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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
11/670,208	02/01/2007	James K. MARTIN	021944-105US	6687

26720	7590	03/01/2010
LOCKE LORD BISSELL & LIDDELL LLP		
ATTN: IP DOCKETING		
600 TRAVIS STREET		
3400 CHASE TOWER		
HOUSTON, TX 77002		

EXAMINER	
ZEC, FILIP	

ART UNIT	PAPER NUMBER
3744	

NOTIFICATION DATE	DELIVERY MODE
03/01/2010	ELECTRONIC

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

Notice of the Office communication was sent electronically on above-indicated "Notification Date" to the following e-mail address(es):

hoip@lockelord.com

VALTRUS EXHIBIT 2039
VERTIV v. VALTRUS IPR2025-00669
1 of 227

Notice of Abandonment

Application No.

11/670,208

Examiner

Filip Zec

Applicant(s)

MARTIN, JAMES K.

Art Unit

3744

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address--

This application is abandoned in view of:

1. ☒ Applicant's failure to timely file a proper reply to the Office letter mailed on 21 August 2009.
 - (a) ☐ A reply was received on _____ (with a Certificate of Mailing or Transmission dated _____), which is after the expiration of the period for reply (including a total extension of time of _____ month(s)) which expired on _____.
 - (b) ☐ A proposed reply was received on _____, but it does not constitute a proper reply under 37 CFR 1.113 (a) to the final rejection. (A proper reply under 37 CFR 1.113 to a final rejection consists only of: (1) a timely filed amendment which places the application in condition for allowance; (2) a timely filed Notice of Appeal (with appeal fee); or (3) a timely filed Request for Continued Examination (RCE) in compliance with 37 CFR 1.114).
 - (c) ☐ A reply was received on _____ but it does not constitute a proper reply, or a bona fide attempt at a proper reply, to the non-final rejection. See 37 CFR 1.85(a) and 1.111. (See explanation in box 7 below).
 - (d) ☒ No reply has been received.
2. ☐ Applicant's failure to timely pay the required issue fee and publication fee, if applicable, within the statutory period of three months from the mailing date of the Notice of Allowance (PTOL-85).
 - (a) ☐ The issue fee and publication fee, if applicable, was received on _____ (with a Certificate of Mailing or Transmission dated _____), which is after the expiration of the statutory period for payment of the issue fee (and publication fee) set in the Notice of Allowance (PTOL-85).
 - (b) ☐ The submitted fee of \$_____ is insufficient. A balance of \$_____ is due.
The issue fee required by 37 CFR 1.18 is \$_____. The publication fee, if required by 37 CFR 1.18(d), is \$_____.
 - (c) ☐ The issue fee and publication fee, if applicable, has not been received.
3. ☐ Applicant's failure to timely file corrected drawings as required by, and within the three-month period set in, the Notice of Allowability (PTO-37).
 - (a) ☐ Proposed corrected drawings were received on _____ (with a Certificate of Mailing or Transmission dated _____), which is after the expiration of the period for reply.
 - (b) ☐ No corrected drawings have been received.
4. ☐ The letter of express abandonment which is signed by the attorney or agent of record, the assignee of the entire interest, or all of the applicants.
5. ☐ The letter of express abandonment which is signed by an attorney or agent (acting in a representative capacity under 37 CFR 1.34(a)) upon the filing of a continuing application.
6. ☐ The decision by the Board of Patent Appeals and Interference rendered on _____ and because the period for seeking court review of the decision has expired and there are no allowed claims.
7. ☒ The reason(s) below:

The abandonment was confirmed by D. Nguyen during the telephone conversation on 2/24/2010.

/Cheryl J. Tyler/
Supervisory Patent Examiner, Art Unit 3744

/Filip Zec/
Examiner, Art Unit 3744

Petitions to revive under 37 CFR 1.137(a) or (b), or requests to withdraw the holding of abandonment under 37 CFR 1.181, should be promptly filed to minimize any negative effects on patent term.



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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
11/670,208	02/01/2007	James K. MARTIN	021944-105US	6687
26720 7590 11/10/2009 LOCKE LORD BISSELL & LIDDELL LLP ATTN: IP DOCKETING 600 TRAVIS STREET 3400 CHASE TOWER HOUSTON, TX 77002			EXAMINER ZEC, FILIP	
			ART UNIT 3744	PAPER NUMBER
			NOTIFICATION DATE 11/10/2009	DELIVERY MODE ELECTRONIC

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hoip@lockelord.com

**VALTRUS EXHIBIT 2039
VERTIV v. VALTRUS IPR2025-00669
3 of 227**

Interview Summary	Application No. 11/670,208	Applicant(s) MARTIN, JAMES K.	
	Examiner Filip Zec	Art Unit 3744	

All participants (applicant, applicant's representative, PTO personnel):

(1) Filip Zec. (3) B. Nelson.

(2) C. Tyler. (4) D. Nguyen.

Date of Interview: 03 November 2009.

Type: a) ☒ Telephonic b) ☐ Video Conference
c) ☐ Personal [copy given to: 1) ☐ applicant 2) ☐ applicant's representative]

Exhibit shown or demonstration conducted: d) ☐ Yes e) ☒ No.
If Yes, brief description: _____.

Claim(s) discussed: 1.

Identification of prior art discussed: US Patent Application Publication 2003/0147214 to Patel and U.S. Patent 6,330,516 to Kammeter.

Agreement with respect to the claims f) ☐ was reached. g) ☐ was not reached. h) ☒ N/A.

Substance of Interview including description of the general nature of what was agreed to if an agreement was reached, or any other comments: See Continuation Sheet.

(A fuller description, if necessary, and a copy of the amendments which the examiner agreed would render the claims allowable, if available, must be attached. Also, where no copy of the amendments that would render the claims allowable is available, a summary thereof must be attached.)

THE FORMAL WRITTEN REPLY TO THE LAST OFFICE ACTION MUST INCLUDE THE SUBSTANCE OF THE INTERVIEW. (See MPEP Section 713.04). If a reply to the last Office action has already been filed, APPLICANT IS GIVEN A NON-EXTENDABLE PERIOD OF THE LONGER OF ONE MONTH OR THIRTY DAYS FROM THIS INTERVIEW DATE, OR THE MAILING DATE OF THIS INTERVIEW SUMMARY FORM, WHICHEVER IS LATER, TO FILE A STATEMENT OF THE SUBSTANCE OF THE INTERVIEW. See Summary of Record of Interview requirements on reverse side or on attached sheet.

/Filip Zec/ Examiner, Art Unit 3744	/Cheryl J. Tyler/ Supervisory Patent Examiner, Art Unit 3744
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Summary of Record of Interview Requirements

Manual of Patent Examining Procedure (MPEP), Section 713.04, Substance of Interview Must be Made of Record

A complete written statement as to the substance of any face-to-face, video conference, or telephone interview with regard to an application must be made of record in the application whether or not an agreement with the examiner was reached at the interview.

Title 37 Code of Federal Regulations (CFR) § 1.133 Interviews Paragraph (b)

In every instance where reconsideration is requested in view of an interview with an examiner, a complete written statement of the reasons presented at the interview as warranting favorable action must be filed by the applicant. An interview does not remove the necessity for reply to Office action as specified in §§ 1.111, 1.135. (35 U.S.C. 132)

37 CFR §1.2 Business to be transacted in writing.

All business with the Patent or Trademark Office should be transacted in writing. The personal attendance of applicants or their attorneys or agents at the Patent and Trademark Office is unnecessary. The action of the Patent and Trademark Office will be based exclusively on the written record in the Office. No attention will be paid to any alleged oral promise, stipulation, or understanding in relation to which there is disagreement or doubt.

The action of the Patent and Trademark Office cannot be based exclusively on the written record in the Office if that record is itself incomplete through the failure to record the substance of interviews.

It is the responsibility of the applicant or the attorney or agent to make the substance of an interview of record in the application file, unless the examiner indicates he or she will do so. It is the examiner's responsibility to see that such a record is made and to correct material inaccuracies which bear directly on the question of patentability.

Examiners must complete an Interview Summary Form for each interview held where a matter of substance has been discussed during the interview by checking the appropriate boxes and filling in the blanks. Discussions regarding only procedural matters, directed solely to restriction requirements for which interview recordation is otherwise provided for in Section 812.01 of the Manual of Patent Examining Procedure, or pointing out typographical errors or unreadable script in Office actions or the like, are excluded from the interview recordation procedures below. Where the substance of an interview is completely recorded in an Examiners Amendment, no separate Interview Summary Record is required.

The Interview Summary Form shall be given an appropriate Paper No., placed in the right hand portion of the file, and listed on the "Contents" section of the file wrapper. In a personal interview, a duplicate of the Form is given to the applicant (or attorney or agent) at the conclusion of the interview. In the case of a telephone or video-conference interview, the copy is mailed to the applicant's correspondence address either with or prior to the next official communication. If additional correspondence from the examiner is not likely before an allowance or if other circumstances dictate, the Form should be mailed promptly after the interview rather than with the next official communication.

The Form provides for recordation of the following information:

- Application Number (Series Code and Serial Number)
- Name of applicant
- Name of examiner
- Date of interview
- Type of interview (telephonic, video-conference, or personal)
- Name of participant(s) (applicant, attorney or agent, examiner, other PTO personnel, etc.)
- An indication whether or not an exhibit was shown or a demonstration conducted
- An identification of the specific prior art discussed
- An indication whether an agreement was reached and if so, a description of the general nature of the agreement (may be by attachment of a copy of amendments or claims agreed as being allowable). Note: Agreement as to allowability is tentative and does not restrict further action by the examiner to the contrary.
- The signature of the examiner who conducted the interview (if Form is not an attachment to a signed Office action)

It is desirable that the examiner orally remind the applicant of his or her obligation to record the substance of the interview of each case. It should be noted, however, that the Interview Summary Form will not normally be considered a complete and proper recordation of the interview unless it includes, or is supplemented by the applicant or the examiner to include, all of the applicable items required below concerning the substance of the interview.

A complete and proper recordation of the substance of any interview should include at least the following applicable items:

- 1) A brief description of the nature of any exhibit shown or any demonstration conducted,
- 2) an identification of the claims discussed,
- 3) an identification of the specific prior art discussed,
- 4) an identification of the principal proposed amendments of a substantive nature discussed, unless these are already described on the Interview Summary Form completed by the Examiner,
- 5) a brief identification of the general thrust of the principal arguments presented to the examiner.
(The identification of arguments need not be lengthy or elaborate. A verbatim or highly detailed description of the arguments is not required. The identification of the arguments is sufficient if the general nature or thrust of the principal arguments made to the examiner can be understood in the context of the application file. Of course, the applicant may desire to emphasize and fully describe those arguments which he or she feels were or might be persuasive to the examiner.)
- 6) a general indication of any other pertinent matters discussed, and
- 7) if appropriate, the general results or outcome of the interview unless already described in the Interview Summary Form completed by the examiner.

Examiners are expected to carefully review the applicant's record of the substance of an interview. If the record is not complete and accurate, the examiner will give the applicant an extendable one month time period to correct the record.

Examiner to Check for Accuracy

If the claims are allowable for other reasons of record, the examiner should send a letter setting forth the examiner's version of the statement attributed to him or her. If the record is complete and accurate, the examiner should place the indication, "Interview Record OK" on the paper recording the substance of the interview along with the date and the examiner's initials.

Continuation of Substance of Interview including description of the general nature of what was agreed to if an agreement was reached, or any other comments: the applicant stated that the reasoning for combining Patel and Kammeter was confusing and incorrect, specifically, the Examiner's response to the argument that Patel teaches away from Kammeter because no where in Patel is stated that said invention would not work if the limitations of Kammeter were implemented on it (the branch control monitoring system vs the distributed system). It was clarified that this statement is not the basis for teaching away from a reference, and is hereby retracted. Further, after reviewing the amended claim 1 and the applicant arguments, the Examiner confirms the prior art rejection under 103 over Patel in view of Kammeter. As the applicant correctly states on page 8 of the arguments submitted 10/20/09, Patel discloses a distributed system wherein the information is sent from multiple locations to a controller, while Kammeter teaches a centralized system wherein the information is sent from multiple locations to a branch control monitor and then to a processing unit. It is clearly stated in Kammeter that "The inclusion of a digital signal processor module allows the branch circuit monitor to make data available, via communications protocols such as Modbus RTU or RS232/RS485/422, to any number of remote sites. The individual branch circuit monitors can be wired in a daisy chain or star network configuration and even connected to the Internet via an appropriate interface device so as to enable centralized billing or auditing of power usage, and remote monitoring of branch circuit conditions." (col 2, lines 41-49). One of ordinary skill in the art would find it obvious to replace the distributing system of Patel with the centralized system of Kammeter in order to allow the remote monitoring of heat loads for each individual power source, wherein the branch control monitor would gather the information from each of multiple sources, relay the information to the controller and thus replace the multiple computer boards (500, FIG. 5) of Patel, of each said individual power sources, which would simplify the overall control system and eliminate a situation where the computer board on location is defected and the signal is not sent to the controller.

Receipt date: 10/20/2009

Doc code: IDS

Doc description: Information Disclosure Statement (IDS) Filed

PTO/SB/08a (07-09)

Approved for use through 07/31/2012. OMB 0651-0031

U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)	Application Number		11670208	
	Filing Date		2007-02-01	
	First Named Inventor	MARTIN, James K.		
	Art Unit	3744		
	Examiner Name	ZEC, Filip		
	Attorney Docket Number	0021944-105US		

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Examiner Initial*	Cite No	Patent Number	Kind Code ¹	Issue Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines where Relevant Passages or Relevant Figures Appear	
/F.Z./	1	7596476		2009-09-29	Rasmussen et al.		

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Examiner Initials*	Cite No	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc), date, pages(s), volume-issue number(s), publisher, city and/or country where published.		T ⁵

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)	Receipt date: 10/20/2009	
	Application Number	11670208
	Filing Date	2007-02-01
	First Named Inventor	MARTIN, James K.
	Art Unit	3744
	Examiner Name	ZEC, Filip
Attorney Docket Number		0021944-105US

1		☐
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If you wish to add additional non-patent literature document citation information please click the Add button **Add**

EXAMINER SIGNATURE			
Examiner Signature	/Filip Zec/	Date Considered	10/23/2009

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through a citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

¹ See Kind Codes of USPTO Patent Documents at www.USPTO.GOV or MPEP 901.04. ² Enter office that issued the document, by the two-letter code (WIPO Standard ST.3). ³ For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document. ⁴ Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST.16 if possible. ⁵ Applicant is to place a check mark here if English language translation is attached.



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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
11/670,208	02/01/2007	James K. MARTIN	021944-105US	6687
26720 7590 10/29/2009 LOCKE LORD BISSELL & LIDDELL LLP ATTN: IP DOCKETING 600 TRAVIS STREET 3400 CHASE TOWER HOUSTON, TX 77002			EXAMINER ZEC, FILIP	
			ART UNIT 3744	PAPER NUMBER
			NOTIFICATION DATE 10/29/2009	DELIVERY MODE ELECTRONIC

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hoip@lockelord.com

**Advisory Action
Before the Filing of an Appeal Brief**

Application No.

11/670,208

Applicant(s)

MARTIN, JAMES K.

Examiner

Filip Zec

Art Unit

3744

--The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

THE REPLY FILED 20 October 2009 FAILS TO PLACE THIS APPLICATION IN CONDITION FOR ALLOWANCE.

1. ☒ The reply was filed after a final rejection, but prior to or on the same day as filing a Notice of Appeal. To avoid abandonment of this application, applicant must timely file one of the following replies: (1) an amendment, affidavit, or other evidence, which places the application in condition for allowance; (2) a Notice of Appeal (with appeal fee) in compliance with 37 CFR 41.31; or (3) a Request for Continued Examination (RCE) in compliance with 37 CFR 1.114. The reply must be filed within one of the following time periods:

- a) ☐ The period for reply expires _____ months from the mailing date of the final rejection.
- b) ☒ The period for reply expires on: (1) the mailing date of this Advisory Action, or (2) the date set forth in the final rejection, whichever is later. In no event, however, will the statutory period for reply expire later than SIX MONTHS from the mailing date of the final rejection.
- Examiner Note: If box 1 is checked, check either box (a) or (b). ONLY CHECK BOX (b) WHEN THE FIRST REPLY WAS FILED WITHIN TWO MONTHS OF THE FINAL REJECTION. See MPEP 706.07(f).

Extensions of time may be obtained under 37 CFR 1.136(a). The date on which the petition under 37 CFR 1.136(a) and the appropriate extension fee have been filed is the date for purposes of determining the period of extension and the corresponding amount of the fee. The appropriate extension fee under 37 CFR 1.17(a) is calculated from: (1) the expiration date of the shortened statutory period for reply originally set in the final Office action; or (2) as set forth in (b) above, if checked. Any reply received by the Office later than three months after the mailing date of the final rejection, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

NOTICE OF APPEAL

2. ☐ The Notice of Appeal was filed on _____. A brief in compliance with 37 CFR 41.37 must be filed within two months of the date of filing the Notice of Appeal (37 CFR 41.37(a)), or any extension thereof (37 CFR 41.37(e)), to avoid dismissal of the appeal. Since a Notice of Appeal has been filed, any reply must be filed within the time period set forth in 37 CFR 41.37(a).

AMENDMENTS

3. ☐ The proposed amendment(s) filed after a final rejection, but prior to the date of filing a brief, will not be entered because
- (a) ☐ They raise new issues that would require further consideration and/or search (see NOTE below);
- (b) ☐ They raise the issue of new matter (see NOTE below);
- (c) ☐ They are not deemed to place the application in better form for appeal by materially reducing or simplifying the issues for appeal; and/or
- (d) ☐ They present additional claims without canceling a corresponding number of finally rejected claims.

NOTE: _____. (See 37 CFR 1.116 and 41.33(a)).

4. ☐ The amendments are not in compliance with 37 CFR 1.121. See attached Notice of Non-Compliant Amendment (PTOL-324).
5. ☐ Applicant's reply has overcome the following rejection(s): _____.
6. ☐ Newly proposed or amended claim(s) _____ would be allowable if submitted in a separate, timely filed amendment canceling the non-allowable claim(s).
7. ☐ For purposes of appeal, the proposed amendment(s): a) ☐ will not be entered, or b) ☐ will be entered and an explanation of how the new or amended claims would be rejected is provided below or appended.
- The status of the claim(s) is (or will be) as follows:
- Claim(s) allowed: _____.
- Claim(s) objected to: _____.
- Claim(s) rejected: _____.
- Claim(s) withdrawn from consideration: _____.

AFFIDAVIT OR OTHER EVIDENCE

8. ☐ The affidavit or other evidence filed after a final action, but before or on the date of filing a Notice of Appeal will not be entered because applicant failed to provide a showing of good and sufficient reasons why the affidavit or other evidence is necessary and was not earlier presented. See 37 CFR 1.116(e).
9. ☐ The affidavit or other evidence filed after the date of filing a Notice of Appeal, but prior to the date of filing a brief, will not be entered because the affidavit or other evidence failed to overcome all rejections under appeal and/or appellant fails to provide a showing a good and sufficient reasons why it is necessary and was not earlier presented. See 37 CFR 41.33(d)(1).
10. ☐ The affidavit or other evidence is entered. An explanation of the status of the claims after entry is below or attached.

REQUEST FOR RECONSIDERATION/OTHER

11. ☒ The request for reconsideration has been considered but does NOT place the application in condition for allowance because:
See Continuation Sheet.
12. ☒ Note the attached Information Disclosure Statement(s). (PTO/SB/08) Paper No(s): 10/20/09
13. ☐ Other: _____.

/Cheryl J. Tyler/
Supervisory Patent Examiner, Art Unit 3744

/Filip Zec/
Examiner, Art Unit 3744

VALTRUS EXHIBIT 2039

Continuation of 11. does NOT place the application in condition for allowance because: The applicant's arguments were unpersuasive. Specifically, applicant's argument that the rationale for combining Patel and Kammeter is merely a conclusory statement is incorrect since in the abstract of Kammeter it is clearly stated that the system in FIG. 1 allows branch circuit monitor to make data available, via communications protocols such as Modbus RTU or RS232/RS485/422, to any number of remote sites. The applicant incorrectly argues that Patel teaches away from Kammeter by stating that Patel does not teach a branch control monitor. In essence, the rejection confirms that Patel does not teach said limitation (branch control monitor) and introduces Kammeter since it teaches said limitation, with a proper rationale, as stated by Kammeter, as referenced in the rejection. Nowhere in Patel is stated that the system of Patel would not work if the branch control monitor is introduced. The rejections remain as stated in the Final Rejection correspondence from 8/21/2009.

IN THE
UNITED STATES PATENT AND TRADEMARK OFFICE

Appl. No.	:	11/670,208	Confirmation No.	:	6687
Applicant	:	James K. Martin	Assignee	:	Liebert Corporation
Filed	:	February 1, 2007	Title	:	THERMAL LOAD LOCATOR
TC/A.U.	:	3744			
Examiner	:	Filip Zec			
Docket No.	:	021944-105US			
Customer No.	:	26720			

Mail Stop AF
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

AMENDMENT

Dear Sir:

In response to the Final Office Action mailed on August 21, 2009, please amend the subject application as set forth herein pursuant Rule 116(b)(2) & (3). This Amendment is filed within two (2) months of the mailing date of the Office Action and, therefore, a timely Advisory Action is earnestly solicited.

Reconsideration and allowance of this application is respectfully requested in light of the arguments and amendments presented herein.

Amendments to the Claims are reflected in the listing of claims beginning on page 2.

Assignee's **Remarks/Arguments** begin on page 5 of this paper.

Amendments to the Claims:

This listing of claims will replace all prior versions and listings of claims in the application:

1. (Previously Presented) A system to cool a plurality of electrical load units with a central cooling unit, comprising:

at least two electrical load sensors coupled to at least two of the electrical load units, each of the at least two electrical load units being coupled to at least one of the electrical load sensors, the electrical load sensors being adapted to sense electrical loads on the electrical load units;

a controller coupled to the electrical load sensors and adapted to receive data from the load sensors;

a central flow conduit coupled to the central cooling unit and adapted to provide cooling fluid to the at least two electrical load units, the central flow conduit being coupled to at least two cooling outlets and the at least two cooling outlets being coupled to the at least two electrical load units, each of the at least two electrical load units being coupled to at least one of the cooling outlets;

at least two control valves coupled to the at least two cooling outlets, each of the at least two cooling outlets being coupled to at least one of the control valves, and the controller being adapted to control proportional flows of the cooling fluid from the central flow conduit in the at least two cooling outlets to the at least two electrical load units based on the sensed electrical loads; and

a branch control monitor configured to sense the electrical loads of the electrical load units via the at least two electrical load sensors, the electrical load sensors coupled to the electrical load units through a plurality of electrical feeds.

2. (Original) The system of claim 1, wherein the sensed electrical load is electrical current.

3. (Canceled)

4. (Previously Presented) The system of claim 1, further comprising a data communication link coupled between the branch control monitor and the controller.
5. (Original) The system of claim 1, wherein the cooling fluid comprises a gas, a liquid, or a combination thereof.
6. (Original) The system of claim 1, further comprising a control bus coupled between the controller and the control valves.
7. (Original) The system of claim 1, further comprising at least two thermal sensors adapted to sense thermal conditions of the at least two electrical load units and provide thermal data to the controller.
8. (Original) The system of claim 1, wherein the electrical load units comprise an electrical cabinet, a rack in the cabinet, or an electrical device.
9. (Original) The system of claim 1, wherein the controller is coupled to the cooling unit.

10. (Previously Presented) A method of cooling a plurality of electrical load units with a central cooling unit, comprising:
delivering electrical current to at least two of the electrical load units;
sensing electrical loads on the at least two electrical load units;
flowing a cooling fluid through a central flow conduit coupled to the central cooling unit into at least two cooling outlets coupled between the central flow conduit and the at least two electrical load units; and
controlling the flow of the cooling fluid proportionately from the central flow conduit in the at least two cooling outlets to the at least two electrical load units based on the sensed electrical loads;
wherein the electrical loads of the at least two electrical load units are sensed from a branch monitoring system by at least two electrical load sensors, the electrical load sensors coupled to the electrical load units through a plurality of electrical feeds.
11. (Original) The method of claim 10, wherein sensing the electrical loads comprises sensing electrical currents to the at least two electrical load units.
12. (Canceled)
13. (Original) The method of claim 10, further comprising sensing thermal conditions of the at least two electrical load units and at least partially controlling the flow of the cooling fluid to the electrical load units based on the sensed thermal conditions.
14. (Original) The method of claim 13, further comprising controlling the flow of the cooling fluid based on the sensed electrical loads prior to sensing changes in the thermal conditions.
15. (Original) The method of claim 10, wherein sensing the electrical loads comprises sensing an electrical load on an electrical cabinet, a rack of one or more cabinets, an electrical device, or a combination thereof.

REMARKS / ARGUMENTS

1. Amendments

Claims 1-2, 4-11, and 13-15 were pending in this application. No claims have been amended, added, or canceled by this response. Hence, claims 1-2, 4-11, and 13-15 remain pending in this application.

2. Response to August 21, 2009 Final Office Action

Assignee thanks the Examiner for the thorough review of the application and the resulting detailed Final Office Action mailed August 21, 2009. For the convenience of the Examiner and for clarity of purpose, Assignee has reproduced the substance of the Office Action below. Assignee's responses immediately follow.

Office Action, pages 3-4 :

3. Claims 1-2, 4-6, 8-11 and 15 are rejected under 35 U.S.C. 103(a) as being unpatentable over U.S. Patent Application Publication 2003/0147214 to Patel et al. (Patel) in view of U.S. Patent 6,330,516 to Kammeter (Kammeter).

4. 2/3

at least two electrical load units based on the sensed electrical loads (par 0036, last sentence), but does not teach that said system further comprises a branch control monitor coupled to the at least two electrical load sensors, the load sensors being coupled to a plurality of electrical feeds, and the electrical feeds being coupled to the electrical load units. Kammeter shows a branch circuit monitor (FIG. 1) comprising a digital signal processor (1, FIG. 1) arranged to carry out various calculations based on a voltage input (2, FIG. 1) from each of a plurality of power sources (3, FIG. 1) and on a current input from each of a plurality of non-contact current sensors (4, FIG. 1) one current sensor being provided between each branch circuit breaker (5, FIG. 1) and a corresponding load (6, FIG. 1) in order to allow said branch circuit monitor to make data

available, via communications protocols such as Modbus RTU or RS232/RS485/422, to any number of remote sites.

Therefore, it would have been obvious to one having ordinary skill in the art at the time the invention was made to modify the system of Patel, to include the branch circuit monitor, as taught by Kammeter, in order to make data available to any number of remote sites.

Assignee does not accede to the Examiner's characterization of Patel and Kammeter as applied to independent claims 1 and 10 and respectfully traverses the above rejection of these claims as being obvious under 35 U.S.C. §103(a).

Obviousness, it will be appreciated, can be a problematic basis for rejection. The Examiner, in deciding that a feature is obvious, has the benefit of an Applicant's disclosure as a blueprint or guide. Even an exceedingly complex solution may seem easy or obvious in hindsight in light of such guide, whereas a person of ordinary skill in the art would have no such guide. Furthermore, once an obviousness rejection has been made, the Applicant is faced with the difficult task of having to prove a negative (i.e., non-obviousness) in order to overcome the rejection. For these reasons, MPEP § 2142 places upon the Examiner the initial burden of establishing a *prima facie* case of obviousness. If the Examiner fails to establish the requisite *prima facie* case, the rejection is improper and cannot stand. *In re Rijckaert*, 9 F.3d 1531, 1532, 28 USPQ2d 1955, 1956 (Fed. Cir. 1993). Only after the Examiner's burden is met does that burden shift to the Applicant to provide sufficient evidence to refute the rejection.

Here, the Examiner contends that it would be obvious to combine the teachings of Patel and Kammeter. Assignee respectfully submits that the Examiner has failed to establish a *prima facie* case of obviousness as required by MPEP § 2142, because the combination of Patel and Kammeter is improper for at least the reasons explained below.

Independent claims 1 and 10 are directed to systems and methods for cooling electrical load units using a central cooling unit and electrical load sensors. The claims recite, among other things, a branch control monitor that senses the electrical loads of the electrical load units via the electrical load sensors. Such a branch control monitor allows power consumption information

for multiple electrical load units to be gathered at a single location. *See, e.g.*, par. [0030] of the specification. This information may then be provided to a controller for cooling the electrical load units as needed. Such a centralized arrangement provides several advantages, including more convenient and efficient monitoring of the power consumed and heat generated by the electrical load units.

The Examiner concedes that Patel's central cooling system does not include a branch control monitor, but contends that Kammeter discloses such a branch control monitor, and that it would have been obvious to combine the branch control monitor of Kammeter with the central cooling system of Patel to arrive at the claimed invention. The rationale advanced by the Examiner for effecting such a combination is to "make data available to any number of remote sites." Office Action, page 4.

First of all, Assignee respectfully submits that the above rationale is merely a conclusory statement, as the Examiner has simply presumed, without any support, that it would be desirable to make the data in Patel's cooling system available to any number of remote sites. The Federal Circuit has found such conclusory statements to be improper, holding that "rejections on obviousness cannot be sustained with mere conclusory statements; instead, there must be some articulated reasoning with some rational underpinning to support the legal conclusion of obviousness." *In re Kahn*, 441 F.3d 977, 988, 78 USPQ2d 1329, 1336 (Fed. Cir. 2006). *See also KSR Int'l Co. v. Teleflex Inc.*, 127 S.Ct. 1727, 1741, 82 USPQ2d 1385, 1396 (2007). Thus, for the present obviousness rejection to stand, the Examiner must at least articulate a reason why someone of ordinary skill in the art using Patel's cooling system would want to modify the system to "make data available to any number of remote sites." Because the Examiner has not articulated any such reasoning, there can be no *prima facie* case of obviousness.

Secondly, combining two references is improper when one of the references **teaches away** from the other reference. *See, e.g., KSR* at 1740, 82 USPQ2d at 1395 ("...when the prior art teaches away from combining certain known elements, discovery of a successful means of combining them is more likely to be nonobvious" (internal citations omitted)); *see also Winner Int'l Royalty Corp. v. Wang*, 202 F.3d 1340, 1349-50, 53 USPQ2d 1580, 1589 (Fed. Cir. 2000)

(If a first reference “did in fact teach away from [a second reference], then that finding alone can defeat [an] obviousness claim.”).

Here, Patel **teaches away** from using the branch control monitor of Kammeter. The reason Patel teaches away is because Patel discloses a **distributed system**, whereas Kammeter discloses a **centralized system**. In Patel, each load in the cooling system measures its own power consumption and reports that consumption directly to a system controller. Thus, the system controller in Patel receives power consumption information from **multiple individual sources**, which is the main reason the Patel system is considered to be “distributed.”

In contrast, power consumption for the various loads in Kammeter is provided from a single source (i.e., a “centralized” system). In Kammeter, current/voltage information from multiple individual loads is gathered at one location by a branch control monitor. A digital signal processor then converts the current/voltage information for each load into power consumption information. The digital signal processor thereafter forwards the power consumption information (via an appropriate bus) to a system controller, such as a billing system, for further processing. Thus, unlike the Patel system controller, the Kammeter system controller (billing system) receives power consumption information for the various loads from a **single source**, namely, the digital signal processor.

Assignee’s position on Patel and Kammeter is supported by at least the following disclosures:

[0049] FIG. 5 depicts a computer board 500 similar to that depicted in FIGS. 3 and 4. The computer board 500 includes a variety of components 505a, 505b, 505c, 505d, and 505e attached thereto. As previously described, the components 505a, 505b, 505c, 505d, and 505e may include one or more processors, microprocessors, network chips, power converters, memory blocks, memory controllers, central processing units, or a variety of other components. In one embodiment, at least one of the components 505a, 505b, 505c, 505d, and 505e includes a sensing device for measuring and reporting the power consumption of the computer board 500. **In such an embodiment, the sensing device enables the computer board 500 itself to report its power consumption, which information may be used by a controller in the system (not shown) to modulate the cooling operation of the system.** A connector 510 is also provided, to permit electrical communication with the connection of the system. This connector 510 may also supply power to the computer board 500.

Patel, par. [0049] (emphasis added).

Thus, as can be seen by the highlighted sentence, the computer board 500 itself measures and reports power consumption directly to a controller in Patel. When several such computer boards 500 are incorporated into the cooling system, as shown in Patel FIG. 2 and/or FIG. 3, the controller ends up receiving power consumption information from multiple different computer boards 500 (i.e., a “distributed” system).

[0050] FIG. 6 shows a lateral cross-sectional view of part of a system in accordance with one embodiment of the invention. In FIG. 6, a housing 610 shields the system's internal components from the environment and also provides a structure or framework within which to mount the variety of components that may be used with or are otherwise part of the system. A computer board 615 is rack mounted within the system. An actuated thermal cell 617 is provided for cooling components 621a and 621b mounted to the computer board 615. The actuated thermal cell 617 may be similar to that shown in FIG. 4, and may include springs 622a and 622b mounted to cold plates 624a and 624b. Multiple boards such as computer board 615 may be mounted within the system using for instance, mounting mechanisms 626a and 626b. The computer board 615 may be in contact with electronic connections (not shown) provided within the system, as are commonly known in the art. **In one embodiment, these electronic connections may incorporate, or may otherwise be monitored by, a sensing device such that the power consumption of each computer board 615 may be measured and reported back to a controller (not shown).**

Patel, par. [0050] (emphasis added).

Here, as well, Patel explains that the power consumption of each one of several computer boards 615 is measured and reported directly back to the controller. There is no teaching or suggestion of an intermediary, such as a branch control monitor between the computer boards 615 and the controller, that gathers the power consumption information at one location first before forwarding the information to the controller.

Kammeter, on the hand, teaches an intermediary in the form of a branch control monitor to gather current/voltage from the various loads at a central location, where the current/voltage may then be converted to power consumption and forwarded to the controller (billing system):

As illustrated in FIG. 1, the branch circuit monitor of the preferred embodiment of the invention includes **a digital signal processor (DSP) 1 arranged to carry out various calculations** based on a voltage input 2 from each of a plurality of power sources 3, and on a current input from each of a plurality of non-contact current sensors 4, one current sensor being provided between each branch circuit breaker 5 and a corresponding load 6.

Kammeter, col. 2, l. 66 to col. 3, l. 6 (emphasis added).

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Reply to Final Office Action of August 21, 2009

The inclusion of a digital signal processor module allows the branch circuit monitor to make data available, via communications protocols such as Modbus RTU or RS232/RS485/422, to any number of remote sites. The individual branch circuit monitors can be wired in a daisy chain or star network configuration and even connected to the Internet via an appropriate interface device so as to enable **centralized billing** or auditing of power usage, and remote monitoring of branch circuit conditions.

Kammeter, col. 2, ll. 41-49 (emphasis added).

As can be seen, in Kammeter, a digital signal processor converts the current/voltage information from multiple loads into power consumption information, then forwards the power consumption information (via an appropriate bus) to the system controller (billing system). Thus, the power consumption information in Kammeter is not provided by multiple individual sources, but rather by a single source, namely, the digital signal processor (hence, a “centralized” system).

From the foregoing excerpts, Patel clearly teaches a cooling system in which each individual load (computer board or computer component) monitors its own power consumption and provides that information directly to the system controller. Nowhere does Patel disclose, suggest, or even hint at, any other alternative arrangements for monitoring the power consumption at the loads. Kammeter, on the other hand, clearly teaches a system in which the power consumption for multiple different loads is provided from a single source. Nowhere does Kammeter disclose, suggest, or even hint at, any other alternative arrangements for monitoring power consumption for its loads.

Moreover, as those having ordinary skill in the art recognized, both distributed systems and centralized systems have advantages over each other. For example, in the distributed system of Patel, the failure of one load monitor would have little or no impact on the other load monitors, as each monitor operates independently of the other. Conversely, in the centralized system of Kammeter, failure of the branch control monitor would very adversely affect the ability of the system to monitor every load. Thus, a person of ordinary skill in the art would interpret Patel as actually **teaching away** from a cooling system where power consumption was measured and provided, not by each individual load, but through a centralized branch control

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monitor. This teaching away necessarily renders the combination of Patel and Kammeter improper under 35 U.S.C. § 103(a).

Accordingly, because the combination of Patel and Kammeter is improper for at least the reasons set forth above, withdrawal of the rejection against independent claims 1 and 10 under 35 USC § 103(a) is respectfully requested.

As for the remaining claims, dependent claims 2, 4-9, 11, and 13-15, although they may recite independently allowable subject matter, these claims depend from independent claims 1 and 10, respectively, and are therefore allowable for at least the same reasons as claims 1 and 10.

3. Conclusion

Claims 1-2, 4-11, and 13-15 are currently pending in this application and Assignee submits that each of these claims is patentable over the cited prior art references. A timely notice of allowance is respectfully requested.

Assignee thanks the Examiner for the consideration and effort on this file. If there are any questions or if additional information is needed, the Examiner is invited to telephone or email the undersigned.

Dated: October 20, 2009

Respectfully submitted,

LOCKE LORD BISSELL & LIDDELL LLP

By /Daniel G. Nguyen/
Daniel G. Nguyen
Reg. No. 42,933
Tel: (713) 226-1292
Fax: (713) 229-2542
Email: dnguyen@lockelord.com

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)	Application Number		11670208	
	Filing Date		2007-02-01	
	First Named Inventor	MARTIN, James K.		
	Art Unit	3744		
	Examiner Name	ZEC, Filip		
	Attorney Docket Number	0021944-105US		

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)	Application Number		11670208
	Filing Date		2007-02-01
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	Art Unit	3744	
	Examiner Name	ZEC, Filip	
	Attorney Docket Number	0021944-105US	

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EXAMINER SIGNATURE

Examiner Signature		Date Considered	
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***EXAMINER:** Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through a citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

¹ See Kind Codes of USPTO Patent Documents at www.USPTO.GOV or MPEP 901.04. ² Enter office that issued the document, by the two-letter code (WIPO Standard ST.3). ³ For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document. ⁴ Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST.16 if possible. ⁵ Applicant is to place a check mark here if English language translation is attached.

**INFORMATION DISCLOSURE
STATEMENT BY APPLICANT**
(Not for submission under 37 CFR 1.99)

Application Number	11670208
Filing Date	2007-02-01
First Named Inventor	MARTIN, James K.
Art Unit	3744
Examiner Name	ZEC, Filip
Attorney Docket Number	0021944-105US

CERTIFICATION STATEMENT

Please see 37 CFR 1.97 and 1.98 to make the appropriate selection(s):

☐ That each item of information contained in the information disclosure statement was first cited in any communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(1).

OR

☒ That no item of information contained in the information disclosure statement was cited in a communication from a foreign patent office in a counterpart foreign application, and, to the knowledge of the person signing the certification after making reasonable inquiry, no item of information contained in the information disclosure statement was known to any individual designated in 37 CFR 1.56(c) more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(2).

☐ See attached certification statement.

☒ Fee set forth in 37 CFR 1.17 (p) has been submitted herewith.

☐ None

SIGNATURE

A signature of the applicant or representative is required in accordance with CFR 1.33, 10.18. Please see CFR 1.4(d) for the form of the signature.

Signature	/Daniel G. Nguyen/	Date (YYYY-MM-DD)	2009-10-20
Name/Print	Daniel G. Nguyen	Registration Number	42933

This collection of information is required by 37 CFR 1.97 and 1.98. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 1 hour to complete, including gathering, preparing and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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The information provided by you in this form will be subject to the following routine uses:

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2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.
3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.
4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).
5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.
6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).
7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.
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VALTRUS EXHIBIT 2039
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26 of 227

Electronic Patent Application Fee Transmittal				
Application Number:		11670208		
Filing Date:		01-Feb-2007		
Title of Invention:		THERMAL LOAD LOCATOR		
First Named Inventor/Applicant Name:		James K. MARTIN		
Filer:		Daniel G. Nguyen		
Attorney Docket Number:		021944-105US		
Filed as Large Entity				
Utility under 35 USC 111(a) Filing Fees				
Description	Fee Code	Quantity	Amount	Sub-Total in USD(\$)
Basic Filing:				
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD(\$)
Miscellaneous:				
Submission- Information Disclosure Stmt	1806	1	180	180
Total in USD (\$)				180

Electronic Acknowledgement Receipt	
EFS ID:	6290243
Application Number:	11670208
International Application Number:	
Confirmation Number:	6687
Title of Invention:	THERMAL LOAD LOCATOR
First Named Inventor/Applicant Name:	James K. MARTIN
Customer Number:	26720
Filer:	Daniel G. Nguyen
Filer Authorized By:	
Attorney Docket Number:	021944-105US
Receipt Date:	20-OCT-2009
Filing Date:	01-FEB-2007
Time Stamp:	16:53:55
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	Deposit Account
Payment was successfully received in RAM	\$ 180
RAM confirmation Number	3230
Deposit Account	121322
Authorized User	

The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayments as follows:

- Charge any Additional Fees required under 37 C.F.R. Section 1.16 (National application filing, search and examination fees)
- Charge any Additional Fees required under 37 C.F.R. Section 1.17 (Patent application and reexamination processing fees)

File Listing:					
Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1		Response.pdf	126573 10561050a81b572a9e9f6dd3b7083b4a03fddc	yes	11
	Multipart Description/PDF files in .zip description				
	Document Description		Start	End	
	Amendment After Final		1	1	
	Claims		2	4	
	Applicant Arguments/Remarks Made in an Amendment		5	11	
Warnings:					
Information:					
2	Information Disclosure Statement (IDS) Filed (SB/08)	IDS.PDF	608158 0c07e18ee096ae1d2aa8886cc368ff1ccc02f1ef	no	4
Warnings:					
Information:					
3	Fee Worksheet (PTO-875)	fee-info.pdf	30070 d4ba16e8f94f5ee342c3f53e26fnd4b6f86cd2	no	2
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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
11/670,208	02/01/2007	James K. MARTIN	021944-105US	6687
26720 7590 08/21/2009 LOCKE LORD BISSELL & LIDDELL LLP ATTN: IP DOCKETING 600 TRAVIS STREET 3400 CHASE TOWER HOUSTON, TX 77002			EXAMINER ZEC, FILIP	
			ART UNIT 3744	PAPER NUMBER
			NOTIFICATION DATE 08/21/2009	DELIVERY MODE ELECTRONIC

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

Notice of the Office communication was sent electronically on above-indicated "Notification Date" to the following e-mail address(es):

hoip@lockelord.com

Office Action Summary	Application No. 11/670,208	Applicant(s) MARTIN, JAMES K.	
	Examiner Filip Zec	Art Unit 3744	

– The MAILING DATE of this communication appears on the cover sheet with the correspondence address –
Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 3 MONTH(S) OR THIRTY (30) DAYS, WHICHEVER IS LONGER, FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
 - If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
 - Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133).
- Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

- 1) ☒ Responsive to communication(s) filed on 29 April 2009.
- 2a) ☒ This action is **FINAL**. 2b) ☐ This action is non-final.
- 3) ☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims

- 4) ☒ Claim(s) 1,2,4-11 and 13-15 is/are pending in the application.
- 4a) Of the above claim(s) _____ is/are withdrawn from consideration.
- 5) ☐ Claim(s) _____ is/are allowed.
- 6) ☒ Claim(s) 1,2,4-11 and 13-15 is/are rejected.
- 7) ☐ Claim(s) _____ is/are objected to.
- 8) ☐ Claim(s) _____ are subject to restriction and/or election requirement.

Application Papers

- 9) ☐ The specification is objected to by the Examiner.
- 10) ☐ The drawing(s) filed on _____ is/are: a) ☐ accepted or b) ☐ objected to by the Examiner.
Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).
Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).
- 11) ☐ The oath or declaration is objected to by the Examiner. Note the attached Office Action or form PTO-152.

Priority under 35 U.S.C. § 119

- 12) ☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).
- a) ☐ All b) ☐ Some * c) ☐ None of:
1. ☐ Certified copies of the priority documents have been received.
 2. ☐ Certified copies of the priority documents have been received in Application No. _____.
 3. ☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

* See the attached detailed Office action for a list of the certified copies not received.

Attachment(s)

- | | |
|--|---|
| 1) ☐ Notice of References Cited (PTO-892) | 4) ☐ Interview Summary (PTO-413)
Paper No(s)/Mail Date. _____ |
| 2) ☐ Notice of Draftsperson's Patent Drawing Review (PTO-948) | 5) ☐ Notice of Informal Patent Application |
| 3) ☐ Information Disclosure Statement(s) (PTO/SB/08)
Paper No(s)/Mail Date _____ | 6) ☐ Other: _____ |

VALTRUS EXHIBIT 2039

DETAILED ACTION

Response to Amendment

1. Applicant's arguments filed 4/29/09 have been fully considered but they are not persuasive.

In reference to the rejection of independent claims 1 and 10, the applicant is arguing that “Patel fails to disclose a key element recited in claims 1 and 10, namely, electrical load sensors that are coupled to at least two of the electrical load units...In contrast, Patel advocates the use of a temperature gauge 100, not an electrical load sensor as required in the claims, to sense and provide temperature information to a controller 90 to control cooling. See, e.g., pars. [0028]-[0029]”. The examiner reiterates that Patel teaches the electrical load sensors used for measuring power consumption (par 0039; entire). Inherently, said load sensors are **thermoelectrically** or even, as the applicant suggested, possibly **electromagnetically** coupled to the computer components (120, FIG. 1) in order to perform said operation. But coupled, they must be. Additionally, Patel teaches that said load sensors may replace the temperature gauge (100, FIG. 1; par 0039, last sentence), which is exactly what the present invention claims with respect to the cooling system, per applicant's arguments on page 8, first paragraph.

In response to applicant's arguments against the references individually, one cannot show nonobviousness by attacking references individually where the rejections are based on combinations of references. See *In re Keller*, 642 F.2d 413, 208 USPQ 871 (CCPA 1981); *In re Merck & Co.*, 800 F.2d 1091, 231 USPQ 375 (Fed. Cir. 1986). In this case, the applicant is trying to argue that Patel does not teach that said cooling system comprises a branch control monitor coupled to the at least two electrical load sensors, the load sensors being coupled to a

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plurality of electrical feeds, and the electrical feeds being coupled to the electrical load units, which is admitted in the 103(a) rejection. However, it is the secondary reference, Kammeter, which shows a branch circuit monitor (FIG. 1) comprising a digital signal processor (1, FIG. 1) arranged to carry out various calculations based on a voltage input (2, FIG. 1) from each of a plurality of power sources (3, FIG. 1) and on a current input from each of a plurality of non-contact current sensors (4, FIG. 1) one current sensor being provided between each branch circuit breaker (5, FIG. 1) and a corresponding load (6, FIG. 1) in order to allow said branch circuit monitor to make data available, via communications protocols such as Modbus RTU or RS232/RS485/422, to any number of remote sites. Thus, it would have been obvious to one having ordinary skill in the art at the time the invention was made to modify the system of Patel, to include the branch circuit monitor, as taught by Kammeter, in order to make data available to any number of remote sites. Thus, the rejection is proper and remains.

Claim Rejections - 35 USC § 103

2. The following is a quotation of 35 U.S.C. 103(a) which forms the basis for all obviousness rejections set forth in this Office action:

(a) A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negated by the manner in which the invention was made.

3. Claims 1-2, 4-6, 8-11 and 15 are rejected under 35 U.S.C. 103(a) as being unpatentable over U.S. Patent Application Publication 2003/0147214 to Patel et al. (Patel) in view of U.S. Patent 6,330,516 to Kammeter (Kammeter).

In reference to claim 1, Patel teaches a system (10, FIG. 2) to cool a plurality of electrical load units (130, FIG. 2) with a central cooling unit (40, FIG. 2), comprising at least two electrical

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load sensors (par 0039, first sentence) coupled to at least two of the electrical load units, each of the at least two electrical load units being coupled to at least one of the electrical load sensors (par 0039, first sentence), the electrical load sensors being adapted to sense electrical loads on the electrical load units (par 0039, entire); a controller (90, FIG. 2) coupled to the electrical load sensors and adapted to receive data from the load sensors (par 0039); a central flow conduit (30, FIG. 2) coupled to the central cooling unit and adapted to provide cooling fluid to the at least two electrical load units, the central flow conduit being coupled to at least two cooling outlets (cooling plates 20, FIG. 2) and the at least two cooling outlets being coupled to the at least two electrical load units (FIG. 2), each of the at least two electrical load units being coupled to at least one of the cooling outlets (FIG. 2); and at least two control valves (140, FIG. 2) coupled to the at least two cooling outlets, each of the at least two cooling outlets being coupled to at least one of the control valves (par 0036), and the controller being adapted to control proportional flows of the cooling fluid from the central flow conduit in the at least two cooling outlets to the at least two electrical load units based on the sensed electrical loads (par 0036, last sentence), but does not teach that said system further comprises a branch control monitor coupled to the at least two electrical load sensors, the load sensors being coupled to a plurality of electrical feeds, and the electrical feeds being coupled to the electrical load units. Kammeter shows a branch circuit monitor (FIG. 1) comprising a digital signal processor (1, FIG. 1) arranged to carry out various calculations based on a voltage input (2, FIG. 1) from each of a plurality of power sources (3, FIG. 1) and on a current input from each of a plurality of non-contact current sensors (4, FIG. 1) one current sensor being provided between each branch circuit breaker (5, FIG. 1) and a corresponding load (6, FIG. 1) in order to allow said branch circuit monitor to make data

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available, via communications protocols such as Modbus RTU or RS232/RS485/422, to any number of remote sites.

