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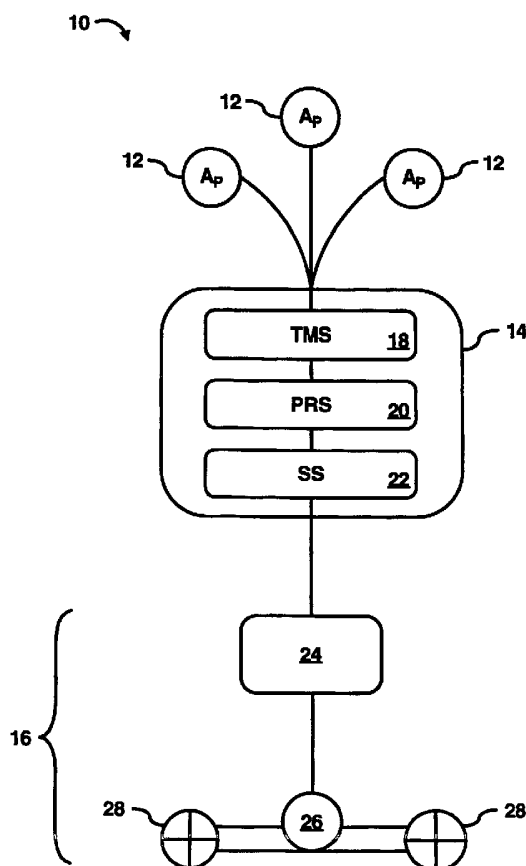
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- (71) Applicant: **HEWLETT-PACKARD DEVELOPMENT COMPANY L.P.** [US/US]; 20555 S.H. 249, Houston, TX 77070 (US). For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: ATMOSPHERIC CONTROL WITHIN A BUILDING



(57) Abstract: A method and system (10) for controlling atmospheric conditions within a building. A conditioned fluid is supplied (100) inside of the building and one or more atmospheric parameters in various locations inside of the building are sensed (102). An empirical atmospheric map is then generated (104) and compared (106) to a template atmospheric map. Pattern differentials are identified (108) therebetween and corrective action to reduce the pattern differentials is determined (110/112/114). One or more of the quantity, quality, and distribution of the conditioned fluid may be varied (116) in accord with the corrective action determination.

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PATENT

ATMOSPHERIC CONTROL WITHIN A BUILDING

CROSS-REFERENCES TO RELATED APPLICATIONS

5 The present invention is related to the following pending applications: Ser. No. 09/970,707, filed October 5, 2001, and entitled "SMART COOLING OF DATA CENTERS", by Patel et al.; Ser. No. XX/XXX,XXX, filed February 19, 2002, and entitled "DESIGNING LAYOUT FOR INTERNET DATACENTER COOLING", by Nakagawa et al; and Ser. No. XX/XXX,XXX, filed Month DD, YYYY, and entitled "DATA CENTER ENERGY
10 MANAGEMENT", by Friedrich et al. Each of the above listed cross-references is assigned to the assignee of the present invention and is incorporated by reference herein.

BACKGROUND

15 The present invention relates to controlling atmospheric conditions within a building. One type of building is a data center that houses numerous electronic packages. Each electronic package is arranged in one of a plurality of racks distributed throughout the data center. A rack may be defined as an Electronics Industry Association (EIA) enclosure and may be configured to house a number of personal computer (PC) boards. The PC boards
20 typically include a number of electronic packages, such as processors, micro-controllers, high speed video cards, memories, semi-conductor devices, and the like. These electronic packages dissipate relatively significant amounts of heat during the operation of the respective components. For example, a typical PC board comprising multiple microprocessors may dissipate approximately 250 W of power. Thus, a rack containing forty
25 (40) PC boards of this type may dissipate approximately 10 KW of power.

