

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

VERTIV CORPORATION

Petitioner

v.

VALTRUS INNOVATIONS LIMITED

Patent Owner

Patent No. 6,862,179

Original Issue Date: March 1, 2005

Title: PARTITION FOR VARYING THE SUPPLY OF COOLING FLUID

Inter Partes Review No. Unassigned

DECLARATION OF JOHN P. ABRAHAM, PH.D.

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I, John P. Abraham declare as follows:

I. INTRODUCTION

1. I am over the age of eighteen (18) and otherwise competent to make this declaration.

2. I have been engaged as an expert witness on behalf of Petitioner Vertiv Corporation, (“Petitioner” or “Vertiv”), and its counsel Nixon Peabody LLP (“Nixon Peabody”), in the above-captioned Petition for *Inter Partes* Review (the “Petition”). I am personally knowledgeable about the matters stated herein and am competent to make this declaration.

3. I am being compensated for my time in connection with this matter at my standard consulting rate. My compensation is in no way dependent on the outcome of this *Inter Partes* Review. The conclusions I present are based on my own judgement. I am not an employee of Vertiv, Nixon Peabody, or of any affiliated companies.

4. This Petition for *Inter Partes* Review involves U.S. Patent No. 6,862,179 (“the ’179 patent”) (Ex. 1001). The ’179 patent is titled, “Partition for Varying the Supply of Cooling Fluid,” and lists Abdlmonem H. Beitelmal and Chandrakant D. Patel as the inventors. The ’179 patent issued with forty-one claims. Claims 1–6, 9–13, and 15 are challenged in this Petition (the “Challenged Claims”).

5. The '179 patent issued on March 1, 2005, from U.S. Application Serial No. 10/303,761, filed on November 26, 2002 (the "'761 application") (Ex. 1001, cover).

6. I understand that according to the USPTO, the '179 patent is currently assigned to Valtrus Innovations Limited ("Valtrus" or "Patent Owner").

7. The '179 patent is directed to a method of cooling a plurality of computer racks "by activating a cooling device and opening a controllable partition configured to vary a supply of cooling fluid within a zone of the data center." Ex. 1001, Abstract. "The zone includes at least one associated rack" and "the temperature of at least one associated rack is sensed" to determine "whether the sensed temperature is within a predetermined temperature range." Ex. 1001, Abstract. I am familiar with the technology described in the '179 patent as of the priority date of November 26, 2002.

8. In preparing this Declaration, I have reviewed the '179 patent (Ex. 1001), the file history of the '179 patent (Ex. 1003), and each of the documents cited herein, and I have considered these documents in light of the general knowledge in the art as of November 26, 2002. In formulating my opinions, I have relied upon my experience in the relevant art. I have also considered the viewpoint of a person having ordinary skill in the art (POSITA) in the field of thermal management data centers and other computing facilities as of November 26, 2002.

9. I have been asked to provide my technical expertise, analysis, insights, and opinions regarding the '179 patent and relevant references that form the basis of the grounds of rejection set forth in the accompanying Petition for *Inter Partes* Review of the '179 patent. As described in detail, I offer the following opinions in this Declaration:

- Claims 1–15 are anticipated by Bash under Patent Owner's apparent construction of the claim term "partition";
- Claims 1–7 and 10–15 are anticipated by Patel under Patent Owner's construction; and
- Under Petitioner's narrower construction of "partition," claims 1–6 and 11–13 are rendered obvious over Bishop in combination with Feeney and in view of Kochavi.

10. In summary, and as will be explained in further detail below, under the broad interpretation of the Challenged Claims that I understand Patent Owner applied to allege infringement in district court litigation, the claimed methods are identically disclosed and thus anticipated by the prior art. Under the narrower claim scope that Petitioner contends reflects the ordinary meaning of "partition" as used in the '179 patent, and which I agree with, the Challenged Claims are nevertheless invalid for obviousness. A person of ordinary skill in the art ("POSITA") would have readily known and performed methods of cooling racks in a data center as

claimed in the '179 patent and would have performed these processes in these simple combinations because the purposes of these localized cooling methods were predictable and well-known in the art as of the filing date of the '761 application, and the results of combinations of these well-known technologies were predictable in view of that knowledge.

II. MY BACKGROUND AND QUALIFICATIONS

11. Throughout the remainder of this Declaration, I will refer to the field of thermal management of data centers and other computing facilities as the “relevant field” or the “relevant art.” In formulating my opinions, I have relied upon my training, knowledge, and experience in the relevant art. A copy of my current curriculum vitae is provided as Appendix A, and it provides a comprehensive description of my academic, project, and employment history, including a list of publications in the relevant art for at least the last 20 years.

12. My expertise qualifies me to perform the type of analysis required in this case for the relevant field. Of particular relevance, I specialize in thermal sciences, which describe the science of flow (e.g., flow of heat, flow of fluids, etc.) and the physical processes that occur during these flows, as well as in thermodynamic cycles and processes. My experience encompasses heat transfer, thermodynamics, and computational fluid dynamics. In particular, I have performed research and consulted for numerous companies on issues related to heat transfer,

flow of heat and fluids, and electronics cooling. I have also consulted on the design, testing, and analysis of Heating, Ventilation, and Air Conditioning (HVAC) systems.

13. I started in the relevant art as a student at the University of Minnesota – Twin Cities, where I earned a Bachelor of Science degree in Mechanical Engineering with a minor in Mathematics in 1997. In 1999, I earned a Master of Science (“MS”) degree from the University of Minnesota – Twin Cities, in the area of thermal-fluid sciences. My MS research project was in the area of heat transfer, fluid flow, and thermodynamics. During my MS work, I designed, built, and tested heat exchangers for use in refrigeration and air conditioning applications.

14. I have taken numerous courses in thermodynamics, fluid mechanics, and heat transfer (as part of my undergraduate and graduate degrees).

15. In 2002, I earned a Ph.D. degree in Mechanical Engineering in the area of thermal-fluid sciences also from the University of Minnesota – Twin Cities, with my thesis on fluid and heat flows in enclosures such as buildings. Throughout my doctoral program, I served as a Teaching Assistant, then as a Graduate Teaching Fellow, and then as adjunct faculty.

16. In 2002, I joined the faculty of the University of St. Thomas in St. Paul, Minnesota, as an Assistant Professor in the Engineering Department. In 2008, I became an Associate Professor at the University of St. Thomas in the Engineering

Department. In 2013, I was promoted to a full professorship at the University of St. Thomas in the Engineering Department, where I currently teach in the area of thermodynamics, heat transfer, and fluid mechanics, including teaching the following classes: Heat Transfer (ENGR 384), Fluid Mechanics (ENGR 383), Advanced Thermal Design (ETLS 591), and Finite Element Analysis (ETLS 777). I have taught courses that cover refrigeration and thermal management of electronics, and I have trained students to solve problems related to cooling of heat-generating devices, such as CPUs and cabinets that contain heat-generating components.

17. I have received several honors and awards during my teaching career, including the University of St. Thomas Engineering Professor of the Year in 2005; the University of St. Thomas John Ireland Award in 2009; and the University of St. Thomas Professor of the Year Award in 2016.

18. I have published peer-reviewed scientific papers detailing my work in heat transfer, fluid flow, thermodynamics, and temperature management of electronics. I have presented my work on these topics at technical conferences.

19. Over the past 20 years, I have served as a consultant to numerous companies to aid in the design or evaluation of fluid flow systems for electronics cooling. Examples of these companies include ADC Telecom (2000),

MicroControl Company (2001), Lockheed Martin (2007–2009), and Remmele Engineering and Northrup Grumman (2002–2005).

20. I have performed my own studies of cooling of electronics, including computer systems and central processing units (“CPUs”), as well as on cabinets and racks that contain heat-generating components.

21. I have published numerous peer-reviewed studies on flow and distribution of fluids through manifolds and thermodynamic cycles (including heat exchangers and cold plates) and cooling of computer systems. I have produced approximately 500 publications, books, book chapters, conference presentations, and patents in areas related to heat transfer, fluid flow, thermodynamics and analysis of structures that convey fluids for heating and cooling. I am also a named inventor on numerous patents that deal with flow and heat transfer.

22. I have been an editor of two highly rated series: *Advances in Heat Transfer* (Dr. John Abraham, Dr. John Gorman & Dr. Wolodymyr Minkowycz, eds., 2012 – Present) and *Advances in Numerical Heat Transfer* (W.J. Minkowycz, E.M. Sparrow & J.P. Abraham). These series bring together world leaders in the thermal sciences, and I have been responsible for the curation, review, and editing of the submissions. I also served as Editor-in-Chief for the journals Numerical Heat Transfer Part A and Numerical Heat Transfer Part B. All of the studies published in these venues deal with heat transfer and/or fluid flow.

23. I have given numerous presentations and publications on atmospheric control techniques, such as cooling techniques and related heat transfer processes.

Some examples include:

- *E.M. Sparrow, J.C.K. Tong, and J.P. Abraham, An Experimental Investigation on a Mass Exchanger for Transferring Water Vapor and Inhibiting the Transfer of Other Gases, International Journal of Heat and Mass Transfer, Vol. 44, pp. 4313-4321, 2001.*
- *E.M. Sparrow, G.L. Martin, J.P. Abraham, and J.C.K. Tong, Air-to-Air Energy Exchanger Test Facility for Mass and Energy Transfer Performance, Transactions of the ASHRAE, Vol. 107, (2) 2001.*
- *Sparrow, E.M., Martin, G.L., Abraham, J.P., and Tong, J.C., Air-to-Air Energy Exchanger Test Facility for Mass and Energy Transfer Performance. American Society of Heating, Refrigeration, and Air-Conditioning Engineers Annual Meeting, Inc., Cincinnati, OH, ASHRAE Symposium Paper, 2001.*
- *Ephraim M. Sparrow, John P. Abraham, and Paul Chevalier, A DOS-Enhanced Numerical Simulation of Heat Transfer and Fluid Flow Through an Array of Offset Fins with Conjugate Heating in the Bounding Solid, ASME International Mechanical Engineering Congress and R & D Expo, Washington, DC, November, 2003.*
- *John P. Abraham and Ephraim M. Sparrow, Methodologies to Enhance the Numerical Simulations of Electronic Cooling, Semi-Therm Conference, San Jose, CA, March 9-10, 2004.*
- *Ronald Major and John Abraham, The Application of Thermal Analysis on a Disk Array, Fluent's 2005 CFD Summit, Detroit, MI, June 7-8, 2005.*
- *E.M. Sparrow, J.P. Abraham, P.W. Chevalier, A DOS-Enhanced Numerical Simulation of Heat Transfer and Fluid Flow*

Through an Array of Offset Fins with Conjugate Heating in the Bounding Solid, Journal of Heat Transfer, Vol. 127, pp. 27-33, 2005.

- *P.W. Chevalier, J.P. Abraham, and E.M. Sparrow, The Design of Cold Plates for the Thermal Management of Electronic Equipment, Journal of Heat Transfer Engineering, Vol. 27, pp. 6-16, 2006.*
- *J.C.K. Tong, E.M. Sparrow, and J.P. Abraham, A Quasi-Analytical Method for Fluid Flow in a Multi-Inlet Collection Manifold, Journal of Fluids Engineering, Vol. 129, pp. 579-586, 2007.*
- *J.C.K. Tong, E.M. Sparrow, and J.P. Abraham, Attainment of Flowrate Uniformity in the Channels that Link a Distribution Manifold to a Collection Manifold, Journal of Fluids Engineering, Vol. 129 (9), pp. 1186-1192, 2007.*
- *J.C.K. Tong, E.M. Sparrow, and J. P. Abraham, Geometric Strategies for Attainment of the Identical Outflows Through all of the Exit Ports of a Distribution Manifold in a Manifold System, Applied Thermal Engineering, Vol. 29, 3552-3560, 2009.*
- *J.P. Abraham and G.S. Mowry, B.D. Plourde, Analysis of Thermal and Fluid Flow Problems, Thermal Packaging and Small Business Innovation Workshop, Eagan, MN, October 5-6, 2010.*
- *E.M. Sparrow, J.M. Gorman, K.S. Friend, and J.P. Abraham, Flow Regime Determination for Finned Heat Exchanger Surfaces with Dimples/Protrusions, Numerical Heat Transfer, Vol. 63, pp. 245-256, 2012.*
- *J.M. Gorman, EM. Sparrow, J.P. Abraham, and G.S. Mowry, Operating Characteristics and Fabrication of a Uniquely Compact Helical Heat Exchanger, Applied Thermal Engineering, Vol. 5, pp. 1070-1075, 2012.*

- *E.M. Sparrow, J. M. Gorman, and J.P. Abraham, Quantitative Assessment of the Overall Heat Transfer Coefficient U, Journal of Heat Transfer, Vol. 135, paper no. 061102, 2013.*
- *J.M. Gorman, M. Carideo, E.M. Sparrow, and J.P. Abraham, Heat Transfer and Pressure Drop Comparison of Louver- and Plain-finned Heat Exchangers Where One Fluid Passes Through Flattened Tubes, Case Studies in Thermal Engineering, Vol. 5, pp. 122-126, 2015.*
- *D. Nguyen, J. M. Gorman, E.M. Sparrow, and J.P. Abraham, Convective Heat Transfer Enhancement Versus Disenhancement: Impact of Fluid-Mover Characteristics, Applied Thermal Engineering, Vol. 90, pp. 242-249, 2015.*
- *J.M. Gorman, E., M. Sparrow, J.P. Abraham, W.J. Minkowycz, Heat Transfer Design Methodology Treating a Heat Exchanger Device and its Fluid-Mover Partner as a Single System, Heat Transfer Engineering, Vol. 38, pp. 841-852, 2017.*

24. A representative sample of the journals in which I have published include: *International Journal of Heat and Mass Transfer; International Journal of Heat and Fluid Flow; Numerical Heat Transfer, Advances in Heat Transfer; Journal of Thermal Science and Engineering Applications; Frontiers in Heat Transfer; Applied Thermal Engineering; Journal of Fluids Engineering; Journal of Heat Transfer; and Journal of Heat Transfer Engineering.*

25. I have also authored multiple publications on computational fluid dynamics (CFD) and even served as the principal investigator on a project dedicated to performing CFD studies for the Supercomputing Institute from 2002–2012. I was a Research Fellow at that Institute for approximately the same time period.

26. A full list of my research works is provided in my CV, which is attached to this report as Appendix A.

27. The '179 patent concerns methods of cooling computer racks in computing facilities such as data centers, including localized monitoring and control of temperature and pressure in data centers. The disclosed systems and methods are applicable to controlling temperature conditions in many types of rooms and buildings, including dedicated computer rooms or data centers. I recognize this technology as being well within the sphere of my experience and expertise, and I understand the technology described in the '179 patent fully. I believe my expertise and education in this field qualify me to explain this technology and address issues of patent validity from the perspective of a person of ordinary skill in the art. I am qualified to submit expert analyses in this proceeding.