Therefore, it would have been obvious to one having ordinary skill in the art at the time the invention was made to modify the system of Patel, to include the branch circuit monitor, as taught by Kammeter, in order to make data available to any number of remote sites.

In reference to claim 2, Patel and Kammeter teach the system as described in the rejection of claim 1, and Patel further teaches that the sensed electrical load is electrical current (power consumption in par 0039).

In reference to claim 4, Patel and Kammeter disclose the system as described in claim 1, and Kammeter further teaches a data communication link (daisy chain or star network configuration, col 2, lines 45-46) coupled between the branch control monitor (11, 1, FIG. 2A) and the controller (the remote sites, col 2, line 44) in order to enable centralized billing or auditing of power usage, and remote monitoring of branch circuit conditions.

Therefore, it would have been obvious to one having ordinary skill in the art at the time the invention was made to modify the system of Patel, to include the data communication link, as taught by Kammeter, in order to enable centralized billing or auditing of power usage, and remote monitoring of branch circuit conditions.

In reference to claim 5, Patel and Kammeter teach the system as described in the rejection of claim 1, and Patel further teaches that the cooling fluid comprises a gas, a liquid, or a combination thereof (par 0022, third and fourth sentences).

In reference to claim 6, Patel and Kammeter disclose the system as described in claim 1, and Kammeter further teaches a Modbus RTU/RS232/RS485/422 protocol (col 2, line 43-44) in order to make data available to any number of remote sites.

Therefore, it would have been obvious to one having ordinary skill in the art at the time the invention was made to modify the system of Patel, to include the control bus, as taught by Kammeter, in order to make data available to any number of remote sites.

In reference to claim 8, Patel and Kammeter teach the system as described in the rejection of claim 1, and Patel further teaches that the electrical load units comprise an electrical cabinet, a rack in the cabinet, or an electrical device (the computer board, par 0034).

In reference to claim 9, Patel and Kammeter teach the system as described in the rejection of claim 1, and Patel further teaches that the controller (90, FIG. 2) is coupled (via 100, FIG. 2) to the cooling unit (40, FIG. 2).

In reference to claims 10, 11 and 15, they claim the method of providing and configuring the apparatus of claims 1, 2 and 8, respectively, thus, they are rejected based on the rejections of claims 1, 2 and 8 above and the associated method steps follow directly from the use of the apparatus.

4. Claims 7, 13 and 14 are rejected under 35 U.S.C. 103(a) as being unpatentable over Patel in view of Kammeter as applied to claims 1 and 10 above, and further in view of U.S. Patent 6,854,287 to Patel et al. (Patel '287).

In reference to claim 7, Patel and Kammeter disclose the system as described in claim 1, but do not teach at least two thermal sensors adapted to sense thermal conditions of the at least two electrical load units and provide thermal data to the controller. Patel '287 shows

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temperature sensors (48, FIG. 2; col) located in the computer systems rack (12, FIG. 2) in order to supply temperature readings to a controller configured to operate the heat exchanger unit, the pump, the valve and the pipe valve (col 7, lines 1-6).

Therefore, it would have been obvious to one having ordinary skill in the art at the time the invention was made to modify the system of Patel and Kammeter, to include multiple temperature sensors, as taught by Patel '287, in order to supply temperature readings to a controller configured to operate the heat exchanger unit, the pump, the valve and the pipe valve.

In reference to claim 13 and 14, they claim the method of providing and configuring the apparatus of claim 7, thus, they are rejected based on the rejection of claim 7 above and the associated method steps follow directly from the use of the apparatus.

Conclusion

5. Applicant's amendment necessitated the new ground(s) of rejection presented in this Office action. Accordingly, **THIS ACTION IS MADE FINAL**. See MPEP § 706.07(a). Applicant is reminded of the extension of time policy as set forth in 37 CFR 1.136(a).

A shortened statutory period for reply to this final action is set to expire THREE MONTHS from the mailing date of this action. In the event a first reply is filed within TWO MONTHS of the mailing date of this final action and the advisory action is not mailed until after the end of the THREE-MONTH shortened statutory period, then the shortened statutory period will expire on the date the advisory action is mailed, and any extension fee pursuant to 37 CFR 1.136(a) will be calculated from the mailing date of the advisory action. In no event, however, will the statutory period for reply expire later than SIX MONTHS from the date of this final action.

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6. Any inquiry concerning this communication or earlier communications from the examiner should be directed to Filip Zec whose telephone number is 571-270-5846. The examiner can normally be reached on Monday-Friday, from 8:30 AM - 5:00 PM.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisors, Frantz Jules or Cheryl Tyler can be reached on 571-272-6681 or 571-272-4834, respectively. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see <http://pair-direct.uspto.gov>. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

/F. Z./
Examiner, Art Unit 3744

/Cheryl J. Tyler/
Supervisory Patent Examiner, Art Unit
3744

8/17/09

Search Notes 	Application/Control No. 11670208	Applicant(s)/Patent Under Reexamination MARTIN, JAMES K.
	Examiner Filip Zec	Art Unit 3744

SEARCHED			
Class	Subclass	Date	Examiner
62	259.2 (limited text search - see search notes history)	1/26/09	FZ
62	259.2	7/30/09	FZ

SEARCH NOTES		
Search Notes	Date	Examiner
Discussed class 62 with B. Doerrler	1/24/09	FZ
See EAST search history notes	1/26/09	FZ
	(updated 7/30/09)	FZ

INTERFERENCE SEARCH			
Class	Subclass	Date	Examiner

	VALTRUS EXHIBIT 2039 VERTIV v. VALTRUS IPR2025-00669
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Index of Claims 	Application/Control No. 11670208	Applicant(s)/Patent Under Reexamination MARTIN, JAMES K.
	Examiner Filip Zec	Art Unit 3744

✓	Rejected	-	Cancelled	N	Non-Elected	A	Appeal
=	Allowed	÷	Restricted	I	Interference	O	Objected

☐ Claims renumbered in the same order as presented by applicant		☐ CPA		☐ T.D.		☐ R.1.47			
CLAIM		DATE							
Final	Original	01/26/2009	07/30/2009						
	1	✓	✓						
	2	✓	✓						
	3	✓	-						
	4	✓	✓						
	5	✓	✓						
	6	✓	✓						
	7	✓	✓						
	8	✓	✓						
	9	✓	✓						
	10	✓	✓						
	11	✓	✓						
	12	✓	-						
	13	✓	✓						
	14	✓	✓						
	15	✓	✓						

EAST Search History

EAST Search History (Prior Art)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
S22	1381	62/259.2.ccls.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT	OR	ON	2009/07/30 13:58
S23	25	("3609991" "4817865" "4997030" "5000079" "5076346" "5207613" "5253484" "5261243" "5315837" "5474120" "5503032" "5718117" "5718628" "5740018" "5903433" "5943211" "6108206" "6134108" "6159091" "6252769" "6427466" "6574104" "6616524").PN. OR ("7086459").URPN.	US-PGPUB; USPAT; USOCR	OR	ON	2009/07/30 14:16
S24	8	("2002/0007643").URPN.	USPAT	OR	ON	2009/07/30 14:26

7/30/2009 4:03:06 PM

C:\Documents and Settings\fzec\My Documents\EAST\Workspaces\11670208.wsp

**IN THE
UNITED STATES PATENT AND TRADEMARK OFFICE**

Appl. No.	:	11/670,208	Confirmation No.	:	6687
Applicant	:	James K. Martin	Assignee	:	Liebert Corporation
Filed	:	February 1, 2007	Title	:	THERMAL LOAD LOCATOR
TC/A.U.	:	3744			
Examiner	:	Filip Zec			
Docket No.	:	021944-105US			
Customer No.	:	26720			

Mail Stop Amendment
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

AMENDMENT

Sir:

In response to the Non-Final Office Action mailed on January 30, 2009, please amend the subject application as set forth herein. This Amendment is electronically filed within three (3) months of the mailing date of the Office Action and, therefore, is timely.

Reconsideration and allowance of this application is respectfully requested in light of the arguments and amendments presented herein.

Amendments to the Claims are reflected in the listing of claims beginning on page 2.

Assignee's **Remarks/Arguments** begin on page 5 of this paper.

Amendments to the Claims:

This listing of claims will replace all prior versions and listings of claims in the application:

1. (Currently Amended) A system to cool a plurality of electrical load units with a central cooling unit, comprising:
at least two electrical load sensors coupled to at least two of the electrical load units, each of the at least two electrical load units being coupled to at least one of the electrical load sensors, the electrical load sensors being adapted to sense electrical loads on the electrical load units;
a controller coupled to the electrical load sensors and adapted to receive data from the load sensors;
a central flow conduit coupled to the central cooling unit and adapted to provide cooling fluid to the at least two electrical load units, the central flow conduit being coupled to at least two cooling outlets and the at least two cooling outlets being coupled to the at least two electrical load units, each of the at least two electrical load units being coupled to at least one of the cooling outlets; [[and]]
at least two control valves coupled to the at least two cooling outlets, each of the at least two cooling outlets being coupled to at least one of the control valves, and the controller being adapted to control proportional flows of the cooling fluid from the central flow conduit in the at least two cooling outlets to the at least two electrical load units based on the sensed electrical loads; and
a branch control monitor configured to sense the electrical loads of the electrical load units via the at least two electrical load sensors, the electrical load sensors coupled to the electrical load units through a plurality of electrical feeds.
2. (Original) The system of claim 1, wherein the sensed electrical load is electrical current.

3. (Canceled) The system of claim 1, further comprising a branch control monitor coupled to the at least two electrical load sensors, the load sensors being coupled to a plurality of electrical feeds, and the electrical feeds being coupled to the electrical load units.
4. (Currently Amended) The system of claim ~~[[3]]~~ 1, further comprising a data communication link coupled between the branch control monitor and the controller.
5. (Original) The system of claim 1, wherein the cooling fluid comprises a gas, a liquid, or a combination thereof.
6. (Original) The system of claim 1, further comprising a control bus coupled between the controller and the control valves.
7. (Original) The system of claim 1, further comprising at least two thermal sensors adapted to sense thermal conditions of the at least two electrical load units and provide thermal data to the controller.
8. (Original) The system of claim 1, wherein the electrical load units comprise an electrical cabinet, a rack in the cabinet, or an electrical device.
9. (Original) The system of claim 1, wherein the controller is coupled to the cooling unit.

10. (Currently Amended) A method of cooling a plurality of electrical load units with a central cooling unit, comprising:
delivering electrical current to at least two of the electrical load units;
sensing electrical loads on the at least two electrical load units;
flowing a cooling fluid through a central flow conduit coupled to the central cooling unit into at least two cooling outlets coupled between the central flow conduit and the at least two electrical load units; and
controlling the flow of the cooling fluid proportionately from the central flow conduit in the at least two cooling outlets to the at least two electrical load units based on the sensed electrical loads;
wherein the electrical loads of the at least two electrical load units are sensed from a branch monitoring system by at least two electrical load sensors, the electrical load sensors coupled to the electrical load units through a plurality of electrical feeds.

11. (Original) The method of claim 10, wherein sensing the electrical loads comprises sensing electrical currents to the at least two electrical load units.

12. (Canceled) The method of claim 10, further comprising sensing the electrical loads on the at least two electrical load units from a branch monitoring system.

13. (Original) The method of claim 10, further comprising sensing thermal conditions of the at least two electrical load units and at least partially controlling the flow of the cooling fluid to the electrical load units based on the sensed thermal conditions.

14. (Original) The method of claim 13, further comprising controlling the flow of the cooling fluid based on the sensed electrical loads prior to sensing changes in the thermal conditions.

15. (Original) The method of claim 10, wherein sensing the electrical loads comprises sensing an electrical load on an electrical cabinet, a rack of one or more cabinets, an electrical device, or a combination thereof.

Electronic Acknowledgement Receipt	
EFS ID:	5242509
Application Number:	11670208
International Application Number:	
Confirmation Number:	6687
Title of Invention:	THERMAL LOAD LOCATOR
First Named Inventor/Applicant Name:	James K. MARTIN
Customer Number:	26720
Filer:	Daniel G. Nguyen
Filer Authorized By:	
Attorney Docket Number:	021944-105US
Receipt Date:	29-APR-2009
Filing Date:	01-FEB-2007
Time Stamp:	15:03:44
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no
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File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1		Response.pdf	230658	yes	10
			132d9619565322c87dce14370f1HB679M126510		

Multipart Description/PDF files in .zip description		
Document Description	Start	End
Amendment/Req. Reconsideration-After Non-Final Reject	1	1
Claims	2	4
Applicant Arguments/Remarks Made in an Amendment	5	10

Warnings:

Information:

Total Files Size (in bytes):	230658
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This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111
If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371
If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

REMARKS / ARGUMENTS

1. Amendments

Independent claim 1 has been amended to incorporate the subject matter of dependent claim 3, which has been canceled. Similarly, independent claim 10 has been amended to incorporate the subject matter of dependent claim 12, which has been canceled.

Assignee submits that no new matter was added by the above amendments.

2. Response to January 30, 2009 Office Action

Assignee thanks the Examiner for the thorough review of the application and the resulting detailed Non-Final Office Action mailed January 30, 2009. For the convenience of the Examiner and for clarity of purpose, Assignee has reproduced the substance of the Office Action below. Assignee's responses immediately follow.

Rejection under 35 U.S.C. § 102(b):

2. Claims 1, 2, 5, 8-11 and 15 are rejected under 35 U.S.C. 102(b) as being anticipated by U.S. Patent Application Publication 2003/0147214 to Patel et al. (Patel).

In reference to claim 1, Patel teaches a system (10, FIG. 2) to cool a plurality of electrical load units (130, FIG. 2) with a central cooling unit (40, FIG. 2), comprising at least two electrical load sensors (par 0039, first sentence) coupled to at least two of the electrical load units, each of the at least two electrical load units being coupled to at least one of the electrical load sensors (par 0039, first sentence), the electrical load sensors being adapted to sense electrical loads on the electrical load units (par 0039, entire); a controller (90, FIG. 2) coupled to the electrical load sensors and adapted to receive data from the load sensors (par 0039); a central flow conduit (30, FIG. 2) coupled to the central cooling unit and adapted to provide cooling fluid to the at least two electrical load units, the central flow conduit being coupled to at least two cooling outlets (cooling plates 20, FIG. 2) and the at least two cooling outlets being coupled to the at least two electrical load units (FIG. 2), each of the at least two electrical load units being coupled to at least one of the cooling outlets (FIG. 2); and at least two control valves (140, FIG. 2) coupled to the at least two cooling outlets, each of the at least two cooling outlets being coupled to at least one of the control valves (par 0036), and the controller being adapted to control proportional

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flows of the cooling fluid from the central flow conduit in the at least two cooling outlets to the
at least two electrical load units based on the sensed electrical loads (par 0036, last sentence).

Assignee does not accede to the Examiner's above characterization of Patel as applied to claims 1 and 10 and respectfully traverses the rejection of these claims. The claimed invention is directed to systems and methods for cooling electrical load units using a central cooling unit. Patel is apparently also directed systems and methods for cooling electrical load units using a central cooling unit. However, the claimed invention is patentable over Patel for at least the reason that Patel does not disclose each and every element recited in claims 1 and 10.

It is well settled that a claim can only be anticipated if each and every element in the claim is found expressly or inherently in a single prior art reference. *See, e.g., Verdegaal Bros. v. Union Oil Co. of California*, 814 F.2d 628, 631, 2 USPQ2d 1051, 1053 (Fed. Cir. 1987). *See also Richardson v. Suzuki Motor Co.*, 868 F.2d 1226, 1236, 9 USPQ2d 1913, 1920 (Fed. Cir. 1989) ("The identical invention must be shown in as complete detail as is contained in the ... claim.")

In the present case, Patel fails to disclose a key element recited in claims 1 and 10, namely, **electrical load sensors** that are coupled to at least two of the electrical load units. Claim 1 recites, for example, at least two electrical load sensors coupled to at least two of the electrical load units. Claim 10 similarly recites **sensing electrical loads** on the electrical load units. These electrical load sensors allow the claimed invention to use **power consumption** instead of temperature as a metric for controlling cooling.

In contrast, Patel advocates the use of a temperature gauge 100, not an electrical load sensor as required in the claims, to sense and provide temperature information to a controller 90 to control cooling. *See, e.g.,* pars. [0028]-[0029]. The Examiner contends that Patel teaches the use of electrical load sensors in par. [0039]. Patel may have made a passing reference to electrical load sensors in the cited paragraph. However, nowhere does Patel expressly or inherently disclose that such electrical load sensors are **coupled** to the electrical load units. None of the figures in Patel even show an electrical load sensor, much less an electrical load sensor that is **coupled** to an electrical load unit. Indeed, a person of ordinary skill in the art could easily

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come away with the impression that Patel's electrical load sensor is **uncoupled** from the electrical load unit, as would be the case, say, for an electromagnetic field based load sensor. Therefore, because Patel does not expressly or inherently disclose electrical load sensors that are **coupled** to electrical load units, as required in the claims, the reference cannot be interpreted as anticipating the claimed invention.

Second, in order to anticipate a claim under 35 U.S.C. 102(b), a prior art reference must also enable the claim it is alleged to anticipate (i.e., the currently pending claims). As the Federal Circuit stated in *Abbott Lab. v. Sandoz*, 544 F.3d 1341, 89 USPQ2d 1161 (Fed. Cir. 2008):

"Anticipation" in patent usage means that the claimed invention was previously known and described in a printed publication, explicitly or inherently. Anticipation is established by documentary evidence, and requires that every claim element and limitation is set forth in a single prior art reference, in the same form and order as in the claim. See *In re Omeprazole Patent Litigation*, 483 F.3d 1364, 1373 (Fed. Cir. 2007); *Continental Can Co. v. Monsanto Co.*, 948 F.2d 1264, 1267 (Fed. Cir. 1991). An anticipating reference must enable that which it is asserted to anticipate. *Omeprazole*, 483 F.3d at 1378 ("To 'anticipate,' the identical subject matter must not only be previously known, but the knowledge must be sufficiently enabling to place the information in the possession of the public."); *Elan Pharmaceuticals, Inc. v. Mayo Found. for Medical Educ. & Research*, 346 F.3d 1051, 1054 (Fed. Cir. 2003) (same).

Id. at 1166 (emphasis added).

In the present case, the invention recited in claims 1 and 10 uses electrical load sensors to monitor **power consumption** (instead of temperature) as a metric for controlling cooling. A detailed description of the invention, including i) where the electrical load sensors may be located in the cooling system, ii) to what components they may be connected, iii) the type of electrical load sensors that may be used (e.g., current versus voltage sensors), iv) other components that may be needed for the electrical load sensors to operate, and so forth, may be found in paragraphs [0028]-[0036] and FIGS. 2-3 of the specification.

Assignee respectfully submits that Patel fails to enable claims 1 and 10 (whether it enables any of its own claims is besides the point). Specifically, Patel does not teach those having ordinary skill in the art how to make and use the claimed invention without undue experimentation. For example, nowhere does Patel disclose what type of load sensor may be used, where it may be connected, or any of the other information itemized in the preceding

paragraph. Patel simply mentions, almost as an aside, that one or more sensing devices may be used for measuring the power consumption of one or more computer components or one or more computer boards. This is in stark contrast to the details Patel provides for the temperature gauge 100, which Patel specifically shows in FIGS. 1-2 as being coupled to cold plates 20 via supply line 30. Patel therefore cannot be considered as enabling the claimed invention.

Accordingly, because Patel fails to disclose each and every element recited in claims 1 and 10, and because Patel also fails to enable the invention claimed in claims 1 and 10, withdrawal of the rejection against these claims under 35 USC § 102(b) is respectfully requested.

Rejection under 35 U.S.C. § 103(a):

4. Claims 3, 4, 6 and 12 are rejected under 35 U.S.C. 103(a) as being unpatentable over Patel in view of U.S. Patent 6,330,516 to Kammeter (Kammeter).

In reference to claim 3, Patel discloses the system as described in claim 1, but does not teach that said system further comprises a branch control monitor coupled to the at least two electrical load sensors, the load sensors being coupled to a plurality of electrical feeds, and the electrical feeds being coupled to the electrical load units. Kammeter shows a branch circuit monitor (FIG. 1) comprising a digital signal processor (1, FIG. 1) arranged to carry out various calculations based on a voltage input (2, FIG. 1) from each of a plurality of power sources (3, FIG. 1) and on a current input from each of a plurality of non-contact current sensors (4, FIG. 1) one current sensor being provided between each branch circuit breaker (5, FIG. 1) and a corresponding load (6, FIG. 1) in order to allow said branch circuit monitor to make data available, via communications protocols such as Modbus RTU or RS232/RS485/422, to any number of remote sites.

Assignee submits that the combination of Kammeter and Patel is improper and respectfully traverses this rejection. Original claims 3 and 12 recite the use of a branch control monitor. Such a branch control monitor allows power consumption information for multiple electrical load units to be gathered at a single location. *See, e.g.*, par. [0030] of the specification. This centralized arrangement provides several advantages, including more convenient and efficient monitoring of the power that is consumed by the electrical load units.

Patel, on the other hand, contemplates a distributed arrangement in which monitoring is conducted by the individual computer boards and/or computer components. For example,

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paragraph [0049] of Patel explains that the sensing device enables the computer board 500 to report its own power consumption information, which may then be used to modulate the cooling operation of the system. Nothing in Patel teaches or suggests the centralized monitoring arrangement that would result from the use of a branch control monitor, as recited in original claims 3 and 12. Indeed, contrary to the claimed invention, Patel's distributed monitoring approach actually teaches away from the use of the branch control monitor recited in claims 3 and 12. This teaching away necessarily renders the combination of Kammeter and Patel improper for a rejection under 35 U.S.C. § 103(a).

Accordingly, because the combination of Patel with Kammeter is improper, withdrawal of the rejection against original independent claims 3 and 12 under 35 USC § 103(a) is respectfully requested.

Consistent with Assignee's above positions, and in an effort to expedite the prosecution of this application, Assignee has now amended independent claims 1 and 10 to incorporate the branch control monitor of claims 3 and 12 (which have accordingly been canceled). Assignee respectfully submits that amended claims 1 and 10 are patentable over the cited references for at least the reasons stated above.

As for the remaining dependent claims 2, 4-9, 11, and 13-15, although they may recite independently allowable subject matter, these claims depend from independent claims 1 and 10, respectively, and are therefore allowable for at least the same reasons as claims 1 and 10.

3. Conclusion

Claims 1-2, 4-11, and 13-15 are currently pending in this application and Assignee submits that each of these claims is patentable over the cited prior art references. A timely notice of allowance is respectfully requested.

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Assignee thanks the Examiner for the consideration and effort on this file. If there are any questions or if additional information is needed, the Examiner is invited to telephone or email the undersigned.

Dated: April 29, 2009

Respectfully submitted,

LOCKE LORD BISSELL & LIDDELL LLP

By /Daniel G. Nguyen/

Daniel G. Nguyen

Reg. No. 42,933

Tel: (713) 226-1292

Fax: (713) 229-2542

Email: dnguyen@lockelord.com

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

PATENT APPLICATION FEE DETERMINATION RECORD Substitute for Form PTO-875					Application or Docket Number 11/670,208		Filing Date 02/01/2007		☐ To be Mailed		
APPLICATION AS FILED – PART I											
(Column 1)			(Column 2)		SMALL ENTITY ☐		OR		OTHER THAN SMALL ENTITY		
FOR	NUMBER FILED	NUMBER EXTRA	RATE (\$)	FEE (\$)			RATE (\$)	FEE (\$)			
☒ BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A				N/A	300			
☐ SEARCH FEE (37 CFR 1.16(k), (l), or (m))	N/A	N/A	N/A				N/A				
☐ EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A				N/A				
TOTAL CLAIMS (37 CFR 1.16(j))	minus 20 = *		X \$	=			X \$	=			
INDEPENDENT CLAIMS (37 CFR 1.16(h))	minus 3 = *		X \$	=			X \$	=			
☐ APPLICATION SIZE FEE (37 CFR 1.16(s))			If the specification and drawings exceed 100 sheets of paper, the application size fee due is \$250 (\$125 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).								
☐ MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))											
* If the difference in column 1 is less than zero, enter "0" in column 2.			TOTAL				TOTAL		300		
APPLICATION AS AMENDED – PART II											
(Column 1)			(Column 2)		(Column 3)		SMALL ENTITY		OR OTHER THAN SMALL ENTITY		
AMENDMENT	04/29/2009	CLAIMS REMAINING AFTER AMENDMENT	HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA		RATE (\$)	ADDITIONAL FEE (\$)	RATE (\$)		ADDITIONAL FEE (\$)	
	Total (37 CFR 1.16(j))	* 14	Minus	** 20	= 0	X \$	=	OR X \$52=		0	
	Independent (37 CFR 1.16(h))	* 2	Minus	*** 3	= 0	X \$	=	OR X \$220=		0	
	☐ Application Size Fee (37 CFR 1.16(s))							OR			
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR			
					TOTAL ADD'L FEE				TOTAL ADD'L FEE		0
AMENDMENT	CLAIMS REMAINING AFTER AMENDMENT	HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA		RATE (\$)	ADDITIONAL FEE (\$)	RATE (\$)		ADDITIONAL FEE (\$)		
	Total (37 CFR 1.16(j))	*	Minus	**	=	X \$	=	OR X \$		=	
	Independent (37 CFR 1.16(h))	*	Minus	***	=	X \$	=	OR X \$		=	
	☐ Application Size Fee (37 CFR 1.16(s))							OR			
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR			
					TOTAL ADD'L FEE				TOTAL ADD'L FEE		
* If the entry in column 1 is less than the entry in column 2, write "0" in column 3. ** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20". *** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3". The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.											

This collection of information is required by 37 CFR 1.16. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 1.

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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
11/670,208	02/01/2007	James K. MARTIN	021944-105US	6687
26720 7590 01/30/2009 LOCKE LORD BISSELL & LIDDELL LLP ATTN: IP DOCKETING 600 TRAVIS STREET 3400 CHASE TOWER HOUSTON, TX 77002			EXAMINER ZEC, FILIP	
			ART UNIT 3744	PAPER NUMBER
			MAIL DATE 01/30/2009	DELIVERY MODE PAPER

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

Office Action Summary	Application No.	Applicant(s)	
	11/670,208	MARTIN, JAMES K.	
	Examiner	Art Unit	
	Filip Zec	3744	

– The MAILING DATE of this communication appears on the cover sheet with the correspondence address –
Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 3 MONTH(S) OR THIRTY (30) DAYS, WHICHEVER IS LONGER, FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
 - If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
 - Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133).
- Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

- 1) ☒ Responsive to communication(s) filed on 28 May 2008.
- 2a) ☐ This action is **FINAL**. 2b) ☒ This action is non-final.
- 3) ☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims

- 4) ☒ Claim(s) 1-15 is/are pending in the application.
- 4a) Of the above claim(s) _____ is/are withdrawn from consideration.
- 5) ☐ Claim(s) _____ is/are allowed.
- 6) ☒ Claim(s) 1-15 is/are rejected.
- 7) ☐ Claim(s) _____ is/are objected to.
- 8) ☐ Claim(s) _____ are subject to restriction and/or election requirement.

Application Papers

- 9) ☐ The specification is objected to by the Examiner.
- 10) ☒ The drawing(s) filed on 01 February 2007 is/are: a) ☒ accepted or b) ☐ objected to by the Examiner.
Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).
Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).
- 11) ☐ The oath or declaration is objected to by the Examiner. Note the attached Office Action or form PTO-152.

Priority under 35 U.S.C. § 119

- 12) ☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).
- a) ☐ All b) ☐ Some * c) ☐ None of:
1. ☐ Certified copies of the priority documents have been received.
 2. ☐ Certified copies of the priority documents have been received in Application No. _____.
 3. ☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

* See the attached detailed Office action for a list of the certified copies not received.

Attachment(s)

- | | |
|--|---|
| 1) ☒ Notice of References Cited (PTO-892) | 4) ☐ Interview Summary (PTO-413) |
| 2) ☐ Notice of Draftsperson's Patent Drawing Review (PTO-948) | Paper No(s)/Mail Date. _____ |
| 3) ☒ Information Disclosure Statement(s) (PTO/SB/08) | 5) ☐ Notice of Informal Patent Application |
| Paper No(s)/Mail Date <u>2/1/07 and 5/28/08</u> . | 6) ☐ Other: _____ |

DETAILED ACTION

Claim Rejections - 35 USC § 102

1. The following is a quotation of the appropriate paragraphs of 35 U.S.C. 102 that form the basis for the rejections under this section made in this Office action:

A person shall be entitled to a patent unless –

(b) the invention was patented or described in a printed publication in this or a foreign country or in public use or on sale in this country, more than one year prior to the date of application for patent in the United States.

2. Claims 1, 2, 5, 8-11 and 15 are rejected under 35 U.S.C. 102(b) as being anticipated by U.S. Patent Application Publication 2003/0147214 to Patel et al. (Patel).

In reference to claim 1, Patel teaches a system (10, FIG. 2) to cool a plurality of electrical load units (130, FIG. 2) with a central cooling unit (40, FIG. 2), comprising at least two electrical load sensors (par 0039, first sentence) coupled to at least two of the electrical load units, each of the at least two electrical load units being coupled to at least one of the electrical load sensors (par 0039, first sentence), the electrical load sensors being adapted to sense electrical loads on the electrical load units (par 0039, entire); a controller (90, FIG. 2) coupled to the electrical load sensors and adapted to receive data from the load sensors (par 0039); a central flow conduit (30, FIG. 2) coupled to the central cooling unit and adapted to provide cooling fluid to the at least two electrical load units, the central flow conduit being coupled to at least two cooling outlets (cooling plates 20, FIG. 2) and the at least two cooling outlets being coupled to the at least two electrical load units (FIG. 2), each of the at least two electrical load units being coupled to at least one of the cooling outlets (FIG. 2); and at least two control valves (140, FIG. 2) coupled to the at least two cooling outlets, each of the at least two cooling outlets being coupled to at least one of the control valves (par 0036), and the controller being adapted to control proportional

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flows of the cooling fluid from the central flow conduit in the at least two cooling outlets to the at least two electrical load units based on the sensed electrical loads (par 0036, last sentence).

In reference to claim 2, Patel teaches the system as described in the rejection of claim 1, and Patel further teaches that the sensed electrical load is electrical current (power consumption in par 0039).

In reference to claim 5, Patel teaches the system as described in the rejection of claim 1, and Patel further teaches that the cooling fluid comprises a gas, a liquid, or a combination thereof (par 0022, third and fourth sentences).

In reference to claim 8, Patel teaches the system as described in the rejection of claim 1, and Patel further teaches that the electrical load units comprise an electrical cabinet, a rack in the cabinet, or an electrical device (the computer board, par 0034).

In reference to claim 9, Patel teaches the system as described in the rejection of claim 1, and Patel further teaches that the controller (90, FIG. 2) is coupled (via 100, FIG. 2) to the cooling unit (40, FIG. 2).

In reference to claims 10, 11 and 15, they claim the method of providing and configuring the apparatus of claims 1, 2 and 8, respectively, thus, they are rejected based on the rejections of claims 1, 2 and 8 above and the associated method steps follow directly from the use of the apparatus.

Claim Rejections - 35 USC § 103

3. The following is a quotation of 35 U.S.C. 103(a) which forms the basis for all obviousness rejections set forth in this Office action:

(a) A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negated by the manner in which the invention was made.

4. Claims 3, 4, 6 and 12 are rejected under 35 U.S.C. 103(a) as being unpatentable over Patel in view of U.S. Patent 6,330,516 to Kammeter (Kammeter).

In reference to claim 3, Patel discloses the system as described in claim 1, but does not teach that said system further comprises a branch control monitor coupled to the at least two electrical load sensors, the load sensors being coupled to a plurality of electrical feeds, and the electrical feeds being coupled to the electrical load units. Kammeter shows a branch circuit monitor (FIG. 1) comprising a digital signal processor (1, FIG. 1) arranged to carry out various calculations based on a voltage input (2, FIG. 1) from each of a plurality of power sources (3, FIG. 1) and on a current input from each of a plurality of non-contact current sensors (4, FIG. 1) one current sensor being provided between each branch circuit breaker (5, FIG. 1) and a corresponding load (6, FIG. 1) in order to allow said branch circuit monitor to make data available, via communications protocols such as Modbus RTU or RS232/RS485/422, to any number of remote sites.

Therefore, it would have been obvious to one having ordinary skill in the art at the time the invention was made to modify the system of Patel, to include the branch circuit monitor, as taught by Kammeter, in order to make data available to any number of remote sites.

In reference to claim 4, Patel and Kammeter disclose the system as described in claim 3, and Kammeter further teaches a data communication link (daisy chain or star network configuration, col 2, lines 45-46) coupled between the branch control monitor (11, 1, FIG. 2A) and the controller (the remote sites, col 2, line 44) in order to enable centralized billing or auditing of power usage, and remote monitoring of branch circuit conditions.

Therefore, it would have been obvious to one having ordinary skill in the art at the time the invention was made to modify the system of Patel, to include the data communication link, as taught by Kammeter, in order to enable centralized billing or auditing of power usage, and remote monitoring of branch circuit conditions.

In reference to claim 6, Patel and Kammeter disclose the system as described in claim 3, and Kammeter further teaches a Modbus RTU/RS232/RS485/422 protocol (col 2, line 43-44) in order to make data available to any number of remote sites.

Therefore, it would have been obvious to one having ordinary skill in the art at the time the invention was made to modify the system of Patel, to include the control bus, as taught by Kammeter, in order to make data available to any number of remote sites.

In reference to claim 12, it claims the method of providing and configuring the apparatus of claim 3, thus, it is rejected based on the rejection of claim 3 above and the associated method steps follow directly from the use of the apparatus.

5. Claims 7, 13 and 14 are rejected under 35 U.S.C. 103(a) as being unpatentable over Patel in view of U.S. Patent 6,854,287 to Patel et al. ('287).

In reference to claim 7, Patel discloses the system as described in claim 1, but does not teach at least two thermal sensors adapted to sense thermal conditions of the at least two

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electrical load units and provide thermal data to the controller. '287 shows temperature sensors (48, FIG. 2; col) located in the computer systems rack (12, FIG. 2) in order to supply temperature readings to a controller configured to operate the heat exchanger unit, the pump, the valve and the pipe valve (col 7, lines 1-6).

Therefore, it would have been obvious to one having ordinary skill in the art at the time the invention was made to modify the system of Patel, to include multiple temperature sensors, as taught by '287, in order to supply temperature readings to a controller configured to operate the heat exchanger unit, the pump, the valve and the pipe valve.

In reference to claim 13 and 14, they claim the method of providing and configuring the apparatus of claim 7, thus, they are rejected based on the rejection of claim 7 above and the associated method steps follow directly from the use of the apparatus.

Conclusion

6. The prior art made of record and not relied upon is considered pertinent to applicant's disclosure.

U.S. Patent Application Publication 2007/0137235 to Heck et al. teaches an arrangement for cooling components in a vehicle.

7. Any inquiry concerning this communication or earlier communications from the examiner should be directed to Filip Zec whose telephone number is 571-270-5846. The examiner can normally be reached on Monday-Friday, from 8:30 AM - 5:00 PM.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisors, Frantz Jules or Cheryl Tyler can be reached on 571-272-6681 or 571-272-4834. The

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fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see <http://pair-direct.uspto.gov>. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

FZ

/Frantz F. Jules/
Supervisory Patent Examiner, Art Unit 3744

Notice of References Cited	Application/Control No. 11/670,208	Applicant(s)/Patent Under Reexamination MARTIN, JAMES K.	
	Examiner Filip Zec	Art Unit 3744	Page 1 of 1

U.S. PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Name	Classification
*	A	US-6,330,516 B1	12-2001	Kammeter, John B.	702/60
*	B	US-2007/0137235 A1	06-2007	Heck et al.	062/259.2
	C	US-			
	D	US-			
	E	US-			
	F	US-			
	G	US-			
	H	US-			
	I	US-			
	J	US-			
	K	US-			
	L	US-			
	M	US-			

FOREIGN PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Country	Name	Classification
	N					
	O					
	P					
	Q					
	R					
	S					
	T					

NON-PATENT DOCUMENTS

*		Include as applicable: Author, Title Date, Publisher, Edition or Volume, Pertinent Pages)
	U	
	V	
	W	
	X	

*A copy of this reference is not being furnished with this Office action. (See MPEP § 707.05(a).)
Dates in MM-YYYY format are publication dates. Classifications may be US or foreign.

Index of Claims 	Application/Control No. 11670208	Applicant(s)/Patent Under Reexamination MARTIN, JAMES K.
	Examiner Filip Zec	Art Unit 3744

✓	Rejected	-	Cancelled	N	Non-Elected	A	Appeal
=	Allowed	÷	Restricted	I	Interference	O	Objected

☐ Claims renumbered in the same order as presented by applicant											☐ CPA		☐ T.D.		☐ R.1.47	
CLAIM		DATE														
Final	Original	01/26/2009														
	1	✓														
	2	✓														
	3	✓														
	4	✓														
	5	✓														
	6	✓														
	7	✓														
	8	✓														
	9	✓														
	10	✓														
	11	✓														
	12	✓														
	13	✓														
	14	✓														
	15	✓														

Search Notes 	Application/Control No. 11670208	Applicant(s)/Patent Under Reexamination MARTIN, JAMES K.
	Examiner Filip Zec	Art Unit 3744

SEARCHED			
Class	Subclass	Date	Examiner
62	259.2 (limited text search - see search notes history)	1/26/09	FZ

SEARCH NOTES		
Search Notes	Date	Examiner
Discussed class 62 with B. Doerrler	1/24/09	FZ
See EAST search history notes	1/26/09	FZ

INTERFERENCE SEARCH			
Class	Subclass	Date	Examiner

	VALTRUS EXHIBIT 2039 VERTIV v. VALTRUS IPR2025-00669
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EAST Search History

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
S1	38	("20030147214" "20040109288" "20050128704" "20050155646" "20050159099" "20050259397" "20050267639" "20050278069" "20050278070" "6415619" "6747872" "6772604" "6829142" "6854287" "6862179" "6868682" "6868683" "6886353" "6945058" "6987370").PN.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT	OR	ON	2009/01/23 18:00
S2	1346	62/259.2.ccls.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT	OR	ON	2009/01/23 18:58
S3	32	S2 and thermal near sensor	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT	OR	ON	2009/01/23 18:58
S4	2826957	S3 and monitor or display	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT	OR	ON	2009/01/23 18:59
S5	19	S3 and (monitor or display)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT	OR	ON	2009/01/23 18:59
S6	7	S3 and branch	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT	OR	ON	2009/01/23 19:00
S8	7	S2 and data with link	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT	OR	ON	2009/01/23 19:01

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S9	0	S1 and data with link	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT	OR	ON	2009/01/23 19:04
S10	1	S1 and branch	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT	OR	ON	2009/01/23 19:04
S11	11	S1 and plurality with sensor	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT	OR	ON	2009/01/23 19:05
S12	0	S2 and plurality with sens\$3 with display	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT	OR	ON	2009/01/23 19:06
S13	7	S2 and plurality with sens\$3 with monitor	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT	OR	ON	2009/01/23 19:06
S14	2	S2 and control near bus	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT	OR	ON	2009/01/23 19:07
S15	1346	62/259.2.ccls.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT	OR	ON	2009/01/26 12:27
S16	32	S15 and thermal near sensor	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT	OR	ON	2009/01/26 12:27
S17	1	S16 and data with link	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT	OR	ON	2009/01/26 12:27
S18	3	"11420784"	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT	OR	ON	2009/01/26 12:30

S19	7	("20030001702" "20030184279" "4004221" "6330516" "6637564" "6713997" "6809509").PN. OR ("7477501").URPN.	US-PGPUB; USPAT; USOCR	OR	ON	2009/01/26 12:31
S20	38	("20030147214" "20040109288" "20050128704" "20050155646" "20050159099" "20050259397" "20050267639" "20050278069" "20050278070" "6415619" "6747872" "6772604" "6829142" "6854287" "6862179" "6868682" "6868683" "6886353" "6945058" "6987370").PN.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT	OR	ON	2009/01/26 13:10
S21	9	S20 and (plurality with sensor with (thermal or temperature))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT	OR	ON	2009/01/26 13:10

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	Filing Date	2007-02-01
	First Named Inventor	MARTIN, James
	Art Unit	3744
	Examiner Name	ALI, Mohammad
	Attorney Docket Number	021944-105US

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/F.Z./	1	6415619		2002-07-09	Bash et al.		

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/F.Z./	2	1448040	EP		2004-08-18	Hitachi, Ltd.		☐

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SERIAL NUMBER	FILING or 371(c) DATE	CLASS	GROUP ART UNIT	ATTORNEY DOCKET NO.		
11/670,208	02/01/2007	062	3744	021944-105US		
RULE						
APPLICANTS James K. MARTIN, Delaware, OH; ** CONTINUING DATA ***** This appln claims benefit of 60/862,538 10/23/2006 ** FOREIGN APPLICATIONS ***** ** IF REQUIRED, FOREIGN FILING LICENSE GRANTED ** 02/23/2007						
Foreign Priority claimed ☐ Yes ☒ No 35 USC 119(a-d) conditions met ☐ Yes ☐ No Verified and /FILIP ZEC/ Acknowledged Examiner's Signature		☐ Met after Allowance Initials	STATE OR COUNTRY OH	SHEETS DRAWINGS 2	TOTAL CLAIMS 15	INDEPENDENT CLAIMS 2
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	1	6945058		2005-09-20	BASH, et al.	
	2	6886353		2005-05-03	PATEL, et al.	
	3	6868683		2005-03-22	BASH, et al.	
	4	6868682		2005-03-22	SHARMA, et al.	
	5	6862179		2005-03-01	BEITELMAL, et al.	
	6	6854287		2005-02-15	PATEL, et al.	
	7	6829142		2004-12-07	BELADY, et al.	
	8	6772604		2004-08-10	BASH, et al.	

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	First Named Inventor	MARTIN, James K.		
	Art Unit			
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	Attorney Docket Number		021944-105US	

	9	6747872		2004-06-08	PATEL, et al.	
	10	6987370		2006-01-17	CHHEDA, et al.	

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	3	20050267639		2005-12-01	SHARMA, et al.	
	4	20050259397		2005-11-24	BASH, et al.	
	5	20050159099		2005-07-21	MALONE	
	6	20050155646		2005-07-21	BASH, et al.	
	7	20050128704		2005-06-16	PATEL	

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	8	20040109288		2004-06-10	BEITELMAL, et al.	
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	1	2004051156	WO	A1	2004-06-17	Hewlett-Packard Development Company, L.P., et al.		☐
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☒ None

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Signature	/D. Brit Nelson/	Date (YYYY-MM-DD)	2007-02-01
Name/Print	D. Brit Nelson	Registration Number	40370

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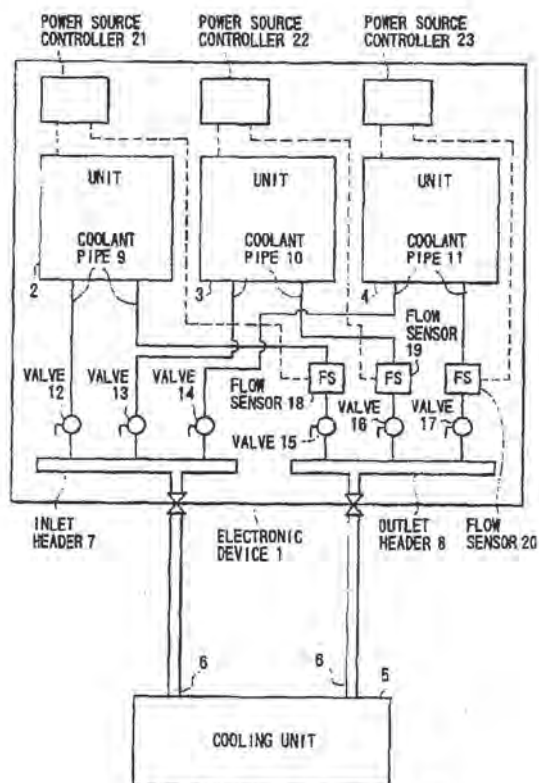
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0 421 743 A2

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BE DE FR GB IT NL(71) Applicant: **NEC CORPORATION**
7-1, Shiba 5-chome Minato-ku
Tokyo 108-01(JP)(72) Inventor: **Umezawa, Kazuhiko, c/o NEC**
Corporation
7-1, Shiba 5-chome
Minato-ku, Tokyo 108-01(JP)(74) Representative: **Smith, Philip Antony et al**
REDDIE & GROSE 16 Theobalds Road
London WC1X 8PL(GB)(54) **Coolant supply apparatus for liquid-cooled electronic device.**

(57) A coolant supply apparatus for a liquid-cooled electronic device includes an inlet header (7), an outlet header (8), and a plurality of valves (12, 13, 14, 15, 16, 17). The inlet header (7) receives a coolant from a cooling unit (5). The outlet header (8) returns the coolant to the cooling unit (5). The plurality of valves (12, 13, 14, 15, 16, 17) are respectively arranged in correspondence with inlet pipes for supplying the coolant from the inlet header (7) to units (2, 3, 4) of the device and with outlet pipes for returning the coolant from the units (2, 3, 4) to the outlet header (8).



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COOLANT SUPPLY APPARATUS FOR LIQUID-COOLED ELECTRONIC DEVICE

Background of the Invention

The present invention relates to an apparatus for supplying a coolant to an electronic device, such as a large data processor, which is cooled by a liquid coolant.

In an electronic device such as a large data processor, semiconductor IC elements used for the device are formed into large scale integrated circuits, and the packing density is greatly increased to optimize the performance of the device. For this reason, the heating density in the device is greatly increased. For such a device, a forced-air cooling system using a cooling fan lacks cooling performance. Therefore, several types of cooling methods have been recently proposed and put into practice, in which a liquid coolant, e.g., water, having a larger heat capacity than air is circulated in a device to cool the device by dissipating generated heat.

In such a liquid-cooled device, as shown in Fig. 4, a device 201 is divided into a plurality of units 202 to 204, and a liquid coolant is supplied to the respective units through different systems. With such an arrangement, even if supply of the liquid coolant to a certain unit must be stopped to perform maintenance thereof, the liquid coolant can be kept supplied to other units. Referring to Fig. 4, the liquid coolant is independently supplied to the units 202, 203, and 204 from a cooling unit 205. When supply of the liquid coolant to the unit 202 is to be stopped, only valves 206 and 207 arranged at the inlet and outlet of the cooling supply system of the unit 202 are required to be closed. In this case, since valves 208 to 211 are open, supply of the liquid coolant to the units 203 and 204 is not stopped.

In the above-described supply apparatus, however, if a device is divided into small units, coolant pipe systems of the same number as that of the units must be installed. This complicates the structure of the cooling unit. In addition, since the number of pipes installed between the cooling unit and the electronic device is increased, the time required for the installation of the pipes is increased. Moreover, the complicated pipe systems in the electronic device interfere with an increase in packing density in the device.

Summary of the Invention

It is an object of the present invention to provide a coolant supply apparatus for a liquid-cooled electronic device, which can simplify the structure

of a cooling unit, facilitate installation, and can protect the device against failure to open valves.

In order to achieve the above object, according to the present invention, there is provided a coolant supply apparatus for circulating/supplying a liquid coolant to a plurality of units of a liquid-cooled electronic device, comprising an inlet header to which the coolant is supplied from a cooling unit, an outlet header for returning the coolant to the cooling unit, and a plurality of valves respectively arranged in correspondence with inlet pipes for supplying the coolant from the inlet header to the units and with outlet pipes for returning the coolant from the units to the outlet header.

Brief Description of the Drawings

Fig. 1 is a block diagram showing an embodiment of the present invention;

Figs. 2A and 2B are views showing a flow sensor;

Fig. 3 is a circuit diagram of a power source controller; and

Fig. 4 is a block diagram showing a conventional coolant supply apparatus for an liquid-cooled electronic device.

Description of the Preferred Embodiment

The present invention will be described below with reference to the accompanying drawings.