The power required to remove the heat dissipated by the electronic packages in a given rack is generally equal to about 10 percent of the power needed to operate the packages. However, the power required to remove the heat dissipated by a plurality of racks in a data center is generally equal to about 50 percent of the power needed to operate the
5 packages in the racks. The disparity in the amount of power required to dissipate the various heat loads between racks of data centers stems from the additional thermodynamic work needed in the data center to cool the air. Racks are typically cooled with fans that operate to move cooling fluid, such as air, across the heat dissipating components, whereas data centers often use reverse power cycles to cool heated return air. The additional work required to
10 achieve the temperature reduction, in addition to the work associated with moving the cooling fluid in the data center and the condenser, often add up to the 50 percent power requirement mentioned above. As such, the cooling of entire data centers presents major challenges beyond those faced with the cooling of individual racks of electronic packages.

15 To substantially guarantee proper operation and to extend the life of the electronic packages arranged in the racks of the data center, it is necessary to maintain the temperatures of the packages within predetermined safe operating ranges. Operation at temperatures above maximum operating temperatures may result in irreversible damage to the electronic packages. In addition, it has been established that the reliabilities of electronic packages,
20 such as semiconductor electronic devices, decrease with increasing temperature. Therefore, the heat energy produced by the electronic packages during operation must thus be removed at a rate that ensures that operational and reliability requirements are met. Because of the relatively large size of data centers and the high number of electronic packages contained therein, it is often expensive to cool data centers within the predetermined temperature
25 ranges.

Data centers are typically cooled by operation of one or more air conditioning units. The compressors of the air conditioning units typically require a minimum of about thirty (30) percent of the required cooling capacity to sufficiently cool the data centers. The other components, such as condensers, air movers (fans), etc., typically require an additional
5 twenty (20) percent of the required cooling capacity. For example, a high density data center with 100 racks, each rack having a maximum power dissipation of 10KW, generally requires 1 MW of cooling capacity. Air conditioning units with a capacity of 1 MW of heat removal generally require a minimum of 300 KW input compressor power in addition to the power needed to drive the air moving devices, e.g., fans, blowers, etc.

10

Conventional data center air conditioning units do not vary their cooling output based on the distributed, location-specific needs of the data center. Typically, the distribution of work among the operating electronic components in the data center is random and is not controlled. Because of work distribution, some components in one location of the data center
15 may be operating at a maximum capacity, while other components in another location of the data center may be operating at various power levels below a maximum capacity. Furthermore, conventional cooling systems typically operate at 100 percent of capacity on a continuous basis, thereby cooling all electronic packages, regardless of need. In other words, data centers are air conditioned on an overall, room-level basis, thereby yielding
20 unnecessarily high operating expenses to sufficiently cool the heat generating components contained in the racks of data centers. Moreover, prior art attempts at cooling use relatively inaccurate and unsophisticated methods of monitoring and adjusting temperature distribution that result in less than optimal data center cooling efficiency.

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BRIEF SUMMARY OF THE INVENTION

According to one embodiment of the present invention, there is provided a method of controlling atmospheric conditions within a building. The method includes the steps of supplying a conditioned fluid inside of the building and sensing one or more atmospheric parameters in various locations inside of the building. From the results of the sensing step, an empirical atmospheric map is then generated and compared to a template atmospheric map. Pattern differentials are identified between the empirical and template atmospheric maps, and corrective action is determined to reduce the pattern differentials. Finally, one or more of the quantity, quality, and distribution of the conditioned fluid is varied. According to another aspect of the present invention, there is provided a system for carrying out an embodiment of the method of the present invention.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

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Features and advantages of the present invention will become apparent to those skilled in the art from the following description with reference to the drawings, in which:

Fig. 1 is a schematic illustration of an embodiment of a system of the present invention; and

Fig. 2 is a flow chart of an embodiment of a method of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

The present invention is not limited in its application to the details of any particular arrangement described or shown, since the present invention is capable of multitudes of
5 embodiments without departing from the spirit and scope of the present invention. First, the principles of the present invention are described by referring to only a limited number of embodiments for simplicity and illustrative purposes. Although only a limited number of
embodiments of the invention are particularly disclosed herein, one of ordinary skill in the art would readily recognize that the same principles are equally applicable to, and can be
10 implemented in all types of atmospheric control systems. Furthermore, numerous specific details are set forth to convey with reasonable clarity the inventor's possession of the present invention, how to make and/or use the present invention, and the best mode in carrying out the present invention known to the inventor at the time of application. It will, however, be apparent to one of ordinary skill in the art that the present invention may be practiced without
15 limitation to these specific details. In other instances, well known methods and structures have not been described in detail so as not to unnecessarily obscure the present invention. Finally, the terminology used herein is for the purpose of description and not of limitation. Thus, the following detailed description is not to be taken in a limiting sense and the scope of the present invention is defined by the claims and their equivalents.