III. MATERIALS REVIEWED

28. I have relied upon my education, knowledge, and experience with thermal management, as well as other materials discussed in this declaration in forming my opinions.

29. For this work, I have been asked to review the '179 patent, including the specification and claims, and the '179 patent's prosecution history (file history). In developing my opinions related to the '179 patent, I have considered the materials cited herein, including those items itemized in the Exhibit Table below:

Exhibit No.	Description
Ex. 1001	U.S. Patent No. 6,862,179 (“the ’179 patent”)
Ex. 1003	Prosecution History of the ’179 patent
Ex. 1004	Infringement Claim Chart for the ’179 Patent in <i>Valtrus Innovations Limited v. Digital Realty Trust, Inc. et al</i> , Case No. 2-24-cv-00139-JRG
Ex. 1005	U.S. Patent Publication No. 2004/0065097 A1 (“Bash”)
Ex. 1006	U.S. Patent No. 6,574,104 B2 (“Patel”)
Ex. 1007	Infringement Claim Chart for the ’179 Patent in <i>Valtrus Innovations Ltd. and Key Patent Innovations Ltd. v. TierPiont, LLC</i> , Case No. 2-24-cv-00777-JRG
Ex. 1008	U.S. Patent Application Publication No. 2002/0149911 (“Bishop”)
Ex. 1009	U.S. Patent No. 6,188,189 (“Blake”)
Ex. 1010	[RESERVED]
Ex. 1011	U.S. Patent No. 5,979,167 (“Kochavi”)
Ex. 1012	Webster’s New Collegiate Dictionary (1979) (definition of “partition”)
Ex. 1013	U.S. Patent No. 5,467,609 (“Feeney”)

30. My review of these materials was informed by my education, my experience in—and knowledge of—the industry, my work as a researcher, and my work as a consultant.

IV. PERSON OF ORDINARY SKILL IN THE ART

31. I have been asked to address validity issues of the '179 patent from the perspective of a person of ordinary skill in the art ("POSITA"), at the time the '179 patent was filed. The field of the invention of the '179 patent relates to: measuring and controlling atmospheric conditions within a computing facility; modeling atmospheric conditions; thermodynamics; fluid dynamics, thermal management of heat generating systems; heat exchangers and other devices and components that are used in heat transfer systems that involve air, refrigerants, or other fluids; piping, pumps, condensers, valves, compressors, fans, HVAC systems and other equipment used in building air conditioning and electronics cooling systems.

32. I have been informed and understand that a POSITA is a hypothetical person who is presumed to be aware of all pertinent prior art, thinks along conventional wisdom in the art, and is a person of ordinary creativity.

33. In forming my opinions, I considered several factors, including the types of problems encountered in the art, the solutions to those problems, the pace of innovation in the field, the sophistication of the technology, and the education level of active workers in the field. In my opinion, a POSITA at the time of the alleged invention of the '179 patent would have at least a bachelor's degree in mechanical or chemical engineering or an equivalent discipline, together with four years of experience in the design and/or operations of atmospheric management

systems for buildings or electronics or computer systems; or a master's degree in mechanical or chemical engineering or an equivalent discipline, with two years of experience in the design and/or operations of atmospheric management systems for buildings or electronics or computer systems.

34. In addition, a POSITA would have been familiar with the principles that the '179 patent admits as being part of the general knowledge of the art, including: CFD software tools, such as FLOVENT/AIRPACK; interchangeability of compressor cooling systems with chiller units, refrigeration systems, cooling tower systems, cooler-condenser systems, and the like; and the use of fans to move cooling fluid across heat dissipating components in racks within data centers. Ex. 1001, 1:35–37; 7:63–67; 16:45–50. I am very familiar with these tools and principles.

35. At all relevant times, I have had a level of skill in the art at least as that of a person of ordinary skill in the art. I am able to provide insight into the understanding of one of ordinary skill in this art at all relevant times by virtue of my education, training, and experience. All of my opinions expressed herein are as viewed through the eyes of a person of ordinary skill in the art as of the November 26, 2002, priority date of the '179 patent.

V. RELEVANT LEGAL STANDARDS

36. I have been asked to provide my opinions regarding whether the claims of the '179 patent are anticipated or would have been obvious to a person having ordinary skill in the art at the time of the alleged invention, in light of the prior art. As a technical expert, I am not offering any legal opinions. Rather, I am offering technical assessments and opinions.

37. Although I am not a lawyer, I have been informed and understand that certain legal standards are to be applied by technical experts in forming opinions regarding the meaning and validity of patent claims. I have applied those standards in forming my technical opinions expressed herein.

A. Claim Construction

38. The patent claims describe the invention made by the inventor and describe what the patent owner owns and what the owner may prevent others from using. I understand that an independent claim sets forth all the requirements that must be met to be covered by that claim. I further understand that a dependent claim does not itself recite all the requirements of the claim but refers to another claim and incorporates all the requirements of the claim to which it refers.

39. I have been informed and understand that in order to properly evaluate the validity of the '179 patent, the terms of the claims must first be interpreted. I have also been informed and understand that during an *inter partes* review

proceeding, the claims are to be given their plain and ordinary meaning, to a person skilled in the art at the time of the invention. I have further been informed and understand that claim terms are given their ordinary and accustomed meaning as they would be understood by one of ordinary skill in the relevant art in view of the language of the claims, the written specification and figures, and the prosecution file history. I understand that an inventor may attribute special meaning to some terms by defining those terms or by otherwise incorporating such meaning in the claims, written specification and figures, or prosecution file history.

40. I have followed these principles in my analysis throughout this declaration. In order to construe the claims, I have reviewed the entirety of the '179 patent and its prosecution history.

B. Prior Art

41. I understand that a printed publication must be publicly available before the invention date of a particular patent claim in order to qualify as “prior art” under 35 U.S.C. § 102(a), that a printed publication must be publicly available more than one year prior to the applicable filing date for the patent in order to qualify as “prior art” under 35 U.S.C. § 102(b), and that the invention by another must be described in an application for patent filed in the United States before the invention date of a particular patent claim in order to qualify as “prior art” under 35 U.S.C. § 102(e).

C. Anticipation

42. I understand that a claim is invalid as anticipated if each and every claim element is identically disclosed, either explicitly or inherently, in a single prior art reference. I understand that a disclosure of an asserted prior art reference can be “inherent” if the element is necessarily present or is the inevitable outcome of the process and/or thing that is explicitly described in the asserted prior art reference.

43. I am also advised that, to serve as an anticipatory reference, the reference itself must provide enough information so that a person of ordinary skill in the art can practice the subject matter of the reference without undue experimentation.

D. Obviousness

44. I understand that where a prior art reference does not disclose all of the elements of a given patent claim, that patent claim is invalid if the differences between the claimed subject matter and the prior art reference are such that the claimed subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the relevant art. Obviousness, as I have been informed and understand, is based on the scope and content of the prior art, the differences between the prior art and the claim, the level of ordinary skill in

the art, and, to the extent that they exist, certain objective indicia of non-obviousness.

45. I have been informed that whether there are any relevant differences between the prior art and the claimed invention is to be analyzed from the view of a person of ordinary skill in the relevant art at the time of the invention. As such, my opinions below as to a person of ordinary skill in the art are as of the time of the invention, even if not expressly stated as such; for example, even if stated in the present tense.

46. In analyzing the relevance of the differences between the claimed invention and the prior art, I have been informed that I must consider the impact, if any, of such differences on the obviousness or non-obviousness of the invention as a whole, not merely some portion of it. The person of ordinary skill faced with a problem is able to apply his or her experience and ability to solve the problem and also look to any available prior art to help solve the problem. A person having ordinary skill in the art is presumed to be aware of all of the relevant art at the time of the invention. The person of ordinary skill is not an automaton, and may be able to fit together the teachings of multiple patents employing ordinary creativity and the common sense that familiar items may have obvious uses in another context or beyond their primary purposes.

47. Obviousness may be shown by demonstrating that it would have been obvious to modify what is taught in a single piece of prior art to create the patented invention. Obviousness may also be shown by demonstrating that it would have been obvious to combine the teachings of more than one item of prior art. I understand that a claimed invention may be obvious if some teaching, suggestion, or motivation exists that would have led a person having ordinary skill in the art to combine the invalidating references. I also understand that this teaching, suggestion, or motivation may come from sources such as explicit statements in the prior art, or from the knowledge of a person having ordinary skill in the art. Alternatively, any need or problem known in the field at the time and addressed by the patent may provide a reason for combining elements of the prior art. I also understand that when there is a design need or market pressure, and there are a finite number of predictable solutions, a person of ordinary skill may be motivated to apply both his skill and common sense in trying to combine the known options in order to solve the problem.

48. I have been informed that a precise teaching in the prior art directed to the subject matter of the claimed invention is not needed. I have been informed that one may take into account the inferences and creative steps that a person of ordinary skill in the art would have employed in reviewing the prior art at the time of the invention. For example, if the claimed invention combined elements known in the

prior art and the combination yielded results that were predictable to a person of ordinary skill in the art at the time of the invention, then this evidence would make it more likely that the claim was obvious. I also understand that a claim can be determined obvious if the claimed combination would have resulted from common sense, would have been obvious to try (such as being one of a relatively small number of possible approaches to the problem that would have been reasonably expected to succeed), or would have been the predictable result of using prior art elements according to their known functions.

49. I have been informed and understand that there are recognized, exemplary, rationales for combining or modifying references to show obviousness of claimed subject matter. Some of the rationales include the following: combining prior art elements according to known methods to yield predictable results; simple substitution of one known element for another to yield predictable results; use of a known technique to improve a similar device (method or product) in the same way; applying a known technique to a known device (method or product) ready for improvement to yield predictable results; choosing from a finite number of identified, predictable solutions, with a reasonable expectation of success; known work in one field of endeavor may prompt variations of it for use in either the same field or a different one based on design incentives or other market forces if the variations are predictable to one of ordinary skill in the art; and some teaching,

suggestion, or motivation in the prior art that would have led one of ordinary skill to modify the prior art reference or to combine prior art teachings to arrive at the claimed invention.

50. I understand that secondary considerations that may indicate non-obviousness include: commercial success of products covered by the patent claims; a long-felt need for the invention; failed attempts by others to make the invention; copying of the invention by others in the field; unexpected results achieved by the invention as compared to the closest prior art; praise of the invention by the infringer or others in the field; the taking of licenses under the patent by others; expressions of surprise by experts and those skilled in the art at the making of the invention; and the patentee proceeded contrary to the accepted wisdom of the prior art. For secondary considerations to be accorded substantial weight, I understand that there must be a nexus between the secondary considerations and the claimed invention. For example, if a secondary consideration results from something other than what is claimed and novel, then there is no nexus. In addition, I understand that another potential factor that can suggest that a claimed invention *was* obvious is the independent simultaneous invention by others.

51. I also understand that secondary considerations of non-obviousness are inadequate to overcome a strong showing on the primary considerations of obviousness. For example, where the inventions represented no more than the

predictable use of prior art elements according to their established functions, the secondary considerations are inadequate to establish non-obviousness.

VI. THE '179 PATENT

A. Overview of the '179 Patent

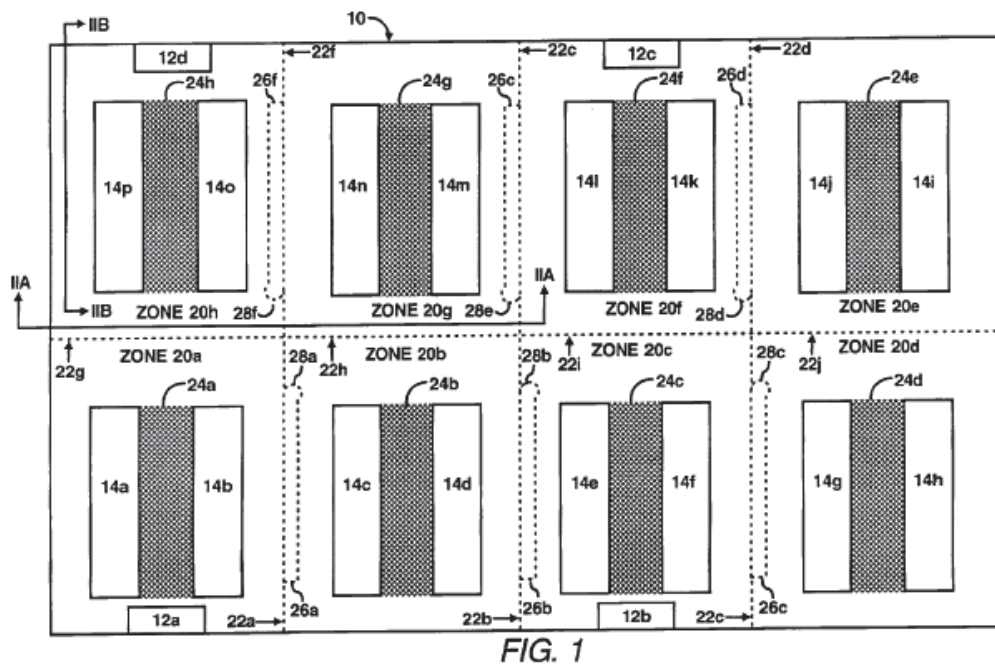
52. As described in the '179 patent, data centers are locations, e.g., rooms, that house racks that hold numerous printed circuit (PC) board electronic systems. Ex. 1001, 1:6–8. PC boards typically include components that dissipate heat during their operation (Ex. 1001, 1:15–19), and which “may be elements of a plurality of subsystems . . . e.g., computers, servers, etc.” (Ex. 1001, 3:60–61).

53. Due to the amount of heat dissipated by the components, measures to remove heat from the racks and the data centers are generally required. Ex. 1001, 1:24–44. These measures can include implementing “fans that operate to move cooling fluid, e.g., air, across the heat dissipating components” and “implement[ing] reverse power cycles to cool heated return air.” Ex. 1001, 1:24–44.

54. Measures to remove heat from the racks and the data centers can be performed by cooling systems, which typically comprise air conditioning units with compressors and “other components, e.g., air movers (fans)” (Ex. 1001, 1:45–2:13) and “plenums” (Ex. 1001, 2:7–9). Plenums are spaces within rooms that facilitate air circulation by providing airflow pathways for heated or cooled air, and usually

have a pressure greater than the atmospheric pressure. In data centers, plenums may be pressurized enclosures located underneath raised floors that support the racks. Ex. 1001, 3:45–49; FIG. 2A.

55. For purposes of the '179 patent, and as shown in Figure 1 below, this “pressurized enclosure 18 may be subdivided into a plurality of zones 20a–20h by a plurality of partitions 22a–22j (e.g., barriers, walls, etc.).” Ex. 1001, 4:11–30; FIG. 1.