Fig. 1 shows an embodiment of the present invention. Referring to Fig. 1, reference numeral 1 denotes an electronic device constituted by a plurality of units, i.e., a unit 2, a unit 3, and unit 4; 5, a cooling unit, connected to the electronic device 1 through a pair of hoses, for circulating a liquid coolant in the electronic device 1; and 7 and 8, inlet and outlet headers, respectively, for distributing the liquid coolant supplied through one system to the respective units.

Valves 12 to 17 are arranged at the connecting portions between the header 7 and pipes 9, 10, and 11 for supplying the coolant to the units 2, 3, and 4. When supply of the coolant to a given unit is to be stopped, corresponding valves are closed. For example, when supply of the coolant to the unit 3 is to be stopped, the valves 14 and 15 are closed. Flow sensors 18, 19, and 20 are arranged in the coolant systems of the respective units on a side opposite to the outlet valves 15 to 17 and the header 8 so as to detect when the flow is stopped in the coolant systems of the respective units. Reference numerals 21, 22, and 23 denote power

source controllers of the units 2, 3, and 4, respectively. Signals from the flow sensors 18, 19, and 20 are respectively supplied to the power controllers 21, 22, and 23 of the units 2, 3, and 4. The liquid coolant supplied from the cooling unit 5 flows to the inlet header 7 through the hose 6. The coolant is then distributed by the header 7 to flow to the pipes 9, 10, 11 for respectively supplying the coolant to the units 2, 3, and 4. After cooling the units 2, 3, and 4, the coolant is collected by the outlet header 8. The coolant then returns to the cooling unit 5 through the hose 6.

As shown in Figs. 2A and 2B, each of the flow sensors 18 to 20 is designed such that a lead switch 25 is opened/closed depending on the position of a float 24 with a magnet. Whether the coolant is flowing or not is detected on the basis of this opening/closing operation of the lead switch 25. Fig. 2A shows a case wherein the coolant is flowing. Fig. 2B shows a case wherein no coolant is flowing. More specifically, the voltage of an input A to a comparator is changed in accordance with opening/closing of the lead switch 25. When the input A is compared with a reference voltage input B, the signal level of an output C from the comparator 26 is changed. Assume that a given one of the flow sensors 18 to 20 detects the flow of the coolant upon input of the output C to the a power source control section 27. In this case, supply of power to a corresponding one of the units is allowed. In contrast to this, assume that no coolant is detected. In this case, if power is being supplied to a corresponding unit, the power is disconnected. If the power is being disconnected, supply of the power is inhibited.

If, for example, supply of the coolant to the unit 2 is to be stopped to perform maintenance thereof, the valves 12 and 13 are closed. At this time, the flow sensor 18 detects that no coolant flows in the pipe system 9 of the unit 2. The detection signal from the sensor 18 is then output to the power source controller 21 so that no power can be supplied to the unit 2 while the flow sensor 18 detects that no coolant flows in the pipe system 9. With this arrangement, even if an operator tries to turn on the power source of the unit 2 while he/she forgets to open the valves 12 and 13 and no coolant is flowing after the maintenance is completed, the power source is not turned on, thus protecting the device.

With the above-described arrangement, since only one pipe system is required between the cooling unit and the electronic device, the structure of the cooling unit can be simplified, and installation there does not require much time. When supply of the coolant to a given unit in the electronic device is required to be stopped for the maintenance of the unit, closing of corresponding valves

is only required. Even if an operator forgets to open given valves, since a corresponding flow sensor detects it and sends a detection signal to the power source controller so as not to turn on the power source of a corresponding unit, failure of the device can be prevented, which is caused when the power source is turned on while no coolant is flowing.

As has been described above, according to the present invention, only one coolant system is arranged between an electronic device and a cooling unit, and a coolant is distributed to the respective units in the device by headers arranged therein. In addition, valves and a flow sensor are arranged at the outlet and inlet of the coolant system to each unit in the device. Moreover, a signal from each flow sensor is supplied to a power source controller of a corresponding unit to inhibit the power source of the unit from being turned on if no coolant is supplied thereto. With these arrangements, the structure of the cooling unit can be simplified, installation is facilitated, and the device can be protected against failure to open valves.

Claims

1. A coolant supply apparatus for circulating/supplying a liquid coolant to a plurality of units of a liquid-cooled electronic device, comprising:

an inlet header to which the coolant is supplied from a cooling unit;

an outlet header for returning the coolant to said cooling unit; and

a plurality of valves respectively arranged in correspondence with inlet pipes for supplying the coolant from said inlet header to the units and with outlet pipes for returning the coolant from the units to said outlet header.

2. An apparatus according to claim 1, further comprising a plurality of power source controllers each of which is adapted to inhibit supply of power to a corresponding one of the units when a flow rate of a corresponding one of said inlet or outlet pipes is not more than a predetermined value.

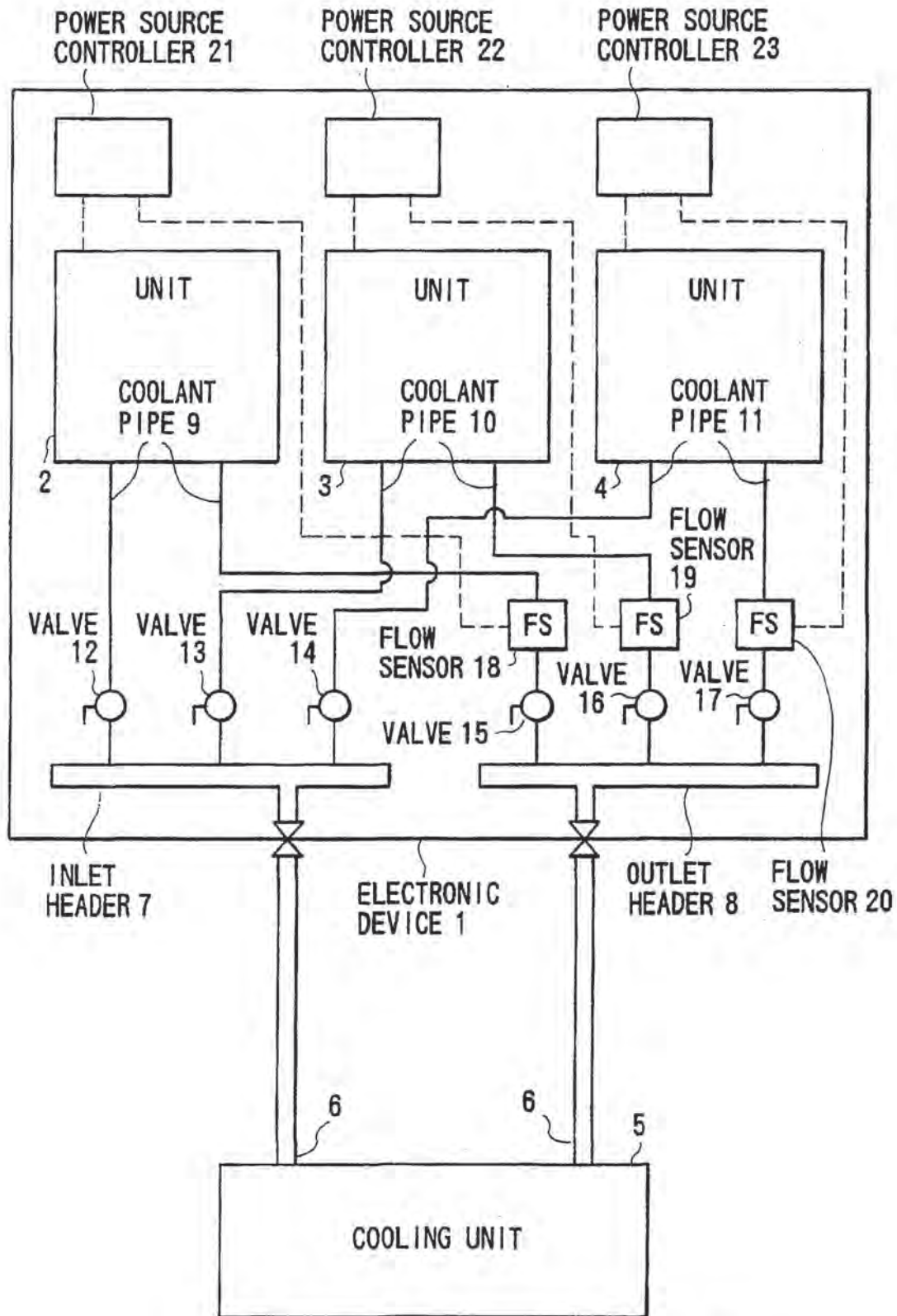


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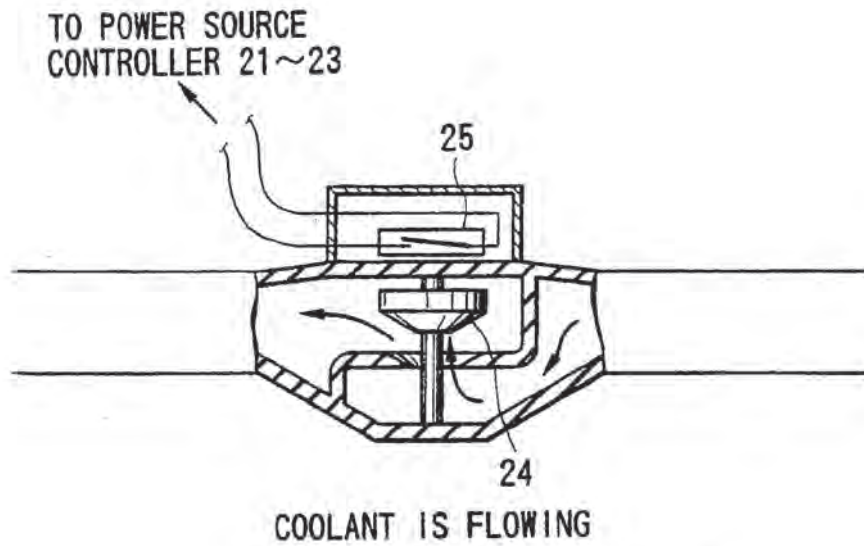


FIG.2A

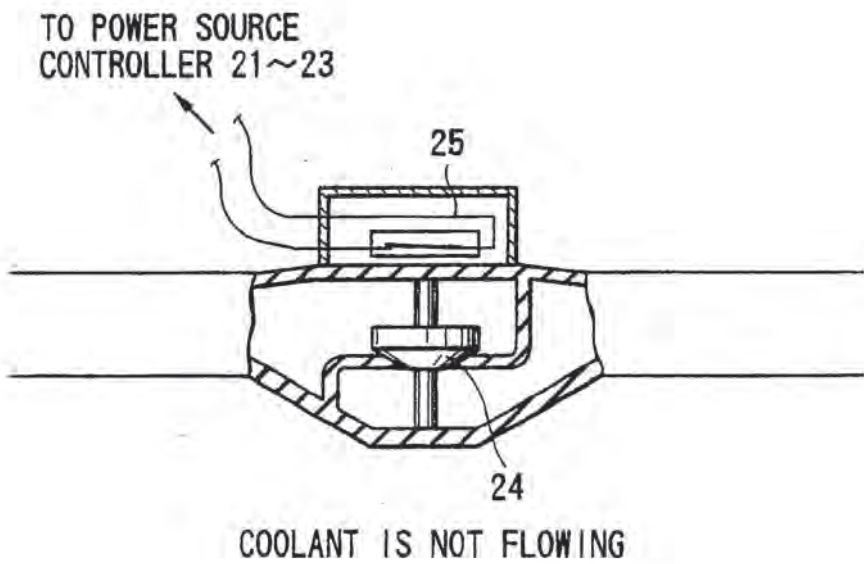


FIG.2B

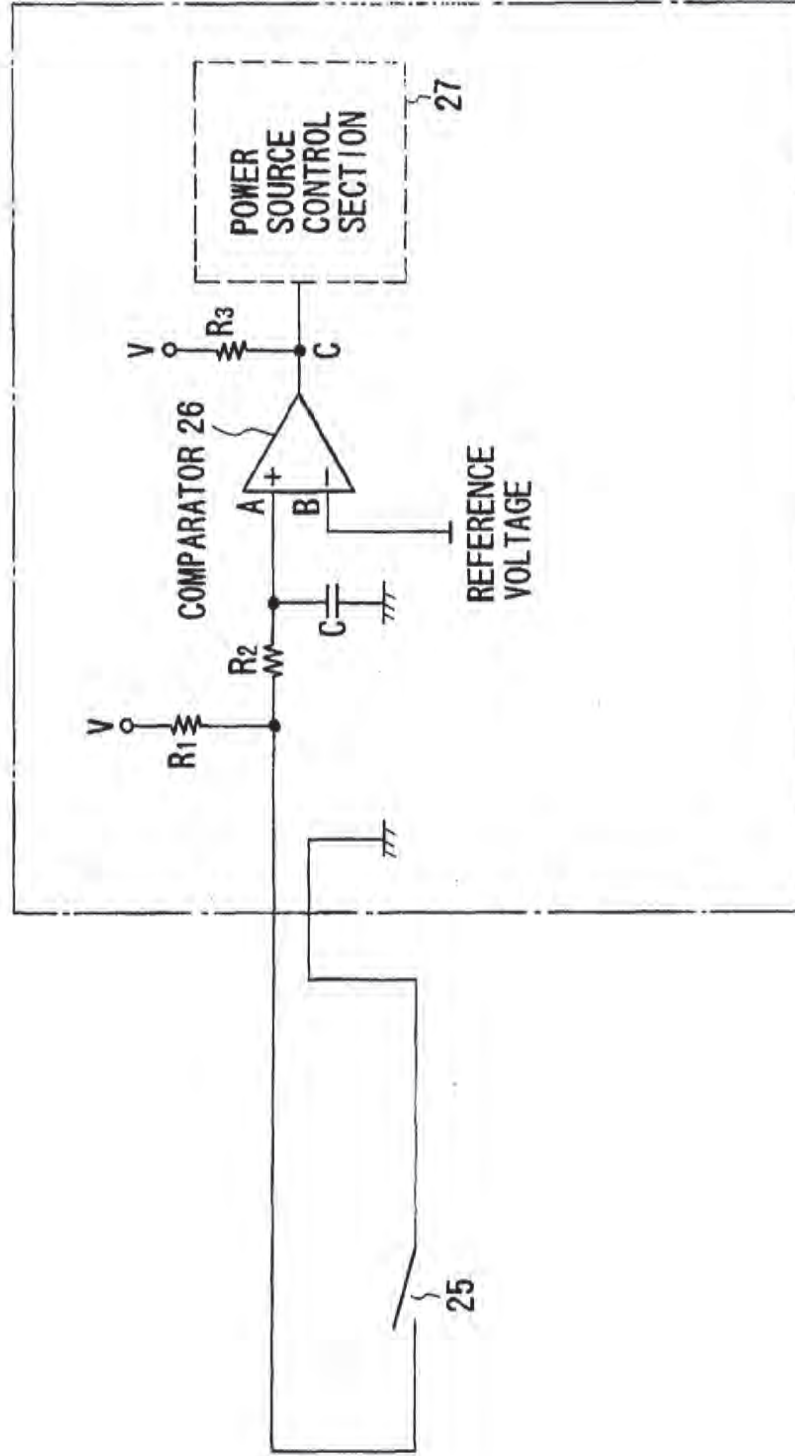


FIG.3

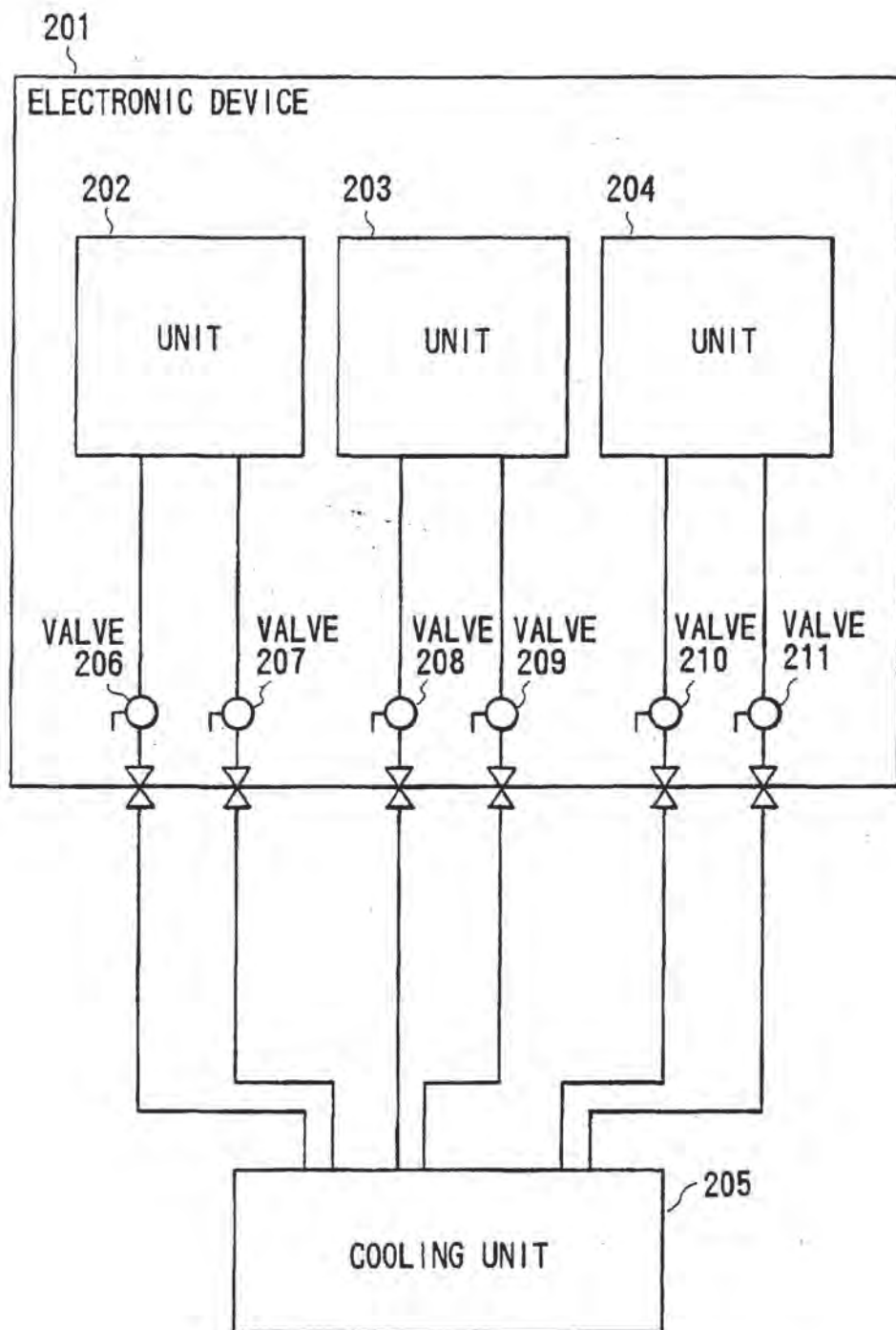


FIG. 4
PRIOR ART



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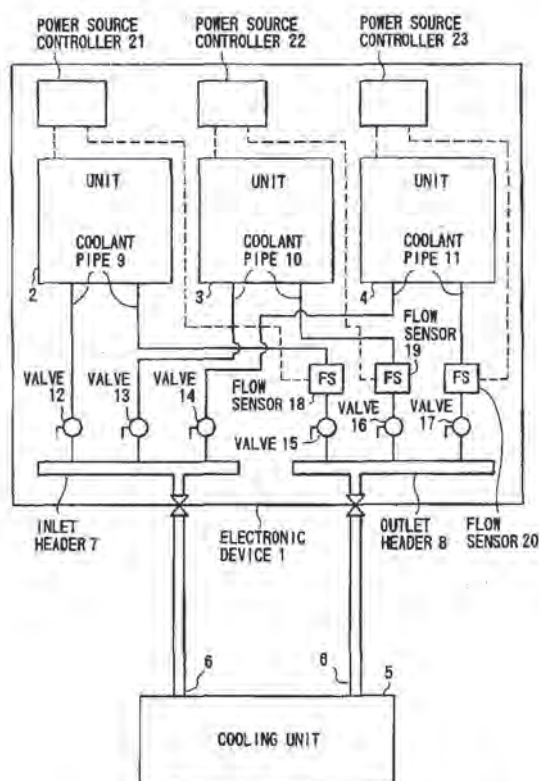
Applicant: **NEC CORPORATION**
7-1, Shiba 5-chome Minato-ku
Tokyo 108-01(JP)

Inventor: **Umezawa, Kazuhiko, c/o NEC**
Corporation
7-1, Shiba 5-chome
Minato-ku, Tokyo 108-01(JP)

Representative: **Smith, Philip Antony et al**
REDDIE & GROSE 16 Theobalds Road
London WC1X 8PL(GB)

Coolant supply apparatus for liquid-cooled electronic device.

A coolant supply apparatus for a liquid-cooled electronic device includes an inlet header (7), an outlet header (8), and a plurality of valves (12, 13, 14, 15, 16, 17). The inlet header (7) receives a coolant from a cooling unit (5). The outlet header (8) returns the coolant to the cooling unit (5). The plurality of valves (12, 13, 14, 15, 16, 17) are respectively arranged in correspondence with inlet pipes for supplying the coolant from the inlet header (7) to units (2, 3, 4) of the device and with outlet pipes for returning the coolant from the units (2, 3, 4) to the outlet header (8).



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European Patent
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EUROPEAN SEARCH REPORT

Application Number

EP 90 31 0795

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
X	US-A-3 334 684 (M.D. ROUSH ET AL.) * the whole document *	1-2	H05K7/20
A	EP-A-0 313 473 (FUJITSU LIMITED) * the whole document *	1	
A	US-A-2 692 961 (W. FONDILLER) * the whole document *	1-2	
A	IBM TECHNICAL DISCLOSURE BULLETIN, vol. 14, no. 11, April 1972, NEW YORK US pages 3375 - 3376; P.J. CUNAVELIS ET AL.: 'DIELECTRIC COOLING SYSTEM' * the whole document *	1	
			TECHNICAL FIELDS SEARCHED (Int. Cl.5)
			H05K
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 07 APRIL 1992	Examiner TOUSSAINT F.M.A.
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(72) Inventors:
• Ota, Shigemi, c/o Hitachi, Ltd., Int. Prop. Group
Chiyoda-ku Tokyo 100-8220 (JP)
• Matsushita, Shinji, c/o Hitachi, Ltd.,
Chiyoda-ku Tokyo 100-8220 (JP)

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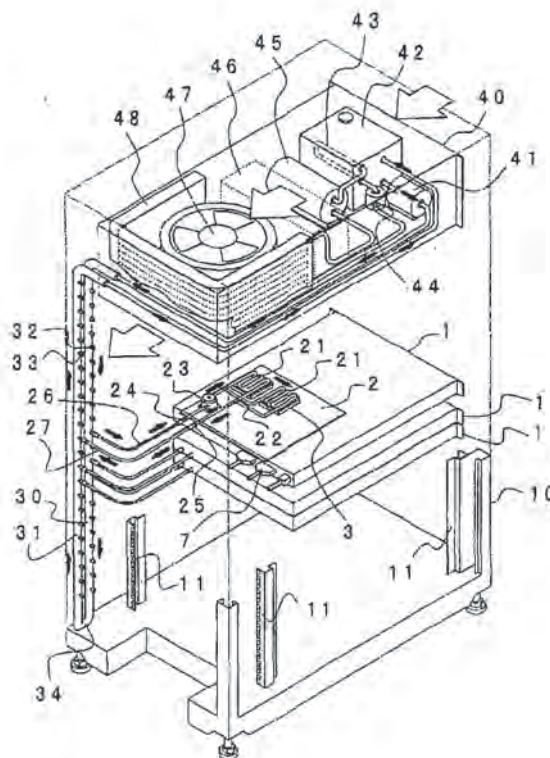
(74) Representative: Strehl Schübel-Hopf & Partner
Maximilianstrasse 54
80538 München (DE)

(71) Applicant: Hitachi, Ltd.
Chiyoda-ku, Tokyo 101-8010 (JP)

(54) Liquid cooling system for a rack-mount server system

(57) A rack-mount server system of a liquid cooling system, in which a heat-generating component such as CPU is cooled by a coolant, is composed of: a plurality of server modules with heat-generating components which are cooled by the circulating coolant; a coolant circulation path to which the server modules are connected in parallel and through which the coolant to cool the server modules is circulated; and a cooling unit connected in the middle of the coolant circulation path, the cooling unit circulating the coolant and cooling the coolant by radiating its heat to the outside air. Furthermore, a bypass route parallel to the server modules and going around the server modules is provided in the coolant circulation path, and the circulation quantity of the coolant is controlled in the bypass route. Alternatively, the flow quantity of the coolant is controlled in each of the server modules. In this manner, the cooling enough to ensure the reliability of a plurality of server modules mounted in the rack cabinet can be achieved.

FIG. 5



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Description

BACKGROUND OF THE INVENTION

[0001] The present invention relates to a cooling method for a rack-mount server system in which a plurality of computers are stacked. More particularly, the present invention relates to a technique effectively applied to the liquid cooling system in which a coolant is circulated.

[0002] In recent years, the rack-mount system has been the mainstream in the system configuration, storage, and installation of a data processing system such as a server. In the rack-mount system, the devices with specific functions are mounted so that they are stacked on each other in a rack cabinet formed based on a particular standard, and the rack-mount system has the advantages as follows: the devices can be freely selected and arranged, the rack-mount server system is excellent in the flexibility and extensibility of the system configuration, and the space occupied by the system can be reduced.

[0003] Particularly, the 19 inch rack cabinet defined in the IEC standard (International Electrical Commission) /EIA standard (The Electrical Industries Association) has been the mainstream of the server system, in which the horizontal width between the posts to mount the devices is defined as 451 mm and the height for mounting the devices is defined as 1U (1 EIA = 44.45 mm).

[0004] Note that FIG. 15 is a perspective view showing the state where the server modules are mounted in the rack cabinet of the conventional rack-mount server system, which is examined as a background of the present invention by the inventors. In the conventional rack-mount server system, a plurality of server modules are mounted in the rack cabinet 10. The rack cabinet 10 is composed of four posts to be the outer frame and four mount angles 11 on which the server modules are mounted.

[0005] The device housing 1 of the server module is attached to the mount angles 11 via metal brackets 8. A main substrate 2 is mounted in the device housing 1, and heat-generating components 3 such as CPU (Central Processing Unit) and LSI (Large Scale Integrated circuit) are mounted on the main substrate 2. A heat radiation fin 4 is attached on each of the heat-generating components 3, and cooling fans 5 are mounted on the upstream side or the downstream side of the radiation fins 4 to deliver the air to the radiation fins 4.

[0006] Usually, devices 6 such as magnetic storage devices are mounted on the front face of the server module and connectors 7 to the outside are mounted on the rear face of the server module.

[0007] In the configuration described above, the outside air is taken by the cooling fans 5 mounted in the device housing 1 from the front face of the devices through the spaces between the devices 6, and after cooling the heat-generating components 3 by the heat

radiation fin 4, the air is exhausted through the spaces between the connectors 7 to the rear face or the side faces of the device.

[0008] The conventional rack-mount server system mainly employs the forced air cooling system as described above in which the air is taken from the front face of the device by the cooling fan 5 mounted in the device housing 1 of the server module and the air is exhausted to the rear face or the side faces of the device after cooling the heat-generating components 3. Note that the technique relating to the forced air cooling system for the rack-mount system is disclosed in Japanese Patent Laid-Open No. 2000-261172.

SUMMARY OF THE INVENTION

[0009] Meanwhile, in the rack-mount system as described above, other devices are similarly mounted above and below the devices of the server module. Therefore, even in the case where the air is taken in and out through the top and bottom plates, the intake and exhaust vents are obstructed and thus it is impossible to achieve the desired cooling effects. Furthermore, in the case where the intake vents are provided on the side face of the devices, the air heated by the exhausted air from the devices is taken in and the cooling efficiency is reduced. Therefore, in the forced air cooling system for the rack-mount system, it is necessary that the air is taken in from the front face of the devices and exhausted from the rear face or the side faces.

[0010] Also, in the rack-mount system, the reduction in thickness of the devices has advanced in recent years so as to achieve the higher density mounting and the space saving of the server modules in the rack cabinet, and the cooling fan mounted in the device is limited to the small cooling fan with a small flow rate. In addition, since devices such as magnetic storage devices are mounted on the front face of the devices and connectors to the outside are arranged on the rear face of the devices, the area for the air intake and exhaust is significantly reduced.

[0011] Also, with the performance development of the server module in the rack-mount system, the performance of CPU or LSI is enhanced, the multiple CPU configuration is increasingly used, and devices such as the magnetic storage devices are operated at higher speed and formed into an array. As a result, the amount of heat generated therein is increased. Therefore, it becomes more and more difficult to ensure the air flow rate required in the forced air cooling.

[0012] Accordingly, an object of the present invention is to provide the cooling method capable of achieving the cooling enough to ensure the reliability of the server modules mounted in the rack cabinet without losing the advantages of the rack-mount system and capable of achieving the smooth radiation of the heat from the high-temperature components mounted on the server module particularly by adopting the liquid cooling system

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even in the case where the performance of the server module is advanced, the thickness the server module is reduced, and the high density mounting technology is advanced.

[0013] For the achievement of the object described above, the present invention provides the configuration including a plurality of rack-mounted server modules having heat-generating components, a cooling unit for radiating heat to the outside, and a coolant circulation path which connects the plurality of server modules to the cooling unit and through which the coolant is circulated, wherein the plurality of server modules are connected to the coolant circulation path in parallel to each other. In this configuration, the liquid cooling system is used as the cooling system of the server modules, wherein the coolant thereof is supplied to each of the devices of the server modules through the coolant circulation path, the coolant drained from each of the devices is transferred to the outside of the devices, and the coolant is cooled in the cooling unit mounted in the rack cabinet and then supplied again to each of the devices of the server modules.

[0014] In the liquid cooling system, the pipe serving as the coolant circulation path to circulate the coolant through the rack cabinet is arranged vertically along the post of the rack cabinet, and the pump functioning as coolant circulation means and the cooling section for cooling the coolant by using a heat exchanger are provided as the cooling unit on the upper side or the lower side of the rack cabinet. Also, the downstream side of the coolant circulation path from the cooling unit is defined as the downstream pipe and the upstream side of the coolant circulation path from the cooling unit is defined as the upstream pipe, and the upstream pipe and the downstream pipe are vertically formed in parallel to each other, and also, the cooled coolant is constantly supplied to the downstream pipe. In this manner, the closed circulation path is formed within the rack cabinet.

[0015] In the server module, a supply port to supply the coolant from outside is formed and the supply port is connected to the internal pipe which is the coolant circulation path inside the device. Also, the internal pipe is extended to heat-generating components such as CPU and LSI. In addition, heat receivers to receive the heat and a drain port to drain the heated coolant to the outside are provided in the server module, and the coolant is transferred by a pump serving as the circulation means incorporated in the device.

[0016] Also, in the server module, the downstream pipe and the upstream pipe are respectively connected to the supply port and the drain port, through which the coolant is circulated. In this manner, the cooled coolant is constantly supplied and a great amount of heat is radiated to the outside of the devices, and thus, the heat-generating components with a relatively high temperature of each of the devices in the server module are cooled.

[0017] Furthermore, in the server module, the hybrid

configuration of the liquid cooling and the air cooling is also available in which the liquid cooling system is used to cool the heat-generating components with a high temperature and the air cooling system is used to cool the heat-generating components with a relatively low temperature. Furthermore, when there are a plurality of heat-generating components with a high temperature, the pipes to circulate the coolant are connected in parallel to each other.

[0018] In addition, in order to facilitate the connection and disconnection of the coolant pipe at the time of mounting and detaching the server module to and from the rack cabinet, the joints with automatic valve are used to connect the pipes on the rack cabinet side to the supply ports on the side of the device of the server module.

[0019] Furthermore, joints as the supply ports and the drain ports are provided and many pairs of the supply port and the drain port are arranged vertically on the downstream pipe and the upstream pipe so that a plurality of server modules can be positioned at any desired positions.

[0020] Also, in order to prevent the variation in flow quantity and ensure the stable cooling performance even in the case where a plurality of server modules are connected to the pipes provided on the rack cabinet side, a pump is incorporated in each of the devices of the server modules so that they can supply and drain the coolant from and to the pipes on the rack cabinet side by itself.

[0021] In addition, in this cooling system, in order to provide the stable cooling performance, the function to detect the temperature of the circulating coolant and control the power of the heat exchanger is given to the cooling unit using the heat exchanger, and thus, the temperature of the coolant passing through the cooling unit can be kept at a constant temperature.

[0022] Also, in order to enhance the introduction of the cooling system for the rack-mount server system according to the present invention, the configuration of the present invention is provided as the rack cabinet in which the pump, the heat exchanger, the cooling unit, the pipes, and the like constituting the liquid cooling system are incorporated.

[0023] Also, in order to provide the redundancy configuration of the cooling system for the rack-mount server system, a plurality of devices operated independently are mounted in the cooling unit, and when a device does not work well, the other device is operated.

[0024] In this specification, a rack-mount server system in which a plurality of server modules having a CPU are mounted is disclosed. However, the present invention is not limited to the server module and it is possible to apply the present invention to the HDD module having heat-generating components with a high temperature and also to a network module.

BRIEF DESCRIPTION OF THE DRAWINGS

[0025]

FIG. 1 is a schematic block diagram showing the system in which a bypass route is not provided;

FIG. 2 is a schematic block diagram showing the system in which a bypass route is provided and a pump is not mounted on each of the devices of the server modules;

FIG. 3 is a schematic block diagram showing the system in which a bypass route is provided and a flow control valve is provided in each of the devices of the server modules;

FIG. 4 is a schematic block diagram showing the system in which a bypass route is provided and a pump is mounted on each of the devices of the server modules;

FIG. 5 is a perspective view showing the state of the system in which server modules are mounted in a rack cabinet;

FIG. 6 is a perspective view showing the fluid connector of the server module;

FIG. 7 is a perspective view showing the state where both the liquid-cooled server modules and the air-cooled server modules are mounted in the rack cabinet;

FIG. 8 is a perspective view showing an example of a cooling unit;

FIG. 9 is a perspective view showing another cooling unit in accordance with another system;

FIG. 10 is a perspective view showing another fluid connector of the server module;

FIG. 11 is a perspective view showing the hybrid configuration of the server module;

FIG. 12 is a perspective view showing the configuration in the case where a plurality of heat-generating parts of the server module are liquid-cooled;

FIG. 13 is a schematic block diagram showing the case where the redundancy for the heat exchanger of the cooling unit is provided;

FIG. 14 is a schematic block diagram showing the case where the redundancy for the main circulation pump of the cooling unit is provided; and

FIG. 15 is a perspective view showing the state where the server modules are mounted in the rack cabinet of the conventional forced air cooling system.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0026] Hereinafter, embodiments of the present invention will be described in detail with reference to the accompanying drawings. Note that components having the same function are denoted by the same reference symbols throughout the drawings for describing the embodiments, and the repetitive description thereof is omitted.

led.

[0027] First, examples of the configuration of the cooling system for the rack-mount server system according to an embodiment of the present invention will be described with reference to FIGS. 1 to 4. FIG. 1 shows the case where the bypass route is not provided, FIG. 2 shows the case where the bypass route is provided and a pump is not mounted on each device of the server module, FIG. 3 shows the case where the bypass route is provided and a flow control valve is provided in each device of the server module, and FIG. 4 shows the case where the bypass route is provided and the pump is mounted on each device of the server module.

[0028] The configuration of the cooling system for the rack-mount server system schematically shown in FIG. 1 does not have the bypass route and includes: a rack cabinet 10; a plurality of (1 to n) server modules 62 provided with a heat receiver 21, an internal pipe 22 in the device, and the like; a main circulation pipe 34 composed of a downstream pipe 30, an upstream pipe 31, and the like; and a cooling unit 52 provided with a main circulation pump 41, a tank 42, a cooling section 43, a heat exchanger 50, and the like.

[0029] As described above, in the case where the bypass route is not provided, the coolant is supplied to each of the devices of the server modules by means of the main circulation pump 41. In this case, the flow quantity of the coolant is evenly distributed to each of the devices when the flow path resistances are equal in each of the devices. Therefore, in the case where there is one device mounted thereon, the flow quantity Q (1/min) of the main circulation pump 41 is supplied to the device, and in the case where there are two devices mounted thereon, the flow quantity $Q/2$ (1/min) is supplied to each of the devices. In the case where there are n devices mounted thereon, the flow quantity Q/n (1/min) is supplied to each of the n devices. As described above, the flow quantity in the devices is changed depending on the number of mounted devices. The change in flow quantity causes the change in the heat quantity to be removed, and resulting in the change in the cooling performance.

[0030] Also, the flow path resistances are usually different in each of the devices of the server modules 62. In this case, when a several number of devices are mounted, a quantity of coolant inversely proportional to the flow path resistance flows in each of the server modules 62, and it becomes difficult to ensure the desired flow quantity for each of the devices.

[0031] Furthermore, the pressure in the pipe is also changed with the change in flow quantity. Since the diameter of the internal pipe 22 of the server module 62 is usually smaller than that of the main circulation pipe 34, the great deal of pressure is applied when the number of mounted devices is small, and there is the possibility that the coolant may leak from the joint portion. For its prevention, it is necessary to increase the diameter of the internal pipe 22 so as not to apply the

great amount of pressure to the pipe. However, since the increase of the diameter requires a large volume, it is unfit for the device using the high-density mounting technology. Therefore, the configuration shown in FIG. 2 is created.

[0032] In the configuration of the cooling system for the rack-mount server system schematically shown in FIG. 2, the bypass route is provided and the pump is not provided in each of the devices of the server modules. The difference from the configuration in FIG. 1 is that the bypass route is provided to the main circulation pipe 34, and a bypass flow control valve 54 is connected to the bypass route.

[0033] In the case where the bypass route is provided and the pump is not provided in each of the devices of the server modules 62 as described above, it is possible to control the change in flow quantity in each device and the change in pressure in the pipes, which are caused by changing the number of mounted devices of the server modules 62. Usually, since the main circulation pipe 34 has a relatively large diameter and the internal pipe 22 has a relatively small diameter, a large quantity of coolant flows in the bypass route with low flow resistance and only a small quantity of coolant flows in each of the devices. Therefore, just providing the bypass route is insufficient.

[0034] Accordingly, it is necessary to provide a bypass flow control valve 54 in the bypass route. The flow quantity in the devices is increased by reducing the flow quantity in the bypass route, and the flow quantity in the devices is reduced by increasing the flow quantity in the bypass route. The flow quantity and the pressure in the pipes can be adjusted in this manner. However, since the flow quantity of coolant is inversely proportional to the flow resistance of the path similar to the configuration shown in FIG. 1, it is difficult to ensure the desired flow quantity for each of the devices. Therefore, the configuration shown in FIG. 3 is created.

[0035] In the configuration of the cooling system for the rack-mount server system schematically shown in FIG. 3, the bypass route is provided and the flow control valve is provided in each of the devices of the server modules. The difference from the configurations in FIGS. 1 and 2 is that a device flow control valve 28 is connected to each of the internal pipes 22 of the server modules 62.

[0036] In the case where the bypass route is provided and the flow control valve 28 is provided in each of the devices of the server modules 62 as described above, the flow quantity through the device is reduced by closing the valve in the device, and the flow quantity through the device is increased by opening the valve in the device in each of the server modules 62. In this configuration, it is possible to achieve the desired flow quantity for each of the devices by the adjustment of the flow control valve 28 in each device together with the adjustment of the flow quantity and the pressure in the pipe by the bypass flow control valve 54. However, it is diffi-

cult to adjust the flow quantity to the desired value when a plurality of devices each having different flow quantities are mounted. Therefore, the configuration shown in FIG. 4 is created.

[0037] In the configuration of the cooling system for the rack-mount server system schematically shown in FIG. 4, the bypass route is provided and the pump is provided in each of the devices of the server modules. The difference from the configurations in FIGS. 1 to 3 is that an internal pump 23 is connected to each of the internal pipes 22 of the server modules 62.

[0038] In the case where the bypass route is provided and the pump is provided in each of the devices of the server modules 62 as described above, the relationship between the flow quantity (flow quantity of the main circulation pump 41) Q through the main circulation pipe 34 and the flow quantities (flow quantity of the internal pump 23 of each of the devices) q through each of the devices of the server modules 62 is set so as to satisfy the following condition:

$$Q > q_1 + q_2 + \dots + q_n \quad (\text{Formula 1})$$

[0039] By doing so, when the device is not mounted, the coolant flows through the bypass route of the main circulation pipe 34, and when the device is connected, the coolant flows through the device. However, most of the coolant flows through the bypass route with low flow resistance. For its prevention, the internal pump 23 is operated to supply and drain the coolant from and to the main circulation pipe 34 by itself, and the flow quantity more than necessary is sent to the bypass route.

[0040] Since this configuration enables the supply and drain by itself, it is possible to achieve the desired flow quantity in accordance with the performance of the internal pumps 23 for the devices of the server modules 62. In addition, when the condition in the above-described Formula 1 is satisfied, it is possible to pass the coolant with the desired flow quantity to each of the devices even in the case where a plurality of devices having different flow quantities are mounted, and thus, it is possible to ensure the stable cooling performance.

[0041] In the following description, the concrete example of the configuration will be described in detail with reference to FIG. 4. More specifically, the rack-mount server system shown in FIG. 4 includes: a rack cabinet 10; a plurality of server modules 62 provided with a heat receiver 21, an internal pipe 22 in the device, and the like; a main circulation pipe 34 composed of a downstream pipe 30, an upstream pipe 31, and the like; and a cooling unit 52 provided with a main circulation pump 41, a tank 42, a cooling section 43, a heat exchanger 50, and the like, and the rack-mount server system shown in FIG. 4 has a configuration as follows.

[0042] In the rack cabinet 10, the circulation system of the main circulation pipe 34 is formed in the mounting direction of the server modules 62, and the coolant is

circulated by means of the main circulation pump 41. Furthermore, the heat of the coolant is radiated to the outside or the heat exchanger 50 cools the circulating coolant. This embodiment shows the cooling system in which the tank 42 is provided as a buffer of the main circulation system, the cooling section 43 is incorporated, and the heat exchanger is used to cool the coolant. Also, the main circulation pump 41, the tank 42, the cooling section 43, and the heat exchanger 50 are assembled together to form the cooling unit 52.

[0043] The server module 62 is a liquid-cooled type of data processing unit, in which the internal pump 23 is incorporated, the coolant is supplied through the internal pipe 23 to a heat-generating component 3, and the coolant is drained out to the outside after cooling the heat-generating component 3 by the heat receiver 21.

[0044] The main circulation pipe 34 is divided at the cooling section 43 into the downstream pipe 30 to which the coolant is drained and into the upstream pipe 31 from which the coolant is supplied. The coolant is supplied to the server module 62 from the downstream pipe 30 and drained to the upstream pipe 31. A plurality of server modules 62 are similarly connected to the main circulation pipe 34. In this case, it is necessary that the flow quantity Q through the main circulation pipe 34 is larger than the sum of the flow quantities q through each of the server modules 62.

[0045] Next, a concrete example of the cooling system for the rack-mount server system according to the embodiment will be described with reference to FIGS. 5 to 7. FIG. 5 is a perspective view showing the state where the server modules are mounted in the rack cabinet, FIG. 6 is a perspective view showing the fluid connector of the server module, and FIG. 7 is a perspective view showing the state where both the liquid-cooled server modules and the air-cooled server modules are mounted in the rack cabinet.

[0046] The rack cabinet 10 has a box shape and is provided with four posts serving as mount angles 11 at the four corners thereof to which the server modules are attached. The main circulation pipe 34 is arranged vertically along the post forming the rack cabinet 10, and the coolant is circulated by the main circulation pump 41. The tank 42 is arranged as the buffer of the coolant in the upstream of the main circulation pump 41, and the main circulation pipe 34 is arranged outside the mount angles 11.

[0047] The heat exchanger 50 employs the system using a cooling medium, in which the evaporated cooling medium is compressed to high pressure in a compressor 45 and delivered to a radiator 48 for cooling medium, and then, cooled by a cooling fan 47 for cooling medium. This cooled cooling medium is liquidized and delivered to an expansion valve 44, in which the cooling medium is evaporated again to cool the cooling section 43, and then, returned to the compressor 45 again.

[0048] The cooling section 43 is incorporated in the tank 42 and cools the coolant in this tank 42. In addition,

the cooling section 43 also has a function to detect the temperature of the circulating coolant and control the cooling power by using a cooling control circuit 46.

[0049] The main circulation pump 41, the tank 42, the cooling section 43, and the heat exchanger 50 are mounted in a cooling unit housing 40 and form the independent cooling unit 52.

[0050] The main circulation pipe 34 is divided at the cooling section 43 into the downstream pipe 30 from which the coolant is drained and the upstream pipe 31 to which the coolant is supplied, and they are arranged in parallel to each other. Downstream joints 32 are provided on the downstream pipe 30 and upstream joints 33 are provided on the upstream pipe 31 so that they are positioned at almost the same height. Furthermore, many pairs of the downstream joint 32 and the upstream joint 33 are arranged vertically.

[0051] These downstream joints 32 and upstream joints 33 have the automatic valve therein, and when the fluid joint is not connected, the valve is automatically closed to prevent the leakage of the liquid. More specifically, the joint with automatic valve has its valve in the connecting joints, and such a valve is formed in each of the male side and the female side of the joints. When the joints are connected, the valves are pushed to each other and the valves are opened, and when the joints are disconnected, the valves are closed by the spring force.

[0052] In the server module 62 according to the embodiment, a main board 2 is provided in the device housing 1 and heat-generating components 3 such as CPU and LSI are mounted on the main board 2. A supply joint 24 serving as a supply port of the coolant from outside is provided on the rear face of the device housing 1, and the internal pipe 22 is laid to the heat-generating components 3, for example, CPU and LSI. Furthermore, the heat receiver 21 for receiving the heat is provided, and the pipe is extended to a drain port to drain the heated coolant to the outside. A drain joint 25 is provided at the drain port.

[0053] Similar to the main circulation pipe 34, the supply joint 24 and the drain joint 25 are the joints with automatic valve. The heat receiver 21 is formed of the material with high heat conductivity and the meandering flow path is formed therein so as to make the contact area to the coolant as large as possible. The flow path is closely contacted to the heat-generating component 3. In addition, the internal pump 23 to deliver the coolant in the device is provided in the middle of the internal pipe 22.

[0054] As the connection method of the internal pipe 22 in the case of cooling a plurality of heat-generating components 3 in the server module 62, there are the serial connection and the parallel connection. However, in the case where the serial connection is used, the coolant is heated by the heat-generating components 3 on the upstream side and the cooling of the heat-generating components 3 on the downstream side is adversely

affected. Therefore, the internal pipe 22 is connected to a plurality of heat-generating components 3 by using the parallel connection.

[0055] In this embodiment, the internal pump 23 provided in the middle of the internal pipe 22 is arranged on the upstream side of the heat-generating components 3 because the heated coolant is sent to the pump 23 and the lifetime and performance of the pump 23 are adversely affected when the pump is arranged on the downstream side of the heat-generating components 3.

[0056] Similar to the usual rack-mounted devices, the server module 62 is mounted on the mount angles 11 of the rack cabinet 10 via metal brackets 8, and the downstream joint 32 of the downstream pipe 30 and the supply joint 24 of the device are connected via a supply tube 26. Also, the upstream joint 33 of the upstream pipe 31 and the drain joint 25 of the device are connected via a drain tube 27. In addition, it is possible to connect a plurality of server modules 62 in the same manner.

[0057] As shown in FIG. 7, not only the liquid-cooled server modules 62 but also the usual air-cooled devices 63 can be mounted on the mount angles 11 of the rack cabinet 10 via the metal brackets 8. Therefore, it is possible to mount both the liquid-cooled server modules 62 and the air-cooled devices 63.

[0058] Subsequently, an example of the liquid cooling system used as the cooling system for the rack-mount server system will be described with reference to FIGS. 4 and 5.

[0059] The coolant is circulated through the main circulation pipe 34 by the main circulation pump 41 regardless of the connection of the server module 62. Also, the cold coolant is constantly supplied to the downstream pipe 30 by the cooling section 43 arranged on the upstream side of the main circulation pump 41. By detecting the temperature of the coolant and adjusting the power of the heat exchanger 50 in the cooling control circuit 46, the coolant with a constant temperature can be supplied to the downstream pipe 30.

[0060] The coolant flows in the server module 62 by connecting the server module 62 to the downstream pipe 30 and the upstream pipe 31 of the main circulation pipe 34. At this time, the server module 62 is connected after filling the coolant. Since the internal pump 23 is incorporated in the server module 62, the coolant is fed to the server module 62 by the operation of the internal pump 23 not by the operation of the main circulation pump 41.

