating a system for cooling electronic equipment, in accordance with a first embodiment of the present disclosure;

FIG. 1B is a diagram illustrating a system for cooling electronic equipment, in accordance with a second embodiment of the present disclosure;

FIG. 1C is a diagram illustrating a system for cooling electronic equipment, in accordance with a third embodiment of the present disclosure;

FIG. 2 is a block diagram of the fan assembly illustrated in FIG. 1A, in accordance with an embodiment of the present disclosure;

FIG. 3 is a block diagram illustrating an example configuration of the controller of FIG. 2, in accordance with an embodiment of the present disclosure;

FIG. 4A is a diagram illustrating an example configuration of a display of the fan assembly illustrated in FIG. 1A, in accordance with an embodiment of the present disclosure;

FIG. 4B is a diagram illustrating an example configuration of a display of the fan assembly illustrated in FIG. 1A, in accordance with an embodiment of the present disclosure;

FIG. 4C is a diagram illustrating an example configuration of a display of the fan assembly illustrated in FIG. 1A, in accordance with an embodiment of the present disclosure;

FIG. 4D is a diagram illustrating an example configuration of a display of the fan assembly illustrated in FIG. 1A, in accordance with an embodiment of the present disclosure;

FIG. 5 is a diagram illustrating a system for cooling electronic equipment, in accordance with an alternative embodiment of the present disclosure;

FIG. 6 is a diagram illustrating a system for cooling electronic equipment, in accordance with an alternative embodiment of the present disclosure;

FIG. 7 is a block diagram of the fan assembly illustrated in FIG. 6, in accordance with an embodiment of the present disclosure;

FIG. 8 is a block diagram illustrating an example configuration of the controller of FIG. 7, in accordance with an embodiment of the present disclosure;

FIG. 9 is a block diagram illustrating an example configuration of the cool air source of FIG. 7, in accordance with an embodiment of the present disclosure;

FIG. 10 is a flow diagram illustrating a method for cooling electronic equipment, in accordance with an embodiment of the present disclosure; and

FIG. 11 is a flow diagram illustrating a method for cooling electronic equipment, in accordance with an embodiment of the present disclosure.

DETAILED DESCRIPTION

[0010] Reference will now be made in detail to the subject matter disclosed, which is illustrated in the accompanying drawings.

[0011] FIG. 1A illustrates a system 100 for cooling electronic equipment, in accordance with an embodiment of the present disclosure. System 100 may include electronic equipment enclosure 101 and cool air source 102. Cool air source may refer to any type of device that generates cool air, such as an air conditioning unit, and the like. The electronic equipment enclosure 101 may include one or more electronic equipment components 108. The electronic equipment enclosure 101 may comprise an equipment cabinet for computing components such as a server rack. The electronic equipment enclosure 101 may receive cool air 104 provided by the cool air source 102 via cool air supply 103. It is contemplated that cool air supply 103 may refer to any flow of cool air between a cool air source 102 and electronic equipment enclosure 101. In FIG. 1A, cool air supply 103 may be implemented through the flow of cool air via ductwork between electronic equipment enclosure 101 and cool air source 102. The electronic equipment enclosure 101 may direct the cool air 104 across the one or more electronic equipment components 108, warming the cool air 104 and dissipating heat generated by the one or more electronic equipment components 108. The electronic equipment enclosure 101 may then return the warmed air 105 to the cool air source 102 via warm air return 107. It is contemplated that warm air return 107 to any flow of warm air between an electronic equipment enclosure 101 and cool air source 102. In FIG. 1A, warm air return 107 may be implemented through the flow of warm air through ductwork, or a full ceiling, the full ceiling representing a plenum for flow of air.

[0012] The cool air source 102 may re-cool the warmed air 105 and re-circulate the cool air 104. Fan assemblies 106 may be coupled to the warm air return 107 and/or the electronic equipment enclosure 101. The fan assemblies 106 may be utilized to direct the warmed air 105 from the electronic equipment enclosure 101 to the cool air source 102 via the warm air return 107. The electronic equipment enclosure 101 may include a pressure sensor 109 (which may comprise a rheostat and/or other pressure sensing device), communicatively coupled to the fan assemblies 106, for detecting a pressure of the interior of the electronic equipment enclosure 101. Pressure sensor 109 may be baffled to shield pressure sensor 109 from a specific air stream such as that from the one or more electronic equipment components 108, for example. A pressure sensor 110 (which may comprise a rheostat and/or other pressure sensing device), communicatively coupled to the fan assemblies 106, for detecting a pressure at the exterior of the electronic equipment enclosure 101. Pressure sensor 110 may be baffled to shield pressure sensor 110 from a specific air stream such as that from the fan assemblies 106, for example.

[0013] The fan speed of each fan assembly 106 may be operable between 0% and 100% of a rated capacity of the fan model (for example, a W1G200 model fan (EC10) may have a rated capacity of 2750 RPM (revolutions per minute)) based on a temperature of the electronic equipment enclosure 101, a temperature of the warm air return 107, a differential temperature between the electronic equipment enclosure 101 and the warm air return 107, a pressure of the electronic equipment enclosure 101 (detected utilizing pressure sensor 109), a pressure of the warm air return 107 (detected utilizing pressure sensor 110), and/or a differential pressure between the electronic equipment enclosure 101 and an exterior of the electronic equipment enclosure (detected utilizing pressure sensor 109 and pressure sensor 110 or, in alternatively, as illustrated in system 500 of FIG. 5, utilizing air flow sensor 109 which may be placed in proximity of fan assembly 106). The fan speed of each fan assembly 106 may be controlled to maintain a specific temperature (including, but not limited to, 65 degrees Fahrenheit or fifteen degrees Celsius), maintain a negative pressure (such as negative 30 ounces-force per square inch), maintain a slightly negative pressure (such as negative .5 ounces-force per square inch), maintain a neutral pressure (where the system 100 is removing the same volume of air from the electronic equipment enclosure 101 as is being forced into the electronic equipment enclosure 101), maintain a positive pressure (such as 25 ounces-force per square inch), and/or maintain a slightly positive pressure (such as 1 ounce-force per square inch). Maintaining a temperature or pressure may require the fan speed to increase or decrease RPM to accommodate changes in airflow rates.

[0014] The fan assemblies 106 may be directly and/or indirectly communicatively coupled. One or more of the fan assemblies 106 may communicate fan speed, fan model type, and/or status information to one or more other fan assemblies 106. The status information may include one or more error conditions. Each of the fan assemblies 106 may be capable of independent operation. However, although the fan speed of each fan assembly may operate independently based on various temperatures and/or pressures, the one or more of the fan assemblies 106 may receive the fan speed and/or the fan model type of the one or more other fan assemblies 106 and adjust the fan speed based on the fan speed and/or the fan model type of the one or more other fan assemblies 106. The one or more of the fan assemblies 106 may adjust the fan speed such that the fan speed substantially matches the fan speed of the one or more other fan assemblies 106, the fan speed exceeds the fan speed of the one or more other fan assemblies 106 by a percentage (including, but not limited to 50% or 75%), and/or the fan speed of the one or more other fan assemblies 106 exceeds the fan speed by a percentage (including, but not limited to 25% or 45%). Further, the one or more fan assemblies 106 may determine that the one or more other fan assemblies 106 have failed or are operating improperly. The one or more fan assemblies 106 may determine that the one or more other fan assemblies 106 have failed or are operating improperly based on status information received from the one or more other fan assemblies 106 and/or based on a failure to receive status information from the one or more other fan assemblies 106. If the one or more fan assemblies 106 determines that the one or more other fan assemblies 106 have failed or are operating improperly the one or more fan assemblies 106 may compensate for the one or more failed or improperly operating fan assemblies 106. For example, the one or more fan assemblies 106 may be operating at 40% capacity and may determine that one or more other fan assemblies 106 have failed (including, but not limited to, by receiving a failed status information from the one or more other fan assemblies 106 or failing to receive status information for the one or more other fan assemblies 106) and may increase the fan speed to 80% capacity to compensate for the one or more failed fan assemblies 106. As the fan assemblies 106 may control the fan speed based on various conditions, if the one or more of the fan assemblies 106 adjusts the fan speed based on the fan speed and/or the fan model of the one or more other fan assemblies 106 and/or to compensate for one or more failed and/or improperly operating other fan assemblies 106, the condition may change and the fan assemblies 106 may control the fan speed in response to the changed condition. However, after a period of time the fan speed of the fan assemblies 106 may balance such that a specific temperature and/or a specific pressure as well as the relationship among the fan speeds of the fan assemblies 106 is maintained.

[0015] Referring to FIG. 1B, a diagram illustrating a system for cooling electronic equipment in accordance with an embodiment of the present disclosure is shown. System 100 may include electronic equipment enclosure 101 and cool air source 102. The electronic equipment enclosure

101 may include one or more electronic equipment components 108. The electronic equipment enclosure 101 may comprise an equipment cabinet for computing components such as a server rack. The electronic equipment enclosure 101 may receive cool air 104 provided by the cool air source 102 via cool air supply 103. In FIG. 1B, cool air supply 103 may be represented as a flow of air through a sub-floor or a raised floor of a data center, facility and the like. The electronic equipment enclosure 101 may direct the cool air 104 supplied by cool air source 102 across the one or more electronic equipment components 108, warming the cool air 104 and dissipating heat generated by the one or more electronic equipment components 108.

[0016] The electronic equipment enclosure 101 may then return the warmed air 105 to the cool air source 102. Warm air return may be implemented through a partial ceiling 112 which directs the flow of air from electronic equipment enclosure 101 and cool air source 102. The cool air source 102 may re-cool the warmed air 105 and re-circulate the cool air 104. Fan assemblies 106 may be utilized to direct the warmed air 105 from the electronic equipment enclosure 101 to the cool air source 102 through the partial ceiling 112 whereby warmed air 105 with higher velocities and volume may be substantially contained and moved, without the requirement of a full ceiling, to the cool air source 102. Warm air 105 with lower velocities and volume will have buoyancy effects to keep the warm air 105 substantially contained and move, without the requirement of a full ceiling, to the cool air source 102. The electronic equipment enclosure 101 may include a pressure sensor 109 (which may comprise a rheostat and/or other pressure sensing device), communicatively coupled to the fan assemblies 106, for detecting an interior pressure of the electronic equipment enclosure 101. Pressure sensor 109 may be baffled to shield pressure sensor 109 from a specific air stream such as that from the one or more electronic equipment components 108, for example. A pressure sensor 110 (which may comprise a rheostat and/or other pressure sensing device), communicatively coupled to the fan assemblies 106, for detecting a pressure at the exterior of the electronic equipment enclosure 101. Pressure sensor 110 may be baffled to shield pressure sensor 110 from a specific air stream such as that from the fan assemblies 106, for example.

[0017] Referring to FIG. 1C, a diagram illustrating a system 100 for cooling electronic equipment, in accordance with a third embodiment of the present disclosure is shown. System 100 may include at least two electronic equipment enclosures 101 and cool air source 102. Electronic equipment enclosures 101 may include one or more electronic equipment components 108. Electronic equipment enclosures 101 may comprise an equipment cabinet for computing components such as a server rack. Electronic equipment enclosures 101 may receive cool air 104 provided by the cool air source 102 via cool air supply 103. In FIG. 1C, cool air supply 103 may be implemented as a flow of air through a sub-floor or a raised floor of a data center and the like. Electronic equipment enclosures 101 may direct the cool air 104 supplied by cool air source 102 across the one or more electronic equipment components 108, warming the cool air 104 and dissipating heat generated by the one or more electronic equipment components 108.