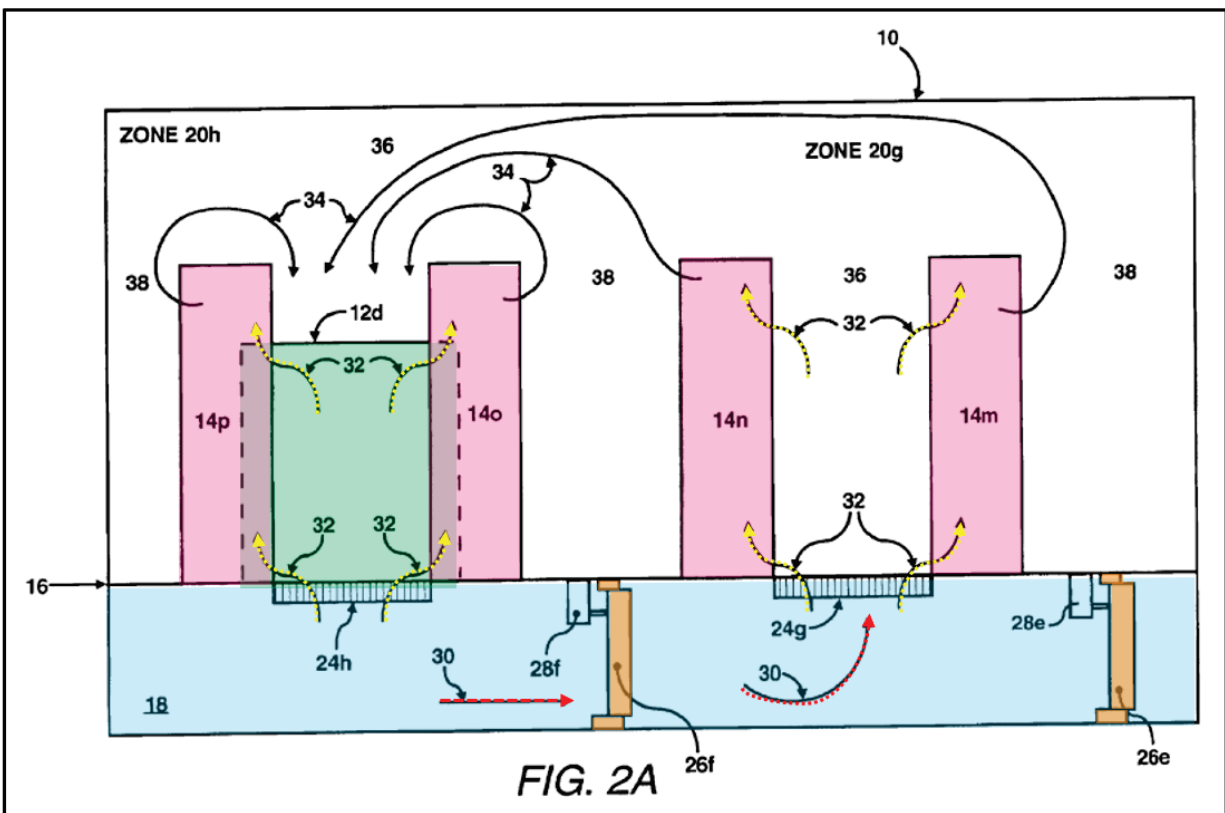
Ex. 1001, FIG. 1.

56. Cooling fluid is supplied to the pressurized enclosure (not shown in Figure 1, but is below the raised floor) and exits through a plurality of vents 24a–24h. Ex. 1001, 4:11–30. As described in the '179 patent, the movement and distribution of the cooling fluid between the different zones in the pressurized

enclosure can be controlled by configuring a plurality of “controllable partitions” (“CPs”) 26a–26f. Ex. 1001, 4:11–30. The configuration of the controllable partitions can be adjusted by respective motors 28a–28f or other actuating devices, like electromagnetic, pneumatic, and like devices. Ex. 1001, 4:11–30.

57. These controllable partitions of the ’179 patent are utilized to cool data centers more efficiently by varying the “supply of cooling fluid within a zone of [a] data center” to meet the localized cooling needs of each zone. Ex. 1001, Abstract. More specifically, the ’179 patent teaches adjusting cooling fluid “flow to and/or from various racks throughout a data center . . . based upon the detected or anticipated temperatures at various locations throughout the data center.” Ex. 1001, 2:67–3:5. “[B]y substantially increasing the cooling fluid flow to those racks dissipating greater amounts of heat and by substantially decreasing the cooling fluid flow to and/or from those racks dissipating lesser amounts of heat, the amount of energy required to operate the cooling system may be relatively reduced.” Ex. 1001, 3:6–11.

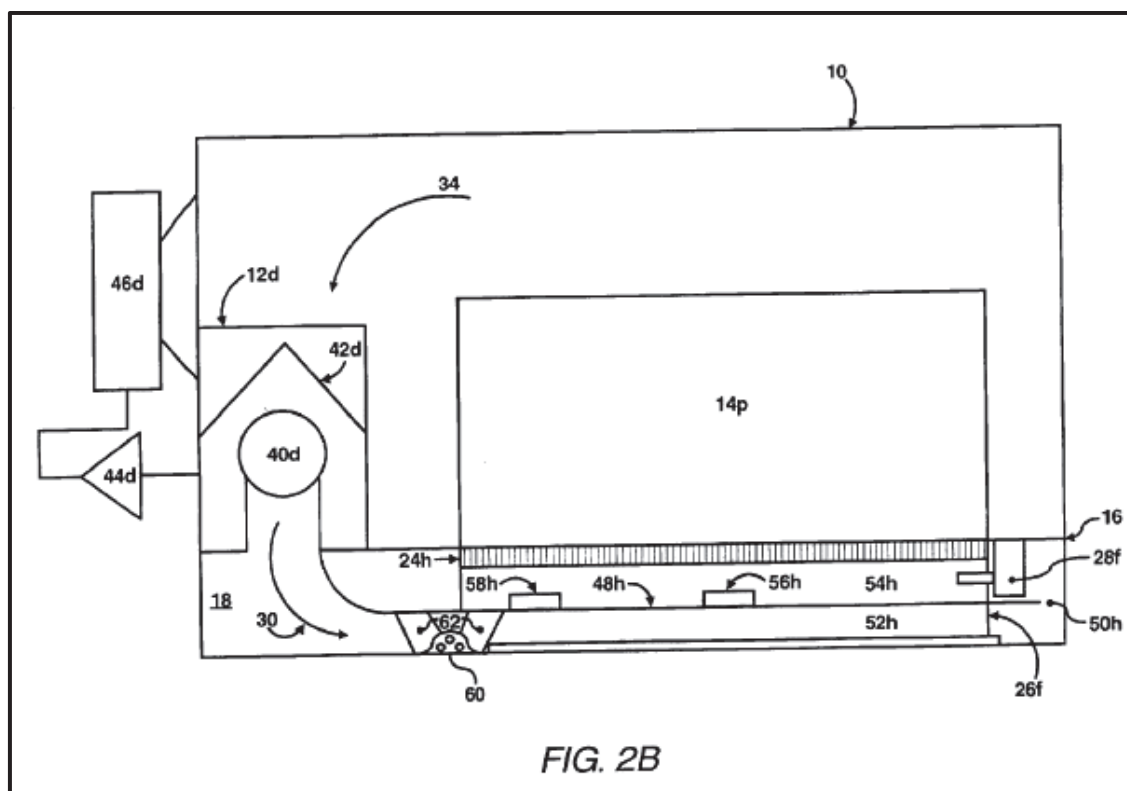
58. The ’179 patent provides Figure 2A, reproduced and annotated below, as an exemplary system in a data center that is capable of such strategic distribution of cooling fluid.



Ex. 1001, FIG. 2A (annotated).

59. Figure 2A shows two zones **20h** and **20g** that contain two racks each, **14p**, **14o**, and **14n**, **14m** (annotated in pink), respectively. Ex. 1001, 4:45–47; 5:8–20. Cooling fluid flows from the cooling system **12d** (annotated in green) into the pressurized enclosure **18** (annotated in blue) under the floor as indicated by the arrows **30** (annotated in red). Ex. 1001, 5:3–5.

60. And as shown in Figure 2B of the '179 patent, reproduced below, “the cooling system **12d** may include a fan **40d** for supplying cooling fluid into the pressurized enclosure **18** (e.g., plenum).” Ex. 1001, 4:48–50.



Ex. 1001, FIG. 2B.

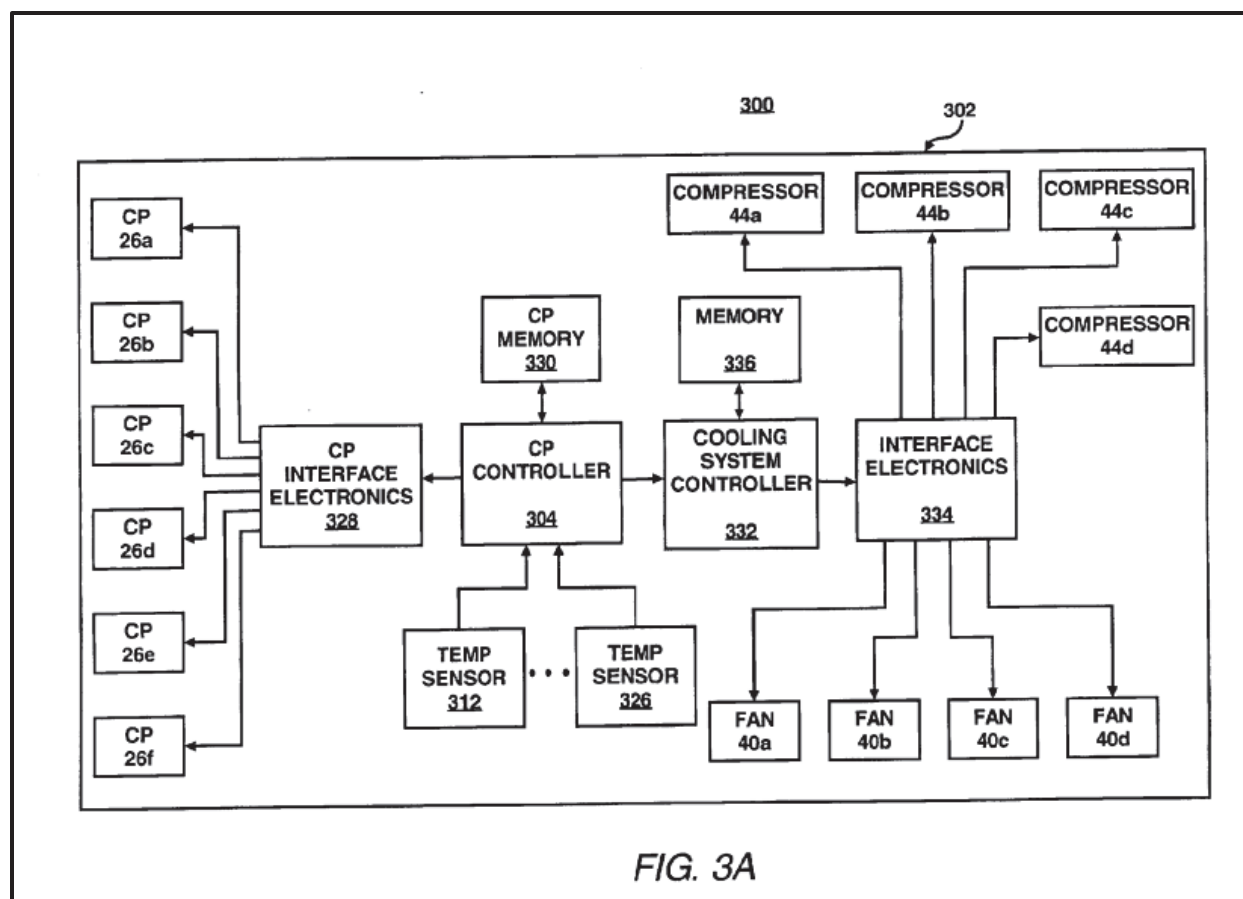
61. Referring again to Figure 2A, the cooling fluid travels from the pressurized enclosure **18** up through the vents **24g** and **24h** into the racks **14m–14p** along the arrows **32** (annotated in yellow). Ex. 1001, 4:19–20; 5:19–20. After the cooling “fluid [is] heated by the heat dissipating components located within the racks **14m–14p**,” (Ex. 1001, 5:20–23) the returned cooling fluid reenters “the cooling system **12d** as indicated by arrows **34** and is cooled by operation of various well-known components of a cooling system.” Ex. 1001, 4:55–60.

62. The '179 patent further teaches that “the zones **20h** and **20g** may receive substantially individualized and localized amounts of cooling fluid according to the heat loads of the respective racks **14m–14p** within each zone **20h**

and **20g**. For example, if the racks **14m** and **14n** in zone **20g** are generating relatively little heat load as compared to racks **14o** and **14p** in zone **20h**, the C[ontrollable] P[artition] **26f** may be controlled to reduce the velocity and/or volume flow rate of the cooling fluid being conveyed therethrough. In this manner, the volume flow rate of cooling fluid available to flow through the vents **24h** and **24g** may be modified.” Ex. 1001, 5:9–19.

63. As can be appreciated from Figure 2A, “the velocity and the volume flow rate of the cooling fluid [delivered to the racks **14m–14p**] may be regulated by varying the shape and/or opening size of the C[ontrollable] P[artition] **26f**” (annotated in orange) to accomplish such individualized and localized cooling. Ex. 1001, 5:6–8.

64. The ’179 patent also provides Figure 3A, reproduced below, which is a block diagram of a control scheme for a cooling system capable of providing localized cooling to racks in a data center. Ex. 1001, 2:45–47.



Ex. 1001, FIG. 3A.

65. As shown in Figure 3A, the '179 patent discloses using a controllable partition controller **304** “to control the operation of” multiple controllable partitions **26a–26f**. Ex. 1001, 8:33–34. The controllable partition controller **304** receives temperature measurements from temperature sensors **312–326**, which are positioned at various positions around the subsystems and/or the racks **14a–14p** and correspond to a respective zone—such as zone **20h** or **20g**, shown in FIG. 2A—in the data center. Ex. 1001, 8:41–46. Based on the measured or anticipated temperatures of the racks (such as racks **14m–14p**) and/or zones (such as zones **20h** and **20g**), the controllable partition controller **304** operates the controllable

partitions **26a–26f** to vary the flow of cooling fluid therethrough to meet the cooling needs of each particular zone. Ex. 1001, 8:37–41.