[0061] In this manner, even in the case where a plurality of server modules 62 are connected, the flow quantity is controlled by the internal pump 23 so that the temperature of the heat-generating components 3 can be a uniform temperature, and a constant flow quantity of the coolant in accordance with the performance of the internal pump 23 can be supplied. However, it is necessary that the flow quantity through the main circulation pipe 34 is larger than the sum of the flow quantities through each of the server modules 62.

[0062] The coolant in the downstream pipe 30 of the main circulation pipe 34 is introduced into the device by the internal pump 23 incorporated in the server module 62, and the coolant reaches the heat-generating component 3 and receives its heat in the heat receiver 21 to cool the heat-generating component 3. Then, the coolant is heated and this heated coolant is drained to the upstream pipe 31 of the main circulation pipe 34.

[0063] Even when a plurality of server modules 62 are mounted, the supply ports are all connected to the downstream pipe 30 and the drain ports are all connected to the upstream pipe 31. Therefore, the coolant with the same temperature by the cooling section 43 is introduced into all of the devices. In addition, the heated coolant is brought together to the upstream pipe 31 and returned to the cooling portion 43, and then, cooled to a predetermined temperature again.

[0064] Next, an example of the configuration to improve the cooling efficiency in the cooling unit of the coolant according to the embodiment will be described with reference to FIG. 8. FIG. 8 is a perspective view showing another cooling unit.

[0065] A cooling fan 47 for cooling the cooling medium is provided in the cooling unit 52 of this configuration, in which the air is taken from the front face of the cooling unit housing 40 and delivered to the radiator 48 for cooling medium, and then, exhausted to the outside. The upstream pipe 31 is led into the cooling unit housing 40 and extended to the front face of the device, and then, led into a coolant radiator 49 provided in the air-intake section on the front face of the device. Thereafter, the pipe is led into the tank 42 which incorporates the cooling section 43 and extended to the downstream pipe 30 through the main circulation pump 41.

[0066] In this configuration, it is possible to reduce the temperature of the heated coolant passing through the upstream pipe 31 by the intake air of the cooling fan 47 for cooling medium in the coolant radiator 49 before the coolant is fed to the tank 42. By doing so, it is possible to reduce the amount of temperature to be reduced in the cooling section 43, and the load on the heat exchanger 50 can be reduced. Therefore, the coolant can be cooled efficiently.

[0067] Furthermore, an example of the configuration of the cooling unit of the coolant in accordance with another system according to the embodiment will be described with reference to FIG. 9. FIG. 9 is a perspective view showing still another cooling unit in accordance with another system.

[0068] In the cooling unit 52 of this system, a coolant cooling fan 51 is arranged in the cooling unit housing 40 so that the air is delivered to the coolant radiator 49, and the upstream pipe 31 is led into the coolant radiator 49 and extended to the downstream pipe 30 via the main circulation pump 41.

[0069] In this configuration, the temperature of the heated coolant passing through the upstream pipe 31 can be reduced by the air delivered by the coolant cool-

ing fan 51 in the coolant radiator 49. The simplified system as shown in FIG. 9 can also be used as the coolant cooling unit 52 in this embodiment.

[0070] Next, an example of another fluid connector of the server module according to the embodiment will be described with reference to FIG. 10. FIG. 10 is a perspective view showing another fluid connector of the server module.

[0071] The server module 62 with this fluid connector is mounted on the mount angles 11 via metal brackets 8 and slide rails 61 so that it can be pulled out to the front. The metal bracket 8 or the slide rail 61 is provided with a supply/drain tube holder 60 in parallel to the supply/drain face of the device, and one ends of the supply/drain tubes 26 and 27 are attached to the supply/drain tube holder 60 so that the supply/drain tubes 26 and 27 can be connected to the supply/drain joints 24 and 25 of the server module 62 when the server module 62 is installed into the rack cabinet 10. The other ends thereof are connected to the upstream/downstream pipes 30 and 31. These supply/drain joints 24 and 25 incorporate the automatic valves.

[0072] In this manner, the supply/drain joints 24 and 25 of the server module 62 are automatically connected to the upstream/downstream pipes 30 and 31 when the server module 62 is installed into the rack cabinet 10, and the supply/drain joints 24 and 25 are automatically disconnected from the upstream/downstream pipes 30 and 31 when the server module 62 is pulled out.

[0073] Next, an example of the hybrid configuration of the server module according to the embodiment will be described with reference to FIG. 11. FIG. 11 is a perspective view showing the hybrid configuration of the server module.

[0074] In the server module 62 with this hybrid configuration, heat-generating components 3 with a high temperature such as CPU and LSI generating a relatively large amount of heat and other heat-generating portions 9 with a low temperature generating a relatively small amount of heat are mounted on the main substrate 2. The liquid cooling system in which the heat is received by the heat receiver 21 is used to cool the heat-generating components 3 with a high temperature, and the air cooling system in which the air is delivered by the cooling fan 5 mounted on the front face of the device of the server module 62 is used to cool the heat-generating portions 9 with a low temperature.

[0075] By doing so, in the server module 62 with this hybrid configuration in which the heat-generating components 3 with a high temperature and the heat-generating portions 9 with a low temperature are mounted, the liquid cooling system and the air cooling system are simultaneously used, and the heat-generating components 3 with a high temperature are cooled by the liquid cooling system and the heat-generating portions 9 with a low temperature are cooled by the air cooling system.

[0076] Furthermore, an example of the configuration in which a plurality of heat-generating parts are liquid-

cooled in the server module according to the embodiment will be described with reference to FIG. 12. FIG. 12 is a perspective view showing the configuration in which a plurality of heat-generating parts of the server module are liquid-cooled.

[0077] In the server module 62 with this configuration, the heat-generating components 3 with a high temperature generating a relatively large amount of heat and other heat-generating portions 9 with a low temperature generating a relatively small amount of heat are mounted on the main substrate 2. In addition, heat-generating portions of devices 6 such as magnetic storage devices generating a relatively large amount of heat are mounted on the front face of the device of the server module 62. In this configuration, similar to the heat-generating components 3 whose heat is received by the heat receivers 21a, the heat-generating portions of the devices 6 are also cooled by circulating the coolant through the internal pipes 22 connected in parallel and receiving its heat in the heat receivers 21b. More specifically, it is possible to cool a plurality of heat-generating parts by the liquid cooling system.

[0078] Since the internal pipe 22 is laid in parallel to the heat-generating components 3 and the heat-generating portions of the devices 6, it is possible to supply the coolant with the same temperature to each of the heat-generating parts. In addition, the serial connection is also applicable to the parts in which the amount of heat generation is small. Furthermore, in the case where the heat in the heat-generating portions 9 can be cooled by the natural air cooling, the cooling fan as shown in FIG. 12 is unnecessary.

[0079] Next, an example of the configuration in which the redundancy for the heat exchanger is formed in the cooling unit according to the embodiment will be described with reference to FIG. 13. FIG. 13 is a schematic block diagram showing the case where the redundancy for the heat exchanger of the cooling unit is provided.

[0080] In the cooling unit 52 with this configuration, the two cooling sections 43 are incorporated in the tank 42 and the two heat exchangers 50a and 50b to cool each of the cooling sections 43 are provided in parallel so that they are operated independently. In this configuration, the coolant can be cooled by the two heat exchangers 50a and 50b and the coolant can be cooled even when either of the heat exchangers does not work. Alternatively, it is also preferable that only one of the two exchangers is operated and the other exchanger is operated when the exchanger is broken.

[0081] Furthermore, an example of the configuration in which the redundancy for the main circulation pump is provided in the cooling unit according to the embodiment will be described with reference to FIG. 14. FIG. 14 is a schematic block diagram showing the case where the redundancy for the main circulation pump of the cooling unit is provided.

[0082] In the cooling unit 52 with this configuration, internal pipes are connected in parallel at an outlet of

the tank 42, and two main circulation pumps 41a and 41b for circulating the coolant in the internal pipes are provided in parallel so that they are operated independently. In addition, a check valve 55 is attached to each of the main circulation pumps 41a and 41b. In this configuration, the coolant is circulated by the two main circulation pumps 41a and 41b, and the coolant can be circulated even when either of the main circulation pumps does not work. Also, since the check valve 55 is attached to each of the main circulation pumps 41a and 41b, the circulation of the coolant in the pumps caused when one of the main circulation pumps 41a and 41b is broken can be prevented even when the main circulation pumps 41a and 41b are connected in parallel.

[0083] As described above, the effects as follows can be achieved by the cooling system for the rack-mount server system according to the embodiments.

(1) Even under the condition that the cooling by the cooling fan cannot be sufficiently performed due to the reduction of the intake and exhaust areas caused by the device thickness reduction and the increase of the pressure loss of the fluid caused by the high density mounting in the rack-mounted device using the forced air cooling, the adoption of the liquid cooling system makes it possible to receive the heat of the heat-generating components 3 with a high temperature by the coolant and to radiate the heat to the outside of the device of the server module 62, and also, the coolant can be smoothly cooled in the cooling unit 52 mounted in the rack cabinet 10.

(2) Since the coolant is circulated by the main circulation pump 41 provided in the main circulation pipe 34 and the server module 62 to be mounted is provided with the internal pump 23 to circulate the coolant in the devices thereof, even in the case where the number of server modules to be mounted (connected) is increased, the flow quantity of the coolant passing through each of the devices can be kept uniform as long as the flow quantity through the main circulation pipe 34 is larger than the sum of the flow quantities through the mounted devices.

(3) By controlling the cooling power to the coolant in the heat exchanger 50 with the control circuit, it becomes possible to supply the coolant with a constant temperature to each of the server modules 62, and therefore, it is possible to provide the highly reliable cooling performance.

(4) Since it is necessary to connect the server module 62 to the main circulation pipe 34 of the cooling unit 52 mounted in the rack cabinet 10 only when the liquid-cooled server modules 62 are mounted, it is also possible to mount the air-cooled device 63 as well as the liquid-cooled devices. In addition, since the joint with automatic valve is used in the fluid connector, it is possible to easily mount and detach the devices of the server modules 62. Fur-

thermore, since a plurality of joints are provided in the main circulation pipe 34, it is possible to mount the server module 62 at the desired position. The system configuration capable of mounting various devices other than the liquid-cooled devices can be provided without losing the advantages of the rack-mount system.

(5) Since only the heat receiver 21, the internal pump 23, and the internal pipe 22 are required to form the cooling configuration in the server module 62, it is possible to simplify the configuration for cooling the devices. Furthermore, the simplification of the cooling configuration leads to the size reduction of the server module 62.

(6) Since it is possible to form the closed cooling unit 52 within the rack cabinet 10, the heat-generating components 3 with a high temperature in the devices of the server module 62 can be cooled without such a special condition that the room temperature is extremely reduced.

(7) Since the coolant cooling unit 52 is assembled as a rack-mounted device and the cooling unit 52 is formed so that it can be mounted on the widely-prevalent rack cabinet 10, the cooling system according to the present invention can be easily introduced without preparing any special rack cabinet 10.

(8) By providing a plurality of heat exchangers 50 or a plurality of main circulation pumps 41 in parallel, the cooling unit 52 can be operated independently. Therefore, the redundancy configuration can be provided in which, when one exchanger or one main circulation pump is broken, the other exchanger or the other main circulation pump is operated.

[0084] According to the present invention, even in the case where the performance of the server module is advanced, the thickness of the server module is reduced, and the high density mounting technology is advanced, the cooling enough to ensure the reliability of the server modules mounted in the rack cabinet can be achieved without losing the advantages of the rack-mount system. In addition, it is also possible to achieve the smooth heat radiation from the high-temperature components mounted on the server module particularly by adopting the liquid cooling system.

[0085] Also, according to the present invention, since the advantages of the rack-mount system are not lost, it is possible to form the rack-mount server system in which the easiness of mounting and the operability inherent in the conventional devices other than the liquid-cooled device are not impaired.

[0086] Furthermore, according to the present invention, the closed cooling unit is formed within the rack cabinet, and the cooling configuration for each of the server modules can be simplified. Therefore, it is possible to achieve the size reduction of the server module and the size reduction of the rack-mount server system.

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Claims

1. A rack-mount server system, comprising:
 - a plurality of server modules with heat-generating components, said heat-generating components being cooled by a circulating coolant; a coolant circulation path to which said server modules are connected in parallel and through which the coolant to cool the server modules is circulated; and
 - a cooling unit connected in the middle of said coolant circulation path, said cooling unit circulating the coolant and cooling said coolant by radiating its heat to the outside air.
2. The rack-mount server system according to claim 1, wherein said coolant circulation path has a bypass route parallel to said server modules and going around said server modules.
3. The rack-mount server system according to claim 2, wherein said coolant circulation path has flow quantity control means in said bypass route to control the flow quantity of the coolant circulating in said server modules.
4. The rack-mount server system according to claim 3, wherein said flow quantity control means increases the flow quantity when reducing the circulation quantity of the coolant to the server modules and said flow quantity control means reduces the flow quantity when increasing the circulation quantity of the coolant to the server modules.
5. The rack-mount server system according to claim 2, wherein said server module has flow quantity control means in a flow path connected to said coolant circulation path.
6. The rack-mount server system according to claim 5, wherein said flow quantity control means is provided on an inflow side of the coolant circulating in the server module.
7. The rack-mount server system according to claim 2, wherein the flow quantity of the coolant through the bypass route of said coolant circulation path is controlled to change the flow quantity of the coolant circulating in said plurality of server modules.
8. The rack-mount server system according to claim 1, wherein each of the server modules has flow quantity control means of the coolant in a part of the coolant circulation path to cool the server modules.
9. The rack-mount server system according to claim 8, wherein said flow quantity control means is provided on an inflow side of the coolant circulating in the server module.
10. The rack-mount server system according to claim 1, wherein joints with automatic valve are provided, with which an inlet and an outlet of the coolant circulating in said server modules to cool the heat-generating components are connected to said coolant circulation path.
11. The rack-mount server system according to claim 10, wherein said joints with automatic valve are arranged in accordance with mount pitch of the server modules to be mounted in the rack-mount server system.
12. The rack-mount server system according to claim 10, wherein said joints with automatic valve are provided so that the connecting/disconnecting direction of the joints corresponds to the mounting direction of the server module.
13. The rack-mount server system according to claim 1, wherein said cooling unit measures the temperature of the coolant discharged to said coolant circulation path and cools the coolant discharged to said coolant circulation path to a predetermined temperature, and the server module controls the flow quantity of the coolant supplied from said coolant circulation path so that the temperature of the heat-generating components cooled by circulating the coolant reaches a predetermined temperature.
14. The rack-mount server system according to claim 1, wherein said cooling unit is provided at the top of the rack cabinet of the rack-mount server system.
15. The rack-mount server system according to claim 1, wherein the flow quantity of the coolant discharged from said cooling unit to said coolant circulation path is larger than the sum of the flow quantities of the coolant circulating in the plurality of server modules connected to said coolant circulation path.
16. A rack cabinet of a rack-mount server system in which a plurality of server modules having heat-generating components such as CPU are mounted, comprising:
 - a coolant circulation path to which said server modules are connected in parallel via joints and through which a coolant to cool the server modules is circulated; and

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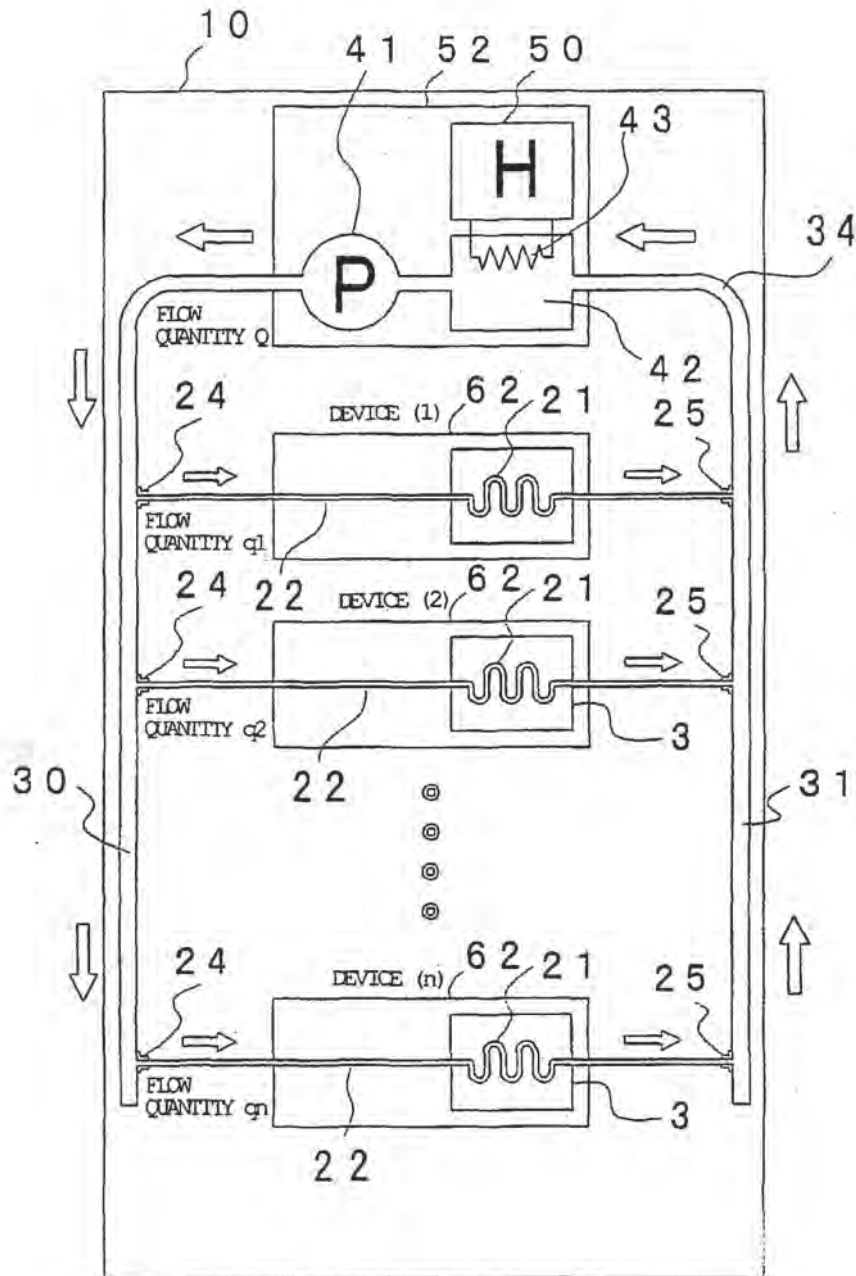
a cooling unit connected in the middle of said coolant circulation path, said cooling unit circulating the coolant and cooling said coolant by radiating its heat to the outside air.

17. The rack cabinet according to claim 16,
wherein said coolant circulation path is arranged vertically along the cabinet, and
said coolant circulation path is arranged on the side of a cable space of the mounted server module. 10
18. The rack cabinet according to claim 16,
wherein said cooling unit is provided at the top of the rack cabinet. 15
19. The rack cabinet according to claim 16,
wherein said cooling unit includes a refrigerating unit to radiate the heat generated in the server module and absorbed in the coolant to the outside air. 20
20. The rack cabinet according to claim 19,
wherein a radiator of said refrigerating unit is cooled by the cooling air flowing in the front/rear direction of the cabinet. 25
21. The rack cabinet according to claim 19,
wherein said joints are arranged in accordance with mount pitch of the server modules mounted in the rack cabinet. 30
22. The rack cabinet according to claim 16,
wherein said joints are provided so that the connecting/disconnecting direction of said joints corresponds to the mounting direction of the server module. 35
23. The rack cabinet according to claim 22,
wherein said joint includes an automatic valve. 40
24. A server module with a heat-generating component such as CPU in a rack-mount server system, comprising: 45
 - a first heat-generating component cooled by a coolant supplied from a cooling unit of a rack cabinet; and
 - a second heat-generating component cooled by the cooling air passing through the server module. 50
25. The server module according to claim 24,
wherein said second heat-generating component is arranged in a front part of the module from which the outside air is delivered, and
said first heat-generating component is ar- 55

anged in a rear part of the module to and from which said coolant is supplied and drained.

26. The server module according to claim 24,
wherein said server module further comprises: joints directed in the mounting direction of the server module, through which the coolant to cool said first heat-generating component is supplied and discharged.
27. The server module according to claim 26,
wherein said joint includes an automatic valve.
28. The server module according to claim 24,
wherein flow quantity control means to control the flow quantity of the coolant to cool said first heat-generating component is provided on an inflow side of said coolant.
29. The server module according to claim 28,
wherein said flow quantity control means controls the flow quantity so that the temperature of said first heat-generating component reaches a predetermined temperature.

FIG. 1



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FIG. 2

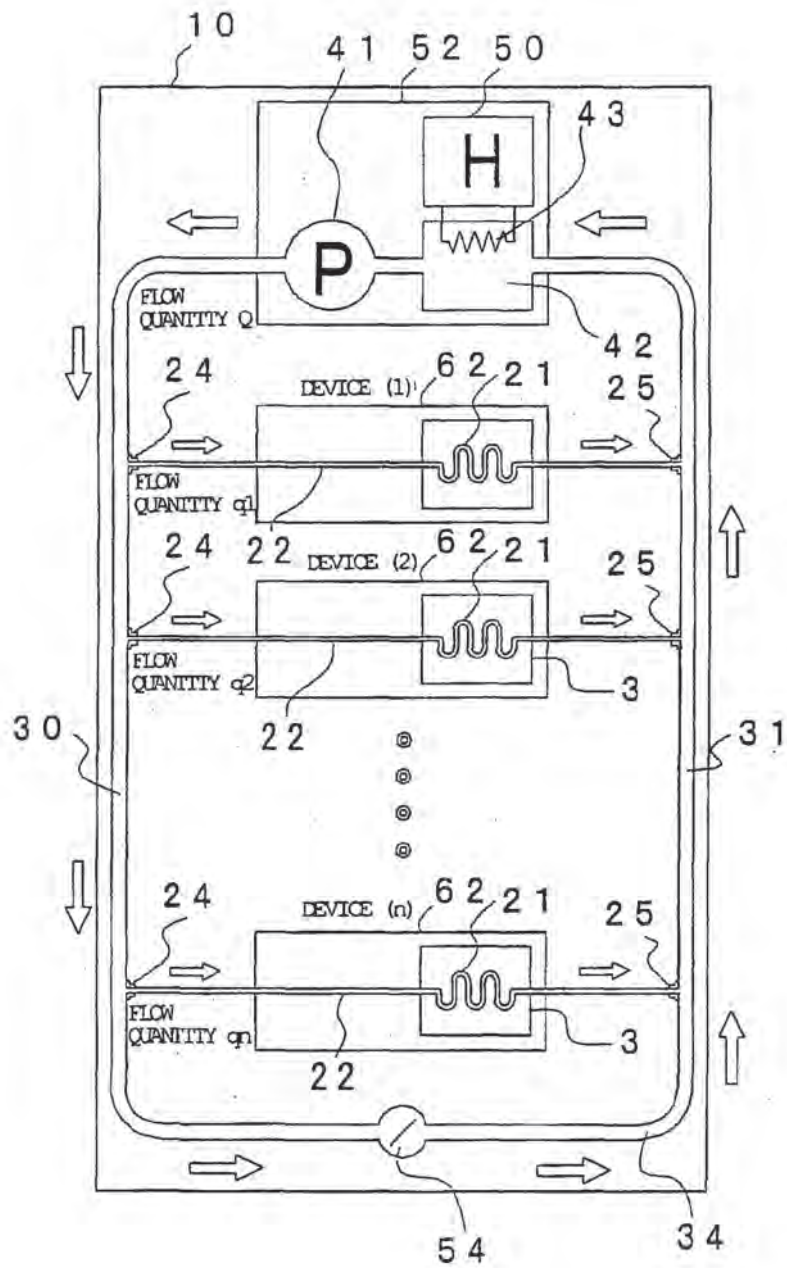


FIG. 3

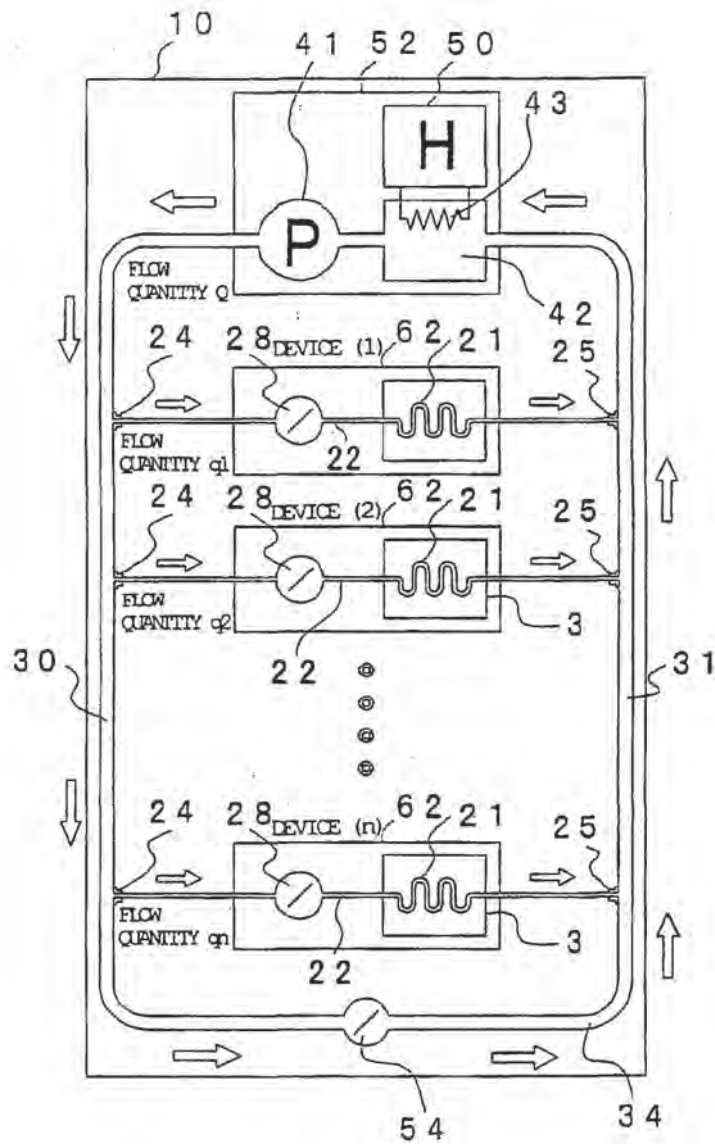


FIG. 4

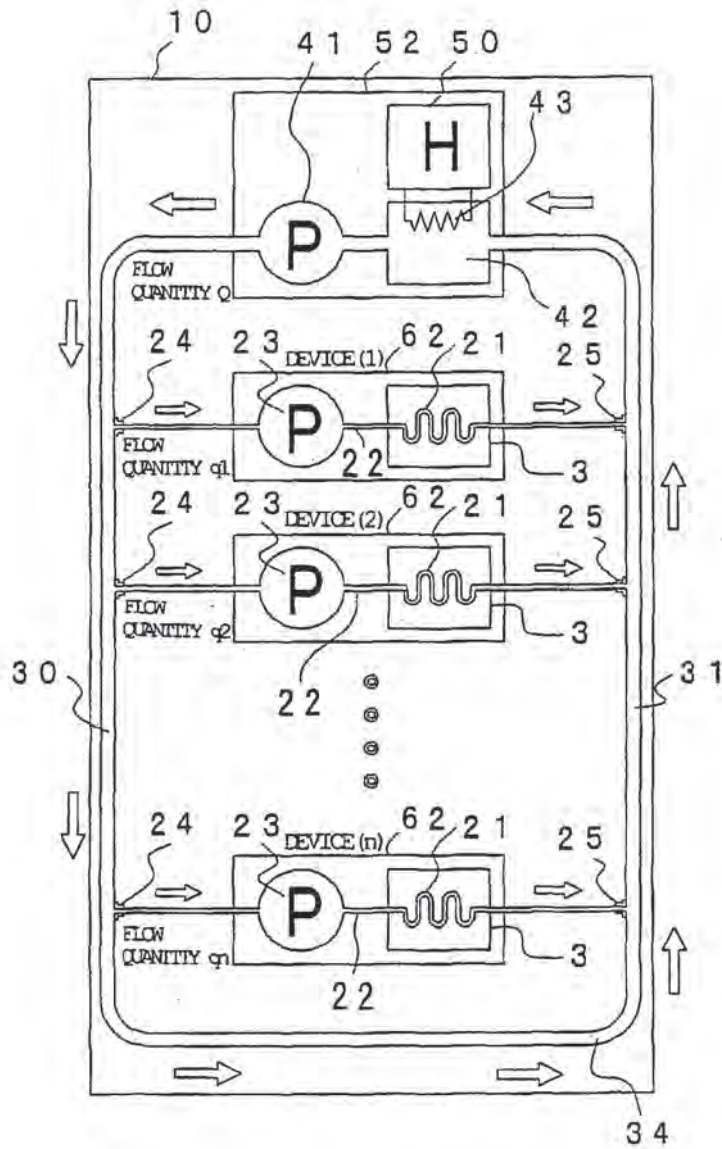


FIG. 5

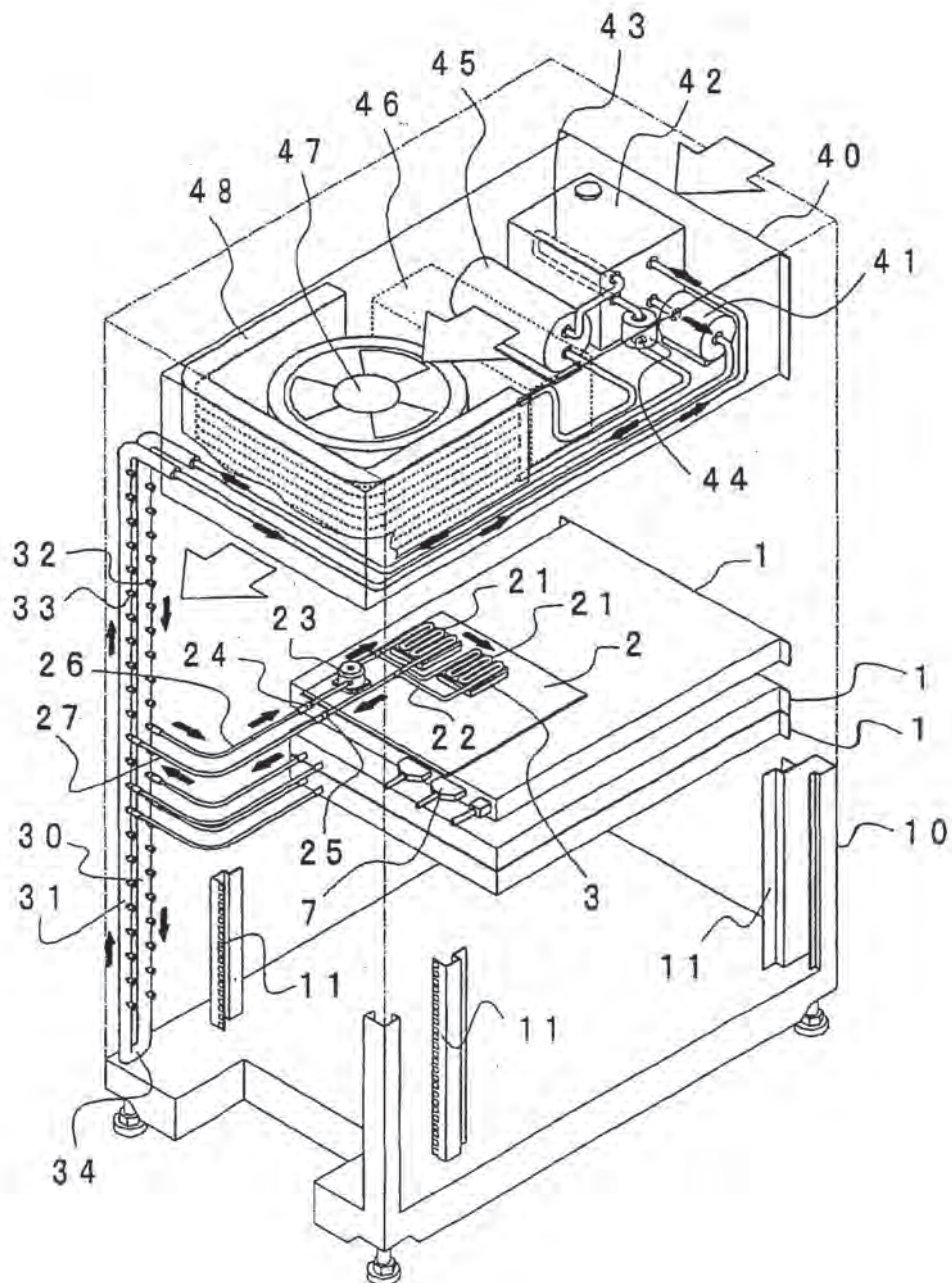


FIG. 6

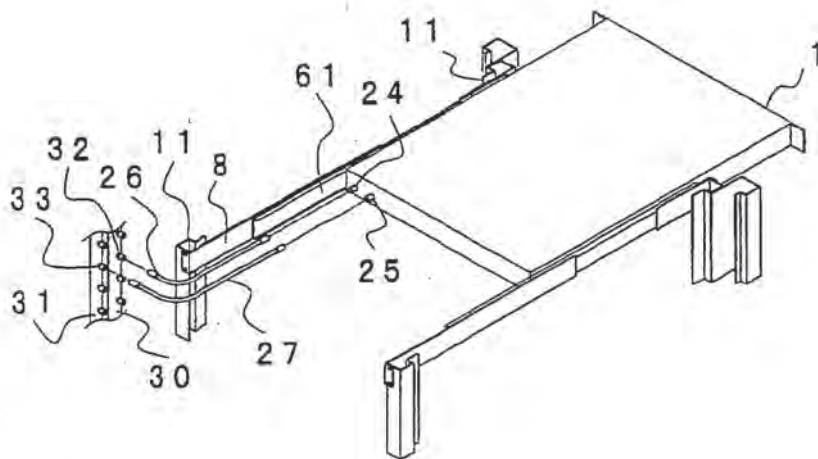


FIG. 7

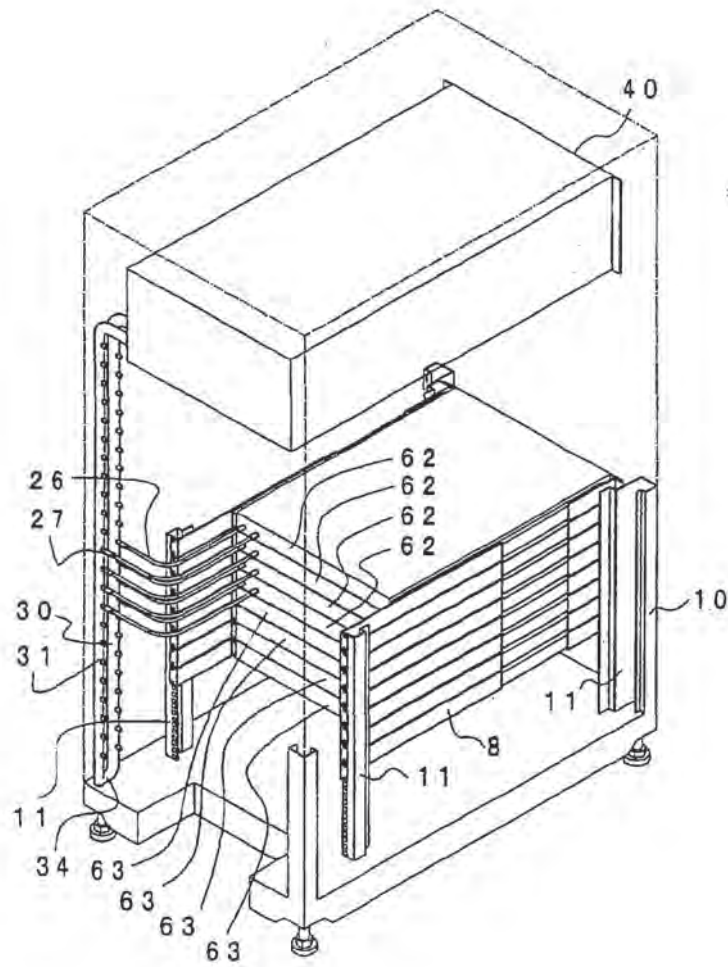


FIG. 8

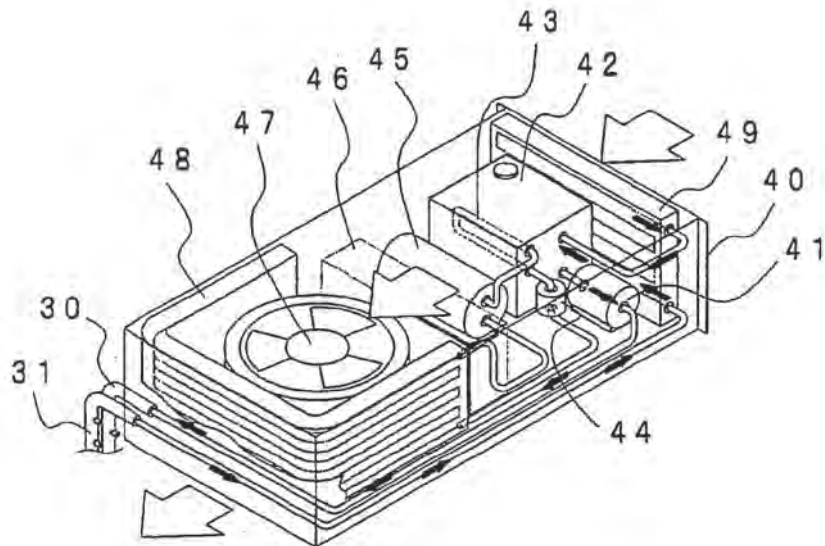


FIG. 9

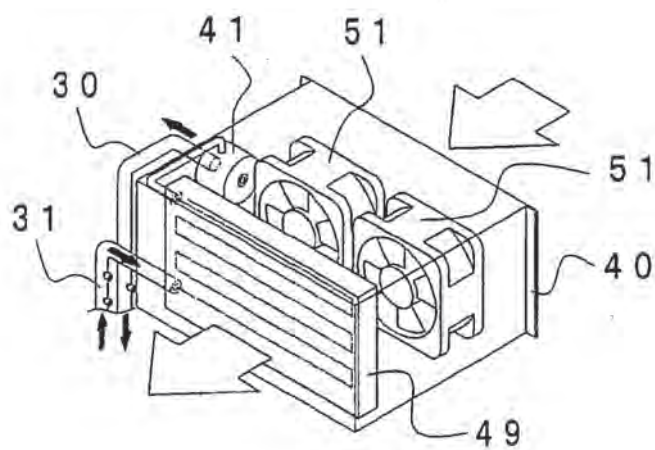


FIG. 10

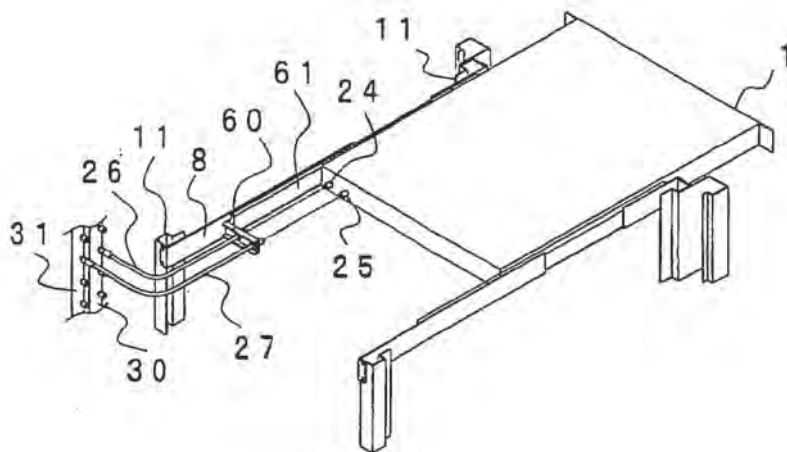


FIG. 11

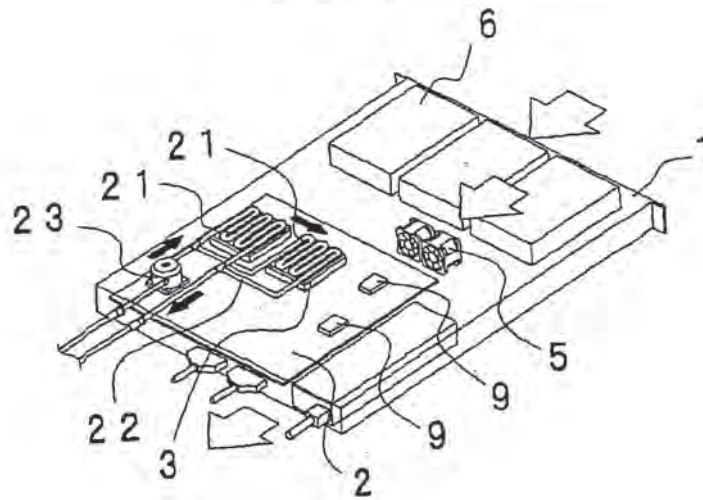


FIG. 12

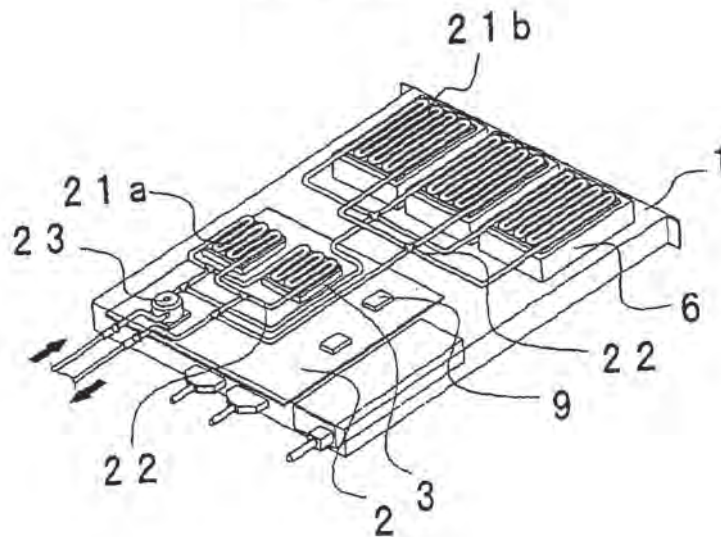


FIG. 13

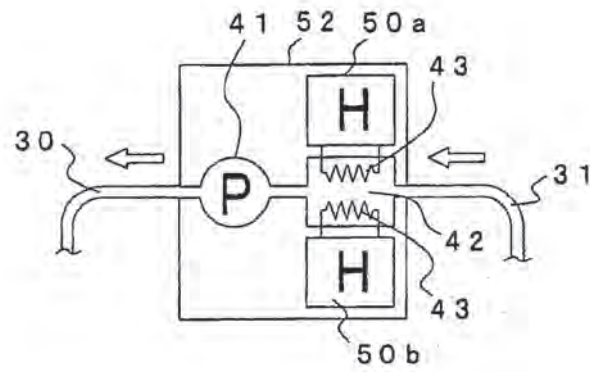


FIG. 14

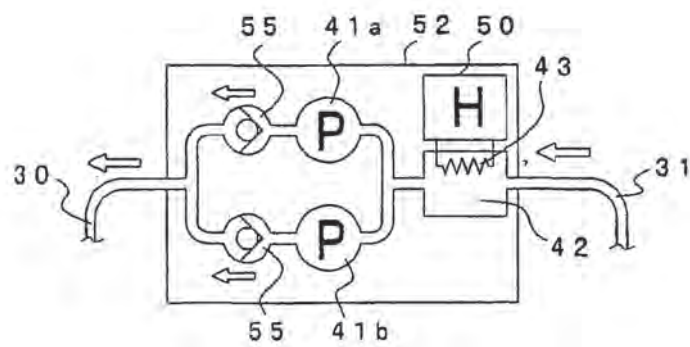
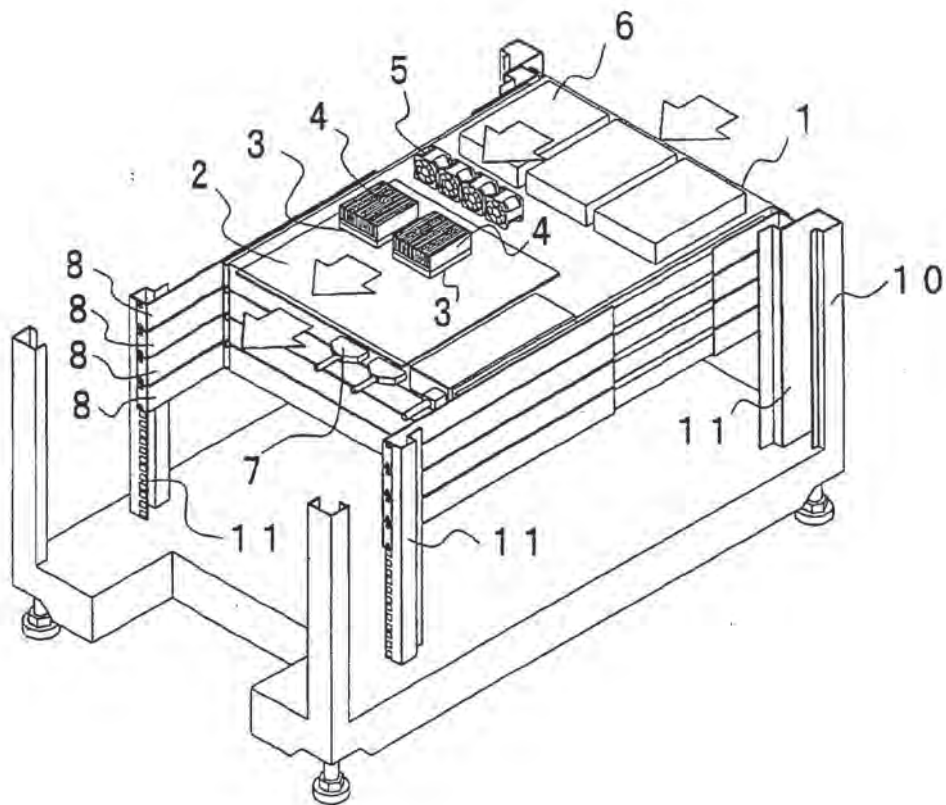


FIG. 15





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(72) Inventors:
• Ota, Shigemi, c/o Hitachi, Ltd., Int. Prop. Group
Chiyoda-ku
Tokyo 100-8220 (JP)
• Matsushita, Shinji, c/o Hitachi, Ltd.,
Chiyoda-ku
Tokyo 100-8220 (JP)

(30) Priority: 14.02.2003 JP 2003036255

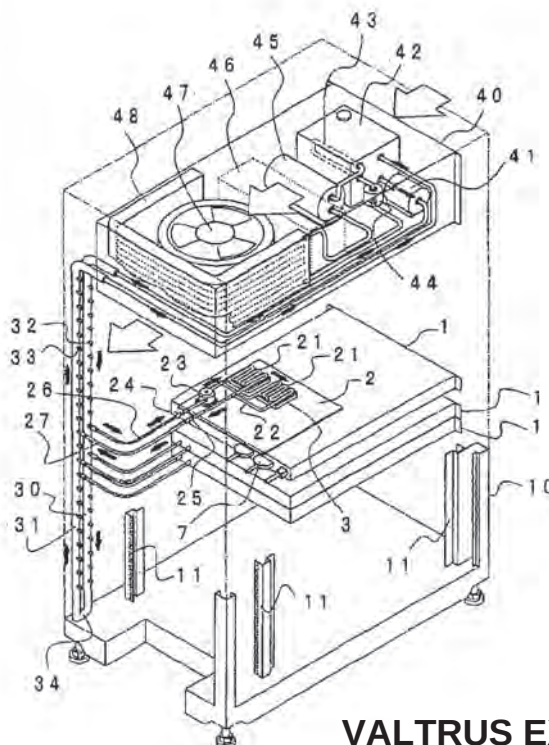
(71) Applicant: Hitachi, Ltd.
Chiyoda-ku,
Tokyo 101-8010 (JP)

(74) Representative: Strehl Schübel-Hopf & Partner
Maximilianstrasse 54
80538 München (DE)

(54) Liquid cooling system for a rack-mount server system

(57) A rack-mount server system of a liquid cooling system, in which a heat-generating component such as CPU is cooled by a coolant, is composed of: a plurality of server modules with heat-generating components which are cooled by the circulating coolant; a coolant circulation path to which the server modules are connected in parallel and through which the coolant to cool the server modules is circulated; and a cooling unit connected in the middle of the coolant circulation path, the cooling unit circulating the coolant and cooling the coolant by radiating its heat to the outside air. Furthermore, a bypass route parallel to the server modules and going around the server modules is provided in the coolant circulation path, and the circulation quantity of the coolant is controlled in the bypass route. Alternatively, the flow quantity of the coolant is controlled in each of the server modules. In this manner, the cooling enough to ensure the reliability of a plurality of server modules mounted in the rack cabinet can be achieved.