[0018] Electronic equipment enclosures 101 may then return the warmed air 105 to the cool air source 102. Warm air return may be implemented with a partial ceiling 112. Partial ceiling 112 may run a width of space between the cool air source 102 and a first electronic equipment enclosure 101. Partial ceiling 112 may run a width of space between a first electronic equipment enclosure and a second electronic equipment enclosure. Cool air source 102 may re-cool the warmed air 105 and re-circulate the cool air 104. Fan assemblies 106 may be utilized to direct the warmed air 105 from the electronic equipment enclosure 101 to the cool air source 102 through the partial ceiling 112 whereby warmed air 105 with higher velocities and volume may be substantially contained and moved, without the requirement of a full ceiling, to the cool air source 102. Warm air 105 with lower velocities and volume will have buoyancy effects to keep the warm air 105 substantially contained and move, without the requirement of a full ceiling, to the cool air source 102. Electronic equipment enclosures 101 may include a pressure sensor 109 (which may comprise a rheostat and/or other pressure sensing device), communicatively coupled to the fan assemblies 106, for detecting an interior pressure of the electronic equipment enclosures 101. Pressure sensor 109 may be baffled to shield pressure sensor 109 from a specific air stream such as that from the one or more electronic equipment components 108, for example. A pressure sensor 110 (which may comprise a rheostat and/or other pressure sensing device), communicatively coupled to the fan assemblies 106, for detecting a pressure at the exterior of the electronic equipment enclosures 101. Pressure sensor 110 may be baffled to shield pressure sensor 110 from a specific air stream such as that from the fan assemblies 106, for example.

[0019] As illustrated in FIG. 2, a fan assembly 106 may include a fan and a controller. For example, fan assembly 106 may comprise a chassis 201, a controller 202 coupled to the chassis 201, a motor 203 coupled to the chassis 201 and operatively coupled to the controller 202, and an impeller 204 (or other fan blade) operably coupled to the motor 203. Chassis 201 may be in the form of a fan cartridge and may be insertable within a chassis of warm air return 107. The controller 202 may be operable to provide varying amounts of power to the motor 203. The motor 203 may be operable to provide varying amounts of motive force to rotate the impeller 204 based on the varying amount of power provided by the controller 202. The motor 203 may also include a tachometer for determining a fan speed by measuring the speed at which the impeller 204 rotates and may communicate the fan speed to the controller 202. In this way, the controller 202 may control a fan speed of the fan assembly 106.

[0020] Chassis may be configured for mounting within a cooling system duct, such as a warm air return that may be employed within a data center cooling system. Chassis may provide support for a cartridge chassis of fan assembly 106. Chassis and cartridge of fan assembly 106 may be configured for convenient insertion in and withdrawal from such a warm air return. Cartridge of fan assembly 106 may be guided and supported, for example, by guide rails that direct the cartridge to a fully engaged position within a duct, or within the electronic equipment enclosure. The guide rails may, for example, be included in a chassis of a cooling system duct. In the fully engaged position, a mechanism with the cartridge of fan assembly 106 may, for example, be engaged with a mating mechanism within the chassis to provide power to the fan assembly 106. Mating "male" and "female" plug ends or card edge and slot mechanisms could be used for such purposes, for example. A locking mechanism, such as a simple hook for example, may be employed to secure the cartridge of fan assembly 106 within the chassis in the engaged position.

[0021] In an illustrative embodiment, a display 110 may positioned within the cartridge of fan assembly to facilitate reading. For example, the display may be located at the front of the cartridge of fan assembly 106 with a panel positioned at an angle to the corresponding vertical surface of a return air path within which the cartridge is mounted. The angle between the display panel and the corresponding duct surface may be chosen to provide easy viewing by an individual located on the floor below the duct in which the cartridge is mounted, by angling the display panel downward, for example. The display panel may be fixed at a predetermined angle (including flush) with the corresponding vertical surface, or the panel may be adjustable to accommodate various duct locations and configurations.

[0022] FIG. 3 illustrates an example configuration of controller 202 of fan assembly 106 as shown in FIG. 2. The controller 202 may comprise a control module 301 and a power module 302. The control module 301 may include a communication interconnect 304 for receiving a temperature of the electronic equipment enclosure 101, receiving a temperature of the warm air return 107, receiving the fan speed and/or the fan model type of one or more fan assemblies 106, communicating a fan speed and/or the fan model type to one or more fan assemblies 106, receiving a pressure of the electronic equipment enclosure 101, receiving a pressure exterior to the electronic equipment enclosure 101, receiving and/or querying status information of one or more fan assemblies 106, and/or communicating status information to one or more fan assemblies 106. The communication interconnect 304 may be communicatively coupled to a backplane of the electronic equipment enclosure 101. The power module 302 may include a power interconnect 303 for receiving power to provide to motor 203 based on directions from the control module 301. The power interconnect 303 may be operatively coupled to a backplane of the electronic equipment enclosure 101. The controller 202 may include a temperature sensor 305 for detecting a temperature of electronic equipment enclosure 101 and/or the warm air return 107.

[0023] The control module 301 may be communicably connected to a display of fan assembly 106. FIGS. 4A-4D illustrate example configurations of the display 401A-401D of the fan assembly 106. The display may include one or more indicators indicating the status of the fan assembly 106 including, but not limited to an indicator indicating whether the fan assembly 106 is operating properly, an indicator indicating whether the temperature detected by the temperature sensor 305 is within an acceptable limit, an indicator whether the capacity of the fan assembly 106 is within an acceptable limit, an indicator displaying the temperature detected by the temperature sensor 305, an indicator displaying the percentage of the capacity of fan assembly 106 that the fan assembly 106 is operating, an indicator indicating an alarm condition, an indicator indicating a heat map of the electronics equipment enclosure 101, and/or a indicator indicating temperature and/or heat trends detected within the electronics equipment enclosure 101. The one or more indicators may be implemented utilizing any technology including, but not limited to a light emitting diode (LED), a liquid crystal display (LCD), a polymer light emitting diode (PLED), plasma, a cathode ray tube (CRT), liquid crystal on silicon (LCOS), an organic light emitting diode (OLED), high temperature polysilicon (HTPS), an active matrix OLED, a surface conductive electron emitting display (SED), and/or a digital light projection display (DLP). The display 401A-401D may be positioned within the fan assembly 106 (such as on an exterior surface of fan assembly 106) to facilitate reading. For example, in FIG. 4D, display 401D is mounted to a panel 402D at an angle A such that the display 401D can be easily read when the fan assembly 106 is associated with the electronics equipment enclosure 101.

[0024] FIG. 6 illustrates a system 600 for cooling electronic equipment, in accordance with an alternative embodiment of the present disclosure. System 600 may include electronic equipment enclosure 101 and cool air source 102. The electronic equipment enclosure 101 may include one or more electronic equipment components 108. The electronic equipment enclosure 101 may comprise an equipment cabinet for computing components such as a server rack. The electronic equipment enclosure 101 may receive cool air 103 provided by the cool air source 102 via cool air supply 111. In FIG. 6, cool air supply may be implemented through a contained space, such as a data center, facility and the like. The electronic equipment enclosure 101 may direct the cool air 103 across the one or more electronic equipment components 808, warming the cool air 103 and dissipating heat generated by the one or more electronic equipment components 108. The electronic equipment enclosure 101 may then return the warmed air 105 to the cool air source 102 via warm air return 107. System 600 of FIG. 6 may include a warm air return 107 implemented in the form of ductwork or a full ceiling for control of the flow of warm air from an electronic equipment enclosure 101 to the cool air source 102. The cool air source 102 may re-cool the warmed air 105 and re-circulate the cool air 103. One or more fan assemblies 106 may be coupled to the warm air return 107 and/or the electronic equipment enclosure 101. The one or more fan assemblies 106 may be utilized to direct the warmed air 105 from the electronic equipment enclosure 101 to the cool air source 102 via the warm air return 107.

[0025] The electronic equipment enclosure 101 may include a pressure sensor 109 (which may comprise a rheostat and/or other pressure sensing device), communicatively coupled to the one or more fan assemblies 106, for detecting a pressure of the electronic equipment enclosure 101. Pressure sensor 109 may be baffled to shield pressure sensor 109 from a specific air stream such as that from the one or more electronic equipment components 108, for example. A pressure sensor 110 (which may comprise a rheostat and/or other pressure sensing device) may be communicatively coupled to the fan assemblies 106, for detecting a pressure exterior to the electronic equipment enclosure. Pressure sensor 110 may be baffled to shield pressure sensor 110 from a specific air stream such as that from the fan assemblies

106, for example. Alternatively, the one or more fan assemblies 106 may include a flow rate sensor (not shown) for detecting a differential pressure between electronics equipment enclosure 101 and a pressure exterior to the electronic equipment enclosure.

[0026] The one or more fan assemblies 106 may each include a fan speed and/or a fan model type. The fan speed of the one or more fan assemblies 106 may be controlled to anywhere between 0% and 100% of a rated capacity (for example, a W1G250 model type fan (EC20) may have a rated capacity of 2750 RPM) based on a temperature of the electronic equipment enclosure 101, a temperature of the warm air return 107, a differential temperature between the electronic equipment enclosure 101 and the warm air return 107, a pressure of the electronic equipment enclosure 101, a pressure of the warm air return 107, and/or a differential pressure between the electronic equipment enclosure 101 and a pressure exterior to the electronic equipment enclosure. The fan speed of the one or more fan assemblies 106 may be controlled to maintain a specific temperature (including, but not limited to, 65 degrees Fahrenheit or fifteen degrees Celsius), maintain a negative pressure (such as negative 30 ounces-force per square inch), maintain a slightly negative pressure (such as negative .5 ounces-force per square inch), maintain a neutral pressure (where the system 600 is removing the same volume of air from the electronic equipment enclosure 101 as is being forced into the electronic equipment enclosure 101), maintain a positive pressure (such as 25 ounces-force per square inch), and/or maintain a slightly positive pressure (such as 1 ounce-force per square inch). Maintaining a temperature or pressure may require the fan speed to increase or decrease revolutions per minute (RPM) to accommodate changes in airflow rates.

[0027] The one or more fan assemblies 106 may be communicatively coupled to the cool air source 102 and may communicate the fan speed and/or the fan model type to the cool air source 102. As the one or more fan assemblies 106 adjust their fan speed to maintain a specific temperature and/or pressure of the electronics equipment enclosure 101 and/or the warm air return 107, the appropriate airflow for the electronics equipment enclosure 101 may be determined based on the fan speed and/or the fan model type. The cool air source 102 may determine the airflow for the electronics equipment enclosure 101 based on the fan speed and/or the fan model type. As the appropriate airflow for the electronics equipment enclosure 101 is then known, the amount of cool air 103 required by the electronics equipment enclosure 101 may then be determined. The cool air source 102 may adjust the amount of cool air 103 provided to the electronics equipment enclosure 101 via the cool air supply 111 based on the airflow for the electronics equipment enclosure 101. Thus, the cool air source 102 provides substantially the exact amount of cool air 103 via cool air supply 111 required by the electronics equipment enclosure 101, resulting in more efficient utilization of cool air source 102. The cool air source 102 may thus not provide more cool air 103 to the electronics equipment enclosure 101 via the cool air supply 111 than is required by the electronics equipment enclosure 101, avoiding excess utilization of the cool air source 102. The cool air source 102 may thus not provide less cool air 103 to the electronics equipment enclosure 101 via the cool air supply 111 than is required by the electronics equipment enclosure 101, avoiding excess utilization of the fan assemblies 106.

[0028] Although the present disclosure has been illustrated and described utilizing one cool air source 102, one electronic equipment enclosure 101, one cool air supply 103, one warm air return 107, and two fan assemblies 106, it should be understood that multiple cool air sources 102 and multiple electronic equipment enclosures 101 may be implemented. It is contemplated that multiple cool air sources 102 may cool multiple electronic equipment enclosures through a common cool air supply 103 and common warm air return 107. Additionally, in an alternative embodiment multiple cool air supplies 103 (such as five or seven), multiple warm air returns 107 (such as two or eight), and/or other numbers of fan assemblies 106 (such as four or twenty-five) may be utilized without departing from the scope of the present disclosure. Further, although the present disclosure has been illustrated and described utilizing two pressure sensors 109 and 110 (and/or flow sensor 507), it should be understood that other numbers of pressure sensors 109 and 110 (and/or flow sensors 507) may be utilized without departing from the scope of the present disclosure.