20

Generally in accord with the present invention, a method and related system are configured to control one or more atmospheric conditions within a building. More specifically, the method and system are configured to adjust one or more of the quantity, quality, and distribution of a conditioned fluid throughout a data center. The method and
25 system are configured to accomplish such control based upon atmospheric mapping and

pattern recognition; using as input, one or more atmospheric parameters measured at various, discrete sensor locations throughout the data center.

In accord with one embodiment of the present invention, the amount of energy typically required to cool a data center may be relatively reduced by strategically distributing cooling fluid, or conditioned air, within the data center by substantially favoring or increasing the cooling fluid flow to locations within the data center having racks that dissipate greater amounts of heat, and by substantially disfavoring or decreasing the cooling fluid flow to locations having racks that dissipate lesser amounts of heat. Thus, instead of operating devices, e.g., compressors, fans, etc., of the cooling system at substantially 100 percent of the anticipated heat dissipation from the racks, those devices may be operated according to the actual location and area specific cooling needs. In addition, the racks may be positioned throughout the data center according to their anticipated heat loads to thereby enable computer room air conditioning (CRAC) units located at various positions throughout the data center to operate in a more efficient manner. In another respect, the positioning of the racks and cooling strategy may be determined through implementation of modeling and metrology of the cooling fluid flow throughout the data center. In addition, the numerical modeling may be implemented to determine the volume flow rate and velocity of the cooling fluid flow through the data center.

20

Referring specifically in detail to the Figures, there is shown in Figure 1 a schematic view of the system 10 that may be used in accordance with an embodiment of the present invention. The system 10 generally includes atmospheric sensors 12, a central processing unit (CPU) 14, and an atmospheric control system 16. The atmospheric control system 16 can be a smart cooling system, exemplified by co-pending U.S. Patent Application Ser. No.

25

09/970,707, filed on October 5, 2001, by Patel et al., assigned to the assignee hereof, and incorporated by reference herein in its entirety. Alternatively, it is contemplated that any type of system directed at controlling atmospheric conditions could be employed, including air-conditioner systems, humidifier systems, filtering systems, fire suppression systems, etc.

5

The atmospheric sensors 12 are used for measuring one or more atmospheric parameter and encompass temperature sensors, such as thermocouples, temperature transducers, thermistors, or the like. The atmospheric sensors 12 could also include humidity sensors, barometric or pressure sensors, fluid velocity sensors, particle sensors, smoke
10 sensors, and the like. The atmospheric sensors 12 are located throughout the portions of a data center type of building (not shown) that are desired to be atmospherically controlled. Specifically, the atmospheric sensors 12 can be positioned in a variety of ways. For example, the atmospheric sensors 12 could be dispersed randomly in various locations and elevations, or aligned according to a predetermined coordinate grid, or placed in alignment with
15 locations of vents and/or racks, or placed in accordance with the recommendations from a computational fluid dynamics model. In any case, it is contemplated that very large data centers, measured in the tens of thousands of square feet, may require thousands of atmospheric sensors 12 spread throughout. The atmospheric sensors 12 are electronically communicated with the CPU 14 either through wiring or via wireless telemetry. In any case,
20 the CPU 14 is capable of keeping track of the location of each atmospheric sensor 12 such that the output of each can be "mapped".