FIG. 5



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VERTIV v. VALTRUS IPR2025-00669
115 of 227



European Patent
Office

EUROPEAN SEARCH REPORT

Application Number
EP 04 00 3191

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	PATENT ABSTRACTS OF JAPAN vol. 2003, no. 04, 2 April 2003 (2003-04-02) & JP 2002 374086 A (HITACHI LTD; HITACHI INFORMATION TECHNOLOGY CO LTD), 26 December 2002 (2002-12-26) * abstract; figures 3,4 *	1,14, 16-19	H05K7/20 G06F1/20
Y	----- EP 0 231 456 A (HASLER AG; ASCOM HASLER AG) 12 August 1987 (1987-08-12) * column 2, line 48 - column 5, line 15; figures 2,3 *	4-6, 8-13,15, 21-23	
X	----- US 2002/124585 A1 (BASH CULLEN E ET AL) 12 September 2002 (2002-09-12) * paragraphs [0021] - [0032]; figures 1,3 *	1,14, 16-21	
Y	----- DE 26 51 015 B1 (ELECTROACUSTIC GMBH, 2300 KIEL; HONEYWELL-ELAC-NAUTIK GMBH, 2300 KIEL) 11 May 1978 (1978-05-11) * column 2, line 48 - column 4, line 32; figure 1 *	4-6,8,9, 13,15	
A	-----		
Y	-----	10-12, 21-23	TECHNICAL FIELDS SEARCHED (IPC) G06F H05K
The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 2 March 2006	Examiner Schneider, F
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

3
EPO FORM 1503 03/02 (P/A/C01)



European Patent
Office

Application Number

EP 04 00 3191

CLAIMS INCURRING FEES

The present European patent application comprised at the time of filing more than ten claims.

- ☐ Only part of the claims have been paid within the prescribed time limit. The present European search report has been drawn up for the first ten claims and for those claims for which claims fees have been paid, namely claim(s):
- ☐ No claims fees have been paid within the prescribed time limit. The present European search report has been drawn up for the first ten claims.

LACK OF UNITY OF INVENTION

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

see sheet B

- ☐ All further search fees have been paid within the fixed time limit. The present European search report has been drawn up for all claims.
- ☐ As all searchable claims could be searched without effort justifying an additional fee, the Search Division did not invite payment of any additional fee.
- ☒ Only part of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the inventions in respect of which search fees have been paid, namely claims:
1-23
- ☐ None of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims, namely claims:



European Patent
Office

LACK OF UNITY OF INVENTION
SHEET B

Application Number
EP 04 00 3191

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

1. claims: 1-9,13-15

The prior art has been identified as JP2002374086 (D1). Said document discloses (see figures 3,4 and the abstract) a rack-mount server system, comprising a plurality of server modules (11) with heat-generating components, said heat-generating components being cooled by a circulating coolant; a coolant circulation path (13) to which said server modules are connected in parallel and through which the coolant to cool the server modules is circulated; and a cooling unit (8) connected in the middle of said coolant circulation path, said cooling unit circulating the coolant and cooling said coolant by radiating its heat to the outside air.

The first subject deals with the following aspect non-disclosed in the prior art : the coolant circulation path has a bypass route parallel to said server modules and going around said server modules and a flow quantity control means in said bypass route to control the flow quantity of the coolant circulating in said server modules (STF1). The objective problem solved by said first subject could be to control the change in flow quantity in each server module and the change in pressure in the pipes, which are caused by changing the number of server modules mounted in the rack (Pb1).

2. claims: 10-12,16-23

From the comparison of claims 10-12,16-23 and the disclosure of D1, the potential Special Technical Feature of the second invention is the joints with automatic valve provided for connecting the server modules to the coolant circulation path (STF2). The objective problem solved by said second subject could be to provide a liquid cooled server module that can be easily mounted in the rack or extracted from the rack. (Pb 2).

3. claims: 24-29

From the comparison of claims 24-29 and the disclosure of D1, the potential Special Technical Feature of the third invention is the second heat-generating component cooled by the cooling air passing through the server module (STF3). The objective problem solved by said second subject could be to provide a simplified and cheaper cooling device for components generating a smaller amount of heat (Pb 3)

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 04 00 3191

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
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02-03-2006

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
JP 2002374086	A	26-12-2002	NONE	
EP 0231456	A	12-08-1987	AU 591729 B2	14-12-1989
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DE 2651015	B1	11-05-1978	NONE	

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

Electronic Acknowledgement Receipt

EFS ID:	3364461
Application Number:	11670208
International Application Number:	
Confirmation Number:	6687
Title of Invention:	THERMAL LOAD LOCATOR
First Named Inventor/Applicant Name:	James K. MARTIN
Customer Number:	26720
Filer:	David B. Nelson
Filer Authorized By:	
Attorney Docket Number:	021944-105US
Receipt Date:	28-MAY-2008
Filing Date:	01-FEB-2007
Time Stamp:	10:26:05
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no
------------------------	----

File Listing:

Document Number	Document Description	File Name	File Size(Bytes) /Message Digest	Multi Part /.zip	Pages (if appl.)
1	Information Disclosure Statement (IDS) Filed	105US_IDS.pdf	771383 eb6e582eb50b1bc0f99b72f52d4db941 22871168	no	4

Warnings:

Information:

2	NPL Documents	105WO_ISR.pdf	112701	no	3
			6d3312b620e82dffc188cc11198fb0e3e042844		
Warnings:					
Information:					
3	NPL Documents	105WO_WritOp.pdf	234416	no	6
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Warnings:					
Information:					
4	Foreign Reference	105US_IDS_ForRef_EP0421743.pdf	324029	no	9
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Warnings:					
Information:					
5	Foreign Reference	105US_IDS_ForRef_EP1448040.pdf	1350317	no	29
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Total Files Size (in bytes):			2792846		
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APPLICATION NUMBER	FILING OR 371(c) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
11/670,208	02/01/2007	James K. MARTIN	021944-105US

CONFIRMATION NO. 6687

26720
LOCKE LORD BISSELL & LIDDELL LLP
ATTN: IP DOCKETING
600 TRAVIS STREET
3400 CHASE TOWER
HOUSTON, TX 77002

Title: THERMAL LOAD LOCATOR

Publication No. US-2008-0092577-A1

Publication Date: 04/24/2008

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Pre-Grant Publication Division, 703-605-4283



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APPLICATION NUMBER	FILING or 371(c) DATE	GRP ART UNIT	FIL FEE REC'D	ATTY DOCKET NO	DRAWINGS	TOT CLAIMS	IND CLAIMS
11/670,208	02/01/2007	3744	1000	021944-105US	2	15	2

CONFIRMATION NO. 6687

FILING RECEIPT

26720
LOCKE LIDDELL & SAPP LLP
ATTN. DOCKETING
600 TRAVIS #3400
HOUSTON, TX 77002

Date Mailed: 02/23/2007

Receipt is acknowledged of this regular Patent Application. It will be considered in its order and you will be notified as to the results of the examination. Be sure to provide the U.S. APPLICATION NUMBER, FILING DATE, NAME OF APPLICANT, and TITLE OF INVENTION when inquiring about this application. Fees transmitted by check or draft are subject to collection. Please verify the accuracy of the data presented on this receipt. **If an error is noted on this Filing Receipt, please mail to the Commissioner for Patents P.O. Box 1450 Alexandria Va 22313-1450. Please provide a copy of this Filing Receipt with the changes noted thereon. If you received a "Notice to File Missing Parts" for this application, please submit any corrections to this Filing Receipt with your reply to the Notice. When the USPTO processes the reply to the Notice, the USPTO will generate another Filing Receipt incorporating the requested corrections (if appropriate).**

Applicant(s)

James K. MARTIN, Delaware, OH;

Assignment For Published Patent Application

LIEBERT CORPORATION, Columbus, OH

Power of Attorney: None

Domestic Priority data as claimed by applicant

This appln claims benefit of 60/862,538 10/23/2006

Foreign Applications

If Required, Foreign Filing License Granted: 02/23/2007

The country code and number of your priority application, to be used for filing abroad under the Paris Convention, is
US11/670,208

Projected Publication Date: 04/24/2008

Non-Publication Request: No

Early Publication Request: No

Title

THERMAL LOAD LOCATOR

Preliminary Class

**VALTRUS EXHIBIT 2039
VERTIV v. VALTRUS IPR2025-00669
123 of 227**

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APPLICATION
for
UNITED STATES LETTERS PATENT
entitled
THERMAL LOAD LOCATOR

by

JAMES K. MARTIN

[0001] TITLE OF THE INVENTION

[0002] Thermal Load Locator

[0003] CROSS REFERENCE TO RELATED APPLICATIONS

[0004] This application claims the benefit of U.S. Provisional Appl. No. 60/862,538, filed October 23, 2006, and is incorporated herein by reference.

[0005] STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

[0006] Not applicable.

[0007] REFERENCE TO APPENDIX

[0008] Not applicable.

[0009] BACKGROUND OF THE INVENTION

[0010] Field of the Invention.

[0011] The present invention relates generally to electronic equipment cabinets and housings, and, more particularly to electronic equipment cabinets having cooling systems.

[0012] Description of the Related Art.

[0013] With the expansion of telecommunication and computer technology, increasing amounts of electronic equipment are required at businesses and other facilities. Large amounts of electronic equipment are often stored in a room devoted to that purpose. As shown in Figure 1, the equipment is generally organized in a cabinet 2 of standard dimensions with multiple horizontal trays 4 to support multiple rows of equipment. The cabinet 2 generally includes sides, 6, back 8, top 10, bottom 12, and a door 14 to gain access to the equipment therein. Power rails, uninterruptible power supplies, and other features can be included. This equipment generates heat, which must be removed from the room in order to maintain stable conditions in the rooms. Because advances in technology have lead to an increased density of the amount of electronic equipment that can be provided in a set amount of space, it has become increasingly difficult to

remove this heat by means of the conventional room air conditioning sized according to traditional practices.

[0014] General purpose cooling systems for rooms and open spaces now are either oversized and inefficient to handle the additional cooling requirements or inadequate for single racks of critical electronic equipment that may incur particular heavy loads. Therefore, it is often necessary to install localized cooling for the cabinets that house this electronic equipment. Some existing commercial suppliers have provided a closed loop refrigerated cooling system coupled to the cabinets. The refrigeration system typically includes a compressor for compressing refrigerant in the system to an elevated pressure, a condenser to cool the refrigerant that is heated by the act of compression, an expansion device that thermodynamically cools the refrigerant, an evaporator that is cooled by the cooled refrigerant flowing therethrough, a fan to move air across the evaporator's surfaces to cool the air whereby the refrigerant in turn absorbs heat from the warmer air, various refrigeration lines for carrying the refrigerant between the components, and a system controller, such as a thermostat. These systems are typically mounted in the bottom or on top of the cabinet. A typical cabinet is about 24" wide and 78" to 84" high. The cooling module can consume about 12"-15" in the bottom of the cabinet or add such amount to the overall height if mounted on top of the cabinet. While having individual cooling systems per cabinet has been well received, it raises the costs per cabinet and adds complexity to the system.

[0015] Another challenge with existing electronic equipment cabinets with built-in cooling coils and fans is that they typically do not respond quickly to large, instantaneous changes in heat load. The cooling system senses the heat after the heat has been generated and then attempts to compensate by extra cooling to lower the temperature back down to an intended set point. The cooling system is therefore responsive to thermal heat after it has been produced. The result can be a wide fluctuation of temperatures in the cabinet, as the cooling system's control system responds to the load change.

[0016] Therefore, there remains a need for an improved cooling system for electronic equipment cabinets.

[0017] BRIEF SUMMARY OF THE INVENTION

[0018] The present invention provides a centralized cooling system can selectively deliver individualized cooling to individual electrical load units, such as individual cabinets, racks of such cabinets, or other cooled units. The system can provide direct cooling from a manifold of cooling outlets in a controlled manner based on the sensed electrical load of a particular cabinet, rack, or other unit. The system generally includes a branch monitoring system coupled to each branch circuit that is monitored from which electrical feeds are coupled to a plurality of electrical load units, and a controller coupled to the branch monitoring system. The controller provides output to control a cooling unit, such as an air conditioner. At least one control valve is further coupled to the controller downstream of the cooling unit generally at each cooling outlet to control an amount of cooling fluid, such as air or liquid, directed to one or more of the electrical load units. Data can be communicated between the branch monitoring system, the controller, the cooling unit, or a combination thereof. If a load and/or a change in load is sensed for a given electrical load unit(s), the controller can actuate a cooling valve coupled to a corresponding cooling outlet and alter the amount of cooling fluid flowing into or around the electrical load unit(s). Further, one or more thermal sensors can be mounted at the load unit to provide feedback from the unit on cooling conditions, so that the controller can make adjustments as necessary.

[0019] The disclosure provides a system to cool a plurality of electrical load units with a central cooling unit, comprising: at least two electrical load sensors coupled to at least two of the electrical load units, each of the at least two electrical load units being coupled to at least one of the electrical load sensors, the electrical load sensors being adapted to sense electrical loads on the electrical load units; a controller coupled to the electrical load sensors and adapted to receive data from the load sensors; a central flow conduit coupled to the central cooling unit and adapted to provide cooling fluid to the at least two electrical load units, the central flow conduit being coupled to at least two cooling outlets and the at least two cooling outlets being coupled to the at least two electrical load units, each of the at least two electrical load units being coupled to at least one of the cooling outlets; and at least two control valves coupled to the at least two cooling outlets, each of the at least two cooling outlets being coupled to at least one of the control valves, and the controller being adapted to control proportional flows of the cooling fluid from the

central flow conduit in the at least two cooling outlets to the at least two electrical load units based on the sensed electrical loads.

[0020] The disclosure also provides a method of cooling a plurality of electrical load units with a central cooling unit, comprising: delivering electrical current to at least two of the electrical load units; sensing electrical loads on the at least two electrical load units; flowing a cooling fluid through a central flow conduit coupled to the central cooling unit into at least two cooling outlets coupled between the central flow conduit and the at least two electrical load units; and controlling the flow of the cooling fluid proportionately from the central flow conduit in the at least two cooling outlets to the at least two electrical load units based on the sensed electrical loads.

[0021] BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

[0022] A more particular description, briefly summarized above, may be had by reference to the embodiments illustrated in the appended drawings, forming part of the present specification and described herein. It is to be noted, however, that the appended drawings illustrate only some embodiments described herein and are therefore not to be considered limiting of the disclosure's scope, in that there can be other equally effective embodiments.

[0023] Figure 1 illustrates in perspective view an existing stack of cabinets to support electronic equipment.

[0024] Figure 2 illustrates a schematic diagram of at least one embodiment of a central cooling system controlled for individual load units, such as cabinets.

[0025] Figure 3 illustrates a schematic diagram of at least one embodiment of a central cooling system controlled for individual load units, such as racks within cabinets.

[0026] DETAILED DESCRIPTION

[0027] The Figures described above and the written description of specific structures and processes below are not presented to limit the scope of what Applicants have invented or the scope of protection for those inventions. Rather, the Figures and written description are provided to teach any person skilled in the art to make and use the inventions for which patent protection

is sought. Those skilled in the art will appreciate that not all features of a commercial implementation of the inventions are described or shown for the sake of clarity and understanding. Persons of skill in this art also appreciate that the development of an actual commercial embodiment incorporating aspects of the present inventions will require numerous implementation-specific decisions to achieve the developer's ultimate goal for the commercial embodiment. Such implementation-specific decisions may include, and likely are not limited to, compliance with system-related, business-related, government-related and other constraints, which may vary by specific implementation, location and from time to time. While a developer's efforts might be complex and time-consuming in an absolute sense, such efforts would be, nevertheless, a routine undertaking for those of skill this art having benefit of this disclosure. The inventions disclosed and taught herein are susceptible to numerous and various modifications and alternative forms. Lastly, the use of a singular term is not intended as limiting of the number of items. Also, the use of relational terms, such as, but not limited to, "top," "bottom," "left," "right," "upper," "lower," "down," "up," "side," and the like are used in the written description for clarity in specific reference to the Figures and are not intended to limit the scope of the invention or the appended claims. The term "coupled," "coupling," "coupler," and like terms are used broadly herein and can include any method or device for securing, binding, bonding, fastening, attaching, joining, inserting therein, forming thereon or therein, communicating, or otherwise associating, for example, mechanically, magnetically, electrically, chemically, directly or indirectly with intermediate elements, one or more pieces of members together and can further include without limitation integrally forming one functional member with another in a unity fashion. The coupling can occur in any direction, including rotationally.

[0028] Figure 2 illustrates a schematic diagram of at least one embodiment of a central cooling system controlled for individual load units, such as cabinets. The system 20 generally includes at least one sensor coupled to at least one electrical load unit of a plurality of electrical load units, a controller coupled to the sensor, a central flow conduit coupled to a central cooling unit, at least one cooling outlet coupled between the central flow conduit and the electrical load unit, and a control valve coupled to the cooling outlet and the controller. The sensor is adapted to sense an electrical load, such as current, on the unit or units to which it is coupled and provide

data to the controller for processing and providing instructions to the control valve and/or cooling unit. These elements will be described in more detail below.

[0029] Thus, at least in some embodiments, the electrical load unit in its cooling demands are anticipated even prior to the actual increase in temperature caused from the increased load. Similarly, when the electrical load unit decreases its need for energy, the change in electrical load is sensed, communicated to the controller and the amount of cooling is adjusted. The early sensing of the electrical load allows the controller to control the anticipated cooling needs based on the electrical load among a distributed network of cooled load units. This proactive control can assist in maintaining a cooling environment, for example, before an increased electrical load generates an higher amount of heat that is sensed by a thermal sensor that then requires compensation to restabilize the system affected by the heat. Further, it is believed that the proactive control helps promote more efficient use and sizing of the cooling unit and overall cooling system, because the cooling capacity can be allocated to specific needs on specific electrical load units on a relatively real time basis. The sensing can help avoid the temperature variations and thermal momentum caused by responding the heat after it has been generated by the load, and then sensed by a thermal sensor.

[0030] More particularly, the system 20 generally includes an electrical distribution center 22 having a branch control monitoring system ("BCMS") 24. A plurality of electrical feeds 26 is coupled between the electrical distribution center 22, and particularly the BCMS 24, and a plurality of electrical load units 36A, 36B, 36C, 36D (collectively designated as 36) coupled to a central cooling system. Such electrical load units could include, without limitation, a cabinet having a plurality of racks disposed therein, the racks themselves mounted within the cabinets, specific processors, disk drives, and other electrical components having electrical needs and therefore electrical loads. The BCMS 24 monitors the individual electrical loads of the branch circuits of, for example, a panelboard through current transformers coupled to the BCMS. The output from the current transformers of the BCMS can be directed to a processor for manipulation and output. A suitable BCMS system is described in U.S. Pat. Appl. No. 11/420,784 and U.S. Pat. Appl. No. 11/420,786, incorporated herein by reference, and owned by

the assignee of this invention, Liebert Corporation, a company of Emerson Electric Co. in the USA. A BCMS can be obtained from the Liebert Corporation, Columbus, Ohio, USA.

[0031] Each of the electrical load units generally require cooling to avoid overheating and possible premature failure caused by the electrical loads. A central cooling unit 28 can be used to provide cooling to the electrical load units. The central cooling unit flows cooling fluid through a central flow conduit 30 which branch to generally a plurality of cooling outlets 32 which are coupled to the electrical load units to be cooled. The cooling medium can be a gas, such as air, or liquid, such as chilled water, and can include air conditioning or water cooled systems. Depending on the cooling needs of the electrical load units, the cooling outlet or outlets can cool individual electrical load units or groups of electrical load units by varying the amount of cooling, such as on a percentage basis, between the distributed electrical load units depending on their individual electrical loads. Generally, a control valve 34, such as an air damper or liquid flow valve, is coupled to each cooling outlet that can control the amount of cooling fluid flowing through the particular cooling outlet to the electrical load unit as a proportion of the overall cooling fluid flowing through the central flow conduit 30 at the particular time. If an increase in an electrical load is sensed for a particular electrical load unit, the controller can direct a greater proportion or amount of cooling flow from the central flow conduit to the particular electrical load unit through the associated cooling outlet.

[0032] Variations are possible. For example, a specific number of electrical load units may have wide variations in electrical loads and one or more other electrical load units may have a relatively constant electrical load. A controllable cooling outlet could be coupled to the varying electrical load units for variable cooling, while a more constant supply of cooling fluid could be provided to the one or more constant electrical load units. In such embodiments, a control valve could optionally be omitted from the constant electrical load units.

[0033] Thus, the control valve 34 can provide a variation in the cooling fluid from the central flow conduit 30 through the cooling outlet 32. The system 20 further includes data and output/input control for the control valve 34. More particularly, the system 20 includes a data communication link 44 from the electrical distribution center 22. A controller 38 can be coupled

to the electrical distribution center and particularly the BCMS via electronic communication through the data communication link 44. The data communication link can be hardwired or wireless, such as microwave, infrared, radio waves, and other modes of communication. The controller 38 can generally include an input and output for receiving the data and outputting process data through a data communication link 48 to the cooling unit 28 for control of the cooling unit. In some embodiments, the controller 38 can be physically integrated with the cooling unit 28 so that data flow between the BCMS and the controller could be represented by a data communication link 50. The controller 38 is also coupled, directly or indirectly, to a control bus 40. The control bus 40 can provide control communication between the controller 38 and the control valve 34. The term "control bus" is used broadly and can include wired or wireless communications. As the load increases or decreases, the controller 38 can direct the control valve 24 to increase or decrease the amount of cooling fluid flowing through a particular cooling outlet 32 with the control valve 34. The controller 38 can also control the cooling unit 28 for more general operation such as cycle times, average temperature in the central flow conduit, and other system wide parameters.

[0034] In some embodiments, the electrical load unit can be further sensed by a temperature sensor or one or more portions of the electrical load unit. The sensor 42 can be coupled to the control buss 40 and provide additional input to the controller 38.

[0035] Figure 3 illustrates a schematic diagram of an embodiment of a central cooling system for racks of electrical cabinets or devices on the racks, as types of electrical load units. The system 20 can further include providing cooling fluid to individual racks of electrical equipment or specific devices that may be assembled in a cabinet or data center. The electrical distribution center 22 could provide electricity to the electrical load units 36 through the BCMS 24. A data communication link 44 is disposed between the BCMS 24 and the controller 38, and can provide input to the controller on the electrical loads. A cooling unit 28 can provide cooling fluid through a central flow conduit 30 coupled to the electrical load unit 36. A cooling outlet 32 is coupled to the central flow conduit 30 for the particular electrical load unit 36A to be cooled. A control valve 34 is coupled to the cooling outlet 32 for control of fluid therethrough between the central flow conduit 30 and the electrical load unit 36A. Other cooling outlets and control valves

can likewise be coupled to the other exemplary electrical load unit 36B, and other electrical load units, such as units 36C and 36D, shown in Figure 2. A control bus 40 is coupled to the control valve 34 for control and operation of the control valve from the controller 38. A data communication link 48 between the controller 38 and the cooling unit 28 and/or control bus 40 provides communication for control.

[0036] The order of steps can occur in a variety of sequences unless otherwise specifically limited. The various steps described herein can be combined with other steps, interlineated with the stated steps, and/or split into multiple steps. Similarly, elements have been described functionally and can be embodied as separate components or can be combined into components having multiple functions.

[0037] The inventions have been described in the context of preferred and other embodiments and not every embodiment of the invention has been described. Obvious modifications and alterations to the described embodiments are available to those of ordinary skill in the art. The disclosed and undisclosed embodiments are not intended to limit or restrict the scope or applicability of the invention conceived of by the Applicants, but rather, in conformity with the patent laws, Applicants intend to fully protect all such modifications and improvements that come within the scope or range of equivalent of the following claims. Further, unless the context requires otherwise, the word "comprise" or variations such as "comprises" or "comprising", should be understood to imply the inclusion of at least the stated element or step or group of elements or steps or equivalents thereof, and not the exclusion of a greater numerical quantity or any other element or step or group of elements or steps or equivalents thereof.

WHAT IS CLAIMED IS:

1. A system to cool a plurality of electrical load units with a central cooling unit, comprising:
at least two electrical load sensors coupled to at least two of the electrical load units, each of the at least two electrical load units being coupled to at least one of the electrical load sensors, the electrical load sensors being adapted to sense electrical loads on the electrical load units;
a controller coupled to the electrical load sensors and adapted to receive data from the load sensors;
a central flow conduit coupled to the central cooling unit and adapted to provide cooling fluid to the at least two electrical load units, the central flow conduit being coupled to at least two cooling outlets and the at least two cooling outlets being coupled to the at least two electrical load units, each of the at least two electrical load units being coupled to at least one of the cooling outlets; and
at least two control valves coupled to the at least two cooling outlets, each of the at least two cooling outlets being coupled to at least one of the control valves, and the controller being adapted to control proportional flows of the cooling fluid from the central flow conduit in the at least two cooling outlets to the at least two electrical load units based on the sensed electrical loads.
2. The system of claim 1, wherein the sensed electrical load is electrical current.
3. The system of claim 1, further comprising a branch control monitor coupled to the at least two electrical load sensors, the load sensors being coupled to a plurality of electrical feeds, and the electrical feeds being coupled to the electrical load units.
4. The system of claim 3, further comprising a data communication link coupled between the branch control monitor and the controller.
5. The system of claim 1, wherein the cooling fluid comprises a gas, a liquid, or a combination thereof.
6. The system of claim 1, further comprising a control bus coupled between the controller and the control valves.

7. The system of claim 1, further comprising at least two thermal sensors adapted to sense thermal conditions of the at least two electrical load units and provide thermal data to the controller.
8. The system of claim 1, wherein the electrical load units comprise an electrical cabinet, a rack in the cabinet, or an electrical device.
9. The system of claim 1, wherein the controller is coupled to the cooling unit.
10. A method of cooling a plurality of electrical load units with a central cooling unit, comprising:
 - delivering electrical current to at least two of the electrical load units;
 - sensing electrical loads on the at least two electrical load units;
 - flowing a cooling fluid through a central flow conduit coupled to the central cooling unit into at least two cooling outlets coupled between the central flow conduit and the at least two electrical load units; and
 - controlling the flow of the cooling fluid proportionately from the central flow conduit in the at least two cooling outlets to the at least two electrical load units based on the sensed electrical loads.
11. The method of claim 10, wherein sensing the electrical loads comprises sensing electrical currents to the at least two electrical load units.
12. The method of claim 10, further comprising sensing the electrical loads on the at least two electrical load units from a branch monitoring system.
13. The method of claim 10, further comprising sensing thermal conditions of the at least two electrical load units and at least partially controlling the flow of the cooling fluid to the electrical load units based on the sensed thermal conditions.
14. The method of claim 13, further comprising controlling the flow of the cooling fluid based on the sensed electrical loads prior to sensing changes in the thermal conditions.
15. The method of claim 10, wherein sensing the electrical loads comprises sensing an electrical load on an electrical cabinet, a rack of one or more cabinets, an electrical device, or a combination thereof.

[0038] ABSTRACT OF THE DISCLOSURE

[0039] A centralized cooling system can selectively deliver individualized cooling to individual electrical load units. The system can provide direct cooling from a manifold of cooling outlets in a controlled manner based on the sensed electrical loads of particular load units. A branch monitoring system monitors the load on electrical feeds that are coupled to electrical load units. A controller is coupled to the branch monitoring system and provides output to control a cooling unit. At least one control valve is further coupled to the controller downstream of the cooling unit generally at each cooling outlet to control an amount of cooling fluid, such as air or liquid, directed to one or more of the units. If a load changes for a given unit, the controller can actuate a cooling valve coupled to a corresponding cooling outlet and alter the amount of cooling fluid flowing into or around the unit(s).

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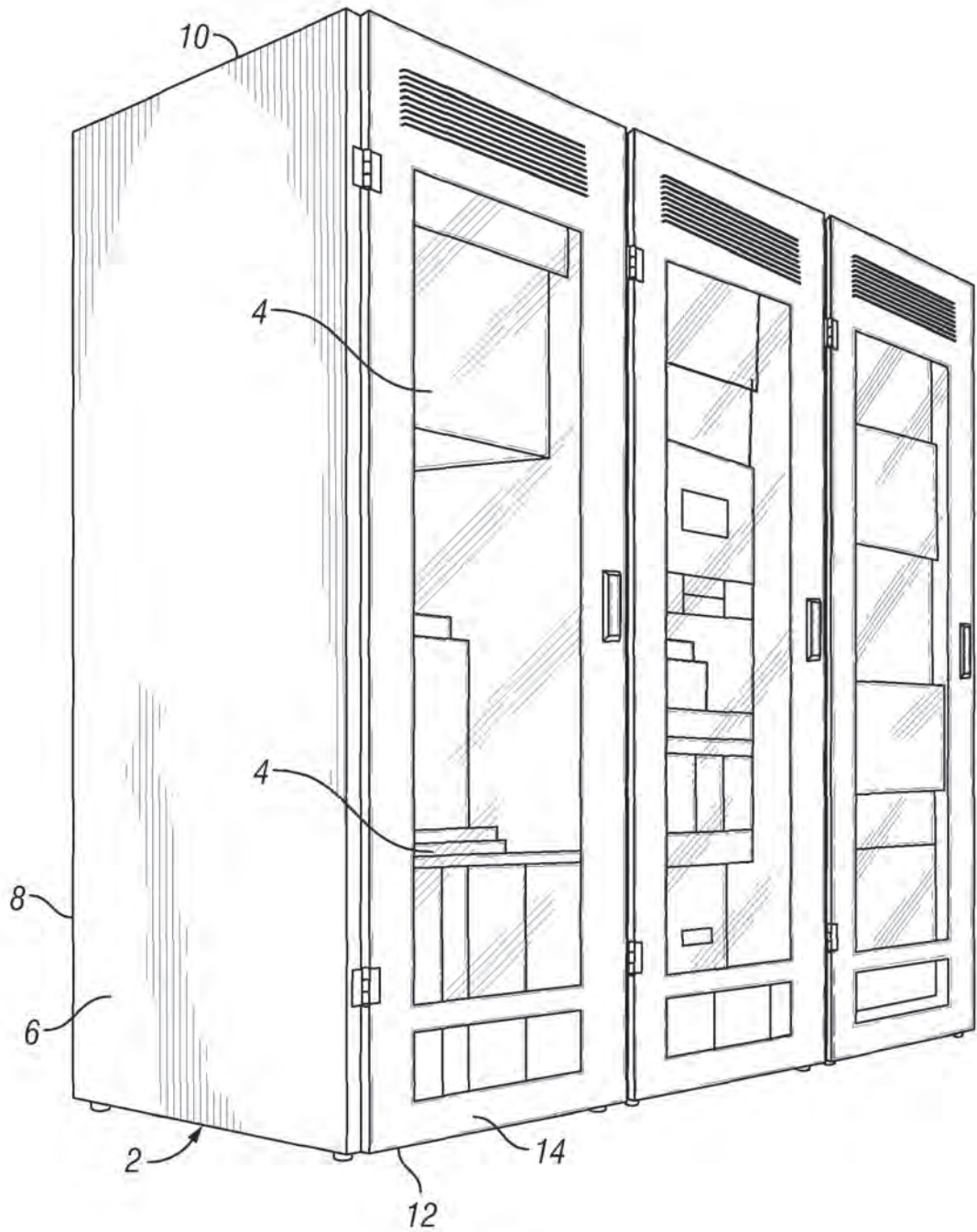
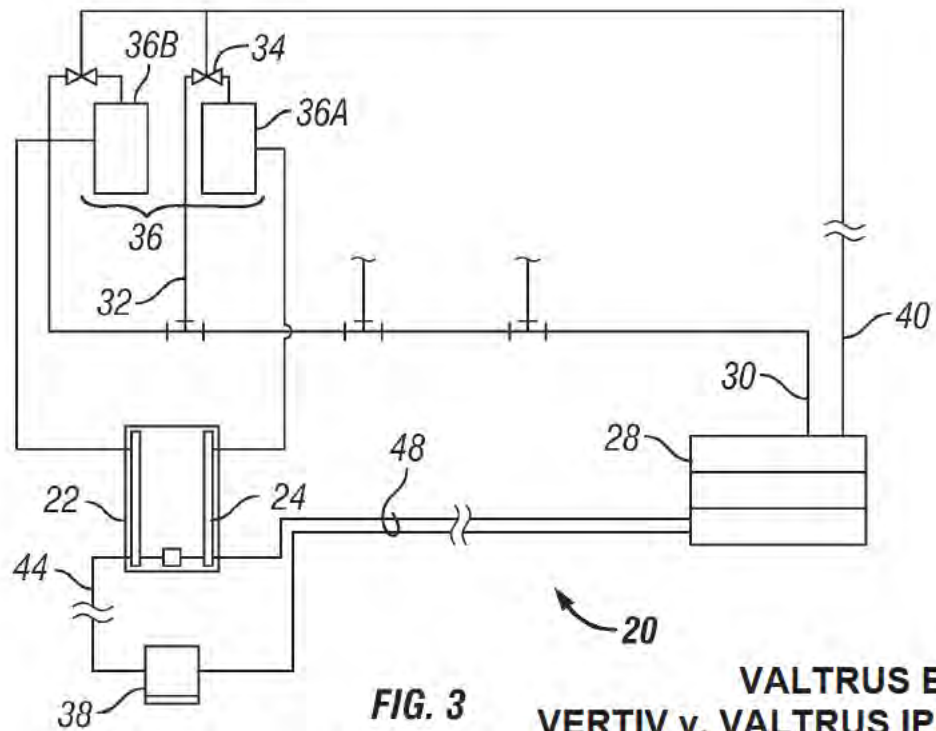
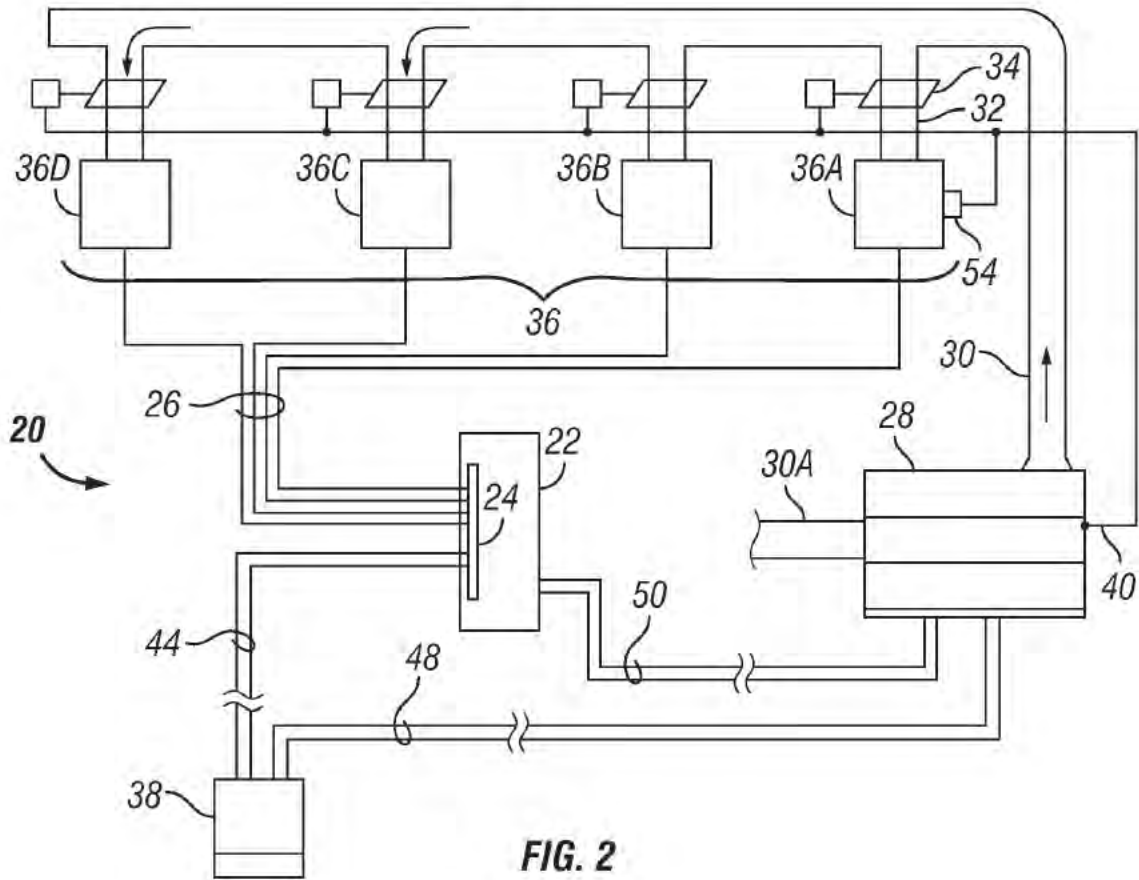


FIG. 1
(Prior Art)

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		Application Number	
Title of Invention	THERMAL LOAD LOCATOR		
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Title of Invention	THERMAL LOAD LOCATOR		

Application Information:

Title of the Invention	THERMAL LOAD LOCATOR		
Attorney Docket Number	021944-105US	Small Entity Status Claimed	☐
Application Type	Nonprovisional		
Subject Matter	Utility		
Suggested Class (if any)		Sub Class (if any)	
Suggested Technology Center (if any)			
Total Number of Drawing Sheets (if any)	2	Suggested Figure for Publication (if any)	
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Art Unit	
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	2	6886353		2005-05-03	PATEL, et al.	
	3	6868683		2005-03-22	BASH, et al.	
	4	6868682		2005-03-22	SHARMA, et al.	
	5	6862179		2005-03-01	BEITELMAL, et al.	
	6	6854287		2005-02-15	PATEL, et al.	
	7	6829142		2004-12-07	BELADY, et al.	
	8	6772604		2004-08-10	BASH, et al.	

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	9	6747872		2004-06-08	PATEL, et al.	
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INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)	Application Number		
	Filing Date		2007-02-01
	First Named Inventor	MARTIN, James K.	
	Art Unit		
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	Attorney Docket Number	021944-105US	

	8	20040109288		2004-06-10	BEITELMAL, et al.	
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	1	2004051156	WO	A1	2004-06-17	Hewlett-Packard Development Company, L.P., et al.		☐
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**INFORMATION DISCLOSURE
STATEMENT BY APPLICANT**
(Not for submission under 37 CFR 1.99)

Application Number	
Filing Date	2007-02-01
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Art Unit	
Examiner Name	
Attorney Docket Number	021944-105US

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☐ See attached certification statement.

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☒ None

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Signature	/D. Brit Nelson/	Date (YYYY-MM-DD)	2007-02-01
Name/Print	D. Brit Nelson	Registration Number	40370

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(71) Applicant: **HEWLETT-PACKARD DEVELOPMENT COMPANY, L.P.** [US/US]; 20555 S.H. 249, Houston, TX 77070 (US).

(72) Inventors: **BASH, Cullen, E.**; 662 Mangels Avenue, San Francisco, CA 94127 (US). **PATEL, Chandrakant, D.**; 37432 Gillett Road, Fremont, CA 94536 (US).

(74) Agent: **LANGE, Richard, P.**; Hewlett-Packard Company, IP Administration, P.O. Box 272400, Mail Stop 35, Fort Collins, CO 80527-2400 (US).

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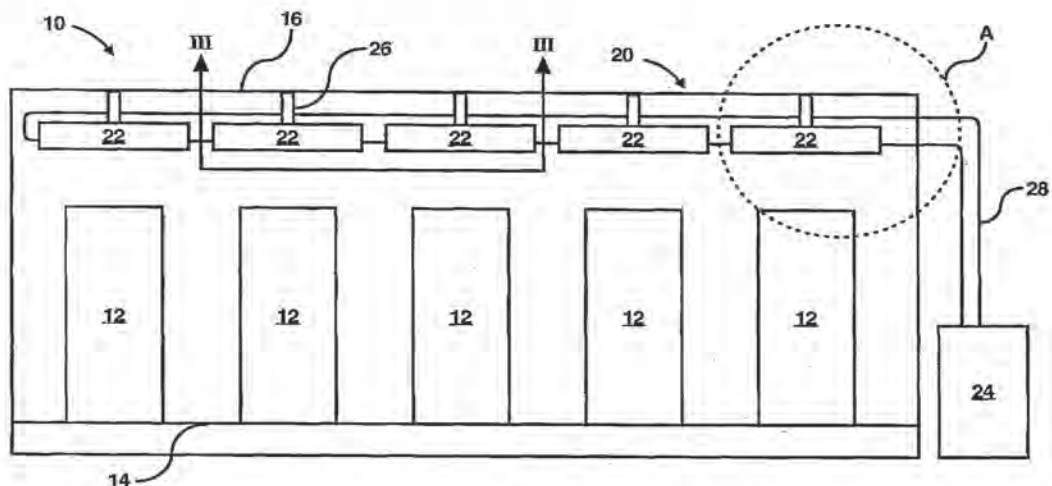
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(54) Title: COOLING SYSTEM WITH EVAPORATORS DISTRIBUTED IN PARALLEL



(57) Abstract: A system (220, 520) and method (300, 600) for cooling a room (210) configured to house a plurality of computer systems (212). A plurality of evaporator units (222, 522) are arranged in parallel and are configured to receive air from the room and to deliver air to the room. The evaporator units are supplied with refrigerant operable to cool the received air in the evaporator units. The air may be controlled in response to temperatures sensed at one or more locations in the room.

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COOLING SYSTEM WITH EVAPORATORS DISTRIBUTED IN PARALLEL

CROSS-REFERENCES

The present invention is a continuation-in-part of co-pending U.S. Application Ser. No. 10/210,040, filed August 2, 2002, and entitled "COOLING SYSTEM", by Patel et al., and is related to the following applications: co-pending U.S. Application Ser. No. XX/XXX,XXX, filed December YY, 2002, and entitled "COOLING SYSTEM WITH EVAPORATORS DISTRIBUTED IN SERIES" by Bash et al.; co-pending U.S. Application Ser. No. 09/970,707, filed October 5, 2001, and entitled "SMART COOLING OF DATA CENTERS", by Patel et al.; U.S. Application Ser. No. 10/157,892 filed on May 31, 2002 (HP Docket No. 100200782-1) entitled "CONTROLLED COOLING OF A DATA CENTER", by Patel et al.; U.S. Application Ser. No. 10/122,010, filed on April 24, 2002, and entitled, "DATA CENTER ENERGY MANAGEMENT SYSTEM", by Friedrich et al.; and pending U.S. Application Ser. No. 09/801,909, filed March 9, 2001, and entitled "MULTI-LOAD REFRIGERATION SYSTEM WITH MULTIPLE PARALLEL EVAPORATORS", by Bash et al., all of which are assigned to the assignee of the present invention and are incorporated by reference herein in their entireties.

FIELD OF THE INVENTION

This invention relates generally to cooling systems.

BACKGROUND OF THE INVENTION

A data center may be defined as a location, e.g., room, that houses computer systems arranged in a number of racks. A standard rack may be defined as an Electronics Industry Association (EIA) enclosure, 78 in. (2 meters) wide, 24 in. (0.61 meter) wide and 30 in. (0.76 meter) deep. Standard racks may be configured to house a number of computer systems, e.g., about forty (40) systems, with future configurations of racks being designed to accommodate up to eighty (80) systems. The computer systems typically include a number of components, e.g.,

one or more of printed circuit boards (PCBs), mass storage devices, power supplies, processors, micro-controllers, semi-conductor devices, and the like, that may dissipate relatively significant amounts of heat during the operation of the respective components. For example, a typical computer system comprising multiple microprocessors may dissipate approximately 250 W of power. Thus, a rack containing forty (40) computer systems of this type may dissipate approximately 10 KW of power.

The power required to transfer the heat dissipated by the components in the racks to the cool air contained in the data center is generally equal to about 10 percent of the power needed to operate the components. 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 components in the racks. The disparity in the amount of power required to dissipate the various heat loads between racks and data centers stems from, for example, the additional thermodynamic work needed in the data center to cool the air. In one respect, racks are typically cooled with fans that operate to move cooling fluid, e.g., air, cooling fluid, etc., across the heat dissipating components; whereas, data centers often implement reverse power cycles to cool heated return air. The additional work required to 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. As such, the cooling of data centers presents problems in addition to those faced with the cooling of the racks.

Conventional data centers are typically cooled by operation of one or more air conditioning units. For example, compressors of air conditioning units typically require a minimum of about thirty (30) percent of the required operating energy to sufficiently cool the data centers. The other components, e.g., condensers, air movers (fans), etc., typically require an additional twenty (20) percent of the required cooling capacity. As an 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 requires 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. Conventional data center air conditioning units do not vary their cooling fluid output based on the distributed needs of the data center. Instead, these air conditioning units generally operate at or near a maximum compressor power even when the heat load is reduced inside the data center.

The substantially continuous operation of the air conditioning units is generally designed to operate according to a worst-case scenario. For example, air conditioning systems are typically designed around the maximum capacity and redundancies are utilized so that the data center may remain on-line on a substantially continual basis. However, the computer systems in the data center may only utilize around 30-50% of the maximum cooling capacity. In this respect, conventional cooling systems often attempt to cool components that may not be operating at a level which may cause their temperatures to exceed a predetermined temperature range. Consequently, conventional cooling systems often incur greater amounts of operating expenses than may be necessary to sufficiently cool the heat generating components contained in the racks of data centers.

Moreover, the future of data center cooling will involve many small (1,000 to 2,000 sq. ft.) and readily deployable data centers that are akin to portable buildings or shipping containers. Current cooling systems, such as chilled water units, are relatively time-consuming to install and difficult to use in such compact data centers.

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SUMMARY OF THE INVENTION

According to one embodiment, the present invention pertains to a method for cooling a room configured to house a plurality of computer systems. In the method there is provided a plurality of evaporator units that are distributed in parallel and that are configured to receive air from the room and to deliver air to the room. The plurality of evaporator units are supplied with refrigerant that is operable to cool the air received from the room. In addition, temperatures are sensed at one or more locations in the room and the temperature of the air is controlled in response to the sensed temperatures at the one or more locations.

According to another embodiment, the invention relates to a system for cooling a room containing a plurality of computer systems. The system includes a plurality of evaporator units that are distributed in parallel and that are configured to receive refrigerant through a refrigerant line and to receive air. The air may be cooled through heat transfer with the refrigerant, and the plurality of evaporator units have at least one fan that is configured to cause air to flow out of the plurality of evaporator units. An evaporator controller is operable to control a supply of the

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refrigerant to the plurality of evaporator units and is operable to control the speed of the at least one fan. A refrigeration system is provided for cooling the refrigerant, and a refrigeration system controller is configured to operate the refrigeration system to vary the temperature of the refrigerant.

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According to yet another embodiment, the present invention pertains to a system for cooling computer systems housed in one or more racks maintained in a room. The system includes means for cooling air including means for receiving cooling fluid. The system also includes means for delivering cooled air to the computer systems and means for measuring
10 temperatures at one or more locations in the room. Additionally, the system includes means for controlling delivery of the cooled air in response to the means for measuring, and a means for controlling the temperature of the cooling fluid.

According to still another embodiment, the present invention pertains to computer
15 readable storage medium on which is embedded one or more computer programs that implement a method of cooling a room configured to house a plurality of computer systems. The one or more computer programs include a set of instructions for providing a plurality of evaporator units that are distributed in parallel and that are configured to receive air from the room and to deliver air to the room. The plurality of evaporator units are supplied with refrigerant that is
20 operable to cool the air received from the room. In addition, temperatures are sensed at one or more locations in the room and the temperature of air is controlled in response to the sensed temperatures at the one or more locations.

BRIEF DESCRIPTION OF THE DRAWINGS

25 Features of the present invention will become apparent to those skilled in the art from the following description with reference to the figures, in which;

FIG. 1 shows a simplified schematic illustration of a room containing a cooling system in accordance with an embodiment of the invention;

FIG. 2 is an enlarged partly cross-sectional view of section A in FIG. 1;

FIG. 3 is a schematic illustration taken along lines III-III of FIG. 1;

5 FIG. 4 is an exemplary block diagram for a cooling system according to an embodiment of the invention;

FIG. 5 shows a flow diagram of an operational mode according to an embodiment of the invention;

10 FIG. 6 shows a simplified schematic illustration of a room containing a cooling system in accordance with another embodiment of the invention;

FIG. 7 is a schematic illustration of a portion of the cooling system of FIG. 6;

FIG. 8 is an exemplary block diagram for a cooling system according to another embodiment of the invention;

15 FIG. 9 shows a flow diagram of an operational mode according to another embodiment of the invention;

FIG. 10 shows a flow diagram of another operational mode according to the embodiment of FIG. 9;

FIG. 11 is a schematic illustration of a cooling system according to another embodiment of the present invention;

20 FIG. 12 shows a flow diagram of yet another operational mode according to the embodiment of FIG. 11; and

FIG. 13 shows a flow diagram of an operational mode associated with the operational mode of FIG. 12.