[0029] As illustrated in FIG. 7, the one or more fan assemblies 606 may comprise a chassis 701, a controller 702 coupled to the chassis 701, a motor 703 coupled to the chassis 701 and operatively coupled to the controller 702, and an impeller 704 (or other fan blade) operably coupled to the motor 703. The controller 702 may be operable to provide varying amounts of power to the motor 703. The motor 703 may be operable to provide varying amounts of motive force to rotate the impeller 704 based on the varying amount of power provided by the controller 702. The motor 703 may also include a tachometer 705 for determining a fan speed by measuring the speed at which the impeller 704 rotates and may communicate the fan speed and/or a fan model type to the controller 702. In this way, the controller 702 may control a fan speed of the one or more fan assemblies 606.

[0030] FIG. 8 illustrates an example configuration of controller 702. The controller 702 may comprise a control module 801 and a power module 802. The control module 801 may include a communication interconnect 804 for receiving a temperature of the electronic equipment enclosure 101, receiving a temperature of the warm air return 107, receiving the fan speed, potentially through a tachometer 705, and/or fan model type of one or more fan assemblies 106, communicating a fan speed and/or a fan model type to one or more fan assemblies 106 and/or to the cool air source 102, receiving a pressure of the electronics equipment enclosure 101, receiving a pressure of an exterior to the electronic equipment enclosure 101, receiving and/or querying status information of one or more fan assemblies 106, and/or communicating status information to one or more fan assemblies 106. The communication interconnect 804 may be communicatively coupled to a backplane of the electronic equipment enclosure 101 and/or the cool air source 102. The power module 802 may include a power interconnect 803 for receiving power to provide to motor 703 based on directions from the control module 801. The power interconnect 803 may be operatively coupled to a backplane of the electronic equipment enclosure 101. The control module 801 may be communicably connected to a display 806 of the one or more fan assemblies 106.

[0031] Backplane of electronic equipment enclosure may include a communications processor that may be implemented in a variety of technologies, including, but not limited to: discrete logic, state logic, microprocessors, microcontrollers, or field programmable gate arrays (FPGAs), for example. A ommunication processor is configured to communicate information from each of the fan assemblies 106 to the other fan assemblies and, in this illustrative embodiment, through an Ethernet connection to other elements of the data center, such as IT and BMS systems. The communications processor may be configured to provide graphs and real-time data, as well as email alerts at user-specified thresholds and to format fan speed data in order to export the data in a variety of files, such as CSV or Excel files, for example. Remote monitoring of operational and environmental information may be provided through an operable connection. The communications processor may support a variety of network and data protocols, such as HTTP, TCP/IP, SNMP, and Modbus, for example.

[0032] FIG. 9 illustrates an example configuration of cool air source 102. As illustrated, cool air source 102 may include a control module 901, a power module 902 communicatively coupled to the control module 901, and a cooling unit 903 operatively coupled to the power module 902. The control module 901 may include a communication interconnect 904, communicatively coupled to the one or more fan assemblies, for receiving the fan speed and/or the fan model type of the one or more fan assemblies. The control module 901 may determine the airflow for the electronics equipment enclosure 101 based on the fan speed and/or the fan model type. The power module 902 may include a power interconnect 905 for receiving power to provide to cooling unit 903 based on directions from the control module 901. The cooling unit 903 may provide a variable amount of cool air 103 between 0% and 100% of the capacity of the cooling unit 903 for the cool air source 102 to provide to the electronics equipment enclosure 101 utilizing the power provided by the power module 902 based on directions from the control module 901. The control module 901 may adjust the amount of cool air 103 that the cool air source 102 provides to the electronics equipment enclosure 101 based on the airflow for the electronics equipment enclosure 101.

[0033] By way of an example, the one or more fan assemblies 106 may comprise two fan assemblies and the control module 901 may receive the fan speed and the fan model types of the two fan assemblies 106 via communication interconnect 904. The control module 901 may receive that the fan model type of the two fan assemblies 106 is W1G200 (EC10) and that the fan speed of the two fan assemblies 106 is 2000 RPM. The control module 901 may determine airflows for the two fan assemblies 106 based on the fan model type and fan speed. The control module 901 may be operable to determine that W1G200 (EC10) model type fans are rated to move 591.5 CFM (cubic feet per minute) at 2750 RPM. The control module 901 may be operable to determine that W1G200 (EC10) model type fans are rated to move 591.5 CFM (cubic feet per minute) at 2750 RPM by looking up this information in a table storing information about the CFM/RPM ratings of different fan model types. CFM may vary in direct proportion to RPM. Thus, the control module 901 may determine airflows for the two fan assemblies 106 by solving the equation $CFM_2/CFM_1 = RPM_2/RMP_1$ or $CFM_2/591.5 = 2000/2750$ CFM or $CFM_2 = 430.182$ CFM. The control module 901 may aggregate the airflow of the two fan assemblies to determine the amount of cool air to provide. Thus, as the airflow for each fan assembly 106 is 430.182 CFM, the control module 901 may determine that the aggregate airflow of the fan assemblies 106 is 860.36 CFM. System 100 may include system impedances and turbulence that may modify the airflow for the fan assemblies 106. System 100 may include system impedances and turbulence such that if the fan speed of fan assemblies were 2750 RPM, their actual airflow within system 100 may be 1100 CFM. As such, the control module 901 may apply a correction to the airflow determined based on the fan model type and speed to account for the system impedances and turbulence. For system 100, the control module 901 may apply the correction by multiplying the airflow by a corrective factor (corrected airflow = airflow * corrective factor) of approximately .93 to account for the system impedances and turbulence such that the airflow of fan assemblies 106 would be 1100 CFM at 2750 RPM rather than 1183 CFM. Thus, the corrected airflow at 2000 RPM may comprise 860.36 CFM * .93 or 800.1348 CFM. As the two fan assemblies 106 adjust their fan speed to maintain a specific temperature and/or pressure of the electronics equipment enclosure 101, the appropriate airflow for the electronics equipment enclosure 101 may be approximately equal to the corrected airflow of the two fan assemblies 106. Based on this corrected airflow of the two fan assemblies 106, the control module 901 may adjust the amount of cool air 103 that the cool air source 102 provides to the electronics equipment enclosure 101 via the cool air supply to approximately equal 800.1348 CFM.

[0034] By way of an additional example, the one or more fan assemblies 106 may comprise two fan assemblies and the control module 901 may receive the fan speed and the fan model types of the two fan assemblies 106 via communication interconnect 904. The control module 901 may receive that the fan model type of the two fan assemblies 106 is W1G250 (EC20) and that the fan speed of the two fan assemblies 106 is 2500 RPM. The control module 901 may determine airflows for the two fan assemblies 106 based on the fan model type and fan speed. The control module 901 may be operable to determine that W1G250 (EC20) model type fans are rated to move 1130.1 CFM (cubic feet per minute) at 2750 RPM. The control module 901 may be operable to determine that W1G250 (EC20) model type fans are rated to move 1130.1 CFM (cubic feet per minute) at 2750 RPM by looking up this information in a table storing information about the CFM/RPM ratings of different fan model types. The control module 901 may determine airflows for the two fan assemblies 106 by consulting a table that correlates different CFMs to different RPMs for the W1G250 (EC20) model type fan. The table correlating different CFMs to different RPMs for the W1G250 (EC20) model type fan may have been created by testing the W1G250 (EC20) model type fan on a test bench and measuring different airflow rates at different RPMs. The control module 901 may determine airflows for the two fan assemblies 106 is 1027.36 CFM at 2500 RPM by consulting the table that correlates different CFMs to different RPMs for the W1G250 (EC20) model type fan. The control module 901 may aggregate the airflow of the two fan assemblies to determine the amount of cool air to provide. Thus, as the airflow for each fan assembly 106 is 1027.36 CFM, the control module 901 may determine that the aggregate airflow of the fan assemblies 106 is 2054.72 CFM. System 100 may include system impedances and turbulence that may modify the airflow for the fan assemblies 106. System 100 may include system impedances and turbulence such that if the fan speed of fan assemblies were 2750 RPM, their actual airflow within system 100 may be 2000 CFM. As such, the control module 901 may apply a correction to the airflow determined based on the fan model type and speed to account for the system impedances and turbulence. For system 100, the control module 901 may apply the correction by multiplying the airflow by a corrective factor (corrected airflow = airflow * corrective factor) of approximately .884 to account for the system impedances and turbulence such that the airflow of fan assemblies 106 would be 2000 CFM at 2750 RPM rather than CFM. Thus, the corrected airflow at 2000 RPM may comprise 2054.72 CFM * .884 or 1816.37 CFM. As the two fan assemblies 106 adjust their fan speed to maintain a specific temperature and/or pressure of the electronics equipment enclosure 101 and/or the warm air return 107, the appropriate airflow for the electronics equipment enclosure 101 may approximately equal the corrected airflow of the two fan assemblies 106. Based on this corrected airflow of the two fan assemblies 106, the control module 901 may adjust the amount of cool air 103 that the cool air source 102 provides to the electronics equipment enclosure 101 via the cool air supply to approximately equal 1816.37 CFM.

[0035] Although the present disclosure has been illustrated and described utilizing one cool air source 102 and one electronic equipment enclosure 101, it should be understood that one or more cool air sources 102 may determine the aggregate airflow of one or more electronic equipment enclosures 101 and may provide the amount of cool air 103 required by one or more electronic equipment enclosures 101 based on the aggregate airflow of the one or more electronic equipment enclosures 101 without departing from the scope of the present disclosure.

[0036] FIG. 10 illustrates a method 1001 for cooling electronic equipment, in accordance with an embodiment of the present disclosure. In step 1001, cool an electronic equipment enclosure by receiving cool air from a cool air source, warming the cool air by directing the cool air across at least one electronic equipment component, and returning the warmed air to the cool air source via a warm air return. In step 1002, control a fan speed of a first fan assembly and an additional fan speed of at least one additional fan assembly, the first fan assembly and the at least one additional fan assembly directing the warmed air from the electronic equipment enclosure to the warm air return. Controlling the fan speed of the first fan assembly and the additional fan speed of the at least one additional fan assembly may comprise controlling the fan speed and the additional fan speed based on at least one of an electronic equipment enclosure temperature, a warm air return temperature, or a detected pressure differential between an interior electronic equipment enclosure pressure and a pressure exterior to the electronic equipment enclosure. In step 1003, adjust the fan speed in relation to the additional fan speed. Adjusting the fan speed in relation to the additional fan speed may comprise adjusting the fan speed in relation to the additional fan speed so that the fan speed substantially matches the additional fan speed. Adjusting the fan speed in relation to the additional fan speed may comprise determining that the at least one additional fan assembly has failed and increasing the fan speed to compensate for the failed at least one additional fan assembly. Adjusting the fan speed in relation to the additional fan speed may comprise determining that the at least one additional fan assembly is operating improperly and increasing the fan speed to compensate for the improperly operating at least one additional fan assembly.