The CPU 14 can be a stand-alone personal computer, a computer board or boards docked within one of the racks in the data center, a computer chip, etc., regardless, the CPU
25 14 includes various software that is loaded thereto. First, the CPU 14 includes software for

generating maps of atmospheric conditions, such as thermal mapping software 18. Thermal mapping software 18 is capable of processing thousands of input data points, such as thousands of sensor signals, and outputting map-like information. For example, a thermal map is composed of temperature contours that define various isothermal regions, or isotherms, of distinct temperatures. The most severe of these isotherms are commonly known as "hot spots". Hot spots may not necessarily correspond in exact location to any given temperature sensor, but may be located between various temperature sensors. Nevertheless, thermal mapping software can extrapolate or triangulate the location of the actual hot spot from the known locations of the temperature sensors. So, if temperature sensors are located in a range of elevations in various latitudinal and longitudinal coordinate positions of a data center, the thermal mapping software can triangulate not only the coordinate position of a hot spot, but also the elevation thereof. The temperature sensor readings provide temperature data and data for calculating temperature gradients, which are used to create a thermal map. In the absence of accurate or comprehensive temperature data, temperature gradients can be used to locate hot spots in the data center by mathematical optimization techniques like steepest gradient, etc. In general, triangulation presents a relatively accurate and efficient approximation technique and, thus, it is possible to use fewer, more sparsely distributed temperature sensors to save on equipment expense and failure modes if desired.

20

Second, the CPU 14 includes software for recognizing pattern differentials in such maps, more commonly known as pattern recognition software 20. Such software basically involves a decoding process in which discriminations in patterns are made without human intervention. Third, strategic software 22 is loaded on the CPU 14 and is used to determine a course of corrective action to minimize or eliminate the pattern differentials by accepting

25

output of the mapping software 18, processing it, and outputting commands to the cooling system 16. It is contemplated that commercial, general purpose mathematical optimization software like MATLAB could be adapted to generate thermal maps and identify hot spots by pattern recognition. It is also contemplated at this time that application-specific neural
5 network algorithms can also be used to do the same.

In response, the cooling system 16 is used to vary one or more of the quantity, quality, and distribution of the cooling fluid used to cool the data center. The cooling system 16 encompasses a chiller unit 24, but those skilled in the art will recognize that multitudes of
10 other types of cooling systems are generally well-known and available for use with the present invention including, for example, refrigeration systems, cooling tower systems, cooler-condenser systems, and the like. In any case, the cooling system 16 also includes one or more variable-speed air movers or blowers 26, and one or more remotely controlled dampers or vents 28. Those skilled in the art will recognize that ventilation structure
15 connecting the blower, vents, etc. are well known in the relevant art of Heating, Ventilating, and Air Conditioning (HVAC).

It is possible to vary any combination of cooling system control variables to change the quantity, quality, and/or distribution of the cooling fluid and thereby adjust the
20 atmospheric conditions within the data center. For example, chiller cycle can be increased or decreased between 0% and 100% of operating capacity to change the cooling quality of the cooling fluid, i.e. temperature, humidity, particulate count, etc. To change the quantity of cooling fluid, such as conditioned air, the speed and/or baffling of the blower 26 can be adjusted, and the percentage opening of the vents 28 can be varied, either individually or
25 collectively. Also, if the vents 28 include individual blowers (not shown), such blowers

could also be adjusted in speed. To change the distribution of conditioned air, one or more of multiple chillers, blowers, and vents can be strategically adjusted to target one or more hot spot locations within the data center. For example, if one corner of the data center is demanding the most significant portion of the cooling needs of the entire data center, then the most proximate chiller(s), blower(s), and vent(s) can be selected, while the other, relatively distant chiller(s), blower(s), and vent(s) can be deactivated or reduced. It is contemplated that any other reasonably foreseen atmospheric control system control variables could also be adjusted.

Referring now to Figure 2, in addition to the embodiment described above, an embodiment of a method of the present invention involves cooperation of the CPU between the temperature sensors and the cooling system. The method of the present invention could also be practiced using other systems besides the one disclosed herein, and thus is not limited thereby. The system disclosed herein is simply one of many possible physical manifestations of the method. As discussed previously, the cooling system supplies a cooling fluid within the data center to cool the equipment within the data center, as shown in block 100. In block 102, the temperature within the data center is sensed in various locations and is communicated to the CPU.

The thermal mapping software converts the point-specific temperature sensor data into information by generating an empirical thermal map therefrom, as depicted in block 104. As discussed above, a thermal map can triangulate hot spots from discrete sensor locations based on mathematical optimization techniques. Hot spots are known to arise in several situations, for example, where electronic packages in a given rack draw exceptional amounts of power due to exceptionally high usage of those packages, and the data center cooling

system cannot supply enough conditioned fluid to alleviate the overheating. Hot spots may also arise when racks output normal amounts of heat, but the data center cooling system is malfunctioning in a specific location, or in general.