DETAILED DESCRIPTION OF THE INVENTION

For simplicity and illustrative purposes, the present invention is described by referring mainly to an exemplary embodiment thereof. In the following description, numerous specific details are set forth in order to provide a thorough understanding of the present invention. It will be apparent however, to one of ordinary skill in the art, that the present invention may be practiced without 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.

According to an embodiment of the present invention, a cooling system may include a heat exchanger unit (HEU) configured to receive cooling fluid (e.g., chilled water, R134a, ethylene glycol mixture, and the like). The HEU may be designed to cause air to exchange heat with the cooling fluid to thereby cool the air. The HEU may also be designed to deliver the cooled air to one or more computer systems. The cooling system may also include a cooling device operable to cool the cooling fluid. The cooling device may comprise one or more of known cooling systems (e.g., a closed loop refrigeration cycle configured to transfer heat with the cooling fluid). The cooling device may therefore include a second generally closed-loop system having refrigerant flowing through a refrigerant line and positioned to receive heat from the cooling fluid.

One or more controllers may be provided to operate the cooling system components. The one or more controllers may be configured to monitor environmental conditions within the room, and more particularly in areas around predetermined computer systems, and manipulate operation of the HEU and the cooling device according to the monitored environmental conditions. For example, the one or more controllers may control the temperature of the cooling fluid and/or the output of the HEU.

In one respect, by manipulating the output of the HEU and the temperature of the cooling fluid, the amount of energy required to cool the computer systems may be relatively low. Thus, according to the embodiment described above, instead of operating components of the cooling device, e.g., compressors, heat exchangers, fans, etc., at substantially 100 percent of the anticipated heat dissipation from the computer systems, those components may be operated according to the actual cooling needs. In addition, the computer systems and the racks in which

they are housed may be positioned throughout the room according to their anticipated heat loads, to additionally increase control over the energy required by the cooling system. Furthermore, as described in U.S. Application Ser. No. 10/122,010, filed on April 24, 2002, the loads may be distributed between various computer systems to further increase energy efficiency of air conditioning resources.

In another respect, the positioning of the racks may be determined through implementation of numerical 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 each of the HEU's.

A more detailed description of the above-described embodiment may be found in co-pending U.S. Application Ser. No. 09/970,707, filed October 5, 2001, which is assigned to the assignee of the present invention and is incorporated by reference herein in its entirety.

Referring first to FIG. 1, there is illustrated a room 10, e.g., a data center, housing a plurality of racks 12, and a cooling system 20. Also illustrated is a raised floor 14 that may be provided to enable placement of wires, tubes, and the like for delivery into and from the racks 12.

The racks 12 may generally house a plurality of components (not shown), e.g., processors, micro-controllers, memories, semi-conductor devices, and the like. The components may be elements of a plurality of subsystems (not shown), e.g., computers, servers, etc. The subsystems and the components may be implemented to perform various electronic, e.g., computing, switching, routing, displaying, and the like, functions. In the performance of these electronic functions, the components, and therefore the subsystems, may dissipate relatively large amounts of heat. Because the racks 12 have been generally known to include upwards of forty (40) or more subsystems, they may require substantially large amounts of cooling fluid to maintain the subsystems and the components generally within a predetermined operating temperature range. According to an embodiment of the invention, by substantially controlling the amount of cooling air delivered to the components and the subsystems located in the racks 12 based upon their respective heat loads, the power consumed by the cooling system 20 to cool and supply the cooling fluid may also be controlled.

The cooling system 20 is illustrated as including a plurality of HEU's 22 and a cooling device 24. The HEU's 22 may be supported from a ceiling 16 of the room 10 by one or more supports 26. The HEU's 22 may comprise any reasonably suitable air conditioning unit designed to receive air and to deliver the received air, e.g., the DATACOOOL environmental control system manufactured and distributed by Liebert of Irvine, California. As can be seen in FIG. 1, the HEU's 22 are positioned to receive air that may become heated by virtue of the heat dissipated by, for example, the computer systems located in the racks 12. Although an HEU 22 is illustrated as positioned over a rack 12, it should be understood that the HEU's 22 may be positioned at various other locations. For example a plurality of HEU's 22 may be positioned to cool a single rack. Determinations of HEU 22 placement within the room 10 may be predicated upon techniques designed to optimize cooling performance and/or energy efficiency.

The HEU's 22 may be positioned to generally supply the racks 12 with cooling air. More particularly, the HEU's 22 may be positioned to supply cooling air to the racks 12 in accordance with their heat dissipation. By way of example, computer systems that undergo higher loads are known to generate greater amounts of heat as compared to computer systems that undergo lower or no loads. Thus, the HEU's 22 may be positioned and operated to supply those computer systems (and racks 12) that generate greater amounts of heat with greater mass flow rates of cooling air and/or relatively lower temperature air. In addition, those computer systems (and racks 12) that generate little or no heat, may likewise, receive little or no cooling air and/or relatively higher temperature air. In this respect, the amount of energy required to operate the HEU's 22 specifically, and the cooling system 20 as a whole, may be substantially optimized according to the demands of the computer systems.

Alternatively, or additionally to the above, because usage of the computer systems contained in the racks 12 may vary at different times of the day, instead of varying the position of the HEU's 22, the load placed on the computer systems may be varied. For instance, as described in co-pending U.S. Application Serial No. 10/122,010, the work load on some of the computer systems may be performed by other computer systems to substantially maximize energy efficiency of the cooling system. In this regard, the load may be transferred, for example, to one location in the room 10 if it is determined that such a load transfer is more energy efficient than under normal operating conditions. Moreover, the load transfer may occur at different times of the day and as load requirements vary.

The cooling device 24 may comprise any reasonably suitable type of cooling device designed to adequately cool the cooling fluid. In addition, the cooling device 24 may include the capability of varying the temperature of the cooling fluid. Some suitable cooling devices may include those that implement air conditioners, heat exchangers, heat pumps, variable capacity
5 chillers, evaporative cooling systems, and the like. For example, the cooling device 24 may comprise a closed-loop refrigeration cycle apparatus having a heat transfer section where the heat from the cooling fluid in a fluid line 28 may be transferred to refrigerant contained in the closed-loop refrigeration cycle apparatus.

Although the cooling device 24 is illustrated as being located outside of the room 10, it
10 should be understood that the cooling device 24 may be positioned within the room 24 without deviating from the scope of the present invention.

The cooling fluid may be configured to flow through the HEU's 22 and return to the cooling device 24 via fluid lines 28. As seen in FIG. 1, the fluid line 28 generally forms a closed loop system in which the cooling fluid may become heated in the HEU's 22 and cooled in the
15 cooling device 24.

Although one room 10 is illustrated in FIG. 1, it should be understood that the room 10 may comprise more than one room and that the cooling system 20 may be configured to cool a plurality of rooms.

With reference now to FIG. 2, there is illustrated an enlarged partly cross-sectional view
20 of section A in FIG. 1. As seen in FIG. 2, the HEU 22 generally comprises, among other things, a plurality of fans 30 and an opening 32. The fans 30 are designed to cause air from the room 10 to flow into the opening 32, as indicated by arrows 34. The fans 30 are also configured to cause the air to flow back out into the room 10, in the manner indicated by arrows 36. It should be understood that the HEU 22 may include additional components and that some of the
25 components described may be removed and/or modified without departing from the scope of the invention.

The fluid line 28 is situated to run through the HEU 22 below the fans 30 and in the direction of air flow from the HEU 22 to the room 10. In this respect, as the air flows by the fluid line 28, heat may be transferred from the air to the cooling fluid contained in the fluid line

28. Consequently, the air flowing out of the HEU 22 may be at a lower temperature relative to the air entering the HEU 22.

A pump 38 may be provided along the fluid line 28 at a location generally upstream of the HEU 22. The pump 38 may be designed to apply sufficient pressure to the cooling fluid entering the HEU 22 to enable the cooling fluid to flow at a predetermined rate through the HEU 22. In this respect, the pump 38 may comprise any pump capable of performing the above-described operations in a reasonably suitable manner. The pump 38 may be configured to supply cooling fluid to a plurality of HEU's 22 and to control the pressure of the cooling fluid flowing through one or more of the HEU's 22. A valve 40 is illustrated between the pump 38 and the HEU 22 along the fluid line 28. The valve 40 may be an electronically controllable valve capable of varying the flow of cooling fluid through the fluid line 28, as well as substantially stopping the flow of the cooling fluid. As a result, the volume flow rate of the cooling fluid through the fluid line 28 extending through the HEU 22 may be manipulated at predetermined levels such that the temperature of the air flowing out of the HEU 22 may be substantially optimized.

Although the pump 38 and the valve 40 are illustrated as separate components, it should be understood that their respective functions may be performed by a single component, e.g., the pump 38. In this example, the pump 38 may be configured as a variable speed pump configured to vary the flow of cooling fluid through the HEU 22.

A pipe 42 may be located along the fluid line 28 at a location downstream of the HEU 22. The pipe 42 may enable cooling fluid that has passed through the HEU 22 to be introduced into cooling fluid entering into the HEU 22. A pipe valve 44 may be positioned along the pipe 42 to substantially control the amount of this cooling fluid introduced into the cooling fluid entering into the HEU 22. The pipe valve 44 may be any reasonably suitable valve (e.g., a three-way valve) capable of controlling the cooling fluid flow through the pipe 42.

In this respect, the temperature of the cooling fluid may thus be further controlled. By way of example, the temperature of the cooling fluid may be increased prior to its introduction into an HEU 22 in a multi-HEU system (see e.g., FIG. 3). In this type of configuration, when one rack 12 is dissipating a greater amount of heat relative to another rack 12, the temperature of cooling air flow supplied to each of these racks may differ from one another. That is, the rack 12

dissipating the greater amount of heat may receive air flow from a first HEU 22 that is at a lower temperature compared to the rack that is dissipating a lesser amount of heat. Consequently, the temperature of the cooling fluid introduced into that first HEU may be at a lower temperature than the cooling fluid introduced into a second HEU.

5 Temperature sensors 46 may be located in a supply portion and a return portion of the fluid line 28 such that a determination may be made as to changes in the cooling fluid temperature prior to and following flow through the HEU 22. This information may be implemented to determine the amount of return cooling fluid to be introduced into the supply portion of the fluid line 28.

10 A temperature sensor 48 e.g., a thermocouple or the like, is illustrated on the rack 12. A single temperature sensor 48 is depicted in FIG. 2 for purposes of simplicity, it should, however, be understood that a plurality of temperature sensors 48 may be positioned at various locations of the rack 12 as well as other areas of the room 12. The temperature sensor 48 may supply temperature readings to a controller (not shown) configured to operate the HEU 22, the pump 38,
15 the valve 40, and the pipe valve 44. In addition, the temperature readings may also be supplied to a controller (not shown) configured to operate the cooling device 24. The manner of information transmittal between the temperature sensor 48 and the controllers may comprise any reasonably suitable arrangement, e.g., wired or wireless connection.

 In place of, or in addition to, the temperature sensor 48, a mobile device (not shown)
20 designed to gather or measure at least one local environmental condition (e.g., temperature, air flow, humidity, etc.) in the room 10 may be implemented. By way of example, a suitable mobile device may comprise the environmental condition detecting device described in co-pending U.S. Application Ser. No. 10/157,892, filed on May 31, 2002 (HP Docket No. 100200782-1) entitled "CONTROLLED COOLING OF A DATA CENTER", by Patel et al., which is assigned to the
25 assignee of the present invention and incorporated by reference herein in its entirety. Information gathered by the mobile device may be transmitted to the controller, which may vary operation of the cooling system 20 in response to the information.

 Alternatively, or in addition to, the above-described environmental condition sensing devices, the amount of heat generated by the computer systems contained in the racks 12, and the
30 resulting necessary cooling requirements, may be anticipated according to the amount of load

placed on the computer systems. A suitable method of implementing anticipated sensing is described in co-pending U.S. Application Ser. No. 09/970,707, which is assigned to the assignee of the present invention and incorporated by reference herein in its entirety.

Referring now to FIG. 3, there is shown a schematic illustration taken along lines III-III of FIG. 1. FIG. 3 illustrates a plurality of HEU's 22 and a plurality of fluid lines 28 emanating from a pair of pumps 38. The illustration also shows that the HEU's 22 include rows of fans 30 located adjacent to the openings 32. Situated beneath each of the fans 30 are fluid lines 28. In addition, located generally upstream of the HEU's 22 are respective valves 40, which may comprise three-way valves. As can be seen in FIG. 3, the pumps 38 may control the supply of cooling fluid through a plurality of HEU's 22. In addition, it may be seen that the valves 40 generally enable control of cooling fluid flow through respective fluid lines 28.

In this respect, the temperature of the air flowing out of the HEU's 22, and more specifically, out of each side of the HEU's 22 may be controlled in substantially independent manners (e.g., by operation a three-way valves (not shown)). In one regard, the flow of cooling fluid through certain HEU's 22 may be restricted or substantially halted, for instance, in situations where the computer systems for which an HEU 22 is configured to cool are in idle states. It should be understood that the configuration of HEU's 22, pumps 38, fluid lines 28, and valves 40 depicted in FIG. 3 is but one manner of a variety of different obtainable configurations. It should also be understood that the specific configuration for any given room may depend upon a multitude of factors, e.g., cooling needs, room configuration, cooling device type, etc. In addition, the fluid lines 28 may be positioned above the fans 30 such that air may substantially be cooled prior to flowing into the fans 30 without deviating from the scope of the present invention.

FIG. 4 is an exemplary block diagram 50 for a cooling system 52 according to an embodiment of the invention. It should be understood that the following description of the block diagram 50 is but one manner of a variety of different manners in which such a cooling system 52 may be operated. In addition, it should be understood that the cooling system 52 may include additional components and that some of the components described may be removed and/or modified without departing from the scope of the invention.

The cooling system 52 includes an HEU controller 54 configured to control the operations of the HEU 56. The HEU controller 54 may comprise a microprocessor, a micro-controller, an application specific integrated circuit (ASIC), and the like. The HEU controller 54 may, for example, control the speed of the fans 58, the operation of the pump 60, the valve 62, and the pipe valve 78. Interface electronics 64 may be provided to act as a control interface between the HEU controller 54 and the HEU 56, pump 60, and valve 62. Alternatively, a control interface may be omitted between the HEU controller 54 and the above-described components as seen with respect to the connection between the HEU controller 54 and, for example, the pipe valve 78. The HEU controller 54 may also be interfaced with a temperature sensor 68, e.g., one or more of the temperature sensors described hereinabove with respect to FIG. 2.

The HEU controller 54 may be interfaced with an HEU memory 66 configured to provide storage of a computer software that provides the functionality of the HEU controller 54, e.g., the speed of the fans, pump operation, etc. The HEU memory 66 may be implemented as a combination of volatile and non-volatile memory, such as dynamic random access memory (DRAM), EEPROM, flash memory, and the like. The HEU memory 66 may also be configured to provide a storage for containing data and/or information pertaining to the manner in which HEU controller 54 may operate the fans 58, the pump 60, the valve 62, and the pipe valve 78. In one respect, the manner of operation of the above-described components may be based according to temperature measurements by the temperature sensor 68.

The HEU controller 54 may be further interfaced with a cooling device controller 70. The interface may be effectuated via a wired protocol, such as IEEE 802.3, etc., wireless protocols, such as IEEE 801.11b, wireless serial connection, Bluetooth, etc., or combinations thereof.

The cooling device controller 70 may be configured to control the operations of the cooling device 72. The cooling device controller 70 may comprise a microprocessor, a micro-controller, an application specific integrated circuit (ASIC), and the like. The cooling device controller 70 is generally configured to manipulate the temperature of the cooling fluid by controlling the operation of the cooling device 72. In this regard, the cooling device 72 may comprise a variable speed compressor, a heat exchanger, a chilled water heat exchanger, a centrifugal chiller, and the like. More particularly, the cooling device controller 70 may be

designed to vary the operation of one or more of the above-recited components to vary the amount of heat transfer on the refrigerant contained in the refrigeration loop of the cooling device 72 to thereby vary the cooling fluid temperature.

Interface electronics (I/F) 74 may be provided to act as an interface between the cooling device controller 70 and the components for operating the cooling device 72, e.g., the supply of voltage to vary the speed of the compressor, control of the heat exchanger (centrifugal chiller) capacity, etc.

The cooling device controller 70 may also be interfaced with a cooling device (CD) memory 76 configured to provide storage of a computer software that provides the functionality of the cooling device 72, e.g., compressor, heat exchanger, and the like, and may be executed by the cooling device controller 70. The CD memory 76 may be implemented as a combination of volatile and non-volatile memory, such as DRAM, EEPROM, flash memory, and the like. The CD memory 76 may also be configured to provide a storage for containing data/information pertaining to the manner in which the compressor (heat exchanger, chiller) may be manipulated in response to, for example, variations in the temperature of the cooling fluid and/or air in the room.

In one respect, the capacity (e.g., the amount of work exerted on the cooling fluid) of the compressor (heat exchanger, chiller, etc.) may be modified to thereby control the temperature and of the cooling fluid. The compressor (heat exchanger, chiller, etc.) may thus be controlled to either increase or decrease the mass flow rate of the refrigerant flowing therethrough. Consequently, when the temperature in the room 10 is below a predetermined range, the capacity of the (heat exchanger, chiller, etc.) may be reduced to substantially reduce the amount of work, thus the amount of energy exerted on the refrigerant. This may lead to a significant reduction in the costs associated with operating the cooling system 52 as compared with conventional cooling systems.

Because the specific type of compressor (heat exchanger, chiller, etc.) to be employed with embodiments of the invention may vary according to individual needs, the invention is not limited to any specific type of compressor (heat exchanger, chiller, etc.). Instead, any reasonably suitable type of compressor (heat exchanger, chiller, etc.) capable of accomplishing certain aspects of the invention may be employed with the embodiments of the invention. The choice of

compressor (heat exchanger, chiller, etc.) may therefore depend upon a plurality of factors, e.g., cooling requirements, costs, operating expenses, etc.

By way of example, if there is a detected or anticipated change in the temperature of a rack, e.g., rack 12, areas surrounding the rack 12, etc., the HEU controller 54 may operate to
5 manipulate the corresponding HEU 56 and/or fan(s) 58 to compensate, e.g., change the volume flow rate, velocity, and other characteristic of the air flow, for the change in temperature. In addition, or as an alternative to the above, the cooling device controller 70 may operate to cause the cooling device 72 to lower the refrigerant temperature. In this respect, each of the racks 12 and/or portions thereof may generally receive substantially only the amount of cooling air
10 necessary to maintain the temperature of the racks 12 within a predetermined temperature range. In addition, the refrigerant, and therefore the cooling fluid, temperature may also be controlled as needed to substantially optimize cooling of the racks 12. By controlling the cooling air flow in the above-described manner, the cooling system 52 may be operated at substantially optimized levels, thereby decreasing the amount of energy and thus the operating costs required to cool the
15 computer systems in the racks 12.

Moreover, the cooling device controller 70 may operate the compressor (heat exchanger, chiller, etc.) in a manner to vary the cooling fluid temperature in response to various degrees of detected increases/decreases in the operation of the HEU 56. More particularly, a look up table (not shown) may be stored in the CD memory 76. The look up table may include information
20 pertaining to the level of compressor speed (heat exchanger capacity, etc.) increase necessary for a detected increase in the operation of the HEU 56. In this respect, the compressor speed (heat exchanger capacity, etc.) may be varied substantially incrementally in response to detected changes in the operation of the HEU 56.

FIG. 5 shows a flow diagram of an operational mode 100 according to an embodiment of
25 the invention. It should be understood that the operational mode 100 may include additional operations and that some of the operations may be removed and/or modified without departing from the scope of the invention. The following description of the operational mode 100 is made with reference to the block diagram 50 illustrated in FIG. 4, and thus makes reference to the elements cited therein.

The operations illustrated in the operational mode 100 may be contained as a utility, program, or a subprogram, in any desired computer accessible medium. In addition, the operational mode 100 may be embodied by a computer program, which can exist in a variety of forms both active and inactive. For example, they can exist as software program(s) comprised of
5 program instructions in source code, object code, executable code or other formats. Any of the above can be embodied on a computer readable medium, which include storage devices and signals, in compressed or uncompressed form.

Exemplary computer readable storage devices include conventional computer system RAM, ROM, EPROM, EEPROM, and magnetic or optical disks or tapes. Exemplary computer
10 readable signals, whether modulated using a carrier or not, are signals that a computer system hosting or running the computer program can be configured to access, including signals downloaded through the Internet or other networks. Concrete examples of the foregoing include distribution of the programs on a CD ROM or via Internet download. In a sense, the Internet itself, as an abstract entity, is a computer readable medium. The same is true of computer
15 networks in general. It is therefore to be understood that those functions enumerated below may be performed by any electronic device capable of executing the above-described functions.

In the operational mode 100, the cooling system 52 is activated at step 110. At step 120, the temperature of one or more racks (Tr) is sensed by temperature sensors, e.g., one or more temperature sensors 68. The temperature sensors may comprise one or more of the above-
20 described temperature sensors, e.g., thermocouple, mobile environmental condition sensing device, etc. The Tr's generally correspond to the heat load of the heat dissipating components and therefore the computer systems contained in the racks, e.g., rack 12. Therefore, the Tr's may be based upon the temperatures of specific heat dissipating components and subsystems. In addition, the Tr's may be based upon the temperatures in the general vicinity of the racks and/or
25 sections of the racks. Thus, those skilled in the art will understand that certain embodiments of the present invention may be employed with temperature sensors located at various positions throughout the room, e.g., room 10. Moreover, use of the term "rack" herein generally refers to racks for supporting computer systems and additionally to sections of the racks as well as areas around the racks. Therefore, the use of the term "rack" throughout the present disclosure is not
30 meant to limit certain aspects thereof to entire racks, but instead, is relied upon to simplify the description of certain embodiments of the present invention.

As an alternative to the temperature sensor 68, the Tr's may be anticipated in the manner described hereinabove and in co-pending U.S. Patent Application Serial No. 09/970,707.

At step 130, it is determined whether each of the Tr's is within a predetermined range of operating temperatures, e.g., between a maximum set point temperature ($T_{\max, \text{set}}$) and a minimum set point temperature ($T_{\min, \text{set}}$). In general, the range of temperatures $T_{\min, \text{set}}$ and $T_{\max, \text{set}}$ pertains to threshold temperatures to determine whether to increase or decrease the flow of cooling air delivered to the racks. This range of operating temperatures may be set according to a plurality of factors. These factors may include, for example, the operating temperatures set forth by the manufacturers of the subsystems and components located in the racks, through testing to determine the optimal operating temperatures, etc. In addition, the predetermined range of operating temperatures may vary from one subsystem to another.

For those racks having Tr's that are within the predetermined range, their temperatures are sensed again at step 120. For those racks determined to have heat loads that do not fall within the predetermined temperature range, i.e., fall outside of $T_{\min, \text{set}}$ and $T_{\max, \text{set}}$, the HEU controller 54 may determine whether those racks have temperatures that are below the $T_{\min, \text{set}}$ at step 140.

The air flow supplied by the HEU 56, and more particularly the fans 58, configured to supply cooling air flow to the racks having Tr's below or equal to the $T_{\min, \text{set}}$, may be decreased at step 150. In addition, and/or alternatively, the temperature of the cooling fluid supplied through the HEU's 56 may be increased to thereby increase the temperature of the air supplied to these racks. As described hereinabove, this may be accomplished by decreasing the work placed on the refrigerant by the cooling device 72 and/or by opening the bypass valve 62. Additionally, the temperature of the air flowing from the HEU 56 may also be increased by causing the valve 78 to enable a lower volume flow rate of cooling fluid to flow therethrough.

The air flow supplied by the HEU 56 configured to supply cooling air flow to the racks having Tr's above the $T_{\min, \text{set}}$, and thus above the $T_{\max, \text{set}}$, may be increased at step 160. In this regard, the HEU controller 54 may increase power to the fans 58 to enable greater air flow to the racks. In addition, and/or alternatively, the HEU controller 54 may increase the flow of cooling fluid through the HEU 56 via operation of the pump 60 and/or the valve 78.

By virtue of certain embodiments of the invention, racks having various Tr's may be supplied with air flow having various characteristics, e.g., temperature, velocity, direction, and the like. That is, for example, in a system comprising a plurality of HEU's 56, air flow may be supplied to racks having higher Tr's by certain HEU's 56 substantially simultaneously with air
5 flow supplied to racks having relatively lower Tr's by other HEU's 56 where each of the racks receives different levels of air flow. Additionally, the temperature of the cooling fluid supplied through the HEU's 56 delivering air flow to racks having higher Tr's may be relatively lower than the temperature of the cooling fluid supplied through the HEU's 56 delivering air flow to racks having lower Tr's. It should thus be appreciated that steps 150 and 160 may be
10 respectively and substantially simultaneously performed by various HEU's 56.

According to an embodiment of the invention, the decrease in volume flow rate and/or velocity of the air flow at step 150 and the increase in volume and/or velocity of the air flow at step 160 may be accomplished by incrementally varying the air flow from the HEU 56. For example, the volume flow rate and/or velocity of the air flow from the HEU 56 may be varied by
15 a predetermined amount during a first iteration. The Tr may be measured at a predetermined time following the variation and steps 130-160 may be repeated. By repeating this process a number of times, the temperature of the rack may be substantially brought within the predetermined range.

At step 170, the cooling device controller 70 may determine whether to vary the cooling
20 fluid temperature, e.g., increase the compressor speed (heat exchanger capacity, etc.). The cooling fluid temperature may be decreased in response to, for example, actual and/or detected increases in Tr. In the alternative, the decrease in cooling fluid temperature may be predicated upon the amount of work performed by the HEU 56. More particularly, as the work performed by the HEU 56 increases, thereby signaling an increase in the Tr, the cooling device controller 70
25 may cause the cooling device 72 to decrease the refrigerant temperature. In addition, when a plurality of HEU's 56 are implemented to cool one or more racks, the cooling device controller 70 may determine whether the total amount of decreases in the volume flow rates of the cooling air exceeds the total amount of increases in the volume flow rates flow of the cooling air. At
step 180, the cooling device controller 70 may determine whether to decrease the cooling fluid
30 temperature.

At step 190, the cooling device controller 70 may cause the cooling fluid temperature to be decreased in response to a determination to do so at step 180. Alternatively, the cooling device controller 70 may cause the cooling fluid temperature to be increased at step 200 in response to a determination to do so at step 180. As described hereinabove, the cooling device controller 70 may operate to vary the temperature of the cooling fluid by varying the speed of the compressor, capacity of the heat exchanger, and the like.

It should be understood that steps 150, 160, and 190 or 200 may be performed substantially simultaneously. More particularly, on a zonal level, temperature readings determined at step 120 for various racks may be implemented in varying the delivery of cooling air to the various racks. Additionally, on a global level, the temperature of the cooling fluid may be varied according to the changes in the cooling requirements of the racks. For example, when the temperature of a rack exceeds a predetermined threshold range, the HEU(s) 56 supplying cooling air flow to that rack may increase the air flow to that rack. Substantially concurrently, the temperature of the cooling fluid may be decreased by an amount relative to the increased rack temperature.

Following steps 190 or 200, the Tr's are sensed again at step 120. In addition, the steps following step 120 may be repeated for an indefinite period of time and may form a closed-loop pattern.

Referring now to FIG. 6, there is illustrated a room 210, e.g., a data center, housing a plurality of computer systems or racks 212, and a cooling system 220. Also illustrated is a raised floor 214 that may be provided to enable placement of wires, tubes, and the like for delivery into and from the racks 212.

The racks 212 may generally house a plurality of components (not shown), e.g., processors, micro-controllers, memories, semi-conductor devices, and the like. The components may be elements of a plurality of subsystems (not shown), e.g., computers, servers, etc. The subsystems and the components may be implemented to perform various electronic functions, e.g., computing, switching, routing, displaying, and the like. In the performance of these electronic functions, the components, and therefore the subsystems, may dissipate relatively large amounts of heat. Because the racks 212 have been generally known to include upwards of forty (40) or more subsystems, they may require substantially large amounts of cooling fluid (e.g.

air) to maintain the subsystems and the components generally within a predetermined operating temperature range. According to an embodiment of the invention, by substantially controlling the amount of cooling air delivered to the components and the subsystems located in the racks 212 based upon their respective heat loads, the power consumed by the cooling system 220 to cool and supply the cooling air may also be controlled.

The cooling system 220 is illustrated as including a plurality of HEU's, or evaporator units or evaporators 222, that are part of a cooling apparatus or refrigeration system 224. The evaporators 222 may be supported from a ceiling 216 of the room 210 by one or more supports 226. The evaporators 222 may comprise any reasonably suitable combination fan-evaporator unit or can comprise a separate fan unit (not shown) and separate evaporator unit (not shown). Finally, the terminology "evaporator" and "evaporator unit" are used synonymously herein and encompass the above-described variations.

As can be seen in FIG. 6, the evaporators 222 are positioned to receive air that may become heated by virtue of the heat dissipated by, for example, the computer systems located in the racks 212. Although an evaporator 222 is illustrated as positioned over a rack 212, it should be understood that the evaporators 222 may be positioned at various other locations. For example, a plurality of evaporators 222 may be positioned to cool a single rack. Determinations of evaporator 222 placement within the room 210 may be predicated upon techniques designed to optimize cooling performance and/or energy efficiency.

The evaporators 222 may be positioned to generally supply the racks 212 with cooling air. More particularly, the evaporators 222 may be positioned to supply cooling air to the racks 212 in accordance with their heat dissipation. By way of example, computer systems that undergo higher loads are known to generate greater amounts of heat as compared to computer systems that undergo lower or no loads. Thus, the evaporators 222 may be positioned and operated to supply those computer systems (and racks 212) that generate greater amounts of heat with greater mass flow rates of cooling air and/or relatively lower temperature air. In addition, those computer systems (and racks 212) that generate little or no heat, may likewise, receive little or no cooling air and/or relatively higher temperature air. In this respect, the amount of energy required to operate the evaporators 222 specifically, and the cooling system 220 as a whole, may be substantially optimized according to the demands of the computer systems.

Alternatively, or additionally to the above, because usage of the computer systems contained in the racks 212 may vary at different times of the day, instead of varying the position of the evaporators 222, the load placed on the computer systems may be varied. For instance, as described in co-pending U.S. Application Serial No. 10/122,010, the work load on some of the computer systems may be performed by other computer systems to substantially maximize energy efficiency of the cooling system. In this regard, the load may be transferred, for example, to one location in the room 210 if it is determined that such a load transfer is more energy efficient than under normal operating conditions. Moreover, the load transfer may occur at different times of the day and as load requirements vary.

The refrigeration system 224 may comprise any reasonably suitable type of refrigeration cycle including a vapor-compression cycle using a multi-phase working medium.

Although the refrigeration system 224 is illustrated as being located outside of the room 210, it should be understood that the refrigeration system 224 may be positioned within the room 210 without deviating from the scope of the present invention.

A cooling fluid, such as refrigerant, may be configured to flow through the evaporators 222 and return to the refrigeration system 224 via a fluid line 228. As seen in FIG. 6, the fluid line 228 generally forms a closed loop system in which the refrigerant may become heated in the evaporators 222 and cooled in the refrigeration system 224.

Although one room 210 is illustrated in FIG. 6, it should be understood that the room 210 may comprise more than one room and that the cooling system 220 may be configured to cool a plurality of rooms.

The evaporators 222 generally comprise, among other things, a plurality of fans 230 and an opening (not shown). The fans 230 are designed to cause air from the room 210 to flow into the opening, as indicated by dashed arrow 234. The fans 230 are also configured to cause the air to flow back out into the room 210, in the manner indicated by arrow 236. Thus, operation and speed of the fans 230 are adjusted to control air temperature and air flow rate. It should be understood that the evaporators 222 may include additional components and that some of the components described may be removed and/or modified without departing from the scope of the invention.

The fluid line 228 is situated to connect to the evaporators 222. In this respect, as liquid refrigerant flows through the fluid line 228 and into the evaporators 222, the refrigerant is expanded. In expanding, the refrigerant absorbs heat from the hot air 234 to provide refrigeration. Thus, heat may be transferred from the air to the refrigerant contained in the fluid line 228. Consequently, the air 236 flowing out of the evaporators 222 may be at a lower temperature relative to the air 234 entering the evaporator 222.

As will be discussed in greater detail with respect to FIG. 7 below, a valve (not shown) may be positioned upstream of each evaporator 222 along the fluid line 228. The valve may be an electronically controllable valve capable of varying the flow of refrigerant through the fluid line 228, as well as substantially stopping the flow of the refrigerant. As a result, the mass flow rate of the refrigerant through the fluid line 228 extending through the evaporator 222 may be manipulated at predetermined levels such that the temperature of the air flowing out of the evaporator 222 may be substantially optimized.

In this respect, the temperature of the refrigerant may thus be further controlled. By way of example, the temperature of the refrigerant may be increased prior to its introduction into a given evaporator 222 in a multi-evaporator system (see e.g., FIG. 7). In this type of configuration, when one rack 212 is dissipating a greater amount of heat relative to another rack 212, the temperature of cooling air flow supplied to each of these racks may differ from one another. That is, the rack 212 dissipating the greater amount of heat may receive air flow from a first evaporator 222 that is at a lower temperature compared to the rack that is dissipating a lesser amount of heat. Consequently, the temperature of the refrigerant introduced into that first evaporator may be at a lower temperature than the refrigerant introduced into a second evaporator.

A temperature sensor 248, e.g., a thermocouple or the like, is illustrated on the rack 212. A single temperature sensor 248 is depicted in FIG. 6 for purposes of simplicity, it should, however, be understood that a plurality of temperature sensors 248 may be positioned at various locations of the rack 212 as well as other areas of the room 212. In other words, the temperature sensors 248 are distributed temperature sensors. The temperature sensor 248 may supply temperature readings to a controller (not shown) configured to operate the evaporator 222, and the valve (not shown). In addition, the temperature readings may also be supplied to a controller

(not shown) configured to operate the refrigeration system 224. The manner of information transmittal between the temperature sensor 248 and the controllers may comprise any reasonably suitable arrangement, e.g., wired or wireless connection.

In place of, or in addition to, the temperature sensor 248, a mobile device (not shown) 5 designed to gather or measure at least one local environmental condition (e.g., temperature, air flow, humidity, etc.) in the room 210 may be implemented. By way of example, a suitable mobile device may comprise the environmental condition detecting device described in co-pending U.S. Application Ser. No. 10/157,892, filed on May 31, 2002 (HP Docket No. 100200782-1) entitled "CONTROLLED COOLING OF A DATA CENTER", by Patel et al., 10 which is assigned to the assignee of the present invention and incorporated by reference herein in its entirety. Information gathered by the mobile device may be transmitted to the controller, which may vary operation of the cooling system 220 in response to the information.

Alternatively, or in addition to, the above-described environmental condition sensing devices, the amount of heat generated by the computer systems contained in the racks 212, and 15 the resulting necessary cooling requirements, may be anticipated according to the amount of load placed on the computer systems. A suitable method of implementing anticipated sensing is described in co-pending U.S. Application Ser. No. 09/970,707, which is assigned to the assignee of the present invention and incorporated by reference herein in its entirety.

Referring now to FIG. 7, there is shown a schematic illustration that illustrates a plurality 20 of evaporators 222 and a fluid line 228 emanating from the refrigeration system 224. The illustration also shows that the evaporators 222 include rows of fans 230 located adjacent to openings 232. It is contemplated that each of the evaporators 222 may include two separate evaporator units, corresponding to the separate rows of fans 230. Alternatively, it is contemplated that each of the evaporators 222 may include just a single evaporator unit 25 corresponding to both rows of fans 230. In addition, located generally upstream of the evaporators 222 are respective valves 278, which may comprise thermal electric valves, thermal expansion valves, or the like. The refrigeration system 224 may control the supply of refrigerant through the plurality of evaporators 222. In addition, it may be seen that the valves 278 generally enable control of refrigerant flow through respective fluid line 228.

In this respect, the temperature of the air flowing out of the evaporators 222, and more specifically, out of each side of the evaporators 222 may be controlled in a substantially independent manner. In one regard, the flow of refrigerant through certain evaporators 222 may be restricted or substantially halted, for instance, in situations where the computer systems for which an evaporator 222 is configured to cool are in idle states. It should be understood that the configuration of evaporators 222, fluid line 228, and valves 278 depicted in FIG. 7 is but one manner of a variety of different obtainable configurations. It should also be understood that the specific configuration for any given room may depend upon a multitude of factors, e.g., cooling needs, room configuration, refrigeration system type, etc. In addition, the fluid line 228, and/or the evaporators 222 may be positioned above or below the fans 230 such that air may substantially be cooled prior to or subsequent to flowing into the fans 230 without deviating from the scope of the present invention.

In accordance with the principles of the present invention, temperature variation among racks in a data center may be reduced through the use of the refrigeration system 224. In this respect, air temperatures of certain parts of the room 210 may be controlled to remain relatively constant (approximately within 5 °C) with respect to other parts of the room 210, while allowing for multiple fluctuating heat loads among the racks 212. That is, according to the principles of the present invention, the mass flow rate of refrigerant flowing into each evaporator 222 is independently metered to compensate for the amount of heat load for each respective rack 212 while the temperature of refrigerant entering each evaporator 222 is substantially equal.

In FIG. 7, the cooling system 220 is illustrated as including a plurality of evaporators 222 which are connected in parallel. The cooling system 220 is a multi-load refrigeration system, which, as referenced throughout the present disclosure, generally refers to refrigeration systems having a plurality of evaporators for cooling multiple heat loads. Because the specific type of evaporator to be used in the present invention will vary according to individual needs, the present invention is not limited to any specific type of evaporator and may thus utilize any type of evaporator which may reasonably accomplish certain goals of the present invention. Examples of suitable evaporators employable in the present invention are available from LYTRON, Inc. of Woburn, Massachusetts, LIEBERT Corporation of Columbus, Ohio, and MODINE Manufacturing Company of Racine, Wisconsin. However, as is readily apparent to those of ordinary skill in the art, any other suitable evaporators may be used in the present invention

without departing from the scope and spirit of the present invention, including automotive and consumer appliance types of evaporators.

Additionally, although FIG. 7 depicts two side-by-side evaporators 222, it is to be understood that the present invention is not limited to two evaporators in a side-by-side parallel arrangement, but rather, the present invention may include any reasonable number of evaporators in any arrangement. In one respect, the number of evaporators may correspond to the number racks 212 of FIG. 6. Accordingly, the two evaporators depicted in FIG. 7 are for illustrative purposes only and thus are not meant to limit the present invention in any respect. Additionally, as is well known to those having ordinary skill in the art, the term "parallel" describes the manner in which a single conduit is separated into a plurality of conduits, such that, the flow of refrigerant through each of the conduits may be independently controlled.

Referring still to FIG. 7, the multi-load refrigeration system 220 possesses a closed loop for refrigerant to flow to and from the evaporators 222. The refrigeration system 220 includes the plurality of evaporators 222, a compressor 250, a condenser 252, and a valve 254. The condenser 252 and the valve 254 of the present invention may include any number of known or heretofore known condensers and valves and thus includes any type of condenser and valve which substantially adequately performs their respective functions within a refrigeration system. Examples of valves suitable for use with the present invention include expansion valves such as capillary tubes, constant pressure expansion valves, and the like.

Additionally, any suitable type of refrigerant may be utilized in the present invention. In fact, the choice of refrigerant will depend upon a plurality of factors, e.g., cooling requirements, environmental impact, cost, etc. Generally speaking, suitable refrigerants include the suite of vapor-compression hydrocarbon refrigerants (CFCs, HCFSs, HFCs or any blend of pure refrigerants). Specific examples of suitable refrigerants include R134a, R290, R600, etc. Moreover, suitable refrigerants may be obtained from any commercial refrigerant manufacturer (e.g., TONG TAI INTERNATIONAL located in Taiwan, R.O.C.).

According to the embodiment illustrated in FIG. 7, the compressor 250 is a variable speed compressor. In other words, the compressor 250 may be controlled to either increase or decrease the mass flow rate of the refrigerant therethrough. Therefore, this embodiment provides for energy efficient thermal management by virtue of the variability of the variable speed

compressor 250. According to the principles of the present invention, a number of different types of variable speed compressors may be utilized for proper operation of the present invention. Thus, in similar fashion to other types of vapor-compression refrigeration systems, the refrigerant flowing through the refrigerant line 228 changes between a gas and a liquid at various positions as the refrigerant circuits the closed loop of the refrigeration system 220.

In operation, refrigerant flowing into each of the evaporators 222 is individually metered. In one respect, the mass flow rate of the refrigerant flowing into each of the evaporators 222 is generally dependent upon the amount of heat produced by a respective rack in the proximity of each evaporator 222. That is, because the level of cooling of the racks (or the air in the immediate vicinity thereof) depends upon the amount of refrigerant flowing into the evaporators 222, the mass flow rate of the refrigerant is metered to allow a controlled amount of refrigerant to enter into the respective evaporators 222. Additionally, according to an embodiment of the invention, the evaporators 222 only receive a relatively necessary amount of refrigerant to adequately cool each respective rack without allowing any significant amount of liquid refrigerant to flow into the compressor 250. In this respect, evaporators 222 in the proximity of respective racks that are producing relatively less heat than other racks may receive relatively less refrigerant. Thus, the temperatures of the racks in a data center may be maintained at a relatively constant temperature to thereby reduce any temperature variation among the racks.

Referring again to FIG. 7, refrigerant enters the variable speed compressor 250 through a compressor inlet 256. The variable speed compressor 250 increases the pressure and temperature of the refrigerant before the refrigerant exits through a compressor outlet 258. The speed of the compressor 30 and thus the level of compression of the refrigerant may be controlled by a proportional, integral, derivative controller with relay ("PID") 260. The controller 260 may also comprise a microprocessor, a micro-controller, an application specific integrated circuit (ASIC), a programmable logic controller (PLC), and the like. The manner in which the compression level is controlled by altering compressor speed will be discussed in greater detail hereinbelow.

The refrigerant thus flows out of the compressor 250 and through the refrigerant line 228 into the condenser 252 through a condenser inlet 262. Within the condenser 252, the refrigerant begins to decrease in temperature while remaining at a constant pressure until the refrigerant

reaches a saturation point. The refrigerant exits the condenser 252 through a condenser outlet 264, typically as a liquid (still at a relatively high pressure and temperature). The refrigerant then flows through the refrigerant line 228 into the expansion valve 254 through an expansion valve inlet 266. The pressure of the refrigerant is reduced within the expansion valve 254.

5 After exiting the expansion valve 254 through an expansion valve outlet 268, the refrigerant flows past a sensor 270 which measures the evaporator saturation temperature (" T_{sat} ") of the refrigerant. Although any suitable type of temperature sensor may be utilized in the present invention, examples of suitable temperature sensors include a thermocouple, thermistor, pressure sensing device if the refrigerant is azeotropic (i.e., evaporator saturation temperature is
10 constant over phase change), and the like. The sensor 270 is connected to the PID 260 via an input line 272. The PID 260 is also connected to the variable speed compressor 250 via an output line 274. The PID 260 is configured to control the speed of the compressor 250 and thus the level of compression the variable speed compressor 250 applies on the refrigerant based upon the measured T_{sat} to thereby control the mass flow rate of the refrigerant throughout the
15 refrigeration system 224. Although any suitable PID may be utilized with the present invention, examples of suitable PIDs include those manufactured by OMEGA Inc. of Stamford, Connecticut, and WATLOW ELECTRIC MANUFACTURING CO. of St. Louis, Missouri. The refrigerant then flows through the refrigerant line 228, which branches out into four evaporator refrigerant lines 276. The evaporator refrigerant lines 276 lead the refrigerant to the evaporators
20 222, and converge back to refrigerant line 228.

As illustrated in FIG. 7, evaporator valves 278 are provided upstream of respective evaporators 222 to individually meter the flow of refrigerant into each of the evaporators 222. It is to be understood that a specific type of evaporator valve 278 is not required to be utilized with the present invention, but rather, any suitable type of controllable metering valve, e.g., a thermal
25 electric valve, may be utilized. An example of a suitable evaporator valve employable in the present invention includes the 625 Series Valves manufactured by PARKER-HANNIFIN CORP. of Cleveland, Ohio. It is also contemplated that one or more of the evaporator valves 278 could be an expansion valve to be used instead of or in conjunction with the expansion valve 254.

As further illustrated in FIG. 7, sensors 280 (e.g., thermocouples, thermistors, pressure
30 sensing devices, etc.) are positioned downstream of respective evaporators 222. The sensors 280

are configured to measure the temperature of the refrigerant (" $T_{\text{evap,out}}$ " or " ΔT_{sup} ") as it exits the respective evaporators 222. The evaporator valves 278 respond to changes in the $T_{\text{evap,out}}$ to meter the flow of the refrigerant into each of the evaporators 222. In one respect, a change in the $T_{\text{evap,out}}$ may cause a bimetallic strip inside the respective evaporator valve 278 to actuate thus manipulating the evaporator valve to vary the flow of refrigerant into the respective evaporators 222. The change in temperature may be relayed to the evaporator valves 276 via respective temperature signal lines 282. After the refrigerant exits the evaporators 222, the refrigerant is once again introduced back into the refrigerant line 228 such that the entire refrigeration process may be repeated. In addition, a sensor 284 (e.g., thermocouple, thermistor, pressure sensing device, etc.) is provided between the evaporators 222 and the variable speed compressor 250 so that the suction temperature (" T_{suction} ") may be measured.

FIG. 8 is an exemplary block diagram for the cooling system 220 according to all embodiments of the present invention. It should be understood that the following description of the block diagram is but one manner of a variety of different manners in which such a cooling system 220 may be operated. In addition, it should be understood that the cooling system 220 may include additional components and that some of the components described may be removed and/or modified without departing from the scope of the invention.

The cooling system 220 includes a controller 286 configured to control the operations of the evaporator 222. The controller 286 may comprise a microprocessor, a micro-controller, an application specific integrated circuit (ASIC), and the like. The controller 286 may, for example, control the power and speed of the fans 230, and the operation of the valves 278. Interface electronics 288 may be provided to act as a control interface between the controller 286 and the evaporator 222, fans 230, and valves 278. Alternatively, a control interface may be omitted between the controller 286 and the above-described components. The controller 286 may also be interfaced with a sensor 270, 280, and/or 284, e.g., one or more of the sensors described hereinabove with respect to FIG. 7.

The controller 286 may be interfaced with a memory 290 configured to provide storage of computer software that provides the functionality of the controller 286, e.g., the speed of the fans, pump operation, etc. The evaporator memory 290 may be implemented as a combination of volatile and non-volatile memory, such as dynamic random access memory (DRAM),

EEPROM, flash memory, and the like. The memory 290 may also be configured to provide a storage for containing data and/or information pertaining to the manner in which controller 286 may operate the fans 230 and the valves 278. In one respect, the manner of operation of the above-described components may be based according to temperature measurements by any or all
5 sensor(s) 270, 280, and 284.

The controller 286 may be further interfaced with a refrigeration system controller 292. The interface may be effectuated via a wired protocol, such as IEEE 802.3, etc., wireless protocols, such as IEEE 801.11b, wireless serial connection, Bluetooth, etc., or combinations thereof.

10 The refrigeration system controller 292 may be configured to control the operations of the refrigeration system 224. The refrigeration system controller 292 may comprise a microprocessor, a micro-controller, an application specific integrated circuit (ASIC), and the like. The refrigeration system controller 292 is generally configured to manipulate the temperature of the refrigerant by controlling the operation of the refrigeration system 224. More
15 particularly, the refrigeration system controller 292 may be designed to vary the operation of the refrigeration system 224 to vary the amount of heat transfer on the refrigerant contained in the refrigeration loop of the refrigeration system 224. It is contemplated that the refrigeration system controller 292 and controller 286 can be integrated into a single controller instead of two separate controllers.

20 Interface electronics (I/F) 294 may be provided to act as an interface between the refrigeration system controller 292 and the components for operating the refrigeration system 224, e.g., the supply of voltage to vary the speed of the compressor, etc.