[0037] FIG. 11 illustrates a method 1101 for cooling electronic equipment, in accordance with an embodiment of the present disclosure. In step 1101, cool at least one electronic equipment enclosure by receiving cool air provided by at least one cool air source, warming the cool air by directing the cool air across at least one electronic equipment component, and returning the warmed air to the at least one cool air source via a warm air return. In step 1102, control at least one fan speed of at least one fan assembly based on a detected pressure differential between an electronic equipment enclosure pressure and a warm air return pressure, the at least one fan assembly coupled to the at least one warm air return. Controlling at least one fan speed of at least one fan assembly based on a detected pressure differential between an interior electronic equipment enclosure pressure and an exterior electronic equipment enclosure pressure may comprise controlling the at least one fan speed of the at least one fan assembly to maintain at least one of a negative pressure, a positive pressure, and/or a negative pressure. In step 1103, determine an airflow of the at least one electronic equipment enclosure. Determining an airflow of the at least one electronic equipment enclosure based on the at least one fan speed and a model type of the at least one fan assembly may comprise determining the at least one fan speed utilizing a tachometer of the at least one fan assembly and communicating the at least one fan speed and the model type of the at least one fan assembly to the at least one cool air source. In step 1104, adjust an amount of the cool air provided by the at least one cool air source may be based on the airflow of the at least one electronic equipment enclosure. The at least one electronic equipment enclosure may comprise a plurality of electronic equipment enclosures and adjusting the amount of the cool air provided by the at least one cool air source may be based on the airflow of the at least one electronic equipment enclosure may comprise adjusting the amount of the cool air provided by the at least one cool air source based on the airflow of the plurality of electronic equipment enclosures. The at least one cool air source may comprise a plurality of cool air sources and adjusting the amount of the cool air provided by the at least one cool air source based on the airflow of the at least one electronic equipment enclosure may comprise adjusting the amount of the cool air provided by the plurality of cool air sources based on the airflow of the at least one electronic equipment enclosure.

[0038] In the present disclosure, the methods disclosed may be implemented as sets of instructions or software readable by a device. Further, it is understood that the specific order or hierarchy of steps in the methods disclosed are examples of exemplary approaches. Based upon design preferences, it is understood that the specific order or hierarchy of steps in the method can be rearranged while remaining within the disclosed subject matter. The accompanying method claims present elements of the various steps in a sample order, and are not necessarily meant to be limited to the specific order or hierarchy presented.

[0039] It is believed that the present disclosure and many of its attendant advantages will be understood by the foregoing description, and it will be apparent that various changes may be made in the form, construction and arrangement of the components without departing from the disclosed subject matter or without sacrificing all of its material advantages. The form described is merely explanatory, and it is the intention of the following claims to encompass and include such changes.

CLAIMS

What is claimed is:

1. A system, comprising:

a cool air source;

an electronic equipment enclosure, the electronic equipment enclosure configured to receive cool air from the cool air source, warm the cool air by directing the cool air across at least one electronic equipment component, and return the warmed air to the cool air source;

a fan assembly including a fan that directs the warmed air from the electronic equipment enclosure, the fan assembly controlling a fan speed of the fan; and

at least one additional fan assembly including an additional fan that directs the warmed air from the electronic equipment enclosure, the at least one additional fan assembly controlling an additional fan speed of the additional fan,

wherein the fan assembly is configured to receive the additional fan speed and the fan assembly adjusts the fan speed in relation to the additional fan speed.

2. The system of claim 1, wherein the fan assembly controls the fan speed based on at least one of an electronic equipment enclosure temperature or a detected pressure differential between an electronic equipment enclosure pressure and an exterior of the electronic equipment enclosure and the at least one additional fan assembly controls the additional fan speed based on at least one of the electronic equipment enclosure temperature or the detected pressure differential between the electronic equipment enclosure pressure and the exterior of the electronic equipment enclosure.

3. The system of claim 1, wherein the fan assembly adjusts the fan speed in relation to the additional fan speed so that the fan speed substantially matches the additional fan speed.

4. The system of claim 1, wherein the fan assembly is configured to determine that the at least one additional fan assembly has failed and increase the fan speed to compensate for the failed at least one additional fan assembly.

5. The system of claim 1, wherein the fan assembly is configured to determine that the at least one additional fan assembly is operating improperly and increase the fan speed to compensate for the improperly operating at least one additional fan assembly.

6. A method, comprising:

cooling an electronic equipment enclosure by receiving cool air from a cool air source, warming the cool air by directing the cool air across at least one electronic equipment component, and returning the warmed air to the cool air source;

controlling a fan speed of a first fan assembly and an additional fan speed of at least one additional fan assembly, the first fan assembly and the at least one additional fan assembly directing the warmed air from the electronic equipment enclosure; and

adjusting the fan speed in relation to the additional fan speed.

7. The method of claim 6, wherein said controlling a fan speed of a first fan assembly and an additional fan speed of at least one additional fan assembly comprises:

controlling the fan speed and the additional fan speed based on at least one of an electronic equipment enclosure temperature or a detected pressure differential between an electronic equipment enclosure pressure and an exterior of the electronic equipment enclosure.

8. The method of claim 6, wherein said adjusting the fan speed in relation to the additional fan speed comprises:

adjusting the fan speed in relation to the additional fan speed so that the fan speed substantially matches the additional fan speed.

9. The method of claim 6, wherein said adjusting the fan speed in relation to the additional fan speed comprises:

determining that the at least one additional fan assembly has failed; and

increasing the fan speed to compensate for the failed at least one additional fan assembly.

10. The method of claim 6, wherein said adjusting the fan speed in relation to the additional fan speed comprises:

determining that the at least one additional fan assembly is operating improperly; and

increasing the fan speed to compensate for the improperly operating at least one additional fan assembly.

11. A system, comprising:

at least one cool air source;

at least one electronic equipment enclosure, the electronic equipment enclosure configured to receive cool air provided by the at least one cool air source, warm the cool air by directing the cool air across at least one electronic equipment component, and return the warmed air to the at least one cool air source; and

at least one fan assembly, the at least one fan assembly including a fan controller that controls a fan speed based on a detected pressure differential between at least one electronic equipment enclosure pressure and a pressure exterior of the at least one electronic equipment enclosure,

wherein the at least one cool air source is configured to receive an airflow measurement of the at least one electronic equipment enclosure and adjust an amount of the cool air provided by the at least one cool air source based on the airflow measurement of the at least one electronic equipment enclosure.

12. The system of claim 11, wherein the airflow measurement is determined based upon at least one of the fan speed of the at least one fan assembly or an airflow meter.

13. The system of claim 11, wherein the fan controller that controls the fan speed to maintain at least one of a negative pressure, a positive pressure, or a neutral pressure.

14. The system of claim 11, wherein the at least one electronic equipment enclosure comprises a plurality of electronic equipment enclosures and the at least one cool air source is configured to adjust an amount of the cool air provided based on an airflow of the plurality of electronic equipment enclosures.

15. The system of claim 11, wherein the at least one cool air source comprises a plurality of cool air sources and the plurality of cool air sources

are configured to adjust an amount of the cool air provided based on the airflow of the at least one electronic equipment enclosure.

16. A method, comprising:

cooling at least one electronic equipment enclosure by receiving cool air provided by at least one cool air source, warming the cool air by supplying the cool air across at least one electronic equipment component, and returning the warmed air to the at least one cool air source;

controlling at least one fan speed of at least one fan assembly based on a detected pressure differential between an electronic equipment enclosure pressure and a pressure exterior to the electronic equipment enclosure;

determining an airflow of the at least one electronic equipment enclosure based on the at least one fan speed of the at least one fan assembly; and

adjusting an amount of the cool air provided by the at least one cool air source based on the airflow of the at least one electronic equipment enclosure.

17. The method of claim 16, wherein said determining an airflow of the at least one electronic equipment enclosure based on the at least one fan speed comprises:

determining the at least one fan speed and fan model type of the at least one fan assembly; and

communicating the at least one fan speed and the fan model type of the at least one fan assembly to the at least one cool air source.

18. The method of claim 16, wherein said controlling at least one fan speed of at least one fan assembly based on a detected pressure differential between an electronic equipment enclosure pressure and a pressure exterior to the electronic equipment enclosure:

controlling the at least one fan speed of the at least one fan assembly to maintain at least one of a negative pressure, a positive pressure, or a neutral pressure.

19. The method of claim 16, wherein the at least one electronic equipment enclosure comprises a plurality of electronic equipment enclosures and said adjusting an amount of the cool air provided by the at least one cool air source based on the airflow of the at least one electronic equipment enclosure comprises:

adjusting the amount of the cool air provided by the at least one cool air source based on an airflow of the plurality of electronic equipment enclosures.

20. The method of claim 16, wherein the at least one cool air source comprises a plurality of cool air sources and said adjusting an amount of the cool air provided by the at least one cool air source based on the airflow of the at least one electronic equipment enclosure comprises:

adjusting the amount of the cool air provided by the plurality of cool air sources based on the airflow of the at least one electronic equipment enclosure.

21. A system, comprising:

a cool air source;

a first electronic equipment enclosure, the first electronic equipment enclosure configured to receive cool air from the cool air source, warm the cool air by directing the cool air across at least one electronic equipment component, and return the warmed air to the cool air source via a warm return formed of a partial ceiling;

a second electronic equipment enclosure, the first electronic equipment enclosure configured to receive cool air from the cool air source, warm the cool air by directing the cool air across at least one electronic equipment component, and return the warmed air to the cool air source via a warm return formed of the partial ceiling, the partial ceiling extending a width between the cool air source and the first electronic equipment enclosure, the partial ceiling extending a width between the first electronic equipment enclosure and the second equipment enclosure;

a fan assembly including a fan that directs the warmed air from the electronic equipment enclosure, the fan assembly controlling a fan speed of the fan; and

at least one additional fan assembly including an additional fan that directs the warmed air from the electronic equipment enclosure, the at least one additional fan assembly controlling an additional fan speed of the additional fan,

wherein the fan assembly is configured to receive the additional fan speed and the fan assembly adjusts the fan speed in relation to the additional fan speed.

22. An apparatus for cooling an electronic equipment enclosure that includes a warm air return for warm electronics exhaust air, comprising:

a plurality of fans;

a plurality of fan controllers; and

a plurality of displays, each fan, each fan controller and each display being configured in a respective cartridge for insertion in a chassis fitted within a warm air return.

23. The apparatus of claim 22, wherein each fan controller of the plurality of fan controllers is configured to receive a pressure reading from the electronic equipment enclosure and to determine a speed of a respective fan based upon the pressure reading.

24. The apparatus of claim 22, wherein each display of the plurality of fan controllers is configured to present operating and alarm information.

25. The apparatus of claim 22, further comprising a communications processor configured to communicate through an electronic link with equipment outside the electronic equipment enclosure.

26. The apparatus of claim 25, wherein the communications processor is configured to relay operating and alarm information to a data center information management system.

27. The apparatus of claim 26, wherein the communications processor is configured to relay information related to a time the plurality of fans have been operating.

28. The apparatus of claim 22, wherein said respective cartridge is configured to communicate with one or more other cartridges.

29. The apparatus of claim 28, wherein each fan controller of the plurality of fan controllers cooperates with the one or more other fan controllers associated with the one or more other cartridges to operate each

of the plurality of fans inserted within the chassis at substantially a same speed.

30. The apparatus of claim 29, wherein each fan controller is configured to increase a speed of its associated fan upon receiving an indication that another fan has failed.