66. The “temperature sensors [**312–326**] need not be stationary.” Ex. 1001, 9:6. For example, a mobile device can be used that “travel[s] around the racks” of the data center to measure temperature or other environmental conditions at various locations. Ex. 1001, 9:10–13.

67. If the measured temperature (T_C) of a rack or zone is below or equal to a minimum set point temperature ($T_{\min, \text{set}}$), the controllable partition controller **304** decreases the volume flow rate and/or the velocity of cooling fluid to those racks. Ex. 1001, FIG. 4A, 13:32–35. And if the measured temperature (T_C) of a rack or zone is above a maximum set point temperature ($T_{\min, \text{set}}$), the controllable partition controller **304** increases the volume flow rate and/or the velocity of cooling fluid to the rack. Ex. 1001, FIG. 4A, 13:47–50.

68. The '179 patent further discloses that the controllable partition controller **304** may be in communication with a cooling system controller **332** that controls the cooling system **302**, which includes compressors **44a–44d** and fans **40a–40d**. Ex. 1001, 9:61–10:65. The “cooling system controller may operate the compressor **44a** and the fan **40a** to increase/decrease the volume flow rate of the cooling fluid flow in response to various degrees of detected increases/decreases in

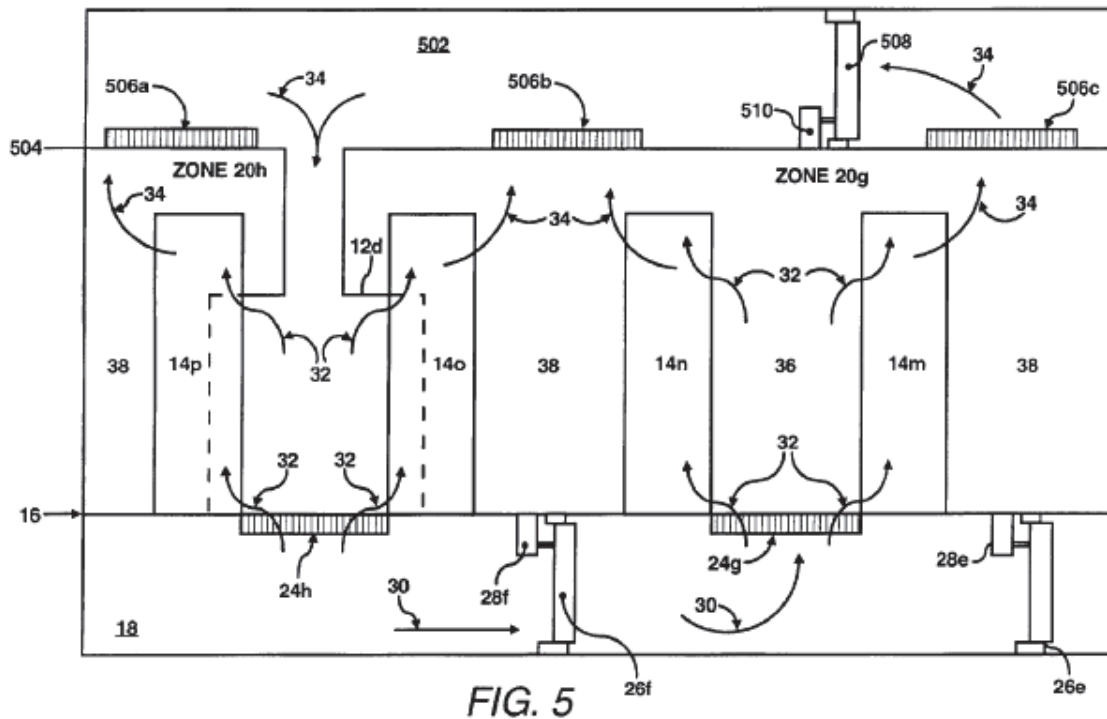
the volume flow rate through the C[ontrollable P[artition] **26a**.” Ex. 1001, 10:16–21.

69. The cooling system controller **332** may also be in communication with pressure sensors that measure the pressure within chambers of the pressurized enclosure **18** shown in FIG. 2A. Ex. 1001, 10:52–58; *see also* Ex. 1001, FIG. 3B. The output of the fans **40a–40d** may be varied by the cooling system controller **332** based on the measured pressures to maintain the pressure of the cooling fluid in various chambers of the pressurized enclosure **18** at a substantially uniform level. Ex. 1001, 11:3–13.

70. If a measured pressure is below or equal to a minimum set point pressure ($P_{\min, \text{set}}$), “the cooling system controller **332** may operate to increase the cooling fluid output, e.g., by increasing the appropriate fan output, at step **470**. Otherwise, if the [measured pressure] is determined to exceed the $P_{\min, \text{set}}$, and thereby exceed the [maximum set point pressure] $P_{\max, \text{set}}$, the cooling system controller **332** may operate to decrease cooling fluid output, e.g., by decreasing the appropriate fan output, at step **472**.” Ex. 1001, FIG. 4B, 15:56–63.

71. Figure 5, reproduced below, illustrates an alternative exemplary arrangement of a cooling system in which the cooling fluid heated by the components in the racks **14a–14p** exits through returns **506a–506c**. Ex. 1001, 16:16–23. “[T]he return flow of cooling fluid may be varied by the operation of a

[second] controllable partition (“CP”) **508**[, which] may be modulated by the operation of a motor **510** in a manner similar to the C[ontrollable] P[artition] **26a-26f** discussed above.” Ex. 1001, 16:16–23. Thus, the ’179 patent discloses meeting the individual cooling needs of various zones by altering both or one of: the delivery of cooling fluid to the racks, and the removal of heated cooling fluid from the racks.



Ex. 1001, FIG. 5.

72. The ’179 patent further discloses implementing computational fluid dynamics (“CFD”) tools to continuously vary the operation of the cooling system to operate according to the actual or anticipated heat loads generated in the racks. Ex. 1001, 17:10–18. CFD tools may be used to create “a numerical model of the data center to [] determine an optimized cooling distribution within the data center.”

Ex. 1001, 17:28–30. For example, a “correlation of one or more of the following properties: velocity of the cooling fluid flowing through various zones of the data center, distribution of temperature and pressure of the cooling fluid in the data center, and the power draw into the racks, may be created based on the numerical modeling.” Ex. 1001, 17:30–41.

73. The numerical model may be used to optimize the manner in which the fan output, volume flow rate, and/or the velocity of cooling fluid are increased or decreased in Figures 4A and 4B. Ex. 1001, 17:42–62. The numerical model may be created by using “any reasonably suitable commercially available computational fluid dynamics (CFD) tool, e.g., FLOVENT, a 3-D modeling software capable of predicting temperature variations based upon fluid flows.” Ex. 1001, 16:45–50.

B. Prosecution History of the ’179 Patent

74. As discussed above, the application for the ’179 patent was filed on November 26, 2002. Ex. 1001, cover. A Non-Final Rejection was issued by the Office on June 14, 2004, rejecting all forty-one claims that were pending at this time. Ex. 1003, 303–04. Claims 1–41 were rejected under the doctrine of obviousness-type double patenting over U.S. Patent No. 6,694,759 (the “’759 patent”). Ex. 1003, 305–06. I have been advised that this doctrine seeks to prevent two patents from granting on inventions that are not patentably different.

75. In a September 14, 2004, Response, the applicant, Hewlett-Packard Company (“Applicant”) did not amend any of the claims. Ex. 1003, 283–96. The Applicant argued that there are differences between the claims of the ’179 patent and the ’759 patent, namely, “Claim 1 of the present invention includes a controllable partition that is operated to vary the supply of cooling fluid to a zone in response to a sensed **temperature** being outside of a predetermined temperature range. Claim 1 of the ’759 patent includes a plurality of automatically adjustable vents that are automatically actuated in response to the **pressure** within the plenum being outside of a predetermined pressure range.” Ex. 1003, 299 (emphasis original). Applicant also argued that the claims differ because the ’179 patent “pertains to manipulation of a controllable partition” and the ’759 patent “pertains to actuation of an automatically adjustable vent.” Ex. 1003, 300–01.

76. On November 19, 2004, the Office issued a Notice of Allowance. Ex. 1003, 268–73.

VII. CLAIM CONSTRUCTION

77. It is my understanding that the claim construction standard includes construing the claim in accordance with the ordinary and customary meaning of such claim as understood by a person of ordinary skill in the art. As explained above, I was at least a person of ordinary skill in the art as of the November 26, 2002, filing date of the ’179 patent.

78. It is my understanding that while Petitioner and the Patent Owner have not yet exchanged claim constructions in any of the related district court proceedings, Patent Owner has served infringement contentions for the '179 patent in *Valtrus Innovations Limited v. Digital Realty Trust, Inc. et al*, Case No. 2-24-cv-00139-JRG (“*Digital Realty I*”) and in *Valtrus Innovations Ltd. and Key Patent Innovations Ltd. v. TierPoint, LLC*, Case No. 2-24-cv-00777-JRG (“*TierPoint*”). I have reviewed Patent Owner’s infringement contentions from *Digital Realty I* and *TierPoint*. Exs. 1004 and 1007. Those infringement contentions show that Patent Owner interprets the claims expansively for purposes of alleging infringement.

79. The table below summarizes my understanding of Patent Owner’s interpretation of the claims based on its infringement contentions, as well what I consider to be the more correct construction based on the claim language and the remainder of the intrinsic record.

Claim Term	Vertiv’s Construction	Valtrus’ Expected Construction
“cooling fluid” (claims 1–4, 6–9, 13–22, 25–28, 32–37, 40)	“cooling air”	“a gas or liquid capable of cooling”
“partition” (claims 1, 9, 16, 22, 27–31, 37–41)	“a barrier or wall that subdivides a space”	“a device capable of manipulating cooling fluid flow”

A. “cooling fluid”

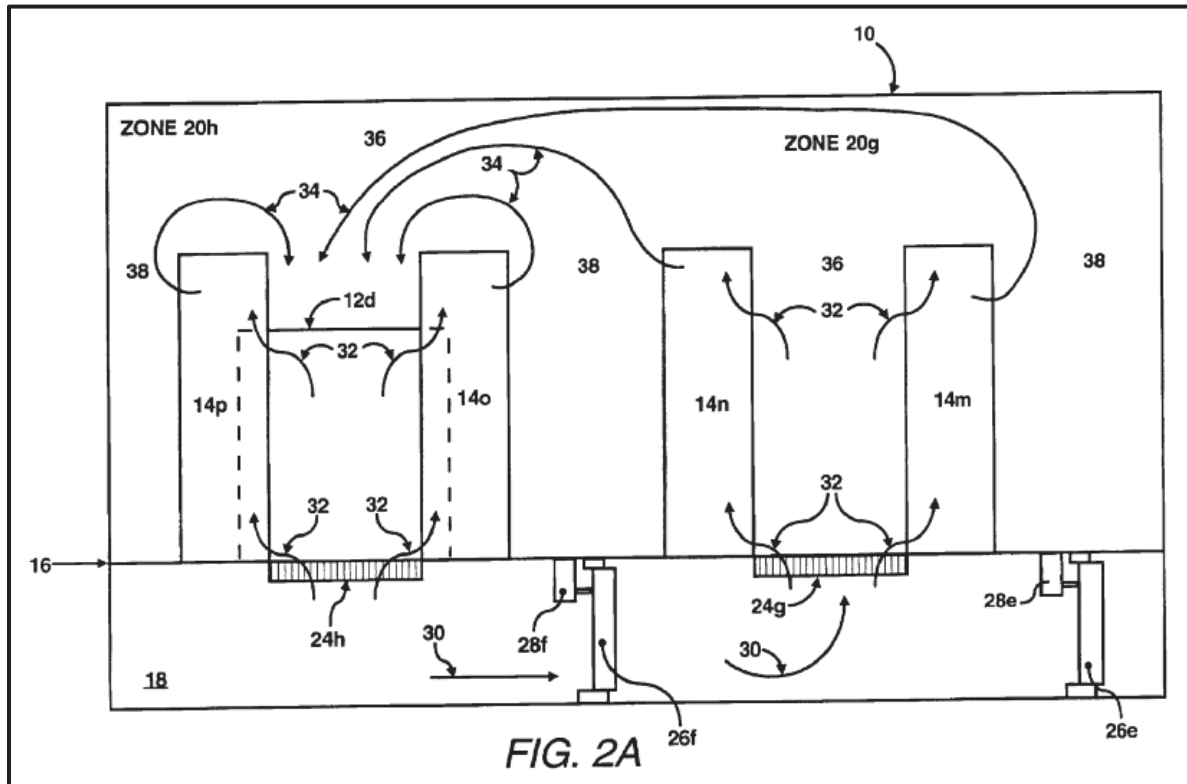
80. This term appears in the one independent claim of the Challenged Claims of the ’179 patent, independent claim 1.

81. It is my opinion that a POSITA reading the claims, specification, and prosecution history of the ’179 patent would understand the term “cooling fluid,” as recited in the ’179 patent claims, to mean “cooling air.”

82. The specification supports this opinion, as it describes cooling fluid as air in numerous instances: “cooling fluid, e.g., air” (Ex. 1001, 1:36); “cooling fluid (e.g., air)” (Ex. 1001, 6:5); “returned cooling fluid (e.g., heated air, return air, etc.)” (Ex. 1001, 6:7–8).

83. There is only one instance in the specification that indicates the cooling fluid could be something other than air: “cooling fluid (e.g., air, other gasses, liquid, etc.).” (Ex. 1001, 2:67–3:1). However, a POSITA reviewing the entire specification would readily observe that the only cooling systems disclosed are those that circulate cooling air through the data center to absorb heat emanating from the computer racks. As discussed in Section VI.A above, the purported invention relates to automatically manipulating the flow and distribution of cooling air in a more strategic and targeted manner based on inputs such as monitored air temperatures and pressures at various locations within the data center.

84. For example, Figure 2A of the '179 patent, reproduced below, shows an exemplary system in a data center that is capable of strategic distribution of cooling fluid, as is indicated by arrows **30**, **32**, and **34**. Ex. 1001, 5:3–6; 5:19–23.



Ex. 1001, FIG. 2A.

85. In relation to cooling system **12d**, the specification teaches: “[a]ir is supplied into the cooling system **12d** from the returned cooling fluid in the data center **10** as indicated by arrows **34**. In operation, the returned cooling fluid enters into the cooling system **12d** as indicated by arrows **34** and is cooled by operation of various well know components of a cooling system (e.g., cooling coil, compressor, condenser, chilled water heat exchange, etc.) and/or in any reasonably suitable manner generally known to those of ordinary skill in the art. Ex. 1001, 4:53–61. A

POSITA would understand this to be teaching devices conventionally used in air conditioning systems to remove heat from the circulating cooling air.