The refrigeration system controller 292 may also be interfaced with memory 296 configured to provide storage of a computer software that provides the functionality of the
25 refrigeration system 224 and may be executed by the refrigeration system controller 292. The memory 296 may be implemented as a combination of volatile and non-volatile memory, such as DRAM, EEPROM, flash memory, and the like. The memory 296 may also be configured to provide a storage for containing data/information pertaining to the manner in which the compressor (heat exchanger, chiller) may be manipulated in response to, for example, variations
30 in the temperature of the refrigerant and/or air in the room.

In one respect, the capacity (e.g., the amount of work exerted on the refrigerant) of the compressor may be modified to thereby control the temperature and of the refrigerant. The compressor may thus be controlled to either increase or decrease the mass flow rate of the refrigerant flowing therethrough. Consequently, when the temperature in the room is below a predetermined range, the capacity of the compressor may be reduced to substantially reduce the amount of work, thus the amount of energy exerted on the refrigerant. This may lead to a significant reduction in the costs associated with operating the cooling system as compared with conventional cooling systems.

Because the specific type of compressor to be employed with embodiments of the invention may vary according to individual needs, the invention is not limited to any specific type of compressor. Instead, any reasonably suitable type of compressor capable of accomplishing certain aspects of the invention may be employed with the embodiments of the invention. The choice of compressor may therefore depend upon a plurality of factors, e.g., cooling requirements, costs, operating expenses, etc.

By way of example, if there is a detected or anticipated change in the temperature of a rack 212, areas surrounding the rack 212, etc., the controller 286 may operate to manipulate the corresponding evaporator 222 and/or fan(s) 230 to compensate, e.g., change the mass flow rate, velocity, and other characteristic of the air flow, for the change in temperature. In addition, or as an alternative to the above, the controller 286 may operate to cause the refrigeration system 224 to lower the refrigerant temperature. In this respect, each of the racks 212 and/or portions thereof may generally receive substantially only the amount of cooling air necessary to maintain the temperature of the racks 212 within a predetermined temperature range. In addition, the refrigerant temperature, and therefore the air temperature, may also be controlled as needed to substantially optimize cooling of the racks 212. By controlling the cooling air flow in the above-described manner, the cooling system 220 may be operated at substantially optimized levels, thereby decreasing the amount of energy and thus the operating costs required to cool the computer systems in the racks 212.

Moreover, the controller 286 may operate the compressor in a manner to vary the refrigerant temperature in response to various degrees of detected increases/decreases in the operation of the evaporator 222. More particularly, a look up table (not shown) may be stored in

the memory 296. The look up table may include information pertaining to the level of compressor speed increase necessary for a detected increase in the operation of the evaporator 222. In this respect, the compressor speed may be varied substantially incrementally in response to detected changes in the operation of the evaporator 222.

5 FIG. 9 shows a flow diagram of an operational mode 300 according to an embodiment of the invention. It should be understood that the operational mode 300 may include additional operations and that some of the operations may be removed and/or modified without departing from the scope of the invention. The following description of the operational mode 300 is made with reference to FIGS. 6-8, and thus makes reference to the elements cited therein.

10 The operations illustrated in the operational mode 300 may be contained as a utility, program, or a subprogram, in any desired computer accessible medium. In addition, the operational mode 300 may be embodied by a computer program, which can exist in a variety of forms both active and inactive. For example, they can exist as software program(s) comprised of program instructions in source code, object code, executable code or other formats. Any of the
15 above can be embodied on a computer readable medium, which include storage devices and signals, in compressed or uncompressed form.

Exemplary computer readable storage devices include conventional computer system RAM, ROM, EPROM, EEPROM, and magnetic or optical disks or tapes. Exemplary computer readable signals, whether modulated using a carrier or not, are signals that a computer system
20 hosting or running the computer program can be configured to access, including signals downloaded through the Internet or other networks. Concrete examples of the foregoing include distribution of the programs on a CD ROM or via Internet download. In a sense, the Internet itself, as an abstract entity, is a computer readable medium. The same is true of computer networks in general. It is therefore to be understood that those functions enumerated below may
25 be performed by any electronic device capable of executing the above-described functions.

In the operational mode 300, the cooling system 220 is activated at step 305. At step 310, the evaporator superheat temperature (" ΔT_{sup} ") for each of the evaporators 222 is sensed by the respective sensors 280. At step 315, it is determined whether the ΔT_{sup} for each of the evaporators 222 is within a predetermined desired range. If the ΔT_{sup} for one of the evaporators
30 222 is within the desired range, then no change is made to the evaporator valve 278 of that

evaporator and the process proceeds to step 335. If, however, the ΔT_{sup} is not within the desired range for any of the evaporators 222, the ΔT_{sup} for that evaporator 222 is compared to an evaporator superheat set point (" $\Delta T_{\text{sup,set}}$ ") at step 320. The $\Delta T_{\text{sup,set}}$ for each of the evaporators 222 is about between 0-5° C and may be set to be approximately the same for each of the
5 evaporators 222.

Thus, for example, if the ΔT_{sup} for one evaporator 222 is lower than the $\Delta T_{\text{sup,set}}$ for that evaporator 222, the evaporator valve 278 for that evaporator 222 is manipulated by a controlled amount to decrease the mass flow rate of the refrigerant flowing into the evaporator 222 at step 325. In addition, by manipulating the evaporator valve 278 to reduce the mass flow of the
10 refrigerant through the evaporator 222, the T_{sup} may be increased and the T_{sat} may be reduced.

If, on the other hand, the ΔT_{sup} for one evaporator 222 is not less than the $\Delta T_{\text{sup,set}}$ for that evaporator 222, the evaporator valve 278 for that evaporator 222 is manipulated to increase the mass flow of the refrigerant therethrough by a controlled amount as indicated at step 330. By way of increasing the mass flow rate of the refrigerant through that evaporator 222, the T_{sup} may
15 decrease and the T_{sat} may increase. After the evaporator valves 278 have been manipulated to either increase or decrease the flow of refrigerant therethrough, the process returns to step 310.

It is to be understood that by way of the principles of the present invention, each of the evaporators 222 may be independently metered. More specifically, any one or all of the evaporator valves 278 may be manipulated to decrease the flow of refrigerant therethrough while
20 another one of the evaporator valves is manipulated to increase the flow of refrigerant therethrough.

Thus, although specific reference is made to the manner of controlling one evaporator 212 and one evaporator valve 278, it is to be understood that steps 310-330 are carried out for each of the evaporators 222, independently of one another and may be done simultaneously.

At step 335, the temperature of one or more racks at any given time (T_r) is sensed by
25 temperature sensors, e.g., one or more temperature sensors 248. The temperature sensors 248 may comprise one or more of the above-described temperature sensors, e.g., thermocouple, mobile environmental condition sensing device, etc. The T_r 's generally correspond to the heat load of the heat dissipating components and therefore the computer systems contained in the

racks, e.g., rack 212. Therefore, the Tr's may be based upon the temperatures of specific heat dissipating components and subsystems. In addition, the Tr's may be based upon the temperatures in the general vicinity of the racks and/or sections of the racks. Thus, those skilled in the art will understand that embodiments of the present invention may be employed to monitor
5 Tr's with temperature sensors 248 located at various positions throughout the room and not only on or near the racks 212. Moreover, use of the term "rack" herein generally refers to racks for supporting computer systems and additionally to sections of the racks as well as areas around the racks. Therefore, the use of the term "rack" throughout the present disclosure is not meant to limit certain aspects thereof to entire racks, but instead, is relied upon to simplify the description
10 of embodiments of the present invention.

As an alternative to the temperature sensor 248, the Tr's may be anticipated in the manner described hereinabove and in co-pending U.S. Patent Application Serial No. 09/970,707.

At step 340, it is determined whether each of the Tr's is within a predetermined range of operating temperatures, e.g., between a maximum set point temperature ($T_{max,set}$) and a
15 minimum set point temperature ($T_{min,set}$). In general, the range of temperatures $T_{min,set}$ and $T_{max,set}$ pertains to threshold temperatures to determine whether to increase or decrease the flow of cooling air delivered to the racks. This range of operating temperatures may be set according to a plurality of factors. These factors may include, for example, the operating temperatures set forth by the manufacturers of the subsystems and components located in the
20 racks, through testing to determine the optimal operating temperatures, etc. In addition, the predetermined range of operating temperatures may vary from one subsystem to another.

For those racks having Tr's that are within the predetermined range, their temperatures are sensed again at step 335, after the process returns to steps 310 and 315. For those racks determined to have heat loads that do not fall within the predetermined temperature range, i.e.,
25 fall outside of $T_{min,set}$ and $T_{max,set}$, the controller 286 may determine whether those racks have temperatures that are below the $T_{min,set}$ at step 345.

If, at step 345, it is determined that one or more Tr's are less than or equal to the $T_{min,set}$, then the air flow supplied by the evaporator 222, and more particularly the fans 230, configured to supply cooling air flow to the racks having Tr's below or equal to the $T_{min,set}$,

may be decreased at step 350. In addition, and/or alternatively, the evaporator controller 286 may increase the flow of refrigerant through the evaporator 222 via operation of the valve(s) 278.

At step 355, the temperatures of the racks 212 are sensed again a subsequent time (T_{rn}). The effect of decreasing the air flow is evaluated at step 360. Here, T_{rn} is compared to T_r , wherein if T_{rn} is greater than T_r , such that decreasing the air flow had its intended effect, then the process returns to step 310. If, however, T_{rn} is not greater than T_r , such that decreasing the air flow did not have its intended effect, then the process proceeds to step 380.

If, at step 345, it is determined that one or more T_r 's are greater than $T_{min, set}$, then the air flow may be increased at step 365. In this regard, the controller 286 may increase power to the fans 230 to enable greater air flow to the racks 212. In addition, and/or alternatively, the evaporator controller 286 may increase the flow of refrigerant through the evaporator 222 via operation of the valve(s) 278.

At step 370, the temperatures of the racks are sensed again a subsequent time (T_{rn}). The effect of increasing the air flow is evaluated at step 375. Here, T_{rn} is compared to T_r , wherein if T_{rn} is less than T_r , such that increasing the air flow had its intended effect, then the process returns to step 310. If, however, T_{rn} is not less than T_r , such that increasing the air flow did not have its intended effect, then the process proceeds to step 380.

By virtue of certain embodiments of the invention, racks having various T_r 's may be supplied with air flow having various characteristics, e.g., temperature, velocity, direction, and the like. That is, for example, in a system comprising a plurality of evaporators 222, air flow may be supplied to racks having higher T_r 's by certain evaporators 222 substantially simultaneously with air flow supplied to racks 212 having relatively lower T_r 's by other evaporators 222 where each of the racks 212 receives different levels of air flow. Additionally, the temperature of the refrigerant supplied through the evaporators 222 delivering air flow to racks having higher T_r 's may be relatively lower than the temperature of the refrigerant supplied through the evaporators 222 delivering air flow to racks having lower T_r 's. It should thus be appreciated that steps 350 and 365 may be respectively and substantially simultaneously performed by various evaporators 222. More particularly, on a zonal level, temperature readings determined at step 335 for various racks may be implemented in varying the delivery of cooling air to the various racks. Additionally, on a global level, the temperature of the refrigerant may be

varied according to the changes in the cooling requirements of the racks. For example, when the temperature of a rack exceeds a predetermined threshold range, the evaporator(s) 222 supplying cooling air flow to that rack may increase the air flow to that rack. Substantially concurrently, the temperature of the refrigerant may be decreased by an amount relative to the increased rack
5 temperature.

According to an embodiment of the invention, the decrease in mass flow rate and/or velocity of the air flow at step 350 and the increase in volume and/or velocity of the air flow at step 365 may be accomplished by incrementally varying the air flow from the evaporator 222. For example, the volume flow rate and/or velocity of the air flow from the evaporator 222 may
10 be varied by a predetermined amount during a first iteration. The T_r may be measured at a predetermined time following the variation and steps 335-365 may be repeated. By repeating this process a number of times, the temperature of the rack may be substantially brought within the predetermined range without having to adjust refrigerant temperature.

At step 380, one or more of the controllers 286 or 292 and memory 290 or 296 are
15 configured to adapt or learn from errors in a prescribed course of action, i.e. record when the change in air flow at steps 350 and 365 did not have the intended effect of correctly adjusting T_r . Accordingly, the controller(s) can attempt to take an opposite course of action the next time the same or similar condition is present. For example, if an increase in air flow at step 365 resulted in T_{rn} being greater than T_r in a given location, then the controller(s) can learn from this
20 unintended effect and instead decrease the air flow the next time such a condition is present in the given location. In addition, step 380 can be used as input to a computational fluid dynamics tool that will be described in greater detail below.

At step 385 the controller 292 may determine whether to vary the refrigerant temperature, e.g., increase the compressor speed. For example, the refrigerant temperature may be decreased
25 in response to, for example, fan speed and actual and/or detected increases in T_r . In other words, if any fan associated with any evaporator is at maximum speed and a respective T_r (or T_r 's) exceeds the predetermined temperature range, then the compressor speed can be increased (and vice versa). Thus, the goal in this example is to achieve optimal energy efficiency by permitting the refrigerant to maintain its highest possible temperature, primarily using the fans to deliver
30 cooling air at a temperature and flow rate that is adequate to cool the racks. As such, a lower

limit is necessarily placed on fan speed so that a minimum mass flow rate of air is delivered to the room from the evaporators.

If the controller(s) determines not to vary the refrigerant temperature at step 385, then the process returns to step 310. In addition, the steps following step 310 may be repeated for an indefinite period of time and may form a closed-loop pattern. Alternatively, if the controller determines to vary the refrigerant temperature, then the process proceeds from step 385 to operational mode 400 of FIG. 10.

FIG. 10 is a flow diagram depicting an operational mode 400 in which the embodiment illustrated in Figs. 6-8 may be practiced. Accordingly, the following description of FIG. 10 will be made with particular reference to those features illustrated in Figs. 6-8. As seen in FIG. 10, after an affirmative decision at step 385 in FIG. 9 is made, the T_{sat} is measured at step 406. The T_{sat} measurement is then relayed to the PID 260 via the input line 272 where it is then compared to a predetermined range at step 408. The predetermined range in step 408 is determined based upon system design and the amount of load variability to be expected among the racks. In general, the predetermined range may depend upon the following: electrical timing requirements, allowable mechanical stress due to thermal expansion, proximity to dew point, etc. If it is determined that the T_{sat} is indeed within the predetermined range, then the process proceeds back to step 310 as indicated by marker A. If, however, it is determined that the T_{sat} is not within the predetermined range, it is then determined whether the T_{sat} is higher than an evaporator saturation temperature set point (" $T_{sat,set}$ ") at step 410. The $T_{sat,set}$ may be determined by determining the optimum operating temperature of each rack and is a function of rack design, rack packaging, the efficiency of the thermal connection between the evaporator and the rack, the design of the evaporator, flow rate of the refrigerant, refrigerant properties, and the like.

If the T_{sat} is equal to or below the $T_{sat,set}$, the speed of the variable speed compressor 250 is reduced by a controlled amount at step 412. By reducing the speed of the variable speed compressor 250, the mass flow rate of the refrigerant entering into the evaporators 222 will be decreased and the T_{sat} will be increased. If, on the other hand, the T_{sat} is higher than the $T_{sat,set}$, the speed of the variable speed compressor 250 is increased by a controlled amount at step 414. Increasing the speed of the variable speed compressor 250 has the effect of increasing the mass flow rate of the refrigerant entering into the evaporators while reducing the T_{sat} . After each of

steps 412 and 414, the T_{sat} is measured once again and the process is repeated at step 406.

FIG. 11 illustrates yet another embodiment incorporating the principles of the present invention. A cooling system 520 of this embodiment is similar to the cooling system 220 as described hereinabove with respect to Figure 6 and thus only those features which are reasonably
5 necessary for a complete understanding of the embodiment of FIG. 11 are described hereinbelow. Two differences are that cooling system 520 includes a constant speed compressor 550 and a programmable logic controller ("PLC") 560. This embodiment provides for thermal management with proper provisioning of inefficient cooling resources. A constant speed
10 compressor 550 is a relatively inefficient cooling resources, but is relatively cheaper and more reliable. This embodiment enables better distribution of cooling resources by independent control of air temperature via control of evaporator superheat.

The cooling system 520 includes a condenser 552, an expansion valve 554, and a plurality of vapor temperature signal lines 572 connected to respective sensors 580 for relaying
15 evaporator superheat temperature readings from the sensors 580 to the PLC 560. Moreover, a plurality of control signal lines 574 are connected from the PLC 560 to respective evaporator valves 578 upstream of respective evaporators 522.

In addition, FIG. 11 depicts the racks 212 to be cooled and shows that each of the temperature sensors 248 are in communication with the PLC 560 via a plurality of rack
20 temperature lines 575. In this respect, according to the principles of the embodiment illustrated in FIG. 11, the temperatures of the racks 212 may be directly relayed to the PLC 560. However, it is within the purview of the present disclosure that the temperature of the racks 212 may be measured by any reasonable means. Modifications to the position of temperature measurement may be accomplished without deviating from the scope and spirit of the present invention.

FIG. 12 shows a flow diagram of the operational mode 600 according to another
25 embodiment of the present invention that is similar to that described in FIG. 9 in which the description thereof is incorporated by reference herein. It should be understood that the operational mode 600 may include additional operations and that some of the operations may be removed and/or modified without departing from the scope of the invention. The following description of the operational mode 600 is made with reference to FIG. 11, and thus makes
30 reference to the elements cited therein.

In the operational mode 600, the cooling system 520 is activated at step 605. At step 610, the evaporator superheat temperature (" ΔT_{sup} ") for each of the evaporators 522 is sensed by the respective sensors 580. At step 615, the ΔT_{sup} for each of the evaporators 522 is compared to a $\Delta T_{\text{sup, set}}$. The $\Delta T_{\text{sup, set}}$ for each of the evaporators 522 is about between 0-5° C and may be set to vary among the evaporators 522. For illustrative purposes only, the following example is made with particular reference to one evaporator 522 and its related components. It is to be understood that each of the following steps are equally applicable to the other evaporators 522 and their relative components, and the steps may be carried out on the other evaporators 522 concurrently with the steps described hereinbelow with respect to any one evaporator 522. Thus, for example, if the ΔT_{sup} for evaporator 522 is lower than the $\Delta T_{\text{sup, set}}$ for that evaporator, the respective evaporator valve 578 is manipulated to decrease the mass flow rate of refrigerant therethrough by a controlled amount at step 620. By decreasing the mass flow rate of refrigerant through the evaporator valve 578, the T_{sat} may be reduced, while the ΔT_{sup} and the rack temperature T_r may be increased. After the mass flow rate of the refrigerant through the evaporator valve 578 has been reduced, the ΔT_{sup} for each of the evaporators is sensed and checked again at steps 610 and 615.

According to the principles of the above-described embodiment, the amount of refrigerant flowing into each of the evaporators 522 may be independently metered by the evaporator valves 578. Thus, the temperature of the racks 512 may be controlled according to the superheat temperature of the refrigerant flowing out of the evaporators 522.

At step 625, the temperature of one or more racks (T_r) is sensed by temperature sensors, e.g., one or more temperature sensors 548. The temperature sensors 548 may comprise one or more of the above-described temperature sensors, e.g., thermocouple, mobile environmental condition sensing device, etc. The T_r 's generally correspond to the heat load of the heat dissipating components and therefore the computer systems contained in the racks, e.g., rack 512. Therefore, the T_r 's may be based upon the temperatures of specific heat dissipating components and subsystems. In addition, the T_r 's may be based upon the temperatures in the general vicinity of the racks and/or sections of the racks. Thus, those skilled in the art will understand that embodiments of the present invention may be employed to monitor T_r 's with temperature sensors 548 located at various positions throughout the room and not only on or near the racks 512. Moreover, use of the term "rack" herein generally refers to racks for supporting

computer systems and additionally to sections of the racks as well as areas around the racks. Therefore, the use of the term "rack" throughout the present disclosure is not meant to limit certain aspects thereof to entire racks, but instead, is relied upon to simplify the description of embodiments of the present invention.

5 As an alternative to the temperature sensor 548, the Tr's may be anticipated in the manner described hereinabove and in co-pending U.S. Patent Application Serial No. 09/970,707.

At step 630, it is determined whether each of the Tr's is within a predetermined range of operating temperatures, e.g., between a maximum set point temperature ($T_{\max, \text{set}}$) and a minimum set point temperature ($T_{\min, \text{set}}$). In general, the range of temperatures $T_{\min, \text{set}}$ and
10 $T_{\max, \text{set}}$ pertains to threshold temperatures to determine whether to increase or decrease the flow of cooling air delivered to the racks. This range of operating temperatures may be set according to a plurality of factors. These factors may include, for example, the operating temperatures set forth by the manufacturers of the subsystems and components located in the racks, through testing to determine the optimal operating temperatures, etc. In addition, the
15 predetermined range of operating temperatures may vary from one subsystem to another.

For those racks having Tr's that are within the predetermined range, their temperatures are sensed again at step 625, after the process returns to steps 610 and 615. For those racks determined to have heat loads that do not fall within the predetermined temperature range, i.e., fall outside of $T_{\min, \text{set}}$ and $T_{\max, \text{set}}$, the controller 586 may determine whether those racks
20 have temperatures that are below the $T_{\min, \text{set}}$ at step 635.

If, at step 635, it is determined that one or more Tr's are less than or equal to the $T_{\min, \text{set}}$, then the air flow supplied by the evaporator 522, and more particularly the fans 530, configured to supply cooling air flow to the racks having Tr's below or equal to the $T_{\min, \text{set}}$, may be decreased at step 640. At step 645, the temperatures of the racks 512 are sensed again a
25 subsequent time (T_{rn}). The effect of decreasing the air flow is evaluated at step 650. Here, T_{rn} is compared to Tr, wherein if T_{rn} is greater than Tr, such that decreasing the air flow had its intended effect, then the process returns to step 610. If, however, T_{rn} is not greater than Tr, such that decreasing the air flow did not have its intended effect, then the process proceeds to step 670.

If, at step 635, it is determined that one or more Tr 's are greater than $T_{min, set}$, then the air flow may be increased at step 655. In this regard, the controller 586 may increase power to the fans 530 to enable greater air flow to the racks 512. At step 660, the temperatures of the racks are sensed again a subsequent time (Tr_n). The effect of increasing the air flow is evaluated at step 665. Here, Tr_n is compared to Tr , wherein if Tr_n is less than Tr , such that increasing the air flow had its intended effect, then the process returns to step 610. If, however, Tr_n is not less than Tr , such that increasing the air flow did not have its intended effect, then the process proceeds to step 670.

By virtue of certain embodiments of the invention, racks having various Tr 's may be supplied with air flow having various characteristics, e.g., temperature, velocity, direction, and the like. That is, for example, in a system comprising a plurality of evaporators 522, air flow may be supplied to racks having higher Tr 's by certain evaporators 522 substantially simultaneously with air flow supplied to racks 512 having relatively lower Tr 's by other evaporators 522 where each of the racks 512 receives different levels of air flow. Additionally, the temperature of the refrigerant supplied through the evaporators 522 delivering air flow to racks having higher Tr 's may be relatively lower than the temperature of the refrigerant supplied through the evaporators 522 delivering air flow to racks having lower Tr 's. It should thus be appreciated that steps 640 and 655 may be respectively and substantially simultaneously performed by various evaporators 522. More particularly, on a zonal level, temperature readings determined at step 625 for various racks may be implemented in varying the delivery of cooling air to the various racks. Additionally, on a global level, the temperature of the refrigerant may be varied according to the changes in the cooling requirements of the racks. For example, when the temperature of a rack exceeds a predetermined threshold range, the evaporator(s) 522 supplying cooling air flow to that rack may increase the air flow to that rack. Substantially concurrently, the temperature of the refrigerant may be decreased by an amount relative to the increased rack temperature.

According to an embodiment of the invention, the decrease in mass flow rate and/or velocity of the air flow at step 640 and the increase in volume and/or velocity of the air flow at step 655 may be accomplished by incrementally varying the air flow from the evaporator 522. For example, the volume flow rate and/or velocity of the air flow from the evaporator 522 may be varied by a predetermined amount during a first iteration. The Tr may be measured at a

predetermined time following the variation and steps 625-655 may be repeated. By repeating this process a number of times, the temperature of the rack may be substantially brought within the predetermined range without having to adjust refrigerant temperature.

At step 670, one or more of the controllers 586 or 592 and memory 590 or 596 are
5 configured to adapt or learn from errors in a prescribed course of action, i.e. record when the change in air flow at steps 640 and 655 did not have the intended effect of correctly adjusting T_r . Accordingly, the controller(s) can attempt to take an opposite course of action the next time the same or similar condition is present. For example, if an increase in air flow at step 655 resulted in T_{rn} being greater than T_r in a given location, then the controller(s) can learn from this
10 unintended effect and instead decrease the air flow the next time such a condition is present in the given location. In addition, step 670 can be used as input to a computational fluid dynamics tool that will be described in greater detail below.

At step 675 the controller 592 may determine whether to vary the refrigerant temperature, e.g. by decreasing mass flow rate through the evaporators 522 based on measured evaporator
15 superheat temperatures. Moreover, the refrigerant temperature may be decreased in response to, for example, fan speed and actual and/or detected increases in T_r . The goal in this example is to achieve optimal energy efficiency by permitting the refrigerant to maintain its highest possible temperature, primarily using the fans to deliver cooling air at a temperature and flow rate that is adequate to cool the racks. As such, a lower limit is necessarily placed on fan speed so that a
20 minimum mass flow rate of air is delivered to the room from the evaporators.

If the controller(s) determines not to vary the refrigerant temperature at step 675, then the process returns to step 610. In addition, the steps following step 610 may be repeated for an indefinite period of time and may form a closed-loop pattern. Alternatively, if the controller determines to vary the refrigerant temperature, then the process proceeds from step 675 to
25 operational mode 700 of FIG. 13.

FIG. 13 is a flow diagram 700 depicting a manner in which the embodiment illustrated in FIG. 11 may be practiced. Accordingly, the following description of FIG. 13 will be made with particular reference to the features illustrated in FIG. 11. As seen in FIG. 13, after an affirmative decision at step 670 in FIG. 12 is made, the T_r is sensed (e.g., with a thermocouple) at 702. The
30 temperature of the rack is relayed to the PLC 560 via temperature lines 575. It is then

determined whether the T_r is within a predetermined range at step 704. The predetermined range in step 704 is determined based upon system design and the amount of load variability expected among the racks. In general, the predetermined range may depend upon the following: electrical timing requirements, allowable mechanical stress due to thermal expansion, proximity to dew point, etc. If the T_r is within the predetermined range, the amount of refrigerant flowing through the evaporator valve 578 is unchanged and the process returns to the operational mode 600 of FIG. 12 as indicated by marker A.

If, however, the T_r is outside the predetermined range, the T_r is compared to a set point temperature to determine whether the T_r is too hot at step 706. The set point temperature is a preferable operating temperature of the component and is generally provided by the component manufacturer. The preferable operating temperature is normally determined based upon the computer equipment manufacturers recommended inlet air temperature, based on a number of different factors. If the T_r is too hot, then the PLC 560 sends a signal via control signal line 574 to the respective evaporator valve 578 instructing the valve to increase the mass flow rate of refrigerant therethrough by a controlled amount at step 708. By increasing the mass flow rate of the refrigerant flowing into the evaporator 522, the T_{sat} may be increased, while the T_r and the ΔT_{sup} may be decreased.

If the T_r is not too hot, the PLC 560 sends a signal via control signal line 574 to evaporator valve 578 instructing the valve to decrease the mass flow rate of refrigerant therethrough by a controlled amount at step 710. By decreasing the mass flow rate of the refrigerant flowing into the evaporator 522, the T_{sat} may be decreased, while the T_r and the ΔT_{sup} may be increased. After these measures have been taken, the T_r is checked again at step 702 and the process repeats.

In accordance with embodiments of the present invention, the cooling requirements of a room configured to house computer systems may be analyzed to substantially optimize the layout of the racks within the room. In one respect, the substantial optimization of the rack layout in the room may enable the cooling system of the data center to operate at generally lower energy and greater efficiency levels by virtue of the reduced workload placed on the components of the cooling systems, e.g., compressors, evaporators, etc. In addition, the cooling requirements may be analyzed to optimize the workload of the computer systems as described above. In this

regard, the actual or anticipated temperatures may be stored in a look-up table and used as references in optimizing the room layout and/or workload distribution. The cooling requirements within the room may be analyzed by operation of any reasonably suitable commercially available computational fluid dynamics (CFD) tool, e.g., FLOVENT, a 6-D
5 modeling software capable of predicting temperature variations based upon fluid flow analyses.

By virtue of the numerical modeling, various cooling devices as well as the evaporators described hereinabove may be positioned throughout the room to substantially control the manner in which the racks receive the cooling fluid.

10 In addition, the cooling devices may also be positioned to substantially maximize and optimize their performances, e.g., to prevent one or more of the cooling devices from operating at substantially excessive levels.

In determining the cooling air distribution requirement within the room, each of the racks may be assigned a heat load which may correspond to a maximum heat load predicted for that rack, e.g., through anticipated power draw. For example, a rack containing 40 subsystems, e.g.,
15 computers, may have a maximum heat load of 10 KW and a rack containing 50 subsystems may have a maximum heat load of 5 KW. By implementing the CFD in this manner, for example in a room containing 100 racks, four cooling devices, and a plurality of evaporators, racks having a potential for relatively larger heat loads may be relatively separately located throughout the data
20 center. In one respect, therefore, the cooling devices and the evaporators within the room may be operated at substantially less than maximum power levels while the racks may receive sufficient amounts of cooling fluid. More specifically, the power required to operate the cooling devices and the evaporators may be regulated to efficiently supply cooling fluid to the racks by providing substantially only that amount of cooling fluid necessary to maintain the racks within
25 nominal operating temperatures.

Additionally, a CFD tool may be implemented substantially simultaneously with the cooling system. More specifically, the CFD tool may be utilized to substantially continuously vary the operation of the cooling system to operate according to the heat loads generated in the racks. In this regard, the anticipated or actual heat loads (e.g., based upon the power draw of the
30 components) on the racks may be inputted into the CFD tool, along with one or more of the

following properties: velocity of the cooling fluid flowing through various sections of the room and the distribution of temperature and pressure of the cooling fluid in the data center, to determine an optimal manner in which, for example, the evaporators may be operated. The velocity of the air flow as well as other atmospheric conditions at various locations within the room may be sensed by a temperature sensor. The sensed conditions may be transmitted or otherwise relayed to the CFD tool to enable the tool to perform the necessary calculations.

In this regard, the CFD tool may be implemented to produce a numerical model of the room to thus determine an optimized cooling distribution within the room. A correlation of one or more of the following properties: velocity of the cooling fluid flowing through various sections of the room, distribution of temperature and pressure of the cooling fluid in the room, and the power draw into the racks, may be created based on the numerical modeling. The correlation may be used to infer thermal conditions throughout the room when only a minimum number of sensors are available during operation of the cooling system. In addition, the correlation may substantially reduce the amount of time required for the CFD tool to perform the computing operations.

By virtue of certain embodiments of the present invention, one of ordinary skill in the art will readily recognize that the amount of energy, and thus the costs associated with cooling the racks located within a room may be substantially reduced. In one respect, by operating the cooling system to supply cooling fluid substantially only as needed by the racks to keep the racks at substantially the same temperature within a predetermined range, the cooling system may be operated at a relatively more efficient manner in comparison with conventional cooling systems.

What has been described and illustrated herein is a preferred embodiment of the invention along with some of its variations. The terms, descriptions and figures used herein are set forth by way of illustration only and are not meant as limitations. Those skilled in the art will recognize that many variations are possible within the spirit and scope of the invention, which is intended to be defined by the following claims -- and their equivalents -- in which all terms are meant in their broadest reasonable sense unless otherwise indicated.

1. A method (300, 600) for cooling a room (210) configured to house a plurality of computer systems (212), said method comprising:

providing a plurality of evaporator units (222, 522) distributed in parallel and configured to receive air from said room and to deliver air to said room;

supplying said plurality of evaporator units with refrigerant, wherein said refrigerant is operable to cool said air in said plurality of evaporator units;

sensing (335, 625) temperatures at one or more locations in said room; and

controlling (345-414, 635-710) the temperature of said air in response to said step of sensing temperatures at said one or more locations.

2. The method according to claim 1, further comprising:

providing a refrigeration system (224) configured to manipulate the temperature of said refrigerant, wherein said controlling step comprises varying (385-414) an output of said refrigeration system to control the temperature of said refrigerant, wherein said refrigeration system comprises a refrigeration loop having a variable speed compressor (250) and having at least one valve (278) configured to meter flow of said refrigerant through at least one of said plurality of evaporator units, and wherein said step of controlling the temperature of said refrigerant comprises controlling (412, 414) the operation of said variable speed compressor, said plurality of evaporator units comprising at least one fan (230) configured to effectuate delivery of said air, said step of controlling at least one of the temperature of said refrigerant and said air comprises varying (150, 160) an output of said fan to control the delivery of air to the room.

3. The method according to claim 2, further comprising:

determining (340) whether said temperatures at said one or more locations in said room are within a predetermined range;

determining (345) whether said temperatures are at least one of less than and equal to a minimum set point temperature in response to said temperatures at one or more locations in said room being outside of said predetermined range;

said controlling step comprises at least one of the following steps:

decreasing (350) delivery of said air to said room in response to said temperatures at said one or more locations being at least one of less than and equal to said minimum set point temperature;

increasing (365) delivery of said air to said room in response to said sensed temperatures being above said minimum set point temperature and outside of said predetermined range;

sensing (355, 370) temperatures again at one or more locations in said room; and
recording (380) whether said decreasing and said increasing steps had their intended effect.

4. The method according to claim 2, further comprising:

sensing (406) a saturation temperature of said refrigerant;

increasing (414) the speed of said variable speed compressor in response to said saturation temperature exceeding a saturation temperature set point;

decreasing (412) the speed of said variable speed compressor in response to said saturation temperature being less than or equal to said predetermined saturation temperature set point;

sensing (310) a superheat temperature of said refrigerant exiting from at least one of said plurality of evaporator units;

manipulating (325) said at least one valve to decrease the flow of refrigerant through said at least one of said plurality of evaporator units in which said superheat temperature of said refrigerant is outside a predetermined superheat temperature range and said superheat temperature of said refrigerant is less than an evaporator superheat temperature set point for said at least one of said plurality of evaporator units; and

manipulating (330) said at least one valve to increase the flow of refrigerant through said at least one of said plurality of evaporator units in which said superheat temperature of said refrigerant is outside said predetermined superheat temperature range and said superheat temperature of said refrigerant exceeds or is equal to said evaporator superheat temperature set point for said at least one of said plurality of evaporator units.

5. The method according to claim 1, further comprising:

providing a refrigeration system (520) configured to manipulate the temperature of said refrigerant, wherein said controlling step comprises varying (675-710) an output of said refrigeration system to control the temperature of said refrigerant;

controlling (706-710) the flow of said refrigerant through said refrigeration system, said refrigeration system having a constant speed compressor (550) and a plurality of valves (578) that meter the flow of said refrigerant respectively through said plurality of evaporator units; and

checking (610) a superheat temperature of said refrigerant flowing through said plurality of evaporator units.

6. The method according to claim 5, further comprising:

manipulating (620) said plurality of valves to decrease the flow of refrigerant respectively through said plurality of evaporator units for each of said plurality of evaporator units in which the respective superheat temperature is less than an evaporator superheat temperature set point; and

sensing (702) a temperature associated with those evaporator units in which said superheat temperature exceeds or is equal to said superheat temperature set point.

7. The method according to claim 6, further comprising:

determining (704) whether said temperature is within a predetermined temperature range;

determining (706) whether said temperature is above a predetermined temperature for those evaporator units in which said temperature is outside said predetermined rack temperature range;

manipulating (710) said plurality of valves to respectively decrease the flow of refrigerant through said plurality of evaporator units for each of those evaporator units in which said temperature is below said predetermined temperature range

manipulating (708) said plurality of valves to respectively increase the flow of refrigerant through said plurality of evaporator units for those evaporator units in which said temperature exceeds said predetermined temperature range.

8. A system (220, 520) for cooling a room (210) containing a plurality of computer systems (212), said system comprising:

a plurality of evaporator units (222, 522) distributed in parallel and configured to receive refrigerant through a refrigerant line and to receive air, wherein said air may be cooled through heat transfer with said refrigerant, said plurality of evaporator units having at least one fan (230) configured to cause said air to flow out of said plurality of evaporator units;

an evaporator controller (286) operable to control a supply of said refrigerant to said plurality of evaporator units and operable to control the speed of said at least one fan;

a refrigeration system (224, 220, 520) for cooling said refrigerant; and

a refrigeration system controller (292) configured to operate said refrigeration system to vary the temperature of said refrigerant.

9. The system according to claim 8, further comprising:

at least one valve (278) configured to meter the flow of said refrigerant through said plurality of evaporator units positioned along said refrigerant line generally upstream of said plurality of evaporator units, wherein said evaporator controller is operable to control the mass flow rate of said refrigerant through said at least one valve;

a variable speed compressor (250) for controlling the flow of said refrigerant through said refrigerant line; and

a refrigeration system controller (292) configured to control said variable capacity compressor.

~~10. The system according to claim 8, further comprising:~~

a constant speed compressor (550) within said refrigeration system;

a plurality of refrigerant temperature sensors (580) in communication with said evaporator controller and respectively positioned downstream of said plurality of evaporator units;

a plurality of distributed temperature sensors (248) in communication with said evaporator controller;

a plurality of temperature signal lines (572, 575) connecting said evaporator controller to said plurality of refrigerant temperature sensors and said plurality of distributed temperature sensors;

a plurality of valves (578) positioned generally upstream of and inline with said plurality of evaporator units; and

a plurality of control signal lines (574) connecting said evaporator controller to said plurality of valves;

wherein said evaporator controller is configured to send signals to each of said valves in response to temperature readings measured by at least one of said plurality of refrigerant temperature sensors and said plurality of distributed temperature sensors.

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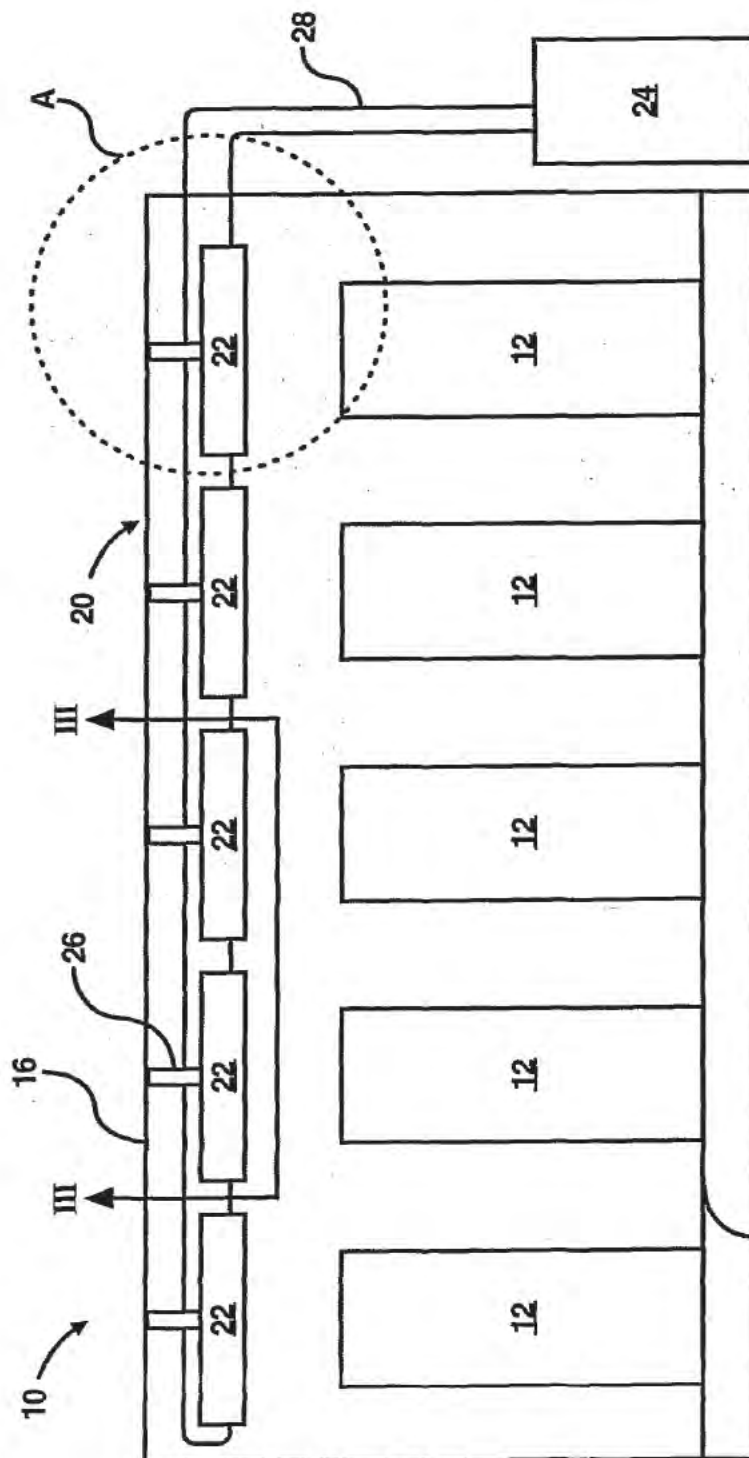


FIG. 1

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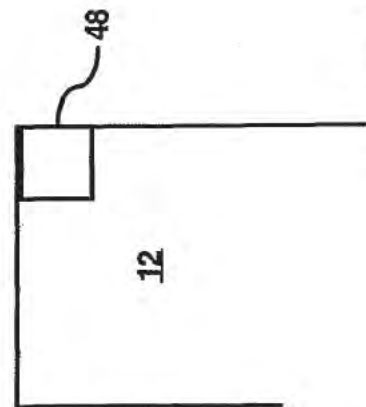
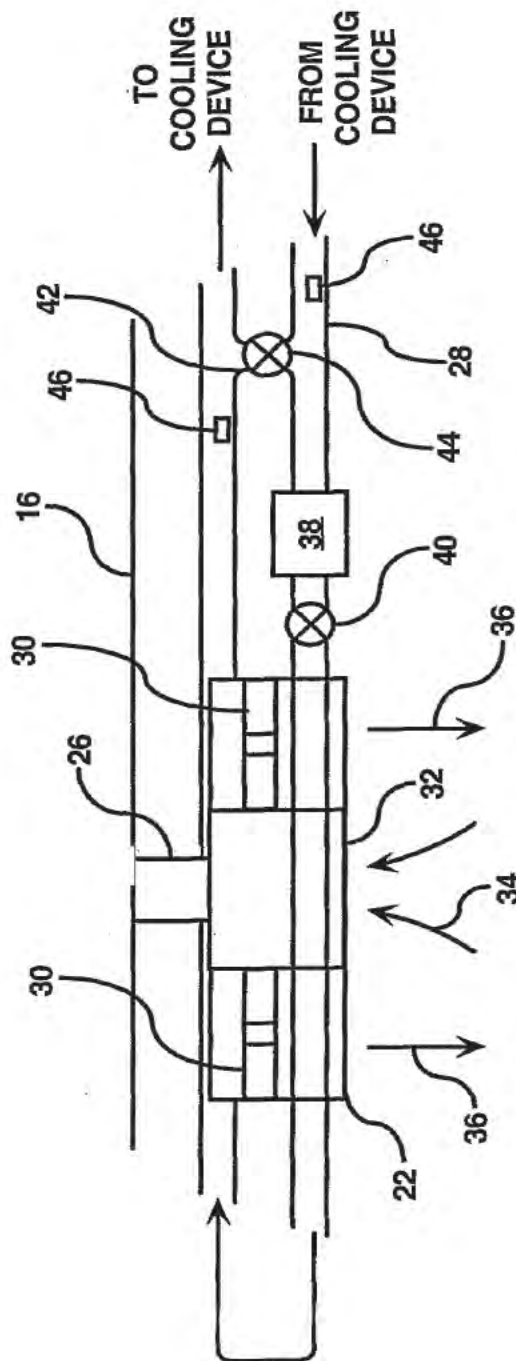


FIG. 2

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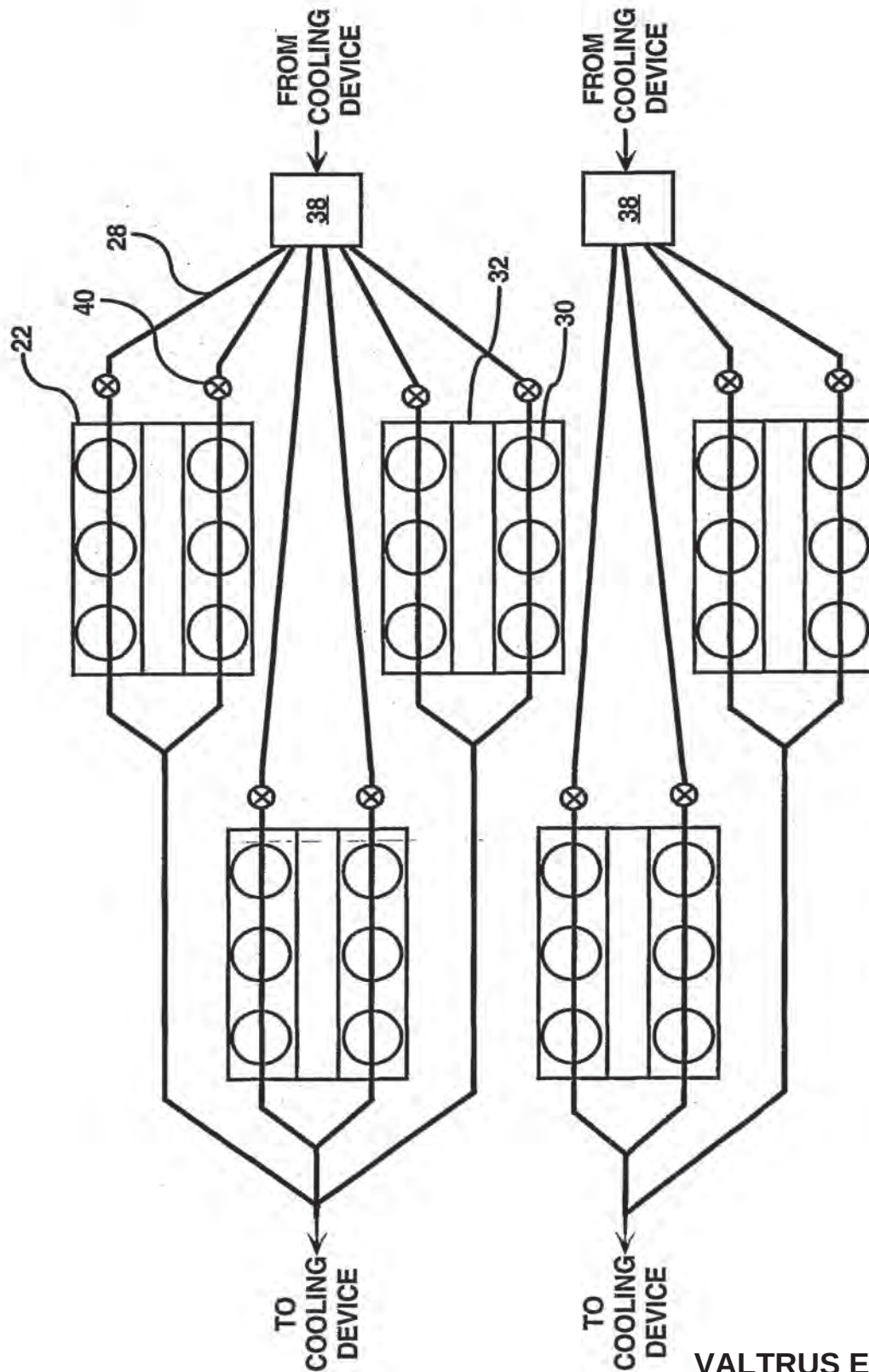