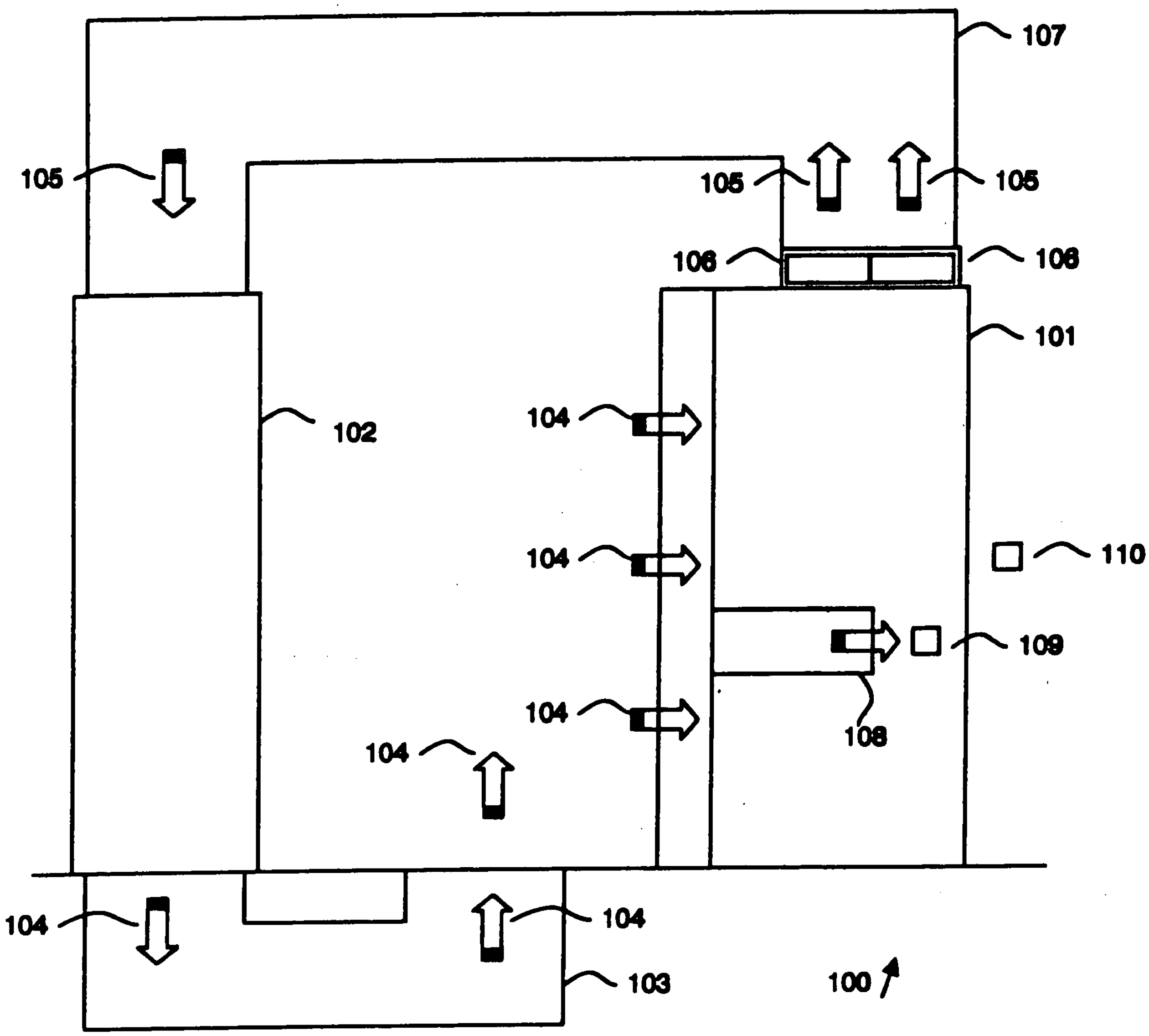
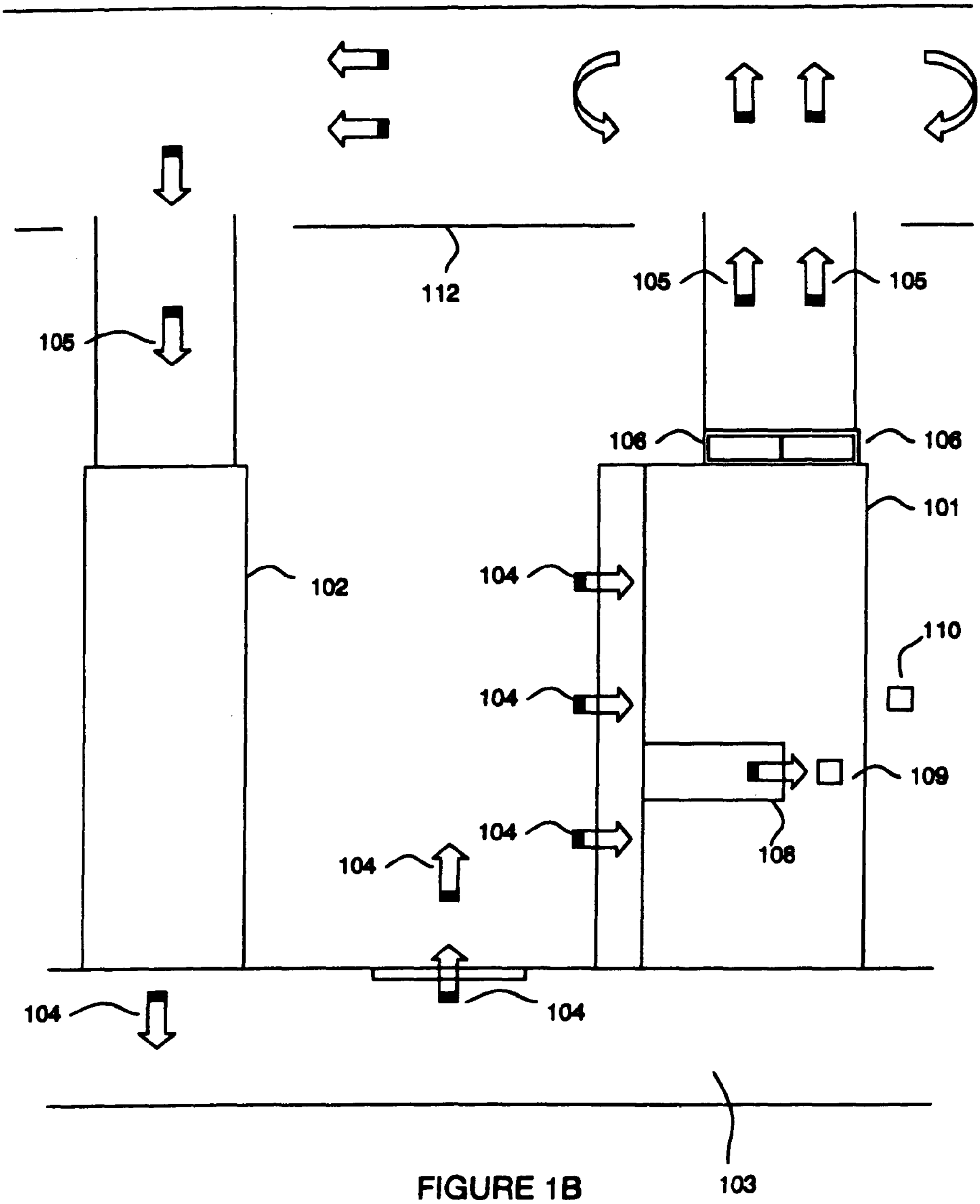

107
105
105
105
106
106
101
102
104
104
110
109
104
108
104
104
104
103
100

FIGURE 1A


112
105
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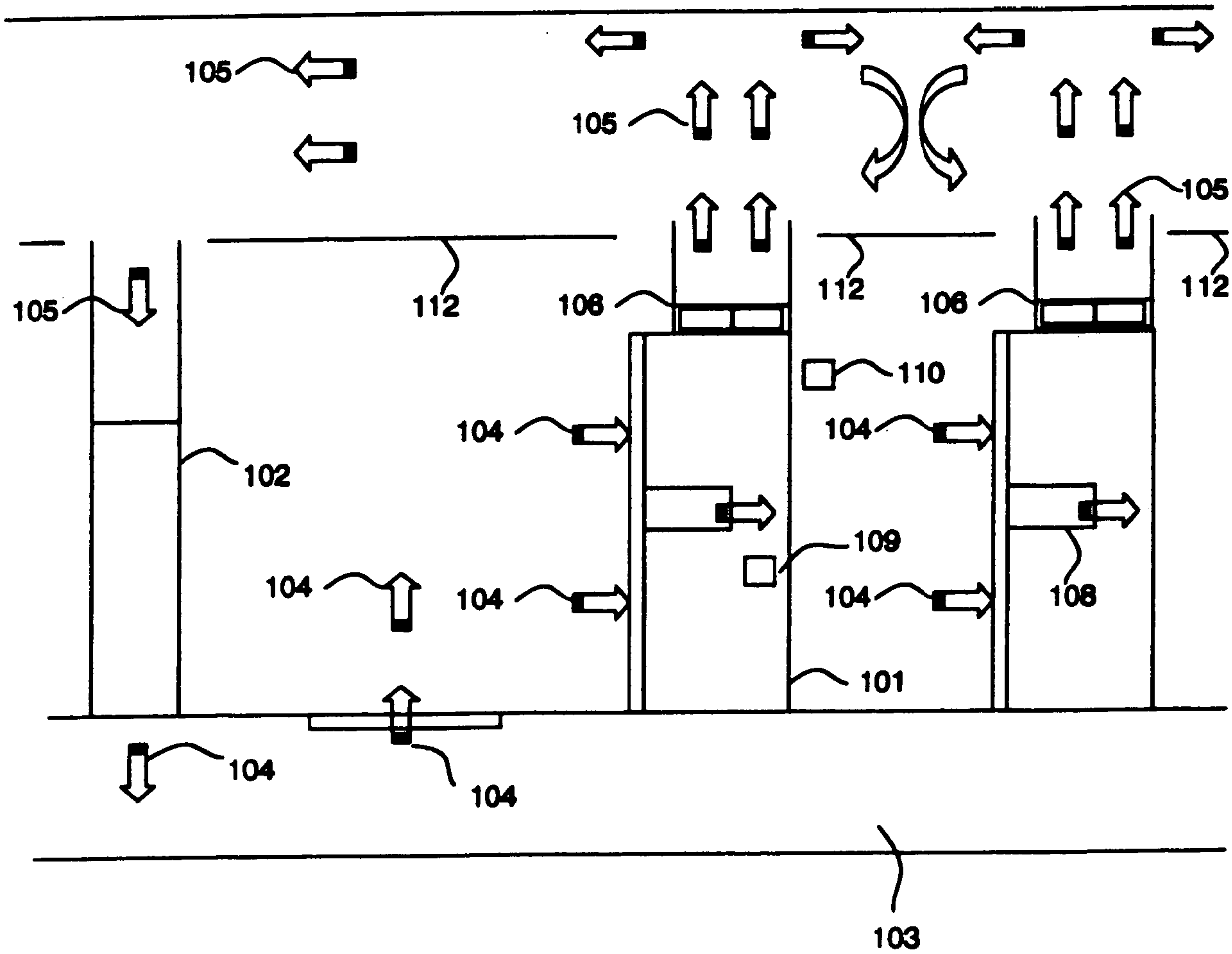
105
106
106
101
102
104
104
110
109
104
104
108
104
104
103

FIGURE 1B


105
105
105
105
112
112
112
106
106
110
104
104
102
109
104
104
104
104
108
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104
104
103