86. As discussed above, the '179 patent specification provides considerable detail regarding components used to circulate cooling air throughout the space, i.e., pressurized enclosure (plenum), floor vents, returns, fans, controllable partitions, etc. *See, e.g.*, Ex. 1001, 4:11–39; 4:47–63. There is no discussion or suggestion of any alternative system in which the cooling fluid distributed throughout the data center space is either a liquid or any gas other than air.

87. I expect Valtrus' construction of cooling fluid to be “a gas or liquid capable of cooling” based on my review of Patent Owner's infringement contentions from *Digital Realty I*. Ex. 1004. For example, Patent Owner asserts that Petitioner's products “manipulat[e a] controllable partition to vary supply of cooling fluid to zone.” In particular, Patent Owner alleges that Petitioner's “iCOM system is used to manipulate the motorized ball valve (controllable partition) from 0% to 100% flow of ***chilled water/glycol***.” Ex. 1004, 27 (emphasis added). As such, Valtrus' implied construction of “cooling fluid” encompasses liquids, such as chilled water/glycol mixtures.

88. Additionally, in relation to other cooling systems that are accused of infringement, Patent Owner focuses on cooling air circulated by air conditioners as

being the relevant “cooling fluid.” Ex. 1004, 11–16. Thus, Valtrus’ construction of cooling fluid also encompasses cooling air.

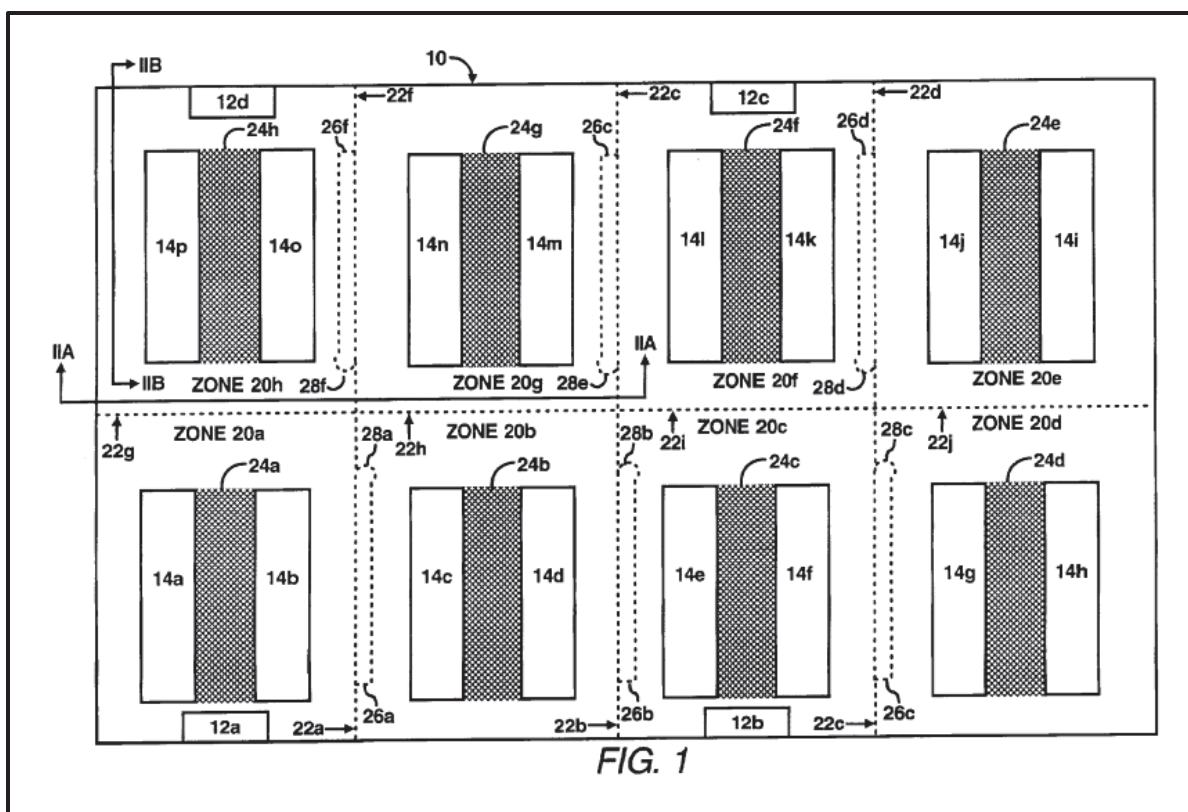
B. “partition”

89. This term appears in the one independent claim of the Challenged Claims of the ’179 patent, independent claim 1.

90. It is my opinion that a POSITA reading the claims, specification, and prosecution history would understand the term “partition,” as recited in the ’179 patent claims, to mean “a barrier or wall that subdivides a space.”

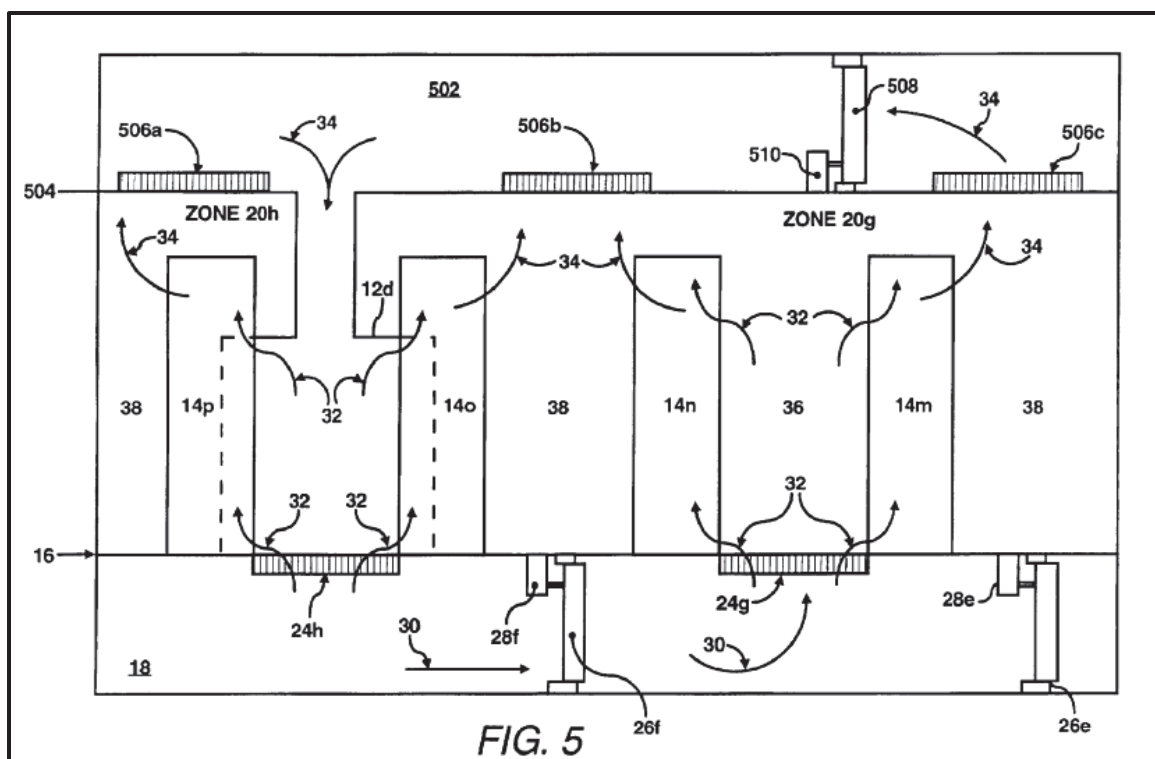
91. The specification supports this opinion, as the only two examples of partitions provided in the specification are barriers and walls: “a plurality of partitions **22a–22j** (e.g., barriers, walls, etc.)” Ex. 1001, 4:15–16. A POSITA would understand this usage to reflect an ordinary dictionary definition meaning of “partition” as “something that divides; *esp* : an interior dividing wall.” Ex. 1012, 4 (definition of “Partition”).

92. Additionally, the only partitions shown in the figures of the ’179 patent and discussed in the text are those that divide the pressured enclosure beneath the raised floor into zones. For example, with reference to Figure 1 of the ’179 patent, reproduced below, “the pressurized enclosure **18** [is] subdivided into a plurality of zones **20a–20h** by a plurality of partitions **22a–22j** (e.g., barriers, walls, etc.)” Ex. 1001, 4:13–16.



Ex. 1001, FIG. 1.

93. As another example, with reference to Figure 5 of the '179 patent, reproduced below, “a controllable partition (‘CP’) **508**” divides “a pressurized enclosure **502**” into two zones. Ex. 1001, 16:13; 16:21. Additionally, as can be seen in Figure 5, controllable partition **26f** divides the space into two zones **20g** and **20h.**” Ex. 1001, 16:9–10; 16:21–23.



Ex. 1001, FIG. 5.

94. Valtrus’ infringement contentions from *Digital Realty I* and *TierPoint* imply a much broader construction of partition to include any device capable of manipulating the flow of cooling fluid. Ex. 1004. For example, Patent Owner asserts that Petitioner’s products include the “controllable partition” of the ’179 patent because one of Petitioner’s products employs a “motorized ball valve (controllable partition)” for controlling chilled water/glycol flow. Ex. 1004, 27. As such, Valtrus’ construction of partition must be broad enough to encompass a valve for controlling chilled water flow.

95. Additionally, Patent Owner asserts that the fans that control air flow in another manufacturer’s (Schneider’s) cooling systems infringe the partition

limitation recited in the '179 patent. Ex. 1004, 31–32. In the *TierPoint* case, Patent Owner identifies as a “controllable partition” a damper in an air duct designed to supply outdoor air into a data center during cold weather. Ex. 1007, 11. Thus, Valtrus’ construction of partition must also be broad enough to encompass a fan or a damper in an air duct. Therefore, it appears that Valtrus would consider any device that can manipulate the flow of a gas or liquid to qualify as a “partition.”

VIII. OVERVIEW OF THE PRIOR ART

A. Bash

96. U.S. Patent Application Publication No. 2004/0065097 (“Bash”) was published on April 8, 2004, and the underlying Patent Application (No. 10/262,879) was filed on October 3, 2002. Ex. 1005, cover. Bash’s disclosure is extremely similar to that of the '179 patent. Like the '179 patent, Bash is directed to “a cooling system for cooling racks in a data center,” and more specifically, to a cooling system “configured to adjust cooling fluid . . . flow to and/or from various racks located throughout a data center, . . . based upon the detected or anticipated temperatures at various locations throughout the data center.” Ex. 1005, Abstract, [0011].

97. Bash discloses a schematic of a data center with an exemplary cooling system in Figure 1, an annotated version of which is provided below. Ex. 1005, [0007].

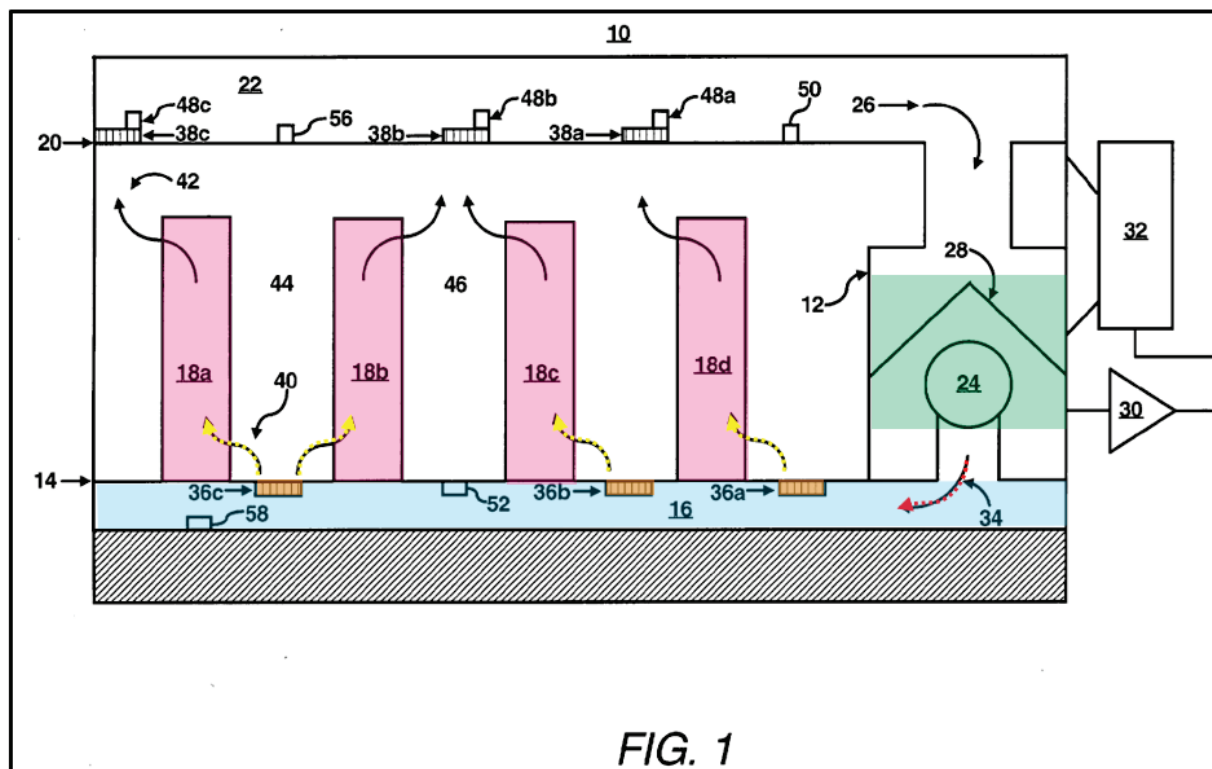


FIG. 1

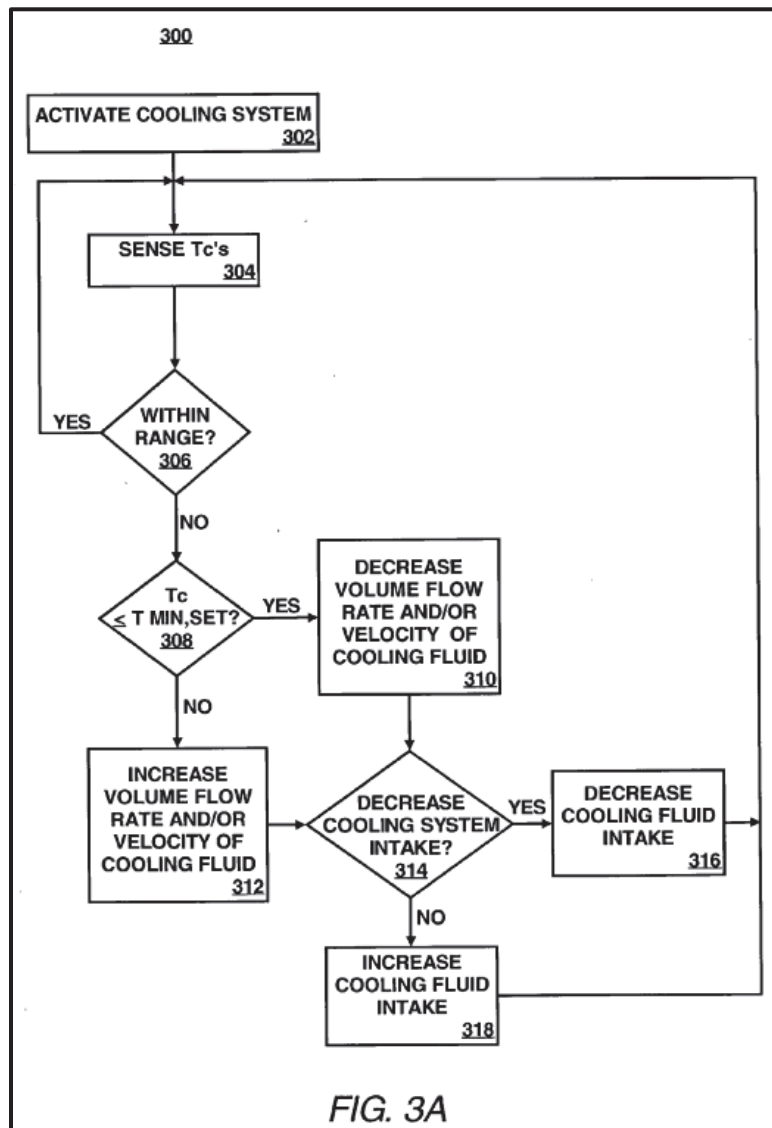
Ex. 1005, FIG. 1 (annotated).