FIG. 3

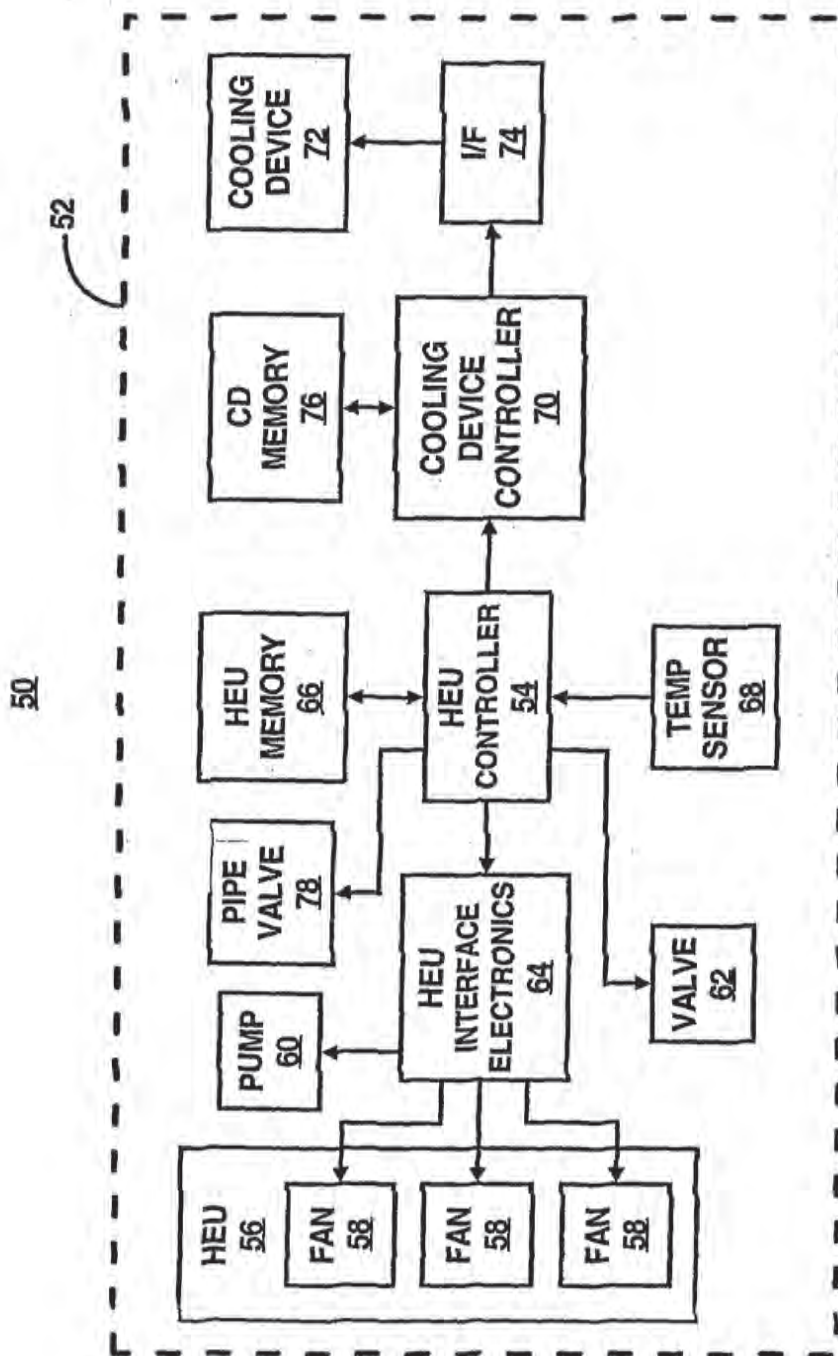


FIG. 4

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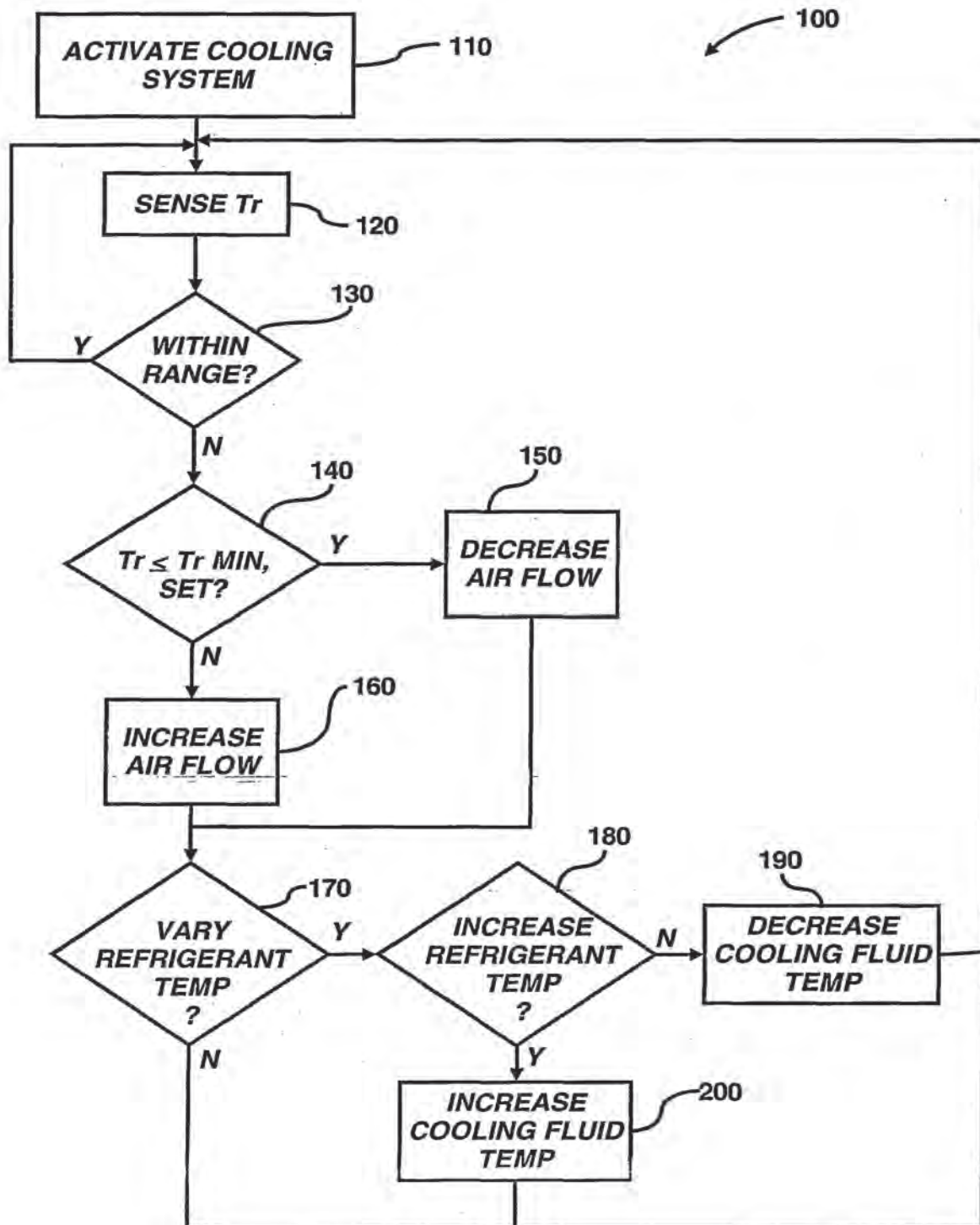


FIG. 5

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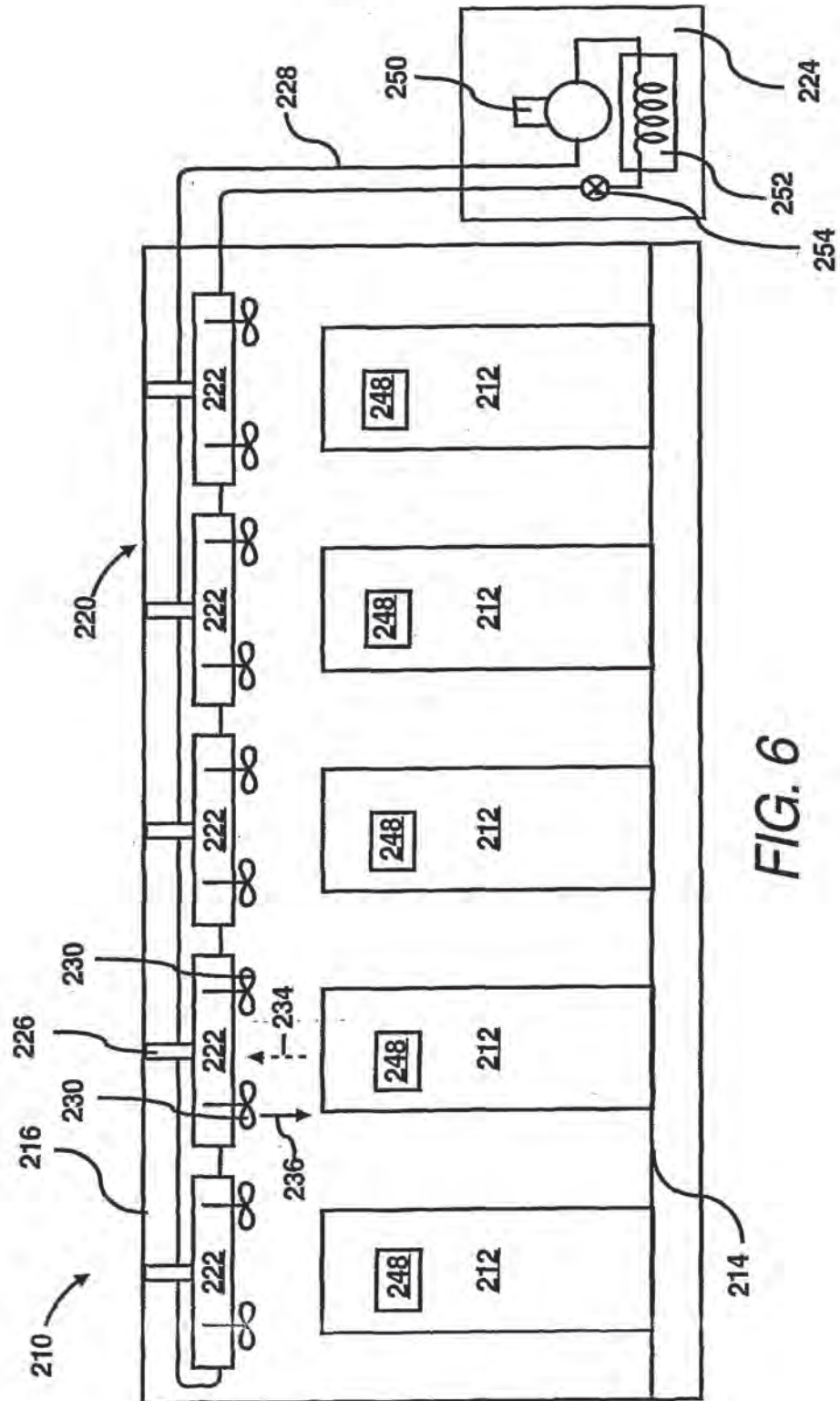


FIG. 6

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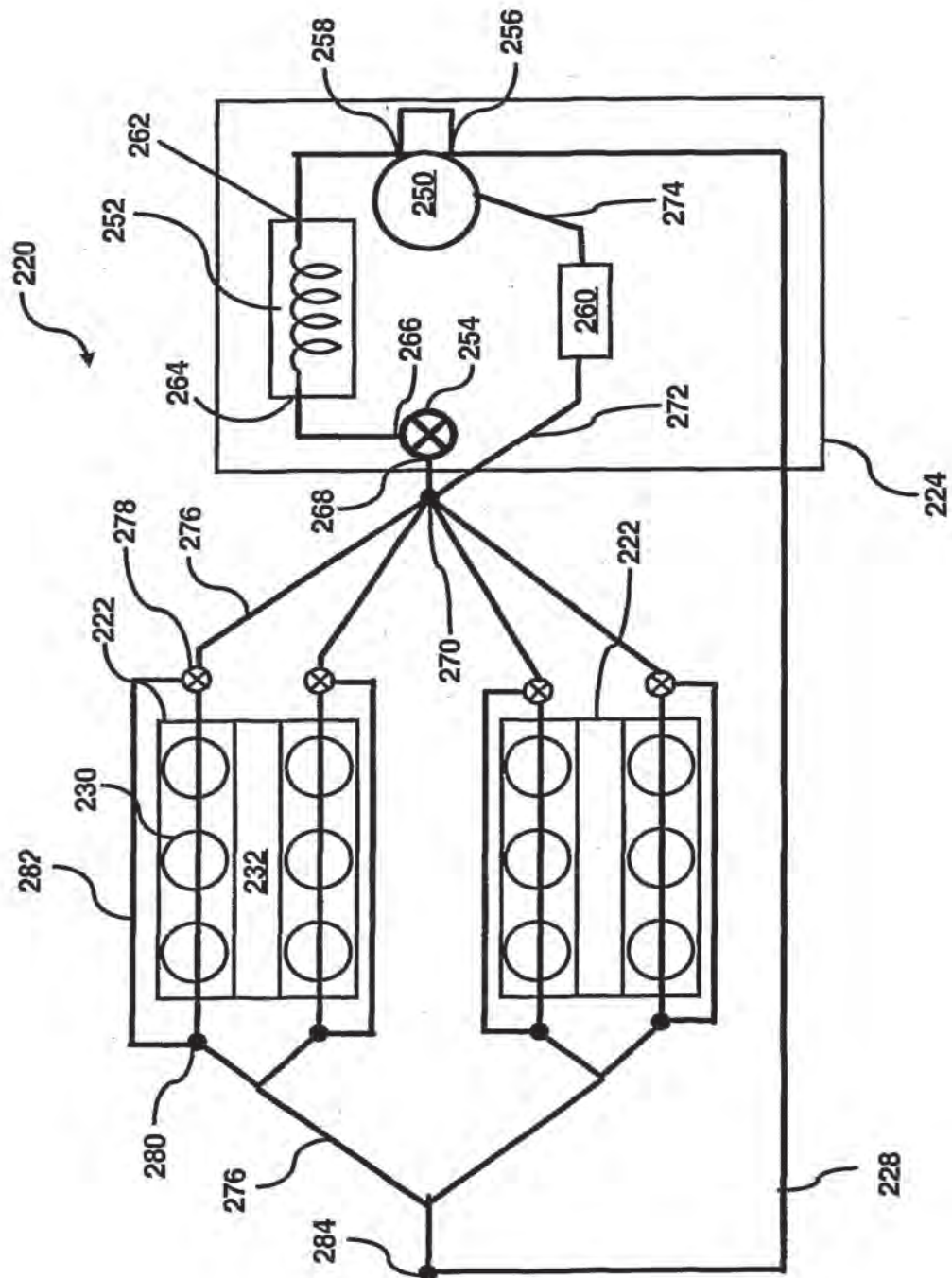


FIG. 7

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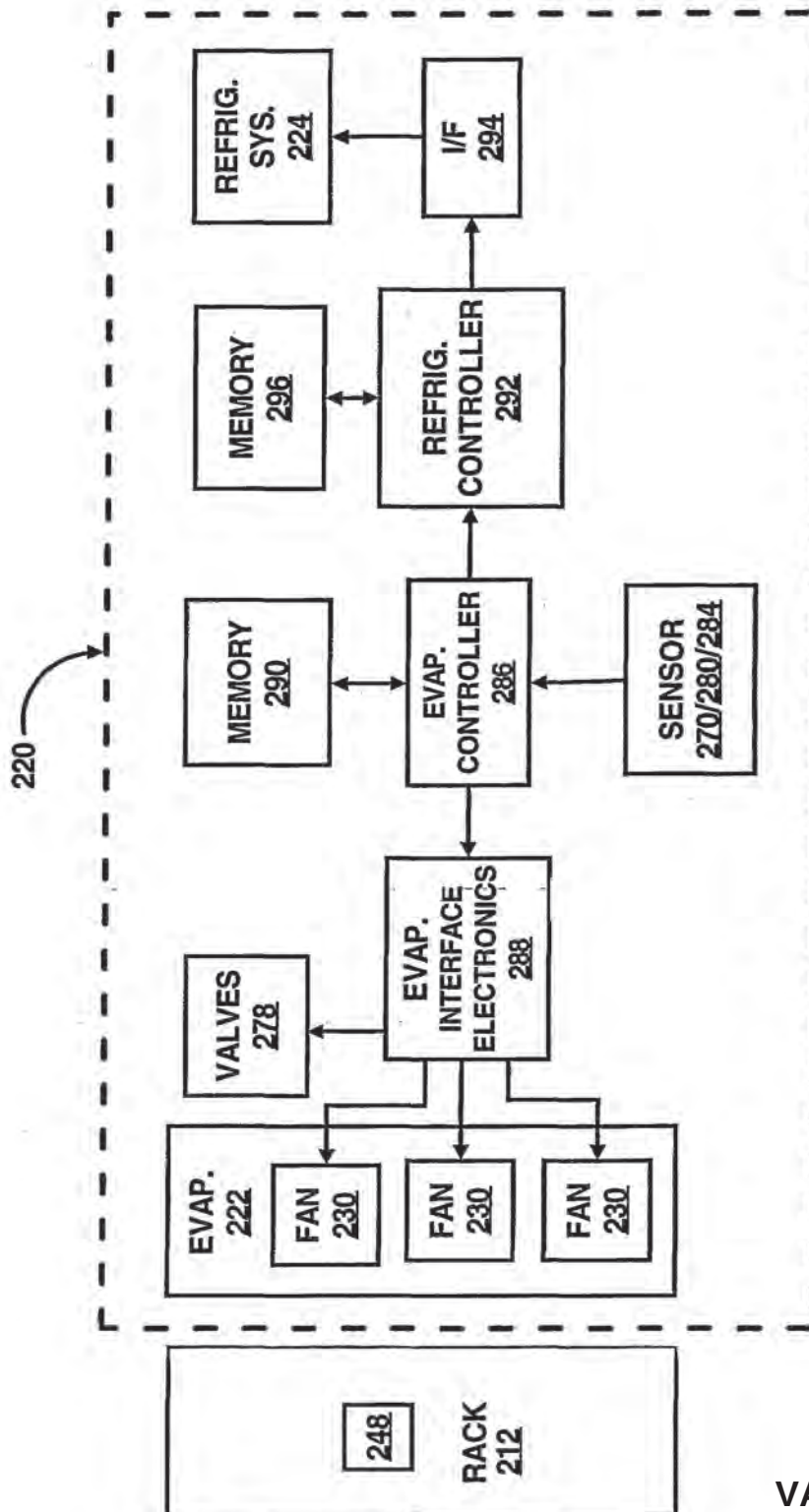


FIG. 8

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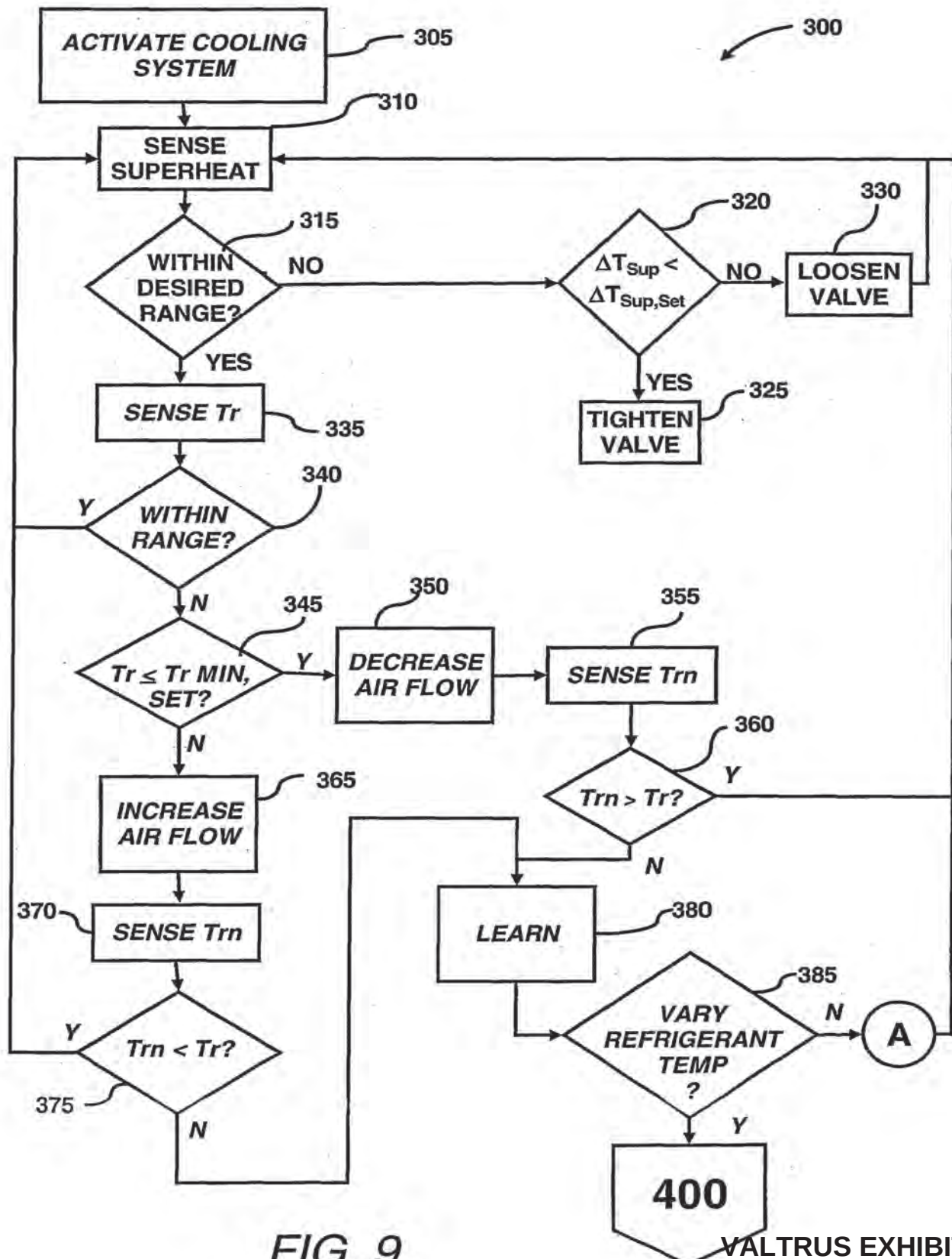


FIG. 9

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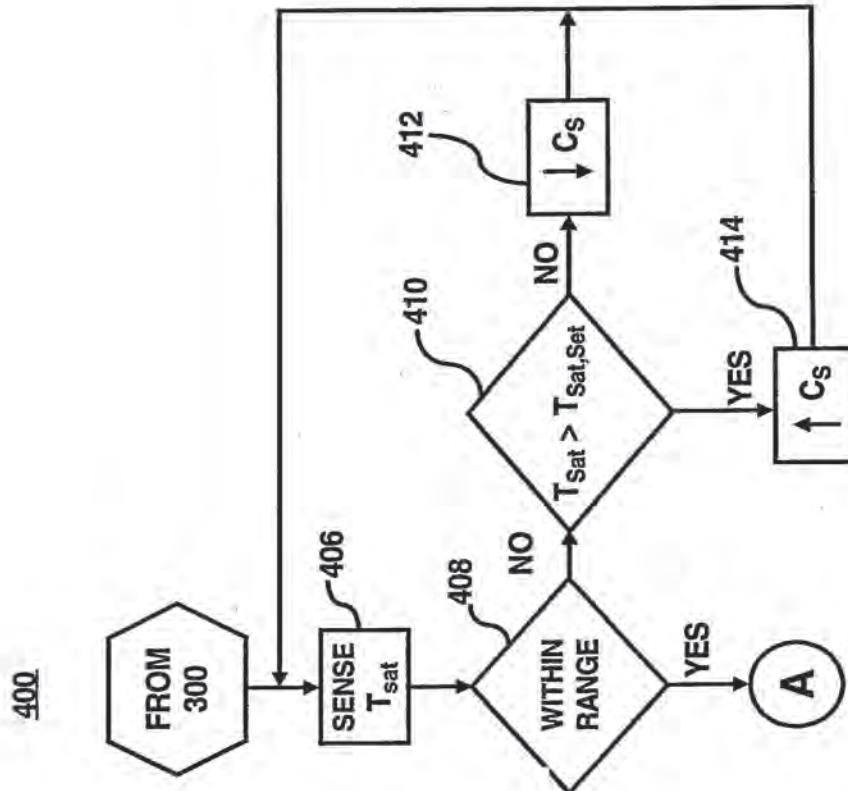


FIG. 10

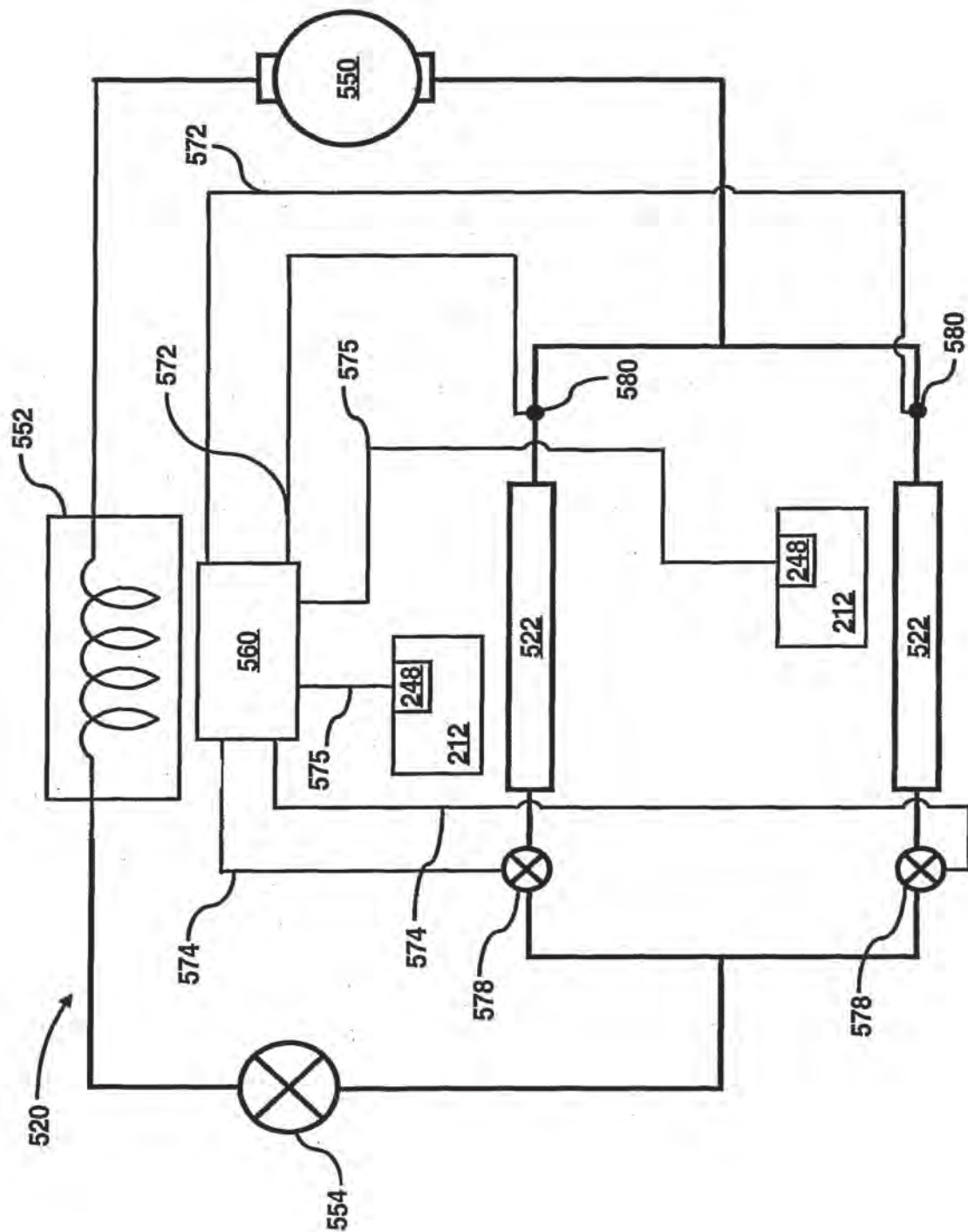


FIG. 11

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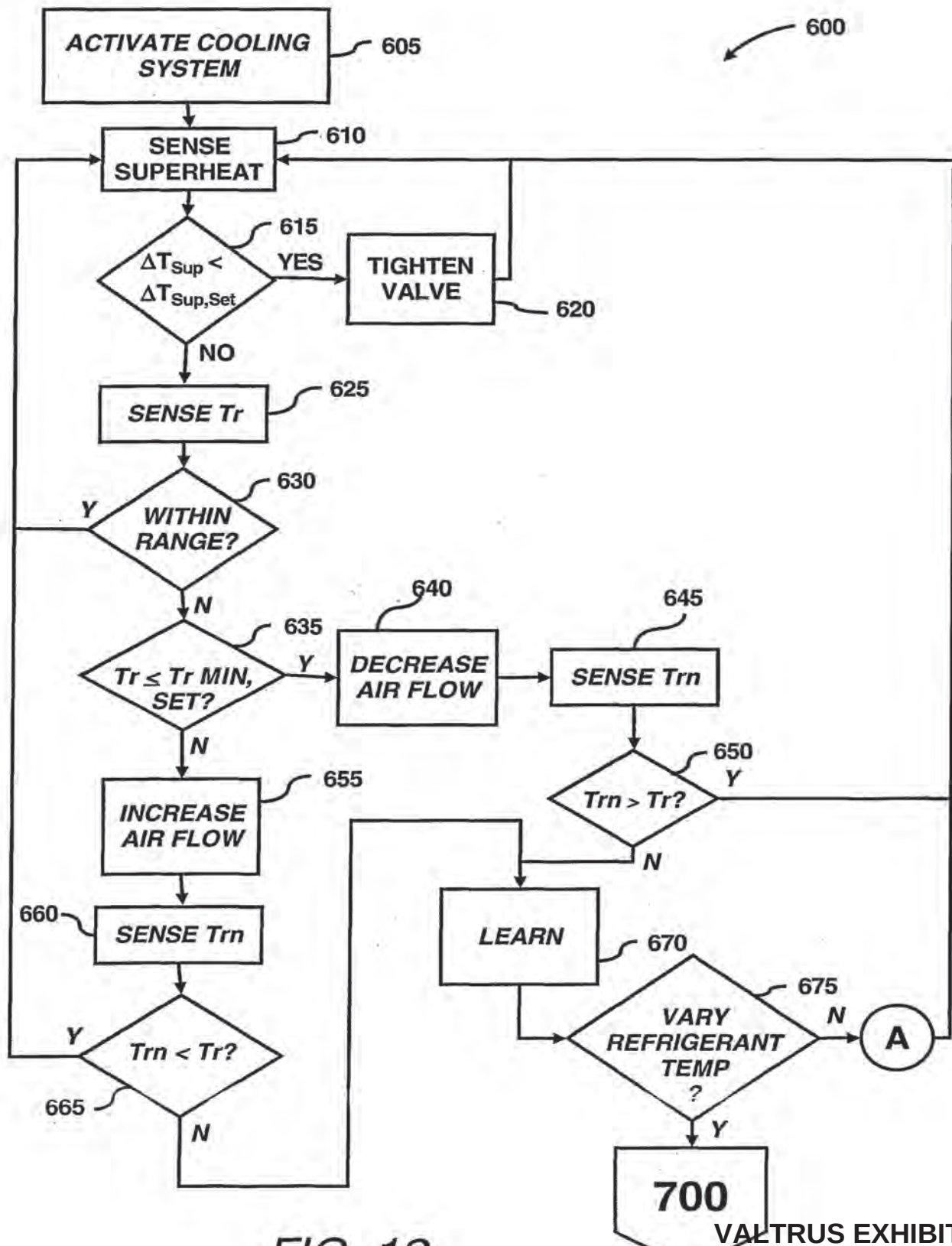


FIG. 12

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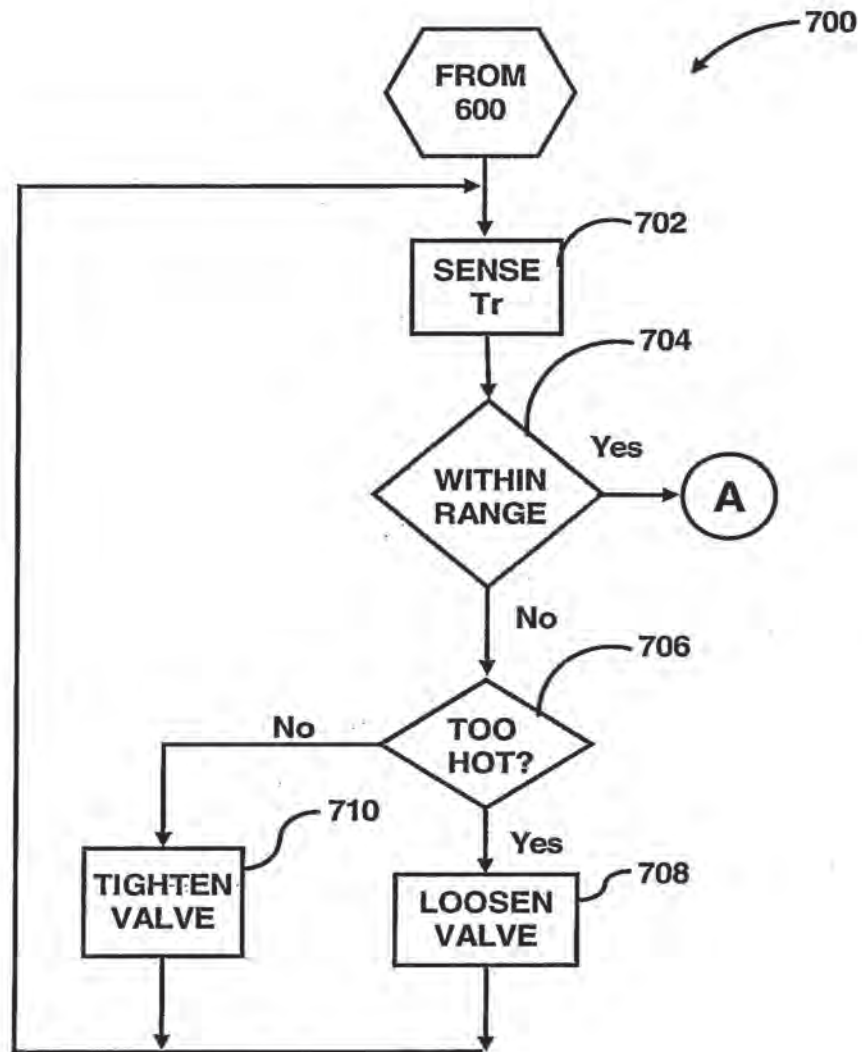


FIG. 13

INTERNATIONAL SEARCH REPORT

International Application No

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A. CLASSIFICATION OF SUBJECT MATTER
 IPC 7 F25B5/02 F25B49/02

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 F25B

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)

EP0-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 867 998 A (GUERTIN LAWRENCE J) 9 February 1999 (1999-02-09) column 1, line 46 -column 11, line 10; figures 1-10	1,5-10
Y	column 4, line 16 -column 4, line 48; figure 1	2,3
X	DE 41 00 749 A (DANFOSS AS) 16 July 1992 (1992-07-16) column 2, line 63 -column 4, line 25; claims 1-10; figures 1-3	1,4-7
Y	column 3, line 68 -column 4, line 9; figure 1	2,3
X	US 5 749 238 A (SCHMIDT FREDE) 12 May 1998 (1998-05-12) * column 2, line 60 - column 4, line 3; figure *	1,5-7
	-/-	

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

☒ Patent family members are listed in annex.

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Date of the actual completion of the international search

23 April 2004

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Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2
 NL - 2280 HV Rijswijk
 Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,
 Fax: (+31-70) 340-3016

Authorized officer

Szilagyi, B

VALTRUS EXHIBIT 2039

INTERNATIONAL SEARCH REPORT

International Application No
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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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VALTRUS EXHIBIT 2039
VERTIV v. VALTRUS IPR2025-00669

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

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(19) World Intellectual Property Organization
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- (71) Applicant (for all designated States except US):
HEWLETT-PACKARD DEVELOPMENT COMPANY, L.P. [US/US]; 20555 S.H. 249, Houston, TX 77070 (US).
- (72) Inventors; and
- (75) Inventors/Applicants (for US only): **PATEL, Chandrakant D.** [US/US]; 37432 Gillett Road, Fremont, CA 94536 (US). **SHARMA, Ratnesh** [IN/US]; 34655 Skylark Drive, Union City, CA 94587 (US). **BASH, Cullen E.** [US/US]; 662 mangels Avenue, San Francisco, CA 94127 (US). **GRAUPNER, Sven** [DE/US]; 842 Dana Street, Mountain View, CA 94041 (US).
- (74) Agent: **LANGE, Richard P.**; IP Administration, P.O. Box 272400, Fort Collins, CO 80527-2400 (US).

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SM, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

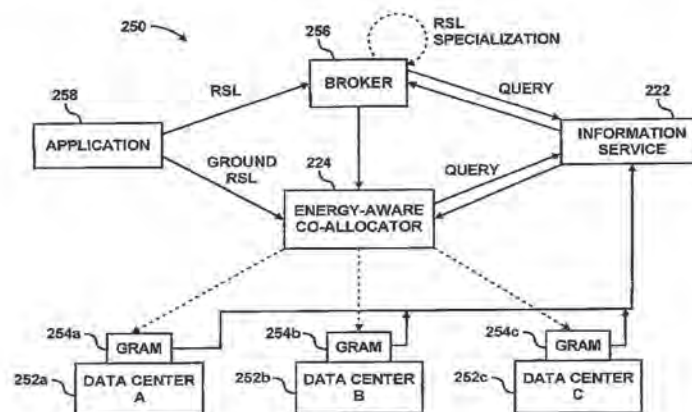
Published:

- with international search report
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(88) Date of publication of the international search report:
5 January 2006

[Continued on next page]

(54) Title: WORKLOAD PLACEMENT AMONG DATA CENTERS BASED ON THERMAL EFFICIENCY



(57) Abstract: A system (202, 205) for workload placement among data centers (100, 252a-252c) includes a plurality of grid resource allocation managers (GRAMs) (254a-254c), wherein the GRAMs (254a-254c) are configured to obtain information from the data centers (100, 252a-252c). The system (202, 250) also includes an information service (222) configured to receive information from the plurality of GRAMs (254a-254c) and a broker (256) configured to receive an application request (258) and to determine resource requirements from the application request (258), wherein the broker (258) is configured to determine which of the data centers (100, 252a-252c) contains adequate resources to perform the requested application (258). The system (202, 252a-252c) further includes a co-allocator (224) configured to receive information pertaining to the data centers (100, 252a-252c) having the adequate resources, wherein the co-allocator (224) is further configured to select one of the data centers (100, 252a-252c) to perform the requested application (258) based upon energy efficiency characteristics of the data centers (100, 252a-252c).

WO 2005/101195 A3



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.

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US2005/012133A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G06F9/50

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 G06F

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, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	C. PATEL: "Energy Aware Grid: Global Workload Placement based on Energy Efficiency" HP LABS: TECHNICAL REPORTS, 'Online! 6 December 2002 (2002-12-06), pages 1-10, XP002351253 Retrieved from the Internet: URL: http://www.hp1.hp.com/techreports/2002/HPL-2002-329.pdf 'retrieved on 2005-10-26! the whole document ----- -/--	1-10

☒ 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
- *E* earlier document 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)
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- *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
- *Z* document member of the same patent family

Date of the actual completion of the international search

26 October 2005

Date of mailing of the international search report

09/11/2005

Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,
Fax: (+31-70) 340-3016

Authorized officer

Michel, T VALTRUS EXHIBIT 2039

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US2005/012133

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	R. BUYYA: "Economic-Based distributed resource management and scheduling for Grid computing" PH.D THESIS CHAPTER 4, 'Online! 12 April 2002 (2002-04-12), pages 47-80, XP002351254 Melbourne, Australia Retrieved from the Internet: URL:http://www.buyya.com/thesis/gridbroker.pdf> 'retrieved on 2005-10-26! page 52, paragraph 4.2.5 - page 53	1,9
Y	J. MOORE ET AL: "A Sense of Place: Toward a Location-aware Information Plane for Data Centers" 'Online! 2 April 2004 (2004-04-02), pages I-12, XP002351255 Retrieved from the Internet: URL:http://www.hpl.hp.com/techreports/2004/HPL-2004-27.pdf> 'retrieved on 2005-10-26! page 7, right-hand column, line 20 - line 39	1,9
A	WO 01/14961 A (PARABON COMPUTATION) 1 March 2001 (2001-03-01) the whole document	1,9
A	S. GRAUPNER: "Globus grid and firewalls: Issues and Solutions in a Utility Data Center Environment" HP LABS TECHNICAL REPORTS, 'Online! 18 November 2002 (2002-11-18), pages I-18, XP002351256 Retrieved from the Internet: URL:http://www.hpl.hp.com/techreports/2002/HPL-2002-278.html> 'retrieved on 2005-10-26! page 3, paragraphs 2.1,2.2	1,9

VALTRUS EXHIBIT 2039

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/US2005/012133

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
WO 0114961	A	01-03-2001	AU 7114200 A	19-03-2001
			CA 2352807 A1	01-03-2001
			EP 1145109 A2	17-10-2001
			JP 2003507812 T	25-02-2003

VALTRUS EXHIBIT 2039

DECLARATION (37 CFR 1.63) FOR UTILITY OR DESIGN APPLICATION USING AN APPLICATION DATA SHEET (37 CFR 1.76)

Title of
Invention

THERMAL LOAD LOCATOR

As the below named inventor(s), I/we declare that:

This declaration is directed to:

- ☒ The attached application, or
- ☐ Application No. _____ filed on _____
- ☐ As amended on _____ (if applicable);

I/we believe that I/we am/are the original and first inventor(s) of the subject matter which is claimed and for which a patent is sought;

I/we have reviewed and understand the contents of the above-identified application, including the claims, as amended by any amendment specifically referred to above;

I/we acknowledge the duty to disclose to the United States Patent and Trademark Office all information known to me/us to be material to patentability as defined in 37 CFR 1.56, including for continuation-in-part applications, material information which became available between the filing date of the prior application and the national or PCT International filing date of the continuation-in-part application.

WARNING:

Petitioner/applicant is cautioned to avoid submitting personal information in documents filed in a patent application that may contribute to identity theft. Personal information such as social security numbers, bank account numbers, or credit card numbers (other than a check or credit card authorization form PTO-2038 submitted for payment purposes) is never required by the USPTO to support a petition or an application. If this type of personal information is included in documents submitted to the USPTO, petitioners/applicants should consider redacting such personal information from the documents before submitting them to the USPTO. Petitioner/applicant is advised that the record of a patent application is available to the public after publication of the application (unless a non-publication request in compliance with 37 CFR 1.213(a) is made in the application) or issuance of a patent. Furthermore, the record from an abandoned application may also be available to the public if the application is referenced in a published application or an issued patent (see 37 CFR 1.14). Checks and credit card authorization forms PTO-2038 submitted for payment purposes are not retained in the application file and therefore are not publicly available.

All statements made herein of my/own knowledge are true, all statements made herein on information and belief are believed to be true, and further that these statements were made with the knowledge that willful false statements and the like are punishable by fine or imprisonment, or both, under 18 U.S.C. 1001, and may jeopardize the validity of the application or any patent issuing thereon.

FULL NAME OF INVENTOR(S)

Inventor one: James K. MARTIN

Signature: James K. Martin

Citizen of: US

Inventor two: _____

Signature: _____

Citizen of: _____

☐ Additional inventors or a legal representative are being named on _____ additional form(s) attached hereto.

This collection of information is required by 35 U.S.C. 115 and 37 CFR 1.63. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 1 minute to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

VALTRUS EXHIBIT 2039
VERTIV v. VALTRUS IPR2025-00669

221 of 227

Electronic Patent Application Fee Transmittal				
Application Number:				
Filing Date:				
Title of Invention:		THERMAL LOAD LOCATOR		
First Named Inventor/Applicant Name:		JAMES K. MARTIN		
Filer:		David B. Nelson/Kay Haggard		
Attorney Docket Number:		021944-105US		
Filed as Large Entity				
Utility Filing Fees				
Description	Fee Code	Quantity	Amount	Sub-Total in USD(\$)
Basic Filing:				
Utility application filing	1011	1	300	300
Utility Search Fee	1111	1	500	500
Utility Examination Fee	1311	1	200	200
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD(\$)
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				
Miscellaneous:				
Total in USD (\$)				1000

Electronic Acknowledgement Receipt

EFS ID:	1484109
Application Number:	11670208
International Application Number:	
Confirmation Number:	6687
Title of Invention:	THERMAL LOAD LOCATOR
First Named Inventor/Applicant Name:	JAMES K. MARTIN
Customer Number:	26720
Filer:	David B. Nelson/Kay Haggard
Filer Authorized By:	David B. Nelson
Attorney Docket Number:	021944-105US
Receipt Date:	01-FEB-2007
Filing Date:	
Time Stamp:	16:09:23
Application Type:	Utility

Payment information:

Submitted with Payment	yes
Payment was successfully received in RAM	\$ 1000
RAM confirmation Number	332
Deposit Account	121322
The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows: Charge any Additional Fees required under 37 C.F.R. Section 1.16 and 1.17	

VALTRUS EXHIBIT 2039

File Listing:

VERTIV v. VALTRUS IPR2025-00669

224 of 227

Document Number	Document Description	File Name	File Size(Bytes)	Multi Part /.zip	Pages (if appl.)
1		021944-105us_PatAppl.pdf	95099	yes	13
	Multipart Description/PDF files in .zip description				
	Document Description		Start	End	
	Specification		1	10	
	Claims		11	12	
	Abstract		13	13	
Warnings:					
Information:					
2	Drawings	021944-105us_dwgs.pdf	69042	no	2
Warnings:					
Information:					
3	Application Data Sheet	021944-105us_ADS.pdf	1352136	no	4
Warnings:					
Information:					
4	Information Disclosure Statement (IDS) Filed	021944-105us_IDS.pdf	804565	no	5
Warnings:					
Information:					
5	Foreign Reference	021944-105us_IDSRef19.pdf	3017226	no	66
Warnings:					
Information:					
6	Foreign Reference	021944-105us_IDSRef18.pdf	174528	no	5
Warnings:					
Information:					
7	Oath or Declaration filed	021944-105us_signedDecl.pdf	70778	no	1
Warnings:					
Information:					

VALTRUS EXHIBIT 20

VERTIV v. VALTRUS IPR2025-006

225 of 2

8	Fee Worksheet (PTO-06)	fee-info.pdf	8348	no	2
Warnings:					
Information:					
Total Files Size (in bytes):			5591722		
This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503. <u>New Applications Under 35 U.S.C. 111</u> If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application. <u>National Stage of an International Application under 35 U.S.C. 371</u> If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course. <u>New International Application Filed with the USPTO as a Receiving Office</u> If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.					

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

PATENT APPLICATION FEE DETERMINATION RECORD

Substitute for Form PTO-875

Application or Docket Number

11,670,208**APPLICATION AS FILED – PART I**

(Column 1) (Column 2)

FOR	NUMBER FILED	NUMBER EXTRA
BASIC FEE (37 CFR 1.16(a), (b), or (c))		
SEARCH FEE (37 CFR 1.16(k), (l), or (m))		
EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))		
TOTAL CLAIMS (37 CFR 1.16(i))	15 minus 20 =	
INDEPENDENT CLAIMS (37 CFR 1.16(h))	2 minus 3 =	*
APPLICATION SIZE FEE (37 CFR 1.16(s))		
MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))		

SMALL ENTITY

OR

**OTHER THAN
SMALL ENTITY**

RATE (\$)	FEE (\$)
X\$ 25	
X\$100	
180	
TOTAL	

OR

RATE (\$)	FEE (\$)
	300
	500
	200
X\$50	
X\$200	
360	
TOTAL	1000

* If the difference in column 1 is less than zero, enter "0" in column 2.

APPLICATION AS AMENDED – PART II

(Column 1) (Column 2) (Column 3)

AMENDMENT A		CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA
	Total (37 CFR 1.16(i))	*	Minus	**	=
	Independent (37 CFR 1.16(h))	*	Minus	***	=
	Application Size Fee (37 CFR 1.16(s))				
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))				

SMALL ENTITY

OR

**OTHER THAN
SMALL ENTITY**

RATE (\$)	ADDITIONAL FEE (\$)
X =	
X =	
180	
TOTAL ADD'T FEE	

OR

RATE (\$)	ADDITIONAL FEE (\$)
X =	
X =	
360	
TOTAL ADD'T FEE	

(Column 1) (Column 2) (Column 3)

AMENDMENT B		CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA
	Total (37 CFR 1.16(i))	*	Minus	**	=
	Independent (37 CFR 1.16(h))	*	Minus	***	=
	Application Size Fee (37 CFR 1.16(s))				
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))				

RATE (\$)	ADDITIONAL FEE (\$)
X =	
X =	
N/A	
TOTAL ADD'T FEE	

OR

RATE (\$)	ADDITIONAL FEE (\$)
X =	
X =	
N/A	
TOTAL ADD'T FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.

** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".

*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".

The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.

This collection of information is required by 37 CFR 1.16. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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