FIGURE 1C

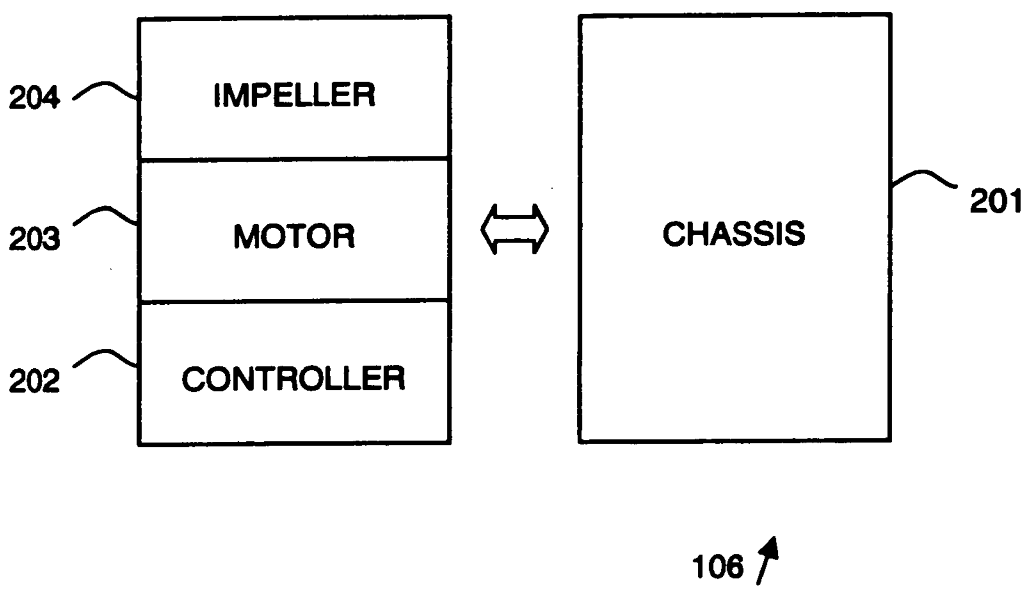

FIGURE 2

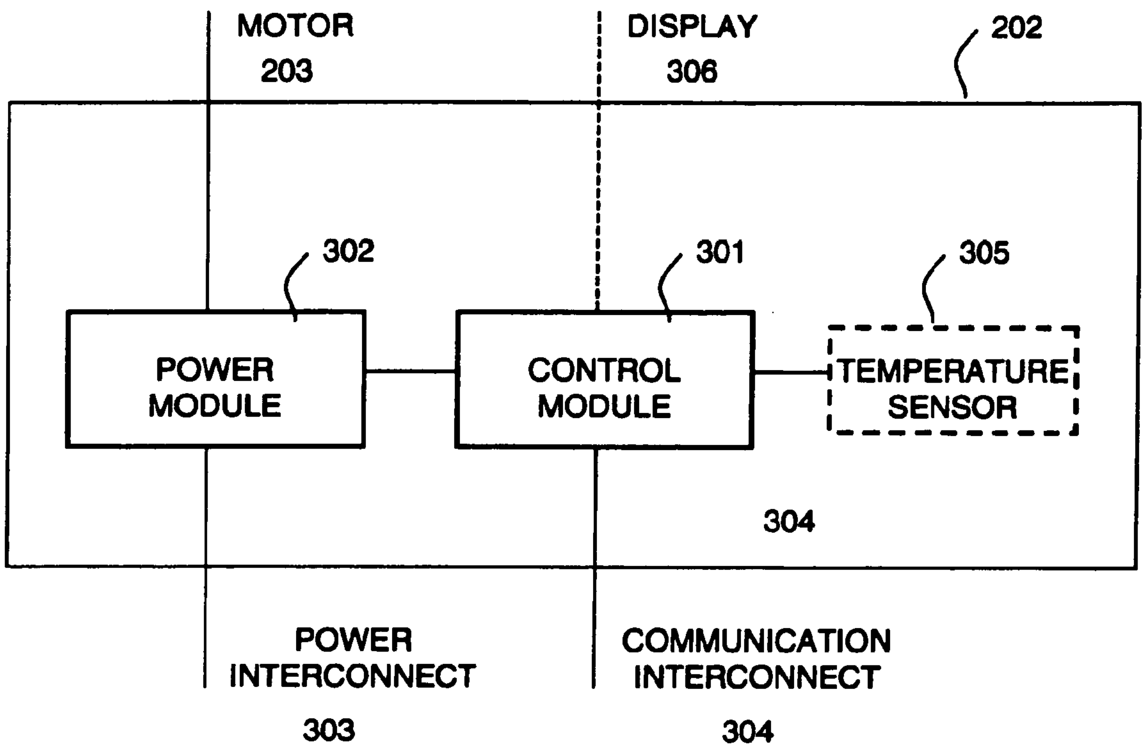
MOTOR
203
DISPLAY
306
202
302
301
305
POWER
MODULE
CONTROL
MODULE
TEMPERATURE
SENSOR
304
POWER
INTERCONNECT
303
COMMUNICATION
INTERCONNECT
304