5 The thermal mapping step may be executed on an instantaneous, snapshot, or sampling basis but, alternatively, this step may be done on a real-time basis. It is also contemplated that the thermal map could be generated directly, without discrete temperature sensors, using thermography technology, based on infrared detection of heat that is emitted by the equipment in the data center. It is further contemplated that the thermal map could be
10 generated by estimating temperature as a function of the power draw to the electronic packages and/or racks within the data center. Thus, the temperature sensing and map generating steps could be accomplished with thermographic equipment and software, or inferring temperature from power draw.

15 The thermal map also provides a powerful visual tool for a data center operator. A typical data center is a highly thermally interdependent environment where thermal performance of each electronic package of each rack affects performance of neighboring packages and racks to various orders of magnitude. Thus, a thermal map also provides a pictorially informative way of identifying the thermal interdependencies across the data
20 center landscape.

As shown in block 106, the pattern recognition software compares the empirical thermal map to a template thermal map. The template thermal map could also be termed a master, or model thermal map. The template basically represents a thermal map of an
25 optimally operating data center cooling system. The template can be dynamic, generated

either in real-time from current operating conditions, or can be static, generated prior to the comparing step 106. Computational fluid dynamics (CFD) software tools, such as FLOVENT/AIRPACK, are widely available and known to those skilled in the art. The CFD tool accepts various inputs for modeling, including heat loads from the racks within the data center, velocity of the cooling fluid flowing throughout the data center, temperature, pressure, and the like in the data center. CFD modeling can be used in the design and layout of a data center, suggesting locations for racks and vents. Alternatively, CFD modeling can be used to output a master, template, or model thermal map to be emulated by adjusting cooling system variables. Instructive in this regard is U.S. Patent Application Ser. No. XX/XXX,XXX, filed on February 19, 2002, and entitled "DESIGNING LAYOUT FOR INTERNET DATACENTER COOLING", by Nakagawa et al., assigned to the assignee hereof and incorporated by reference herein in its entirety.

After, or while, the empirical thermal map is compared to the model thermal map, the pattern recognition software is also applied to recognize pattern differentials therebetween, as depicted in block 108. Pattern recognition is also commonly referred to as template matching, masking, etc. For example, in the case of data center cooling, thermal hot spots can be identified. Once identified, an initial classification step occurs as depicted by block 110. Certain isotherms may exceed a predetermined range of temperature, size, etc., and thus can be targeted for elimination or reduction. Alternatively, if all isotherms are within the predetermined range of temperature, size, etc., then the cooling system simply maintains current operating conditions and settings, as depicted in block 112.

Upon recognizing the pattern differentials, the strategic software is used to determine the corrective action required to eliminate or at least reduce pattern differentials within the

data center, as depicted in block 114. Control variable data, such as the location of the vents, the capacity of the blower, and the capacity of the chiller, are used to determine how most efficiently to cool the data center. In addition, the thermal map data is also used, such as the location, size, and intensity of the isotherms. Specifically, the above-mentioned data sets are
5 correlated to develop an optimally efficient course of corrective action.

In block 116, based on the corrective action selected, one or more of the quantity, quality, and distribution of the conditioned fluid of the cooling system is varied. For example, if the size and/or intensity of an hot spot isotherm is relatively small, then the
10 cooling system can merely adjust the opening size of the vent closest to the location of the isotherm. If, on the other hand, the size and/or intensity of an isotherm is relatively large, then multiple vents can be adjusted in addition to increasing the chiller cycle. Similarly, if the cooling system included multiple chillers, the chiller most proximate the isotherm could be increased in cycle. In general, the quantity and/or quality of the cooling fluid can be
15 decreased, or maintained, for locations of the data center that exhibit pattern differentials within a predetermined acceptable range. In contrast, the quantity and/or quality of the cooling fluid may be increased for locations of the data center that exhibit pattern differentials outside of a predetermined acceptable range. Finally, the method is carried out such that the temperature sensing step through the step of varying the conditioned air can be a
20 continuous loop.