98. As shown in Figure 1 of Bash, “cooling fluid flows out of the raised floor **14** through a plurality of dynamically controllable vents **36a-36c** [(orange)] that generally operate to control the velocity and the volume flow rate of the cooling fluid therethrough.” Ex. 1005, [0018]. The cooling fluid then “absorb[s] dissipated heat as it flows through the racks **18a-18d** [(pink)]. This heated cooling fluid may flow into the lowered ceiling through a plurality of dynamically controllable returns **38a-38c** that generally operate to control the velocity, direction, and the volume flow rate of the heated cooling fluid therethrough.” Ex. 1005, [0019]. Bash also teaches “varying the shape and/or opening size of the vents **36a-36c** and/or the returns **38a-38c**” such that “the racks **18a-18d** may receive substantially

individualized and localized amounts of cooling fluid according to their heat loads.”

Ex. 1005, [0019].

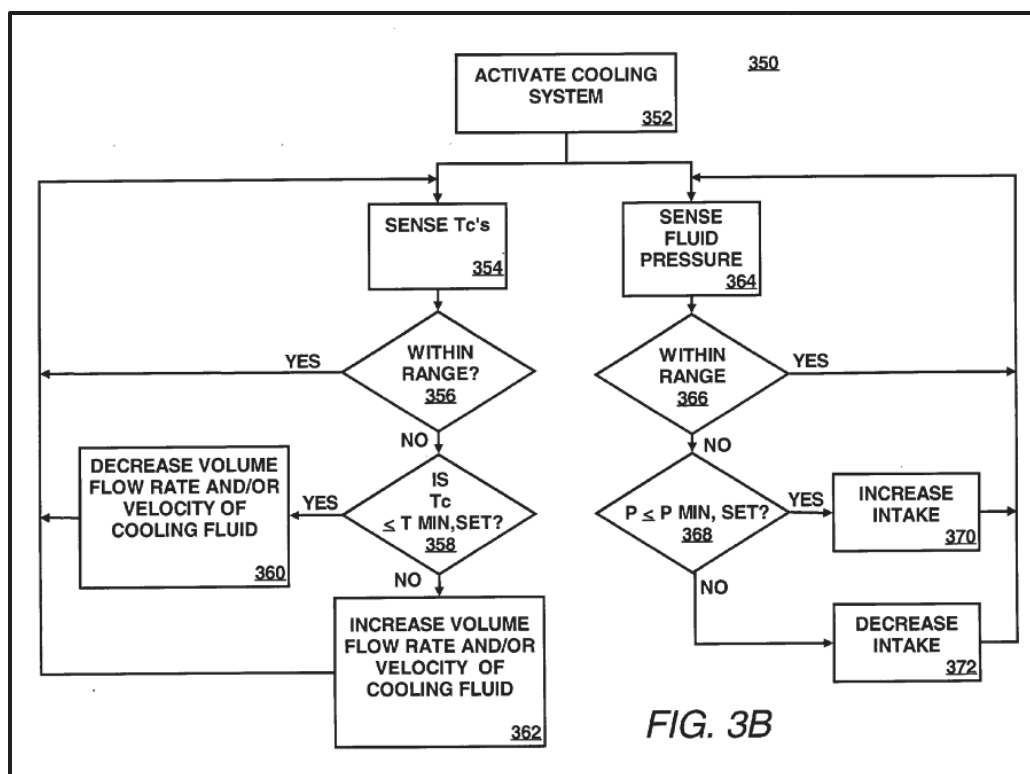
99. Figure 3A of Bash, reproduced below, provides further details regarding providing individualized and localized amounts of cooling air to racks in a data center based on measured temperatures.



Ex. 1005, FIG. 3A.

100. As shown in Figure 3A of Bash, Bash teaches measuring the temperatures (T_c) of individual components or locations at step **304** and then determining “whether each of the measured temperatures are individually within a predetermined range of operating temperatures” at step **306**. Ex. 1005, [0049]. “If the [measured temperatures] T_c ’s of some of the racks are below or equal to the [(minimum set point temperature)] $T_{\min, \text{set}}$, the return controller **210** and/or the vent controller **228** may operate to decrease the volume flow rate and/or the velocity of cooling fluid circulating about those racks at step **310**.” Ex. 1005, [0051]. Alternatively, “[i]f the [measured temperatures] T_c ’s of some of the racks exceed the $T_{\min, \text{set}}$ (i.e., also exceed the $T_{\max, \text{set}}$), the return controller **210** and/or the vent controller **228** may operate to increase the volume flow rate and/or the velocity of cooling fluid circulating about those racks at step **312**.” Ex. 1005, [0052].

101. Similar to Figure 3A, Figure 3B of Bash, reproduced below, provides further details regarding providing individualized and localized amounts of cooling air to racks in a data center based on measured temperatures and/or pressures.



Ex. 1005, FIG. 3B.

102. As shown in Figure 3B of Bash, Bash teaches measuring at step 364 the “pressure of the cooling fluid returning to the cooling system 12,” such as by a “pressure sensor (e.g., the pressure sensor 56, 58, etc.).” Ex. 1005, [0060]. The “cooling system controller 246 [then] determine[s] whether the measured pressure is within a predetermined pressure range, e.g., a predetermined minimum set point pressure ($P_{\min, \text{set}}$) and a predetermined maximum set point pressure ($P_{\max, \text{set}}$), at step 366.” Ex. 1005, [0060].

103. Bash teaches that “[i]f the absolute value of the P is determined to be below or equal to the $P_{\min, \text{set}}$, the cooling system controller 246 may operate to increase the cooling fluid intake, e.g., by increasing the speed of the fan 24 at step

370. Otherwise, if the absolute value of the P is determined to exceed the $P_{\min, \text{set}}$, and thereby exceed the $P_{\max, \text{set}}$, the cooling system controller **246** may operate to decrease the intake of the cooling fluid, e.g., by decreasing the compressor capacity and/or the fan speed, at step **372.**” Ex. 1005, [0062].

104. Additionally, Bash discloses utilizing “a mobile device . . . to gather or measure at least one local environmental condition (e.g., temperature, pressure, air flow, humidity, etc.) in the data center **10.**” Ex. 1005, [0032]. The mobile device can travel around the racks to measure temperatures and pressures to be evaluated, for example, via the process shown in the flow diagrams of Figures 3A and 3B. Ex. 1005, [0048].

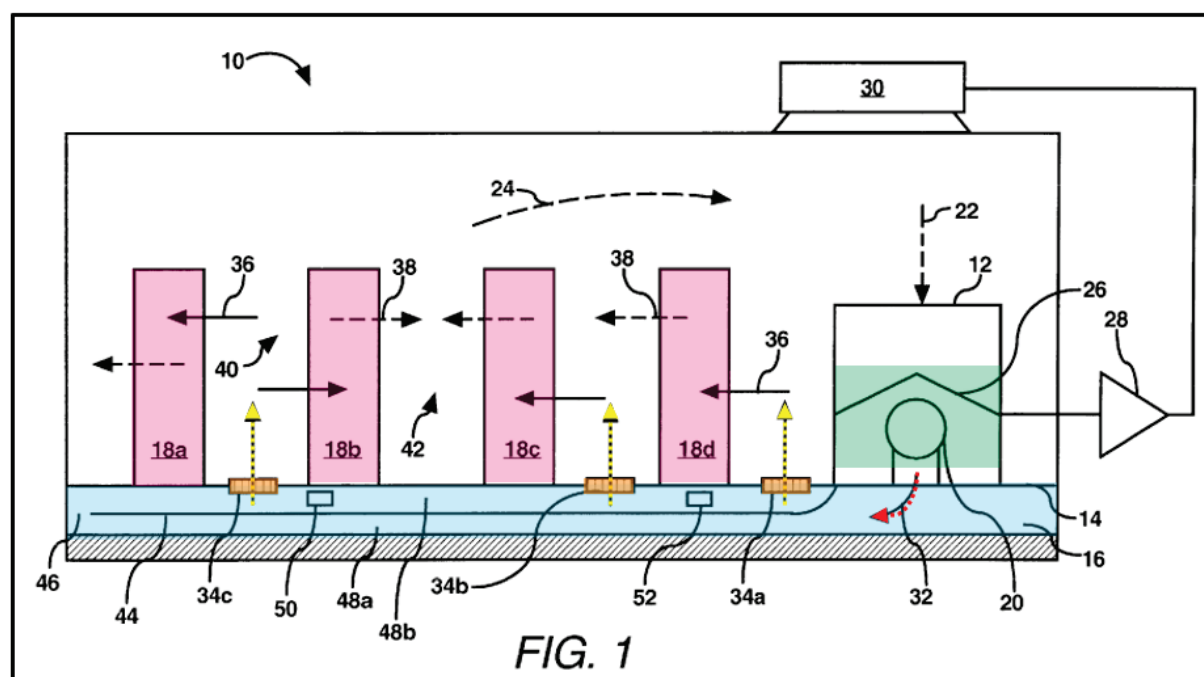
105. Bash also mentions the conventional practice of numerically modeling the cooling requirements of data centers “by operation of any reasonably suitable commercially available computational fluid dynamics (CFD) tool, e.g., FLOVENT.” Ex. 1005, [0064]. “By virtue of the numerical modeling, various air conditioning units as well as the vents . . . may be positioned throughout the data center to substantially control the manner in which the racks receive the cooling fluid. In addition, the air conditioning units may also be positioned to substantially maximize and optimize their performances” Ex. 1005, [0064].

106. Additional details about the disclosures of Bash are set forth in Section IX below.

B. Patel

107. U.S. Patent No. 6,574,104 (“Patel”) issued on June 3, 2003, and the underlying Patent Application (No. 09/970,707) was filed on October 5, 2001. Ex. 1006, cover. The specification of Patel is also very similar to the specification of the ’179 patent.

108. The cooling systems and methods of Patel can be understood with reference to Figure 1 of Patel, an annotated version of which is provided below, which shows “a simplified schematic illustration of a data center **10** containing a cooling system **12**.” Ex. 1006, 4:8–9.

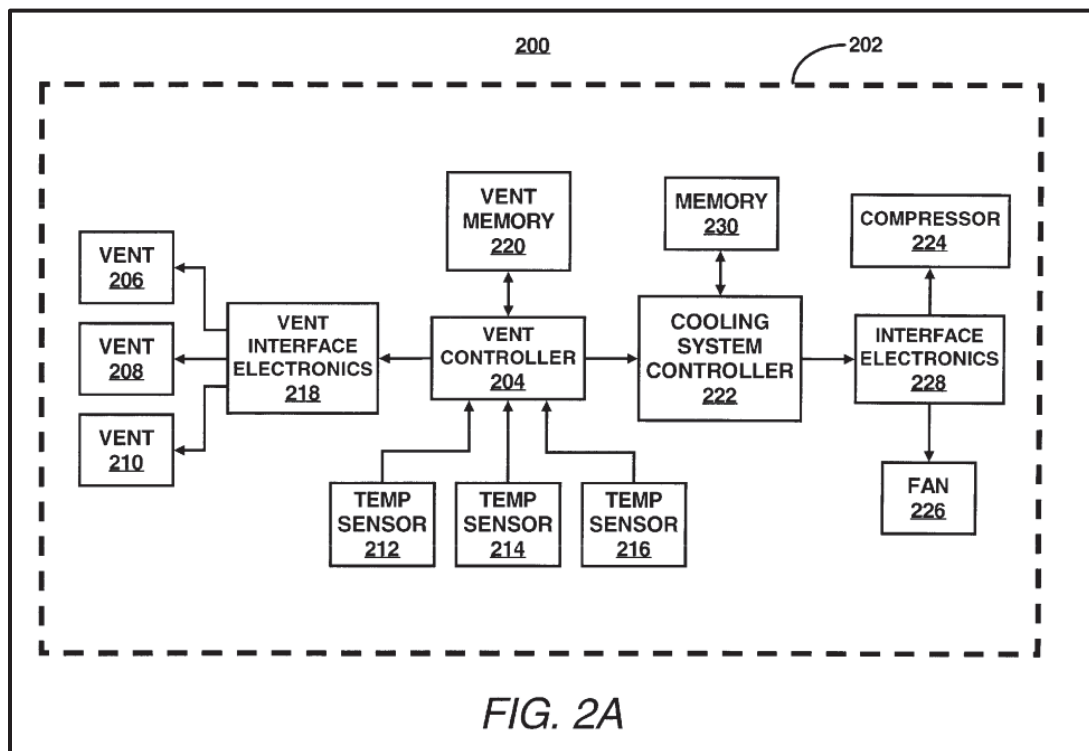


Ex. 1006, FIG. 1 (annotated).

109. As shown in Figure 1 of Patel, Patel teaches supplying a cooling fluid (air) from a cooling system **12** into a space (plenum) **16** (annotated in blue) below

a raised floor **14** of a data center. Ex. 1006, 4:11–15. The cooling fluid then “flows out of the raised floor **14** through a plurality of dynamically controllable vents **34a-34c** [(annotated in orange)] that generally operate to control the velocity and the volume flow rate of the cooling fluid therethrough.” Ex. 1006, 5:8–11. “[T]he velocity and the volume flow rate of the cooling fluid may be regulated by varying the shape and/or opening size of the vents **34a-34c**” so that “the racks **18a-18d** [(annotated in pink)] may receive substantially individualized and localized amounts of cooling fluid according to their heat loads.” Ex. 1006, 5:11–17.