FIGURE 3

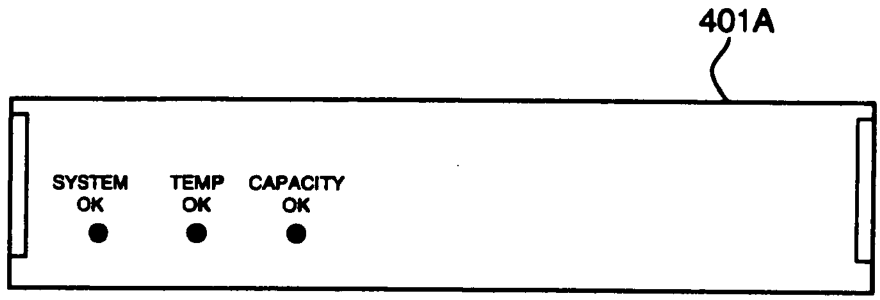

FIGURE 4A

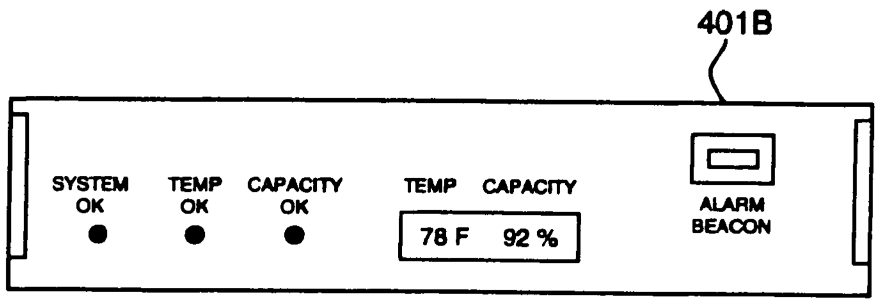

FIGURE 4B

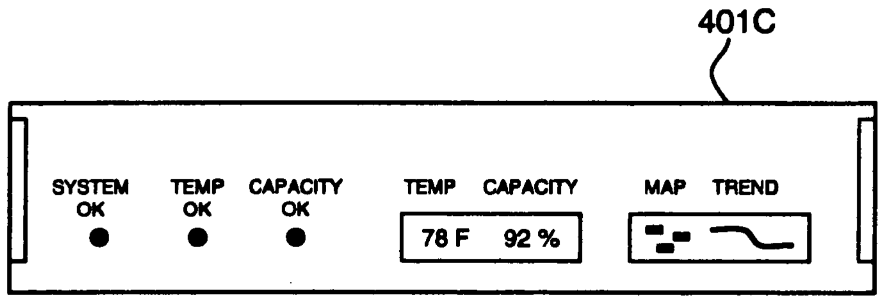

FIGURE 4C

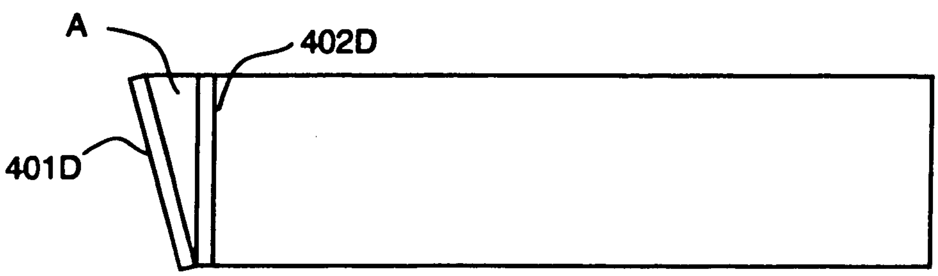

FIGURE 4D

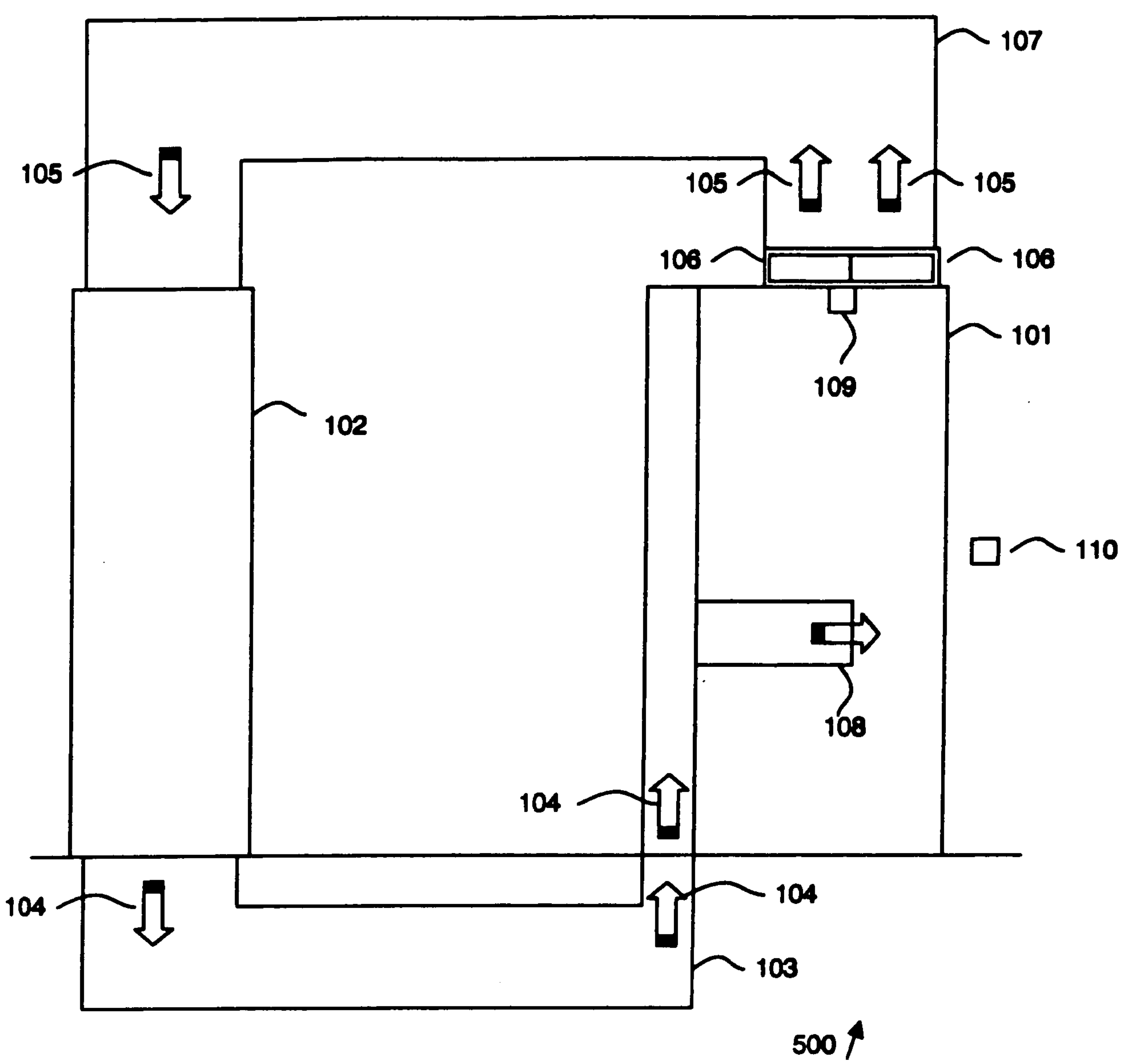

FIGURE 5

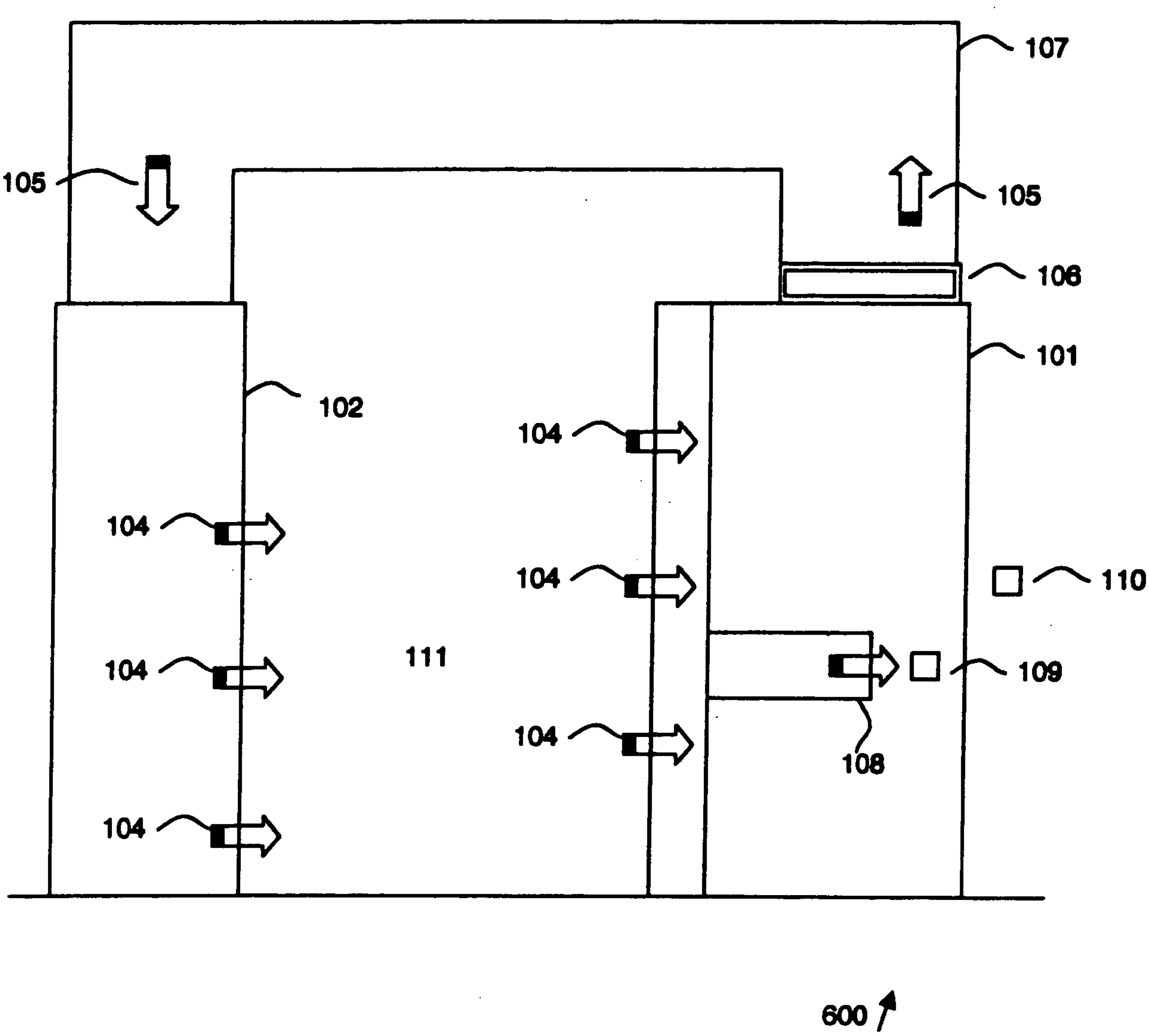
107
105
105
106
101
102
104
104
104
104
104
104
111
110
109
108
600

FIGURE 6

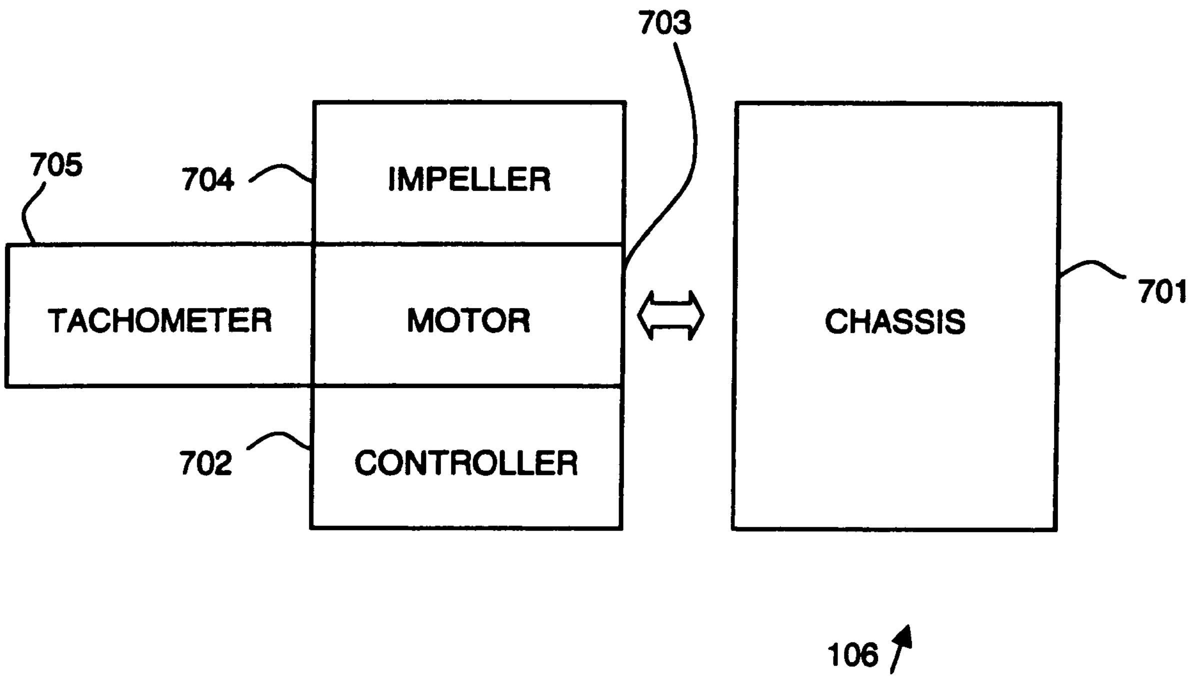
703
705
704
IMPELLER
TACHOMETER
MOTOR
CHASSIS
701
702
CONTROLLER
106

FIGURE 7

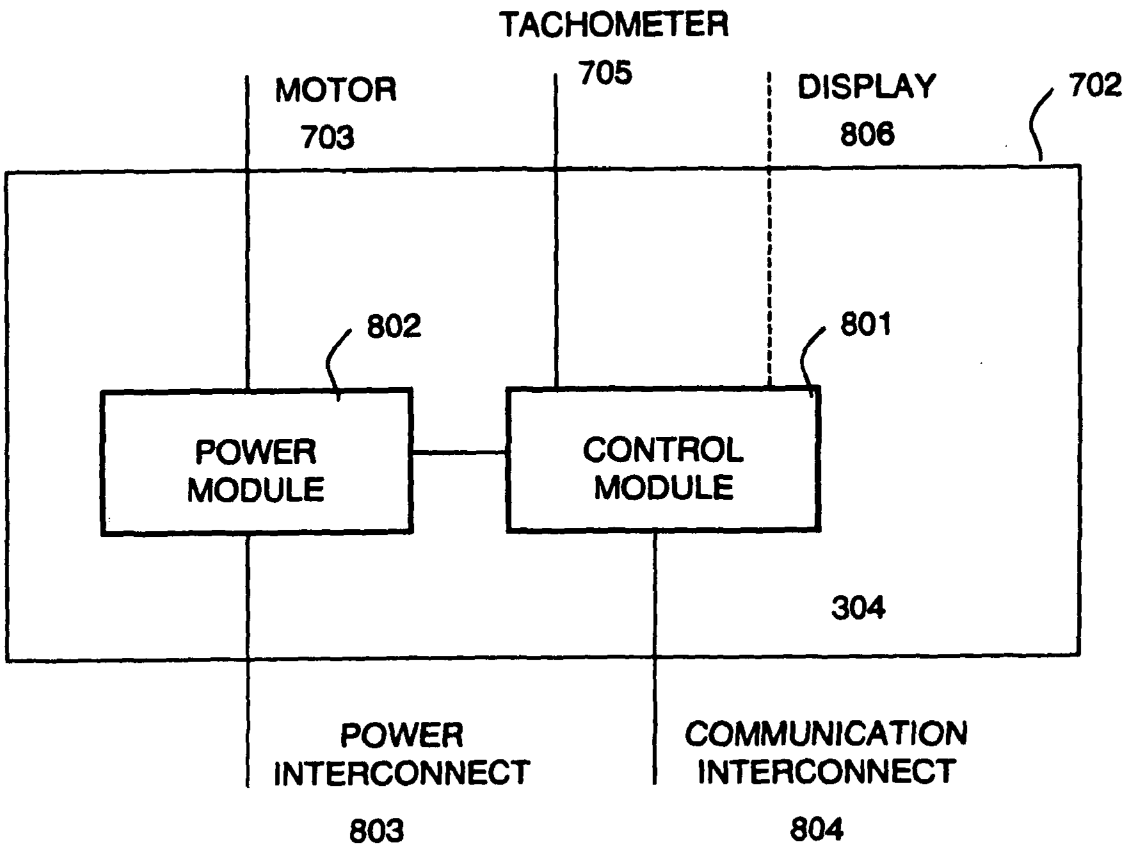
TACHOMETER
705
MOTOR
703
DISPLAY
806
702
802
801
POWER MODULE
CONTROL MODULE
304
POWER INTERCONNECT
803
COMMUNICATION INTERCONNECT
804

FIGURE 8

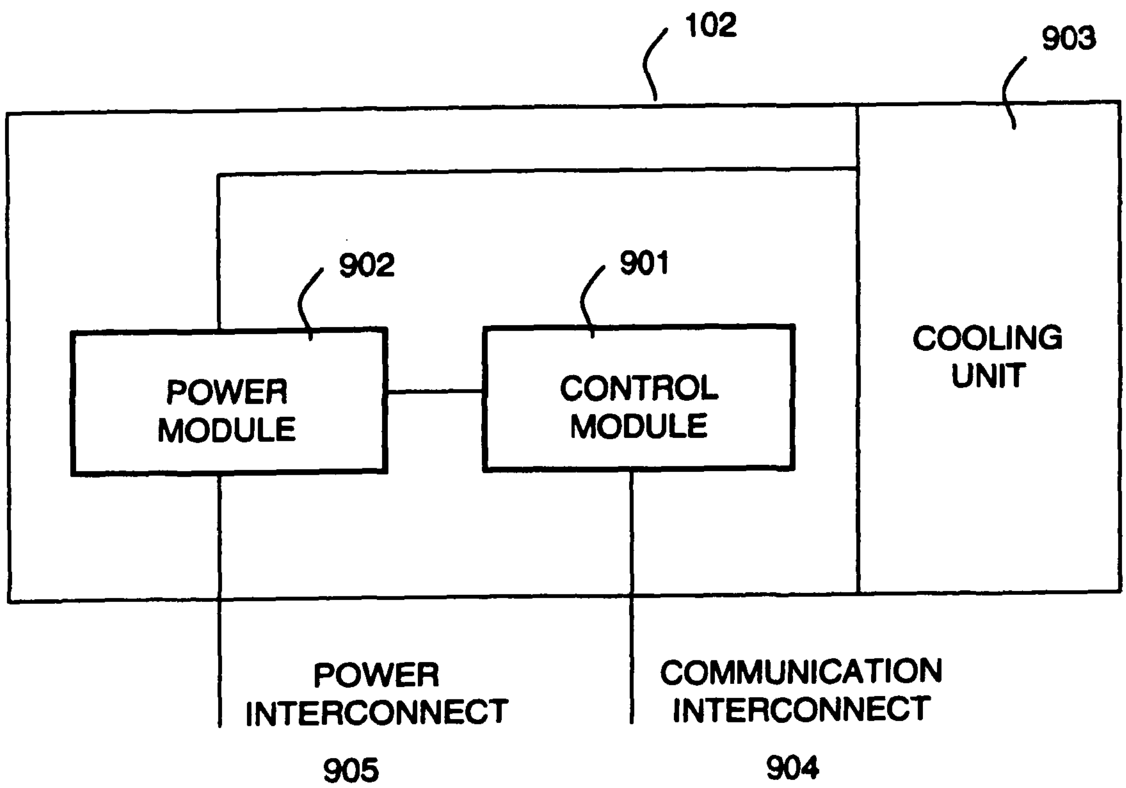
102
903
902
901
POWER MODULE
CONTROL MODULE
COOLING UNIT
POWER INTERCONNECT
905
COMMUNICATION INTERCONNECT
904