Those of ordinary skill in the art will recognize that the present invention is capable of substantially reducing the energy consumption associated with cooling a data center, by virtue of using directed, location-specific cooling instead of diffused, room-level cooling.
25 More particularly, the cooling system can be operated relatively more efficiently compared to

the prior art by virtue of a more precise method of tracking and using actual temperature measurement as an input to cooling system control. In other words, the present invention provides methodology for extracting a large amount of discrete, location-specific temperature data points and converting same into more continuous, fluid-like information in the form of a thermal map. The present invention is suited for use with applications requiring thousands of sensors, or even just a few well-placed sensors. Regardless, the present invention enables use of the spaces between the sensor locations to be included in assessing or triangulating the locations, size, and intensity of hot spots, resulting in more accurate hot spot reduction than the prior art allows for. Therefore, compared to the prior art and for a given size data center, the present invention presents a more accurate and efficient cooling method, thus requiring fewer and smaller cooling devices and less energy consumption.

While the present invention has been described in terms of a limited number of embodiments, it is apparent that other forms could be adopted by one skilled in the art. In other words, the teachings of the present invention encompass any reasonable substitutions or equivalents of claim limitations. For example, other modes of carrying out the method steps could be used in addition to those described here, and the method could be practiced independently of the specific system disclosed herein. Those skilled in the art will appreciate that other applications, including those outside of data center cooling, are possible with this invention. Accordingly, the present invention is not limited to only cooling of data centers, but rather applies broadly to many other environmental control systems, including particulate filtering, HVAC, etc. Accordingly, the scope of the present invention is to be limited only by the following claims.

1 What is claimed is:

2 1. A method of controlling atmospheric conditions within a building, said
3 method comprising the steps of:

4 supplying (100) a conditioned fluid inside said building;
5 sensing (102) at least one atmospheric parameter in a plurality of locations
6 inside said building;

7 generating (104) an empirical atmospheric map from the results of said
8 sensing step;

9 comparing (106) said empirical atmospheric map to a template atmospheric
10 map; and

11 identifying (108) pattern differentials between said empirical and template
12 atmospheric maps.

13 2. The method as claimed in claim 1, further comprising the steps of:

14 determining (110/112/114) corrective action to reduce said pattern
15 differentials; and

16 varying (116) at least one of the quantity, quality, and distribution of said
17 conditioned fluid in accord with said determining step.

18 3. The method as claimed in claim 2, wherein said supplying step
19 comprises the step of operating a system (10) having at least one of a plurality of vents (28),

20 at least one blower (26), and at least one source of conditioned air (24), and further wherein

21 said determining step comprises correlating at least one of the location, size, and intensity of

22 said pattern differentials to at least one of the location of said plurality of vents, the speed of

23 said at least one blower, and the capacity of said at least one source of conditioned air.

1 4. The method as claimed in claim 1, wherein said generating step
2 comprises using thermal mapping software (18) to process input from said sensing step and to
3 produce output in the form of said empirical atmospheric map.

4 5. A method of cooling a data center having equipment therein, said
5 method comprising the steps of:

6 supplying (100) a cooling fluid within said data center to cool said equipment
7 within said data center;

8 sensing (102) temperature within said data center in a plurality of locations;

9 generating (104) an empirical thermal map of said data center from the results
10 of said sensing step;

11 comparing (106) said empirical thermal map to a template thermal map; and

12 identifying (108) pattern differentials between said empirical and template
13 thermal maps.

14 6. The method as claimed in claim 5, further comprising the steps of:

15 determining (110/112/114) corrective action to reduce said pattern
16 differentials; and

17 varying (116) at least one of the quantity, quality, and distribution of said
18 cooling fluid in accord with said determining step.

19 7. The method as claimed in claim 6, wherein said supplying step
20 comprises operating a system (10) having at least one of a plurality of vents (28), at least one
21 blower (26), and at least one source of conditioned air (24).

22 8. The method as claimed in claim 7, wherein said determining step
23 comprises correlating at least one of the location, size, and intensity of said pattern
24 differentials to at least one of the location of said plurality of vents, the speed of said at least
25 one blower, and the capacity of said at least one source of conditioned air.