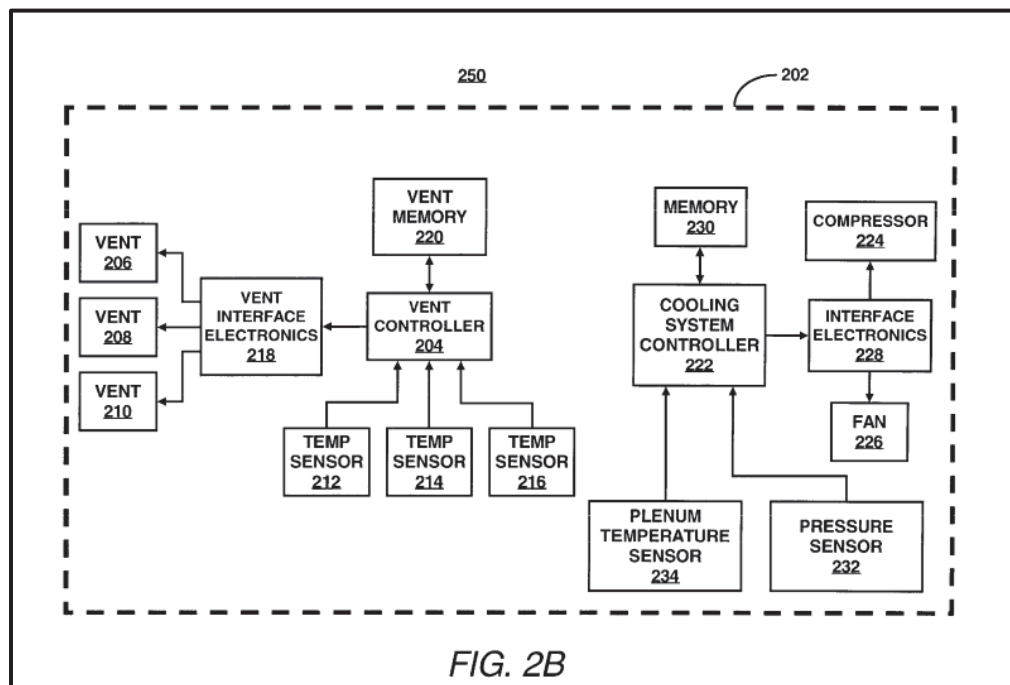
110. Patel also discloses a block diagram for an exemplary control scheme for a cooling system, which is shown in Figure 2A, reproduced below.



Ex. 1006, FIG. 2A.

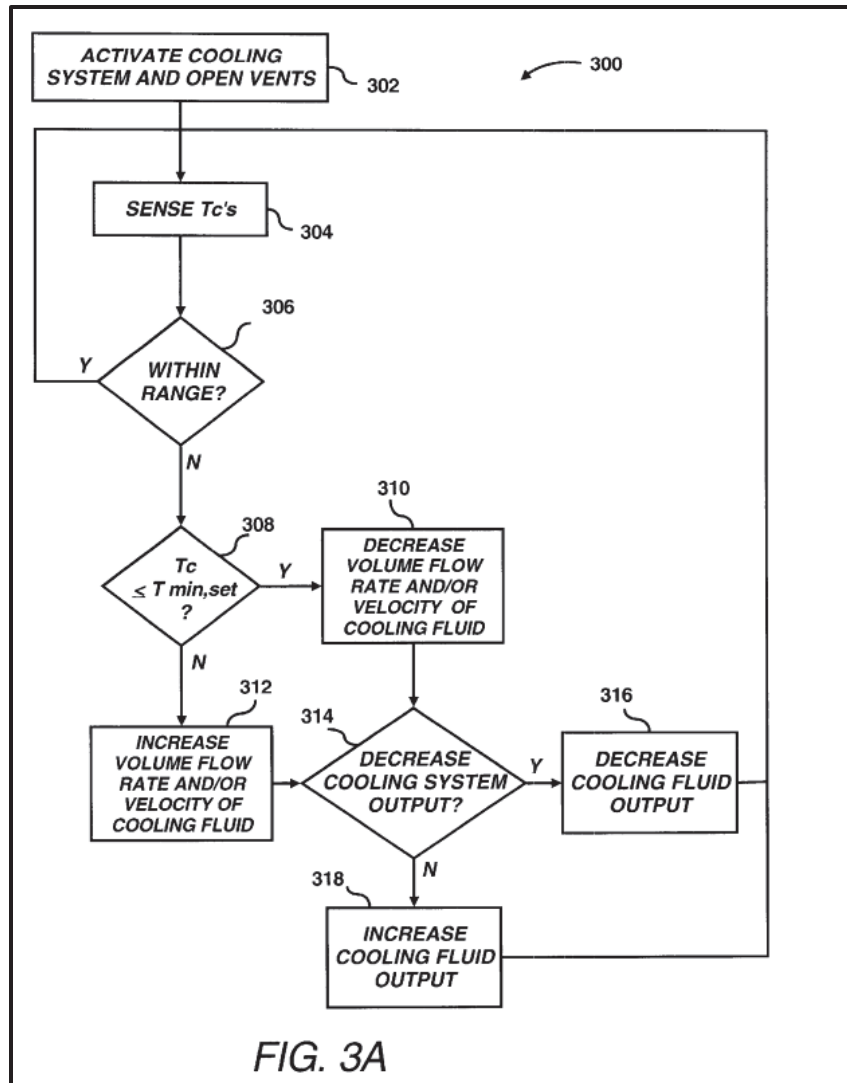
111. As shown in Figure 2A, Patel teaches a vent controller **204** to control the operation of vents **206–210** and “the flow of cooling fluid therethrough” based on “the detected or anticipated temperatures of the racks **18a-18d** or portions thereof.” Ex. 1006, 7:8–15.

112. Additionally, Patel teaches using a cooling system controller **222** to manipulate “the output of the fan **226** . . . based upon the measured pressure of” the space (plenum) **16** below the raised floor **14** of the data center “to vary the amount of cooling fluid supplied to space **16**, to thereby substantially maintain the pressure of the cooling fluid . . . at a substantially uniform level.” Ex. 1006, 9:24–29. This can be seen in Figure 2B of Patel, reproduced below.



Ex. 1006, FIG. 2B.

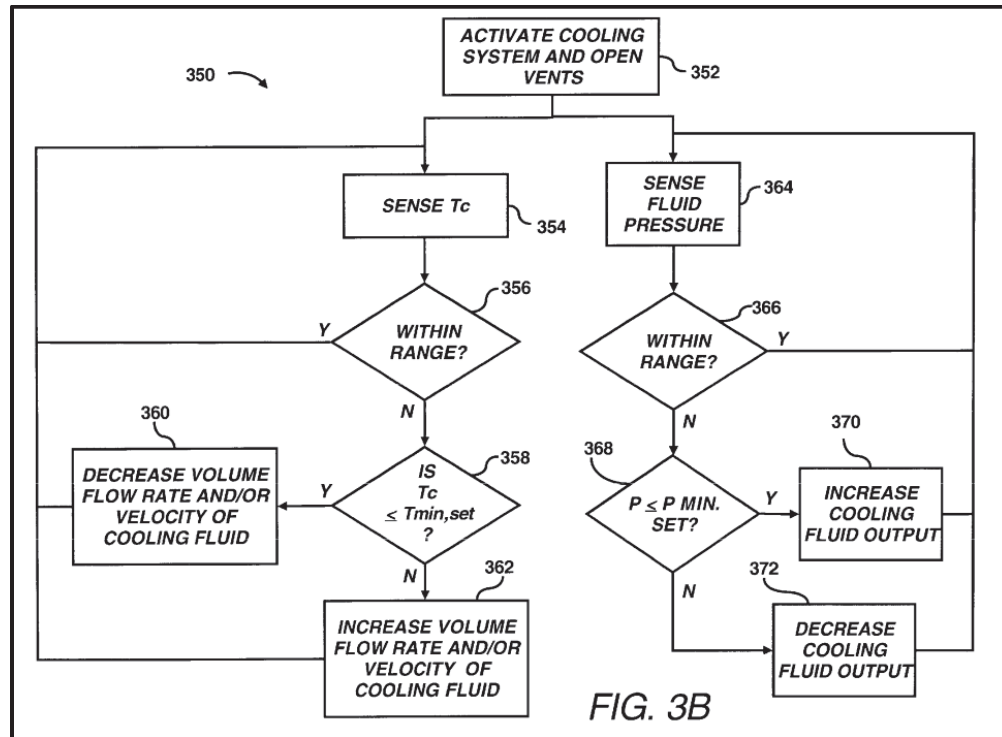
113. Patel also discloses measuring temperatures via temperature sensors located at various positions throughout the data center and determining whether each measured temperature is within a predetermined range of operating temperatures. Ex. 1006, 10:16–28, 38–43. If a measured temperature is outside of the predetermined range, the cooling system may decrease or increase “either or both the volume flow rate and the velocity of the cooling fluid” to meet the localized cooling needs of the racks. Ex. 1006, 11:6–23. An exemplary flow diagram of this method is shown in Figure 3A of Patel, reproduced below.



Ex. 1006, FIG. 3A.

114. Patel also teaches measuring the pressure within the space (plenum) **16** below the raised floor **14** of the data center via a pressure sensor **232** and determining whether the measured pressure is within a predetermined pressure range. Ex. 1006, 12:52–60. “If the measured pressure is not within the predetermined pressure range,” the cooling system controller **222** “determine[s] whether to increase or decrease the supply of fluid” to the space (plenum) **16** below

the raised floor 14. Ex. 1006, 13:1–7. An exemplary flow diagram of this method is shown in Figure 3B of Patel, provided below.



Ex. 1006, FIG. 3B.

115. Patel also mentions the known practice of numerically modeling the cooling requirements of data centers “by operation of any reasonably suitable commercially available computational fluid dynamics (CFD) tool, e.g., FLOVENT.” Ex. 1006, 13:55–60. “By virtue of the numerical modeling, various air conditioning units as well as the vents . . . may be positioned throughout the data center to substantially control the manner in which the racks receive the cooling fluid. In addition, the air conditioning units may also be positioned to substantially maximize and optimize their performances.” Ex. 1006, 13:60–66.

116. Additional details about the disclosures of Patel are set forth in Section IX below.

C. Bishop

117. U.S. Patent Application Publication No. 2002/0149911 (“Bishop”) was published on October 17, 2002, and the underlying Patent Application (No. 09/833,722) was filed on April 12, 2001. Ex. 1008, cover. Bishop is directed to “air cooling systems for electronic equipment and more specifically to a plenum based system for delivering cool[ing] air to an electronic equipment cabinet.” Ex. 1008, [0003].

118. Bishop explains that, prior to Bishop’s filing date (and therefore prior to the filing date of the ’179 patent), “many companies locate racks of computer servers and other electronic modules in special ‘critical environment’ computing and warehousing rooms” (i.e., data centers) to meet their computing and database needs. Ex. 1008, [0005]. One problem with storing so many electronic modules in one location is that “during operation, electronic modules generate heat,” and if the “generated heat is not dissipated quickly enough, the heat can cause the [electronic] module[s] to malfunction or, when extreme, can destroy the [electronic] modules.” Ex. 1008, [0009].

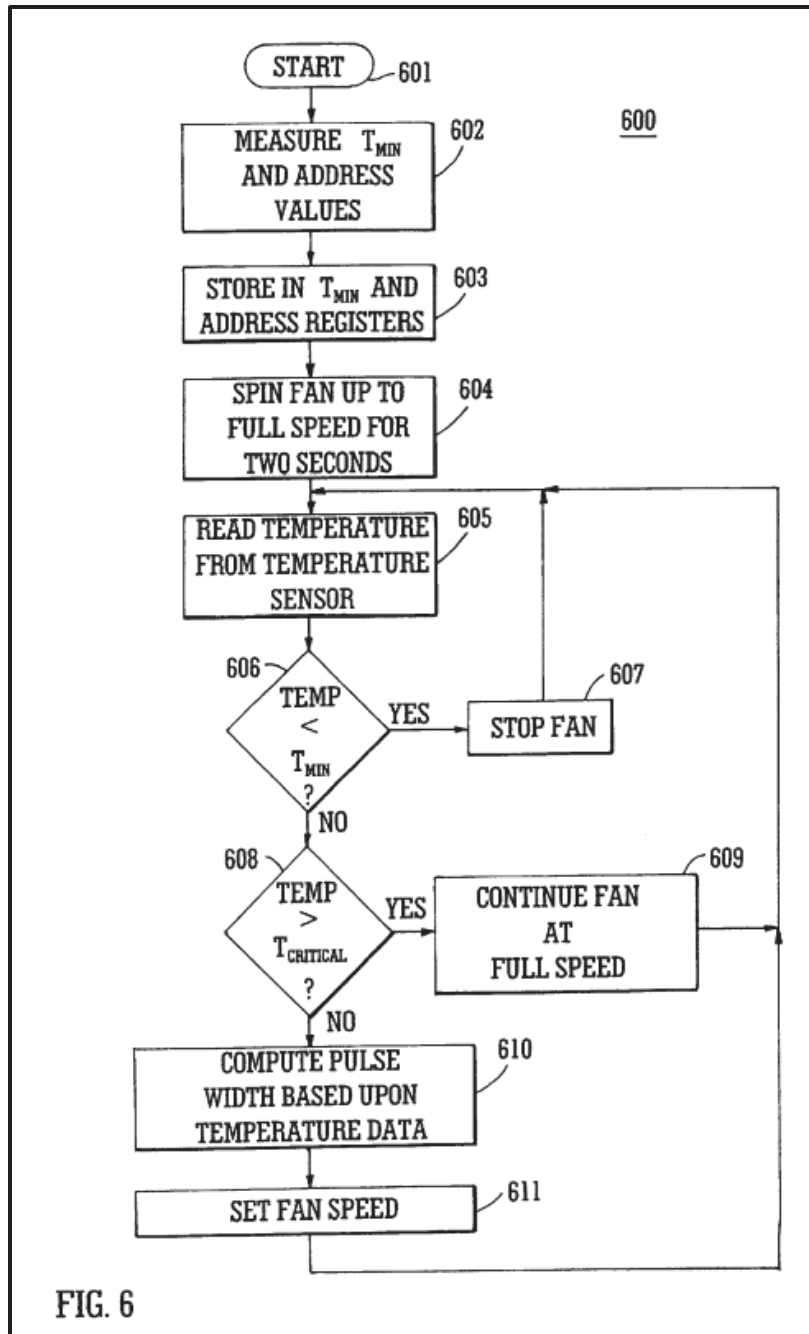
119. Thus, Bishop explains that the “industry has developed several different ways in which to cool electronic modules,” such as using fans to “draw air

. . . over the heat generating devices.” Ex. 1008, [0010]. Another way of cooling racks in a data center that was known prior to the filing date of Bishop “has been to raise the floor in the environment so that a space exists below the surface that supports the module cabinets. Then cooling air is pumped through floor tiles into the critical environment. Environment temperature is then monitored at various locations and the cooling air temperature and/or volume is adjusted to maintain the environment at the desired temperature.” Ex. 1008, [0012].