FIGURE 9

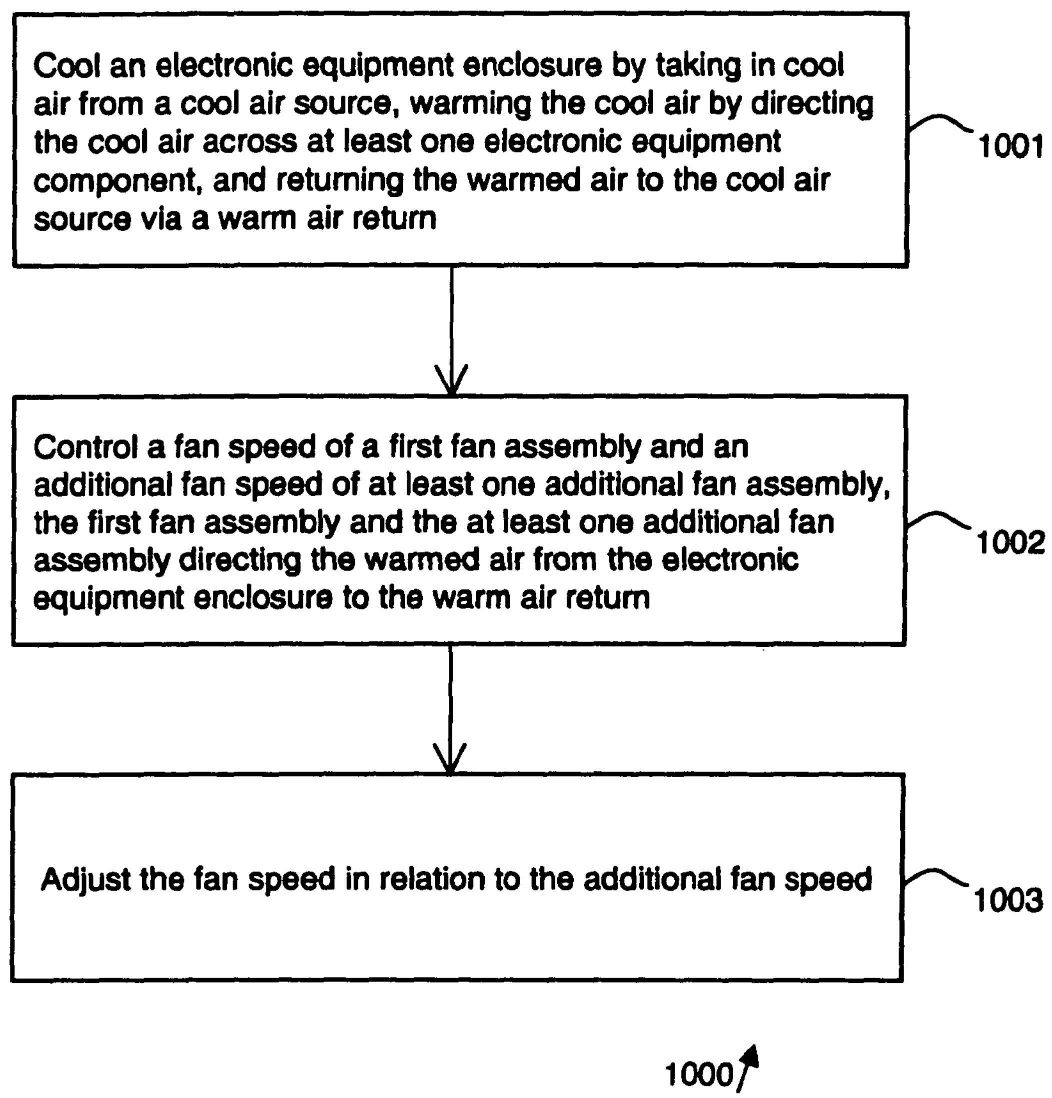
Cool an electronic equipment enclosure by taking in cool air from a cool air source, warming the cool air by directing the cool air across at least one electronic equipment component, and returning the warmed air to the cool air source via a warm air return
1001
Control a fan speed of a first fan assembly and an additional fan speed of at least one additional fan assembly, the first fan assembly and the at least one additional fan assembly directing the warmed air from the electronic equipment enclosure to the warm air return
1002
Adjust the fan speed in relation to the additional fan speed
1003
1000

FIGURE 10

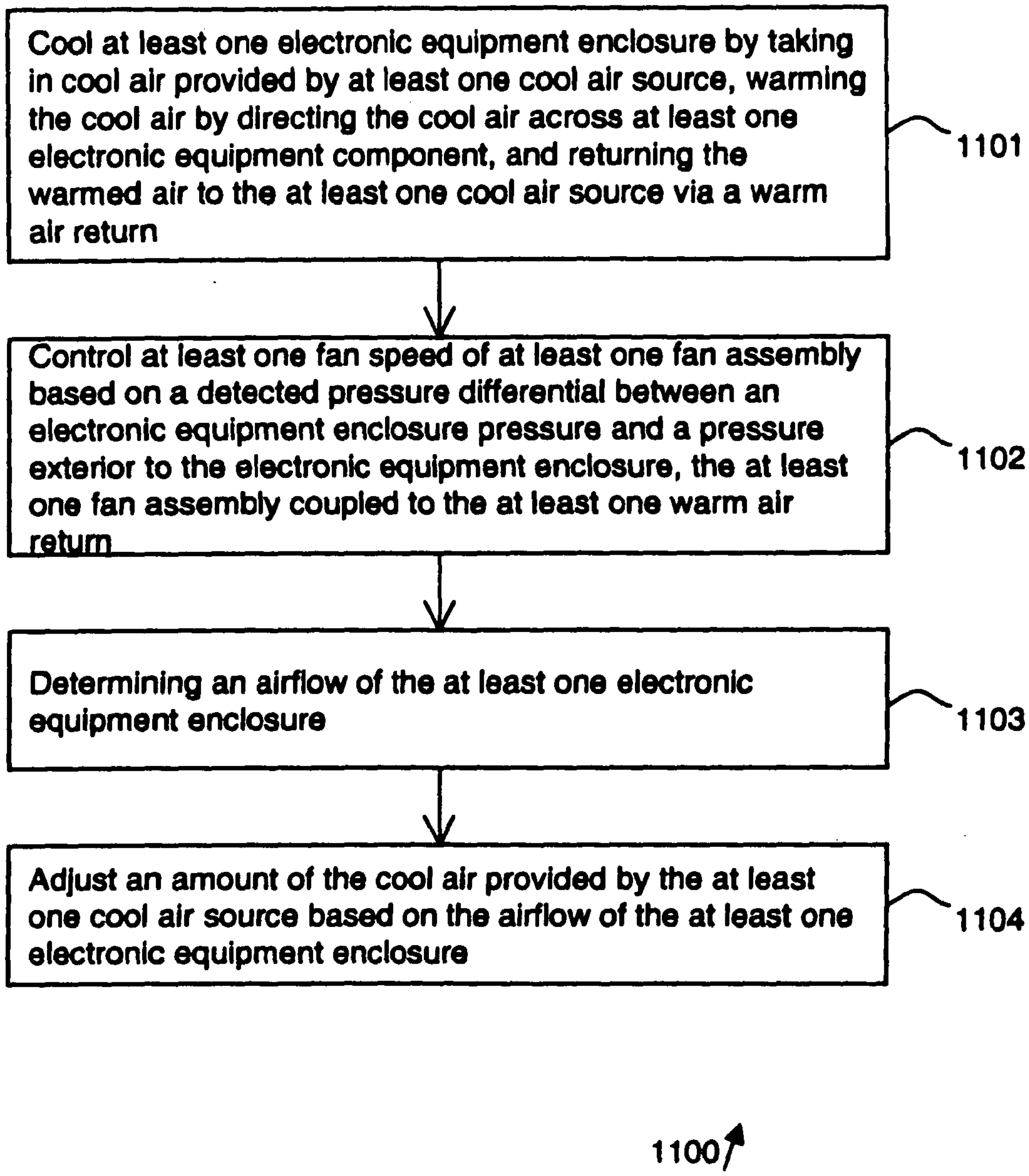
Cool at least one electronic equipment enclosure by taking in cool air provided by at least one cool air source, warming the cool air by directing the cool air across at least one electronic equipment component, and returning the warmed air to the at least one cool air source via a warm air return
1101
Control at least one fan speed of at least one fan assembly based on a detected pressure differential between an electronic equipment enclosure pressure and a pressure exterior to the electronic equipment enclosure, the at least one fan assembly coupled to the at least one warm air return
1102
Determining an airflow of the at least one electronic equipment enclosure
1103
Adjust an amount of the cool air provided by the at least one cool air source based on the airflow of the at least one electronic equipment enclosure
1104
1100

FIGURE 11

INTERNATIONAL SEARCH REPORT

International application No. PCT/US 08/10306

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - H05K 7/20 (2008.04)

USPC - 361/695

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
USPC: 361/695

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
USPC: 361/687,690-692,694-697,724 (text searched)

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
PubWEST(USPT,PGPB,EPAB,JPAB); Google Scholar
Search Terms - fan, control, speed, indicator, chassis, display, electronic, pressure differential, cartridge

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5,168,424 A (Bolton et al.) 01 December 1992 (01.12.1992), entire document, especially col 1, ln 47-53 and col 4, ln 1-20	1-30
Y	US 2004/0243280 A1 (Bash et al.) 02 December 2004 (02.12.2004), entire document, especially para [0032]	1-30
Y	US 2006/0111816 A1 (Spalink et al.) 25 May 2006 (25.05.2006), entire document, especially para [0089]	2, 7, 11-20, and 23
Y	US 2004/0196631 A1 (Ueda et al.) 07 October 2004 (07.10.2004), entire document, especially para [0048]	3, 8, 29, and 30
Y	US 2007/0080653 A1 (Wei et al.) 12 April 2007 (12.04.2007), entire document, especially para [0022]	22-30
Y	US 6,101,459 A (Tavallaei et al.) 08 August 2000 (08.08.2000), entire document, especially col 7, ln 1-5	22-30
A	US 2004/0190246 A1 (Arbogast et al.) 30 September 2004 (30.09.2004), entire document, especially para [0034]	1-30
A	US 6,247,898 B1 (Henderson et al.) 19 June 2001 (19.06.2001), entire document, especially Abstract	1-30

☐ Further documents are listed in the continuation of Box C. ☐

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
06 November 2008 (06.11.2008)	19 NOV 2008

Name and mailing address of the ISA/US	Authorized officer:
Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-3201	Lee W. Young PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774