1 / 2

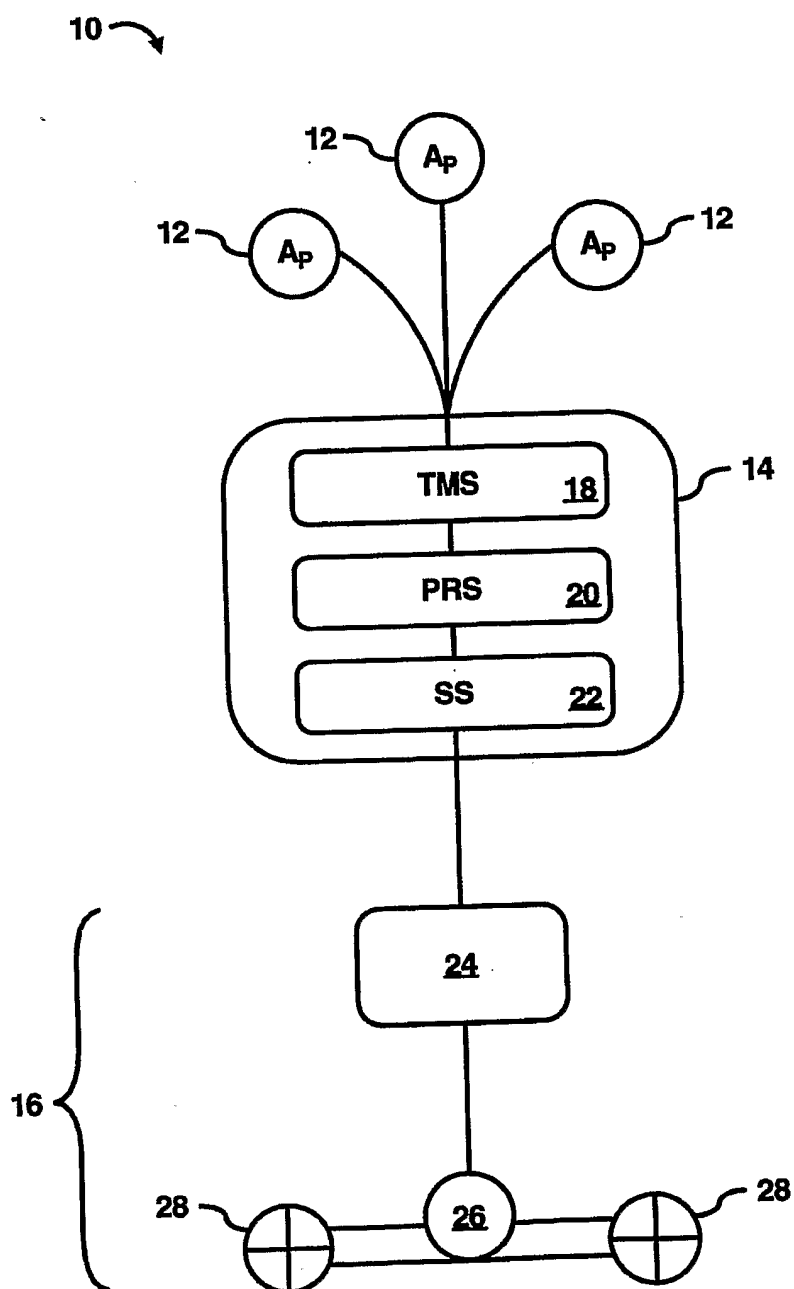


FIG. 1

2 / 2

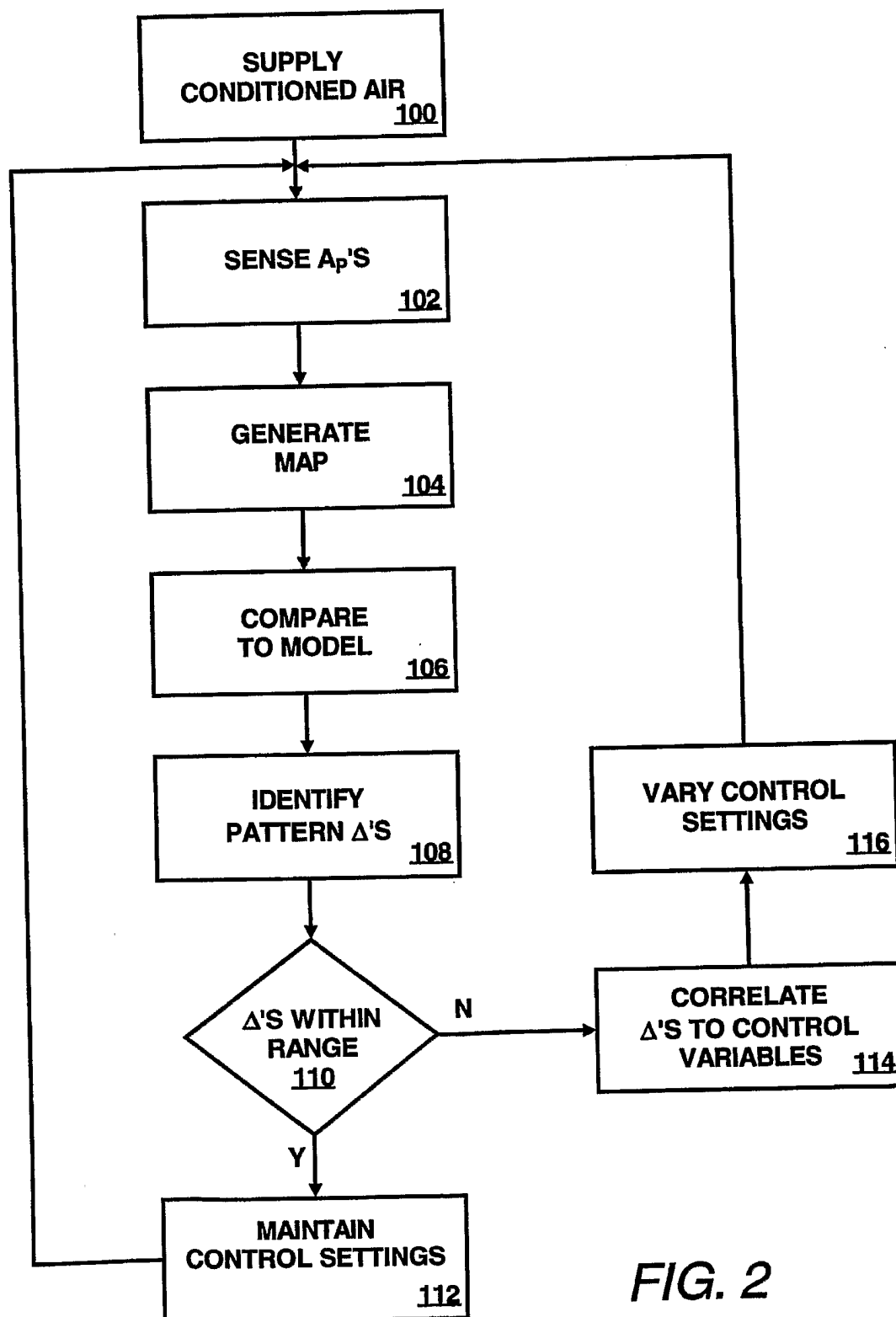


FIG. 2

INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 03/11545

A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 F24F11/00 G05D23/19 H05K7/20

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)

IPC 7 F24F G05D H05K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 769 315 A (DREES KIRK H) 23 June 1998 (1998-06-23) abstract; claims 1,3,11-13 ---	1-8
A	PATENT ABSTRACTS OF JAPAN vol. 018, no. 565 (M-1694), 28 October 1994 (1994-10-28) & JP 06 201175 A (TOSHIBA CORP), 19 July 1994 (1994-07-19) abstract ---	1-8
A	PATENT ABSTRACTS OF JAPAN vol. 1996, no. 11, 29 November 1996 (1996-11-29) & JP 08 170849 A (DAIKIN IND LTD), 2 July 1996 (1996-07-02) abstract --- -/--	

☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

* Special categories of cited documents :

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

17 July 2003

Date of mailing of the international search report

24/07/2003

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INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 03/11545

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5 649 766 A (BLAKE MARTIN K P) 22 July 1997 (1997-07-22) -----	

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/US 03/11545

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