120. As another example of a cooling solution that was known prior to the filing date of Bishop, Bishop discusses meeting the individualized cooling needs of various locations in a data center by “identify[ing] temperatures throughout a critical environment at relatively small spatial intervals and then adjust[ing] air flow through baffled raised floor tiles within the environment to even out environment temperature.” Ex. 1008, [0017].

121. Yet another known solution mentioned by Bishop is to “provide cabinet monitoring equipment including temperature sensors inside cabinet housings that are linked to a processor. The processor can then monitor temperature in the cabinets and generate an alarm when the temperature inside any given cabinet exceeds some threshold level. In this way IT personnel are alerted when the temperature within a cabinet is dangerously high and can take steps to remedy the problem.” Ex. 1008, [0018].

122. Bishop also discusses U.S. Patent No. 6,188,189 (Ex. 1009, “Blake”), which issued on February 13, 2001, as another example of a known cooling scheme. Ex. 1008, [0029]. In the localized cooling scheme of Blake, temperatures are measured by a plurality of temperature sensors. Ex. 1009, 10:37–40. As can be seen with reference to Figure 6 of Blake, provided below, “[i]f [one of] the sensed temperature[s] is less than the minimum temperature value (step **606**), the corresponding cooling fan is simply stopped (step **607**). If the measured temperature exceed[s] the critical temperature (step **608**), the corresponding fan is allowed to continue full speed operation (step **609**). Otherwise, in the subsequent operation **610**, pulse width (or duty cycle, if you will) is computed for each fan based upon the measured temperature), and the fan speed is set accordingly (step **611**).” Ex. 1009, 10:23–31.

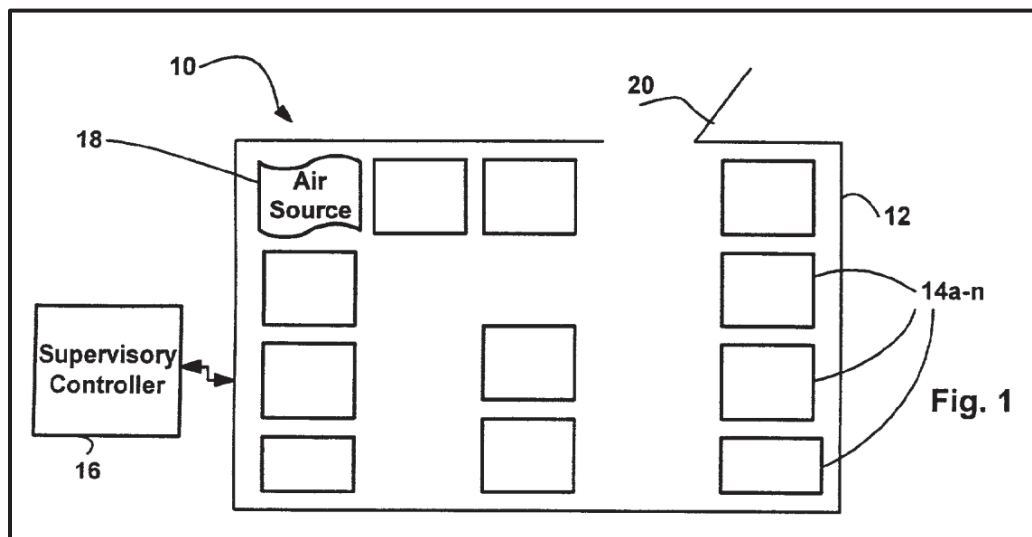


Ex. 1009, FIG. 6.

123. Due to concerns with inefficiencies with these prior solutions, Bishop identifies “a need for an air delivery system that can automatically alter air volume to module cabinets based on cabinet and/or component temperature. Moreover, there is a need for a system that automatically tracks critical environment

temperatures throughout a data center environment and provides information regarding the same.” Ex. 1008, [0032].

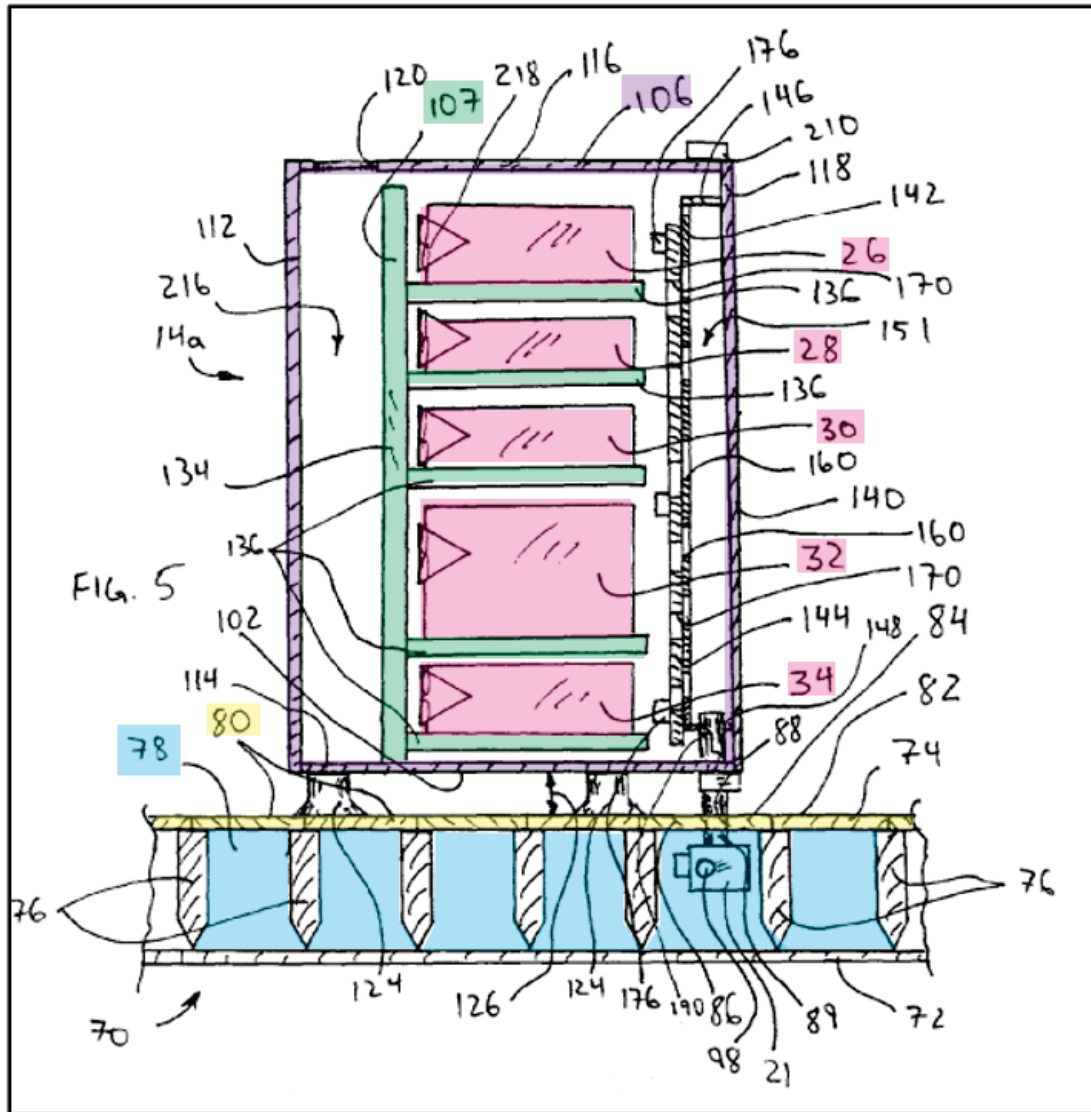
124. Bishop teaches cooling systems and methods for a critical environment room **10** with “a plurality of electronic module cabinet assemblies **14a-n** [] arranged in a spaced format,” as shown in Figure 1 of Bishop, provided below. Ex. 1008, [0062]. “An air source **18** is located inside [the critical] environment **10** and provides cooling air.” Ex. 1008, [0062]. Additionally, “a supervising controller **16** is located outside environment **10** but links to various components within environment **10** via one or more data buses that enable supervising controller **16** to monitor and control environment characteristics.” Ex. 1008, [0062].



Ex. 1008, FIG. 1.

125. Bishop provides additional details on one of the cabinet assemblies **14a** in Figure 5, an annotated version of which is provided below. Ex. 1008, [0064]. Bishop discloses that the cabinet assembly **14a** includes a housing **106** (annotated

in purple), a shelving unit **107** (annotated in green) and five electronic modules **26**, **28**, **30**, **32** and **34** (annotated in pink). Ex. 1008, [0067]. Each cabinet **14a** also has an internal temperature sensor **73** and an external temperature sensor **77** (shown in Figure 5). Ex. 1008, [0067]; *see also* Ex. 1008, FIG. 2.



Ex. 1008, FIG. 5 (annotated).

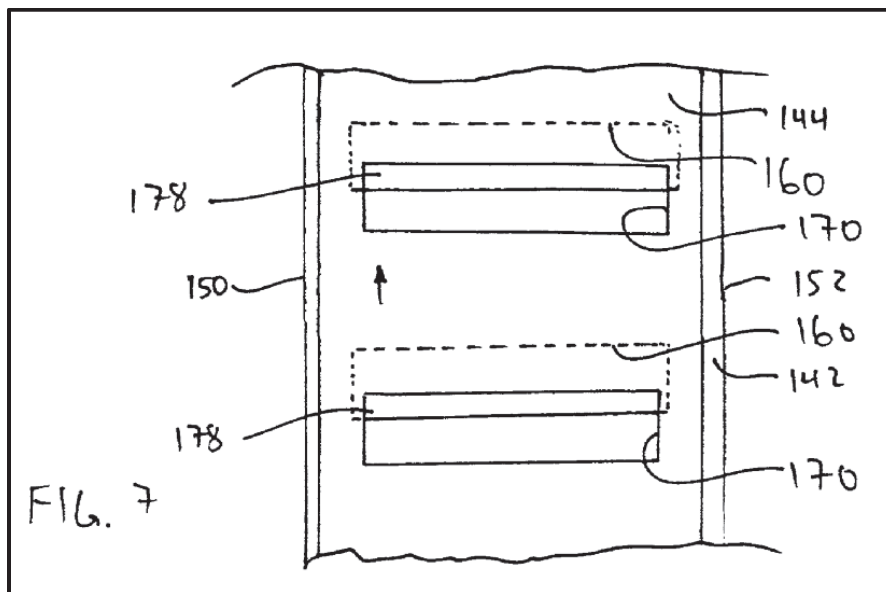
126. Still referring to Figure 5 of Bishop, the cooling air source **18** provides cool air within space **78** (annotated in blue) below the support tiles **80** annotated in

yellow) that serve as a floor on which the cabinet assembly **14a** sits. Ex. 1008, [0063]. “Some of the tiles are . . . special control tiles (e.g., **84**)” that “facilitate delivery of cool air from space **78** directly into cabinet assemblies (e.g., **14a**) thereabove.” Ex. 1008, [0064]. The “control tile **84** also includes a cooling controller unit **21**” that “includes a damper and a processor (not separately illustrated).” Ex. 1008, [0065].

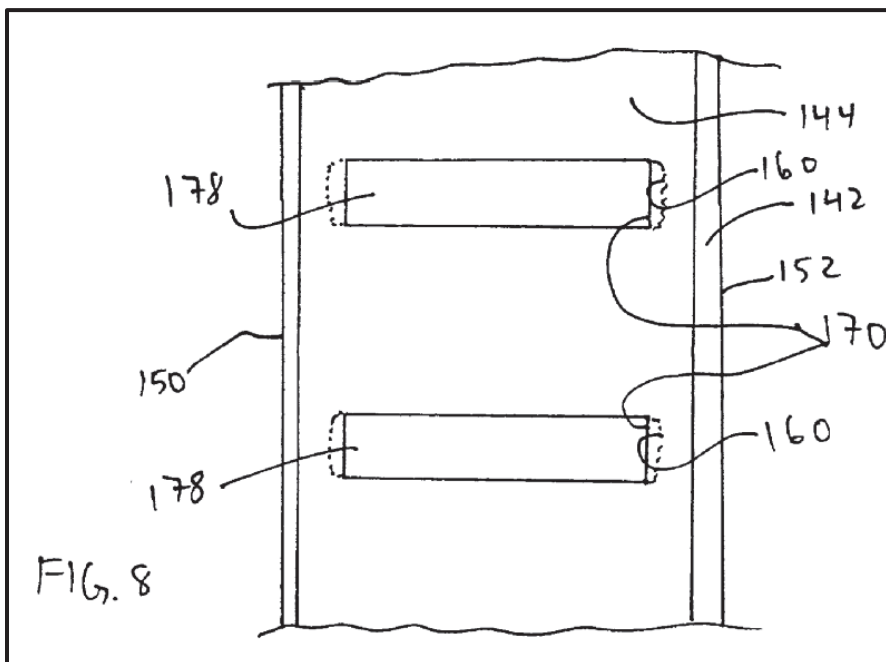
127. Bishop further discloses that the cabinet assembly **14a** includes a wall member **142** with multiple openings **160**. Ex. 1008, [0072]. The cabinet assembly **14a** also has a baffle member **144** that “has a size, shape and construction that is similar to wall member **142**.” Ex. 1008, [0073]. For example, the baffle member **144** has openings **170** that “have shapes similar to openings **160**.” Ex. 1008, [0073].

128. As shown in Figures 7 and 8 of Bishop, provided below, the baffle **144** can be aligned or misaligned with the wall member **142** to vary the effective size of the openings through which “air within space **151** is forced through” to deliver air “directly to the front faces of electronic modules **26**, **28**, **30**, **32** and **34**, respectively.” Ex. 1008, [0080]. For example, “[i]n FIG. 7, baffle **144** is positioned in a relatively low orientation with respect to wall member **142** and therefore openings **170** are misaligned with openings **160** and the effective openings **178** are relatively small. In FIG. 8, baffle **144** is positioned relative to wall member **142**

such that openings **170** are aligned with openings **160** and the effective openings **178** are maximized.” Ex. 1008, [0074].



Ex. 1008, FIG. 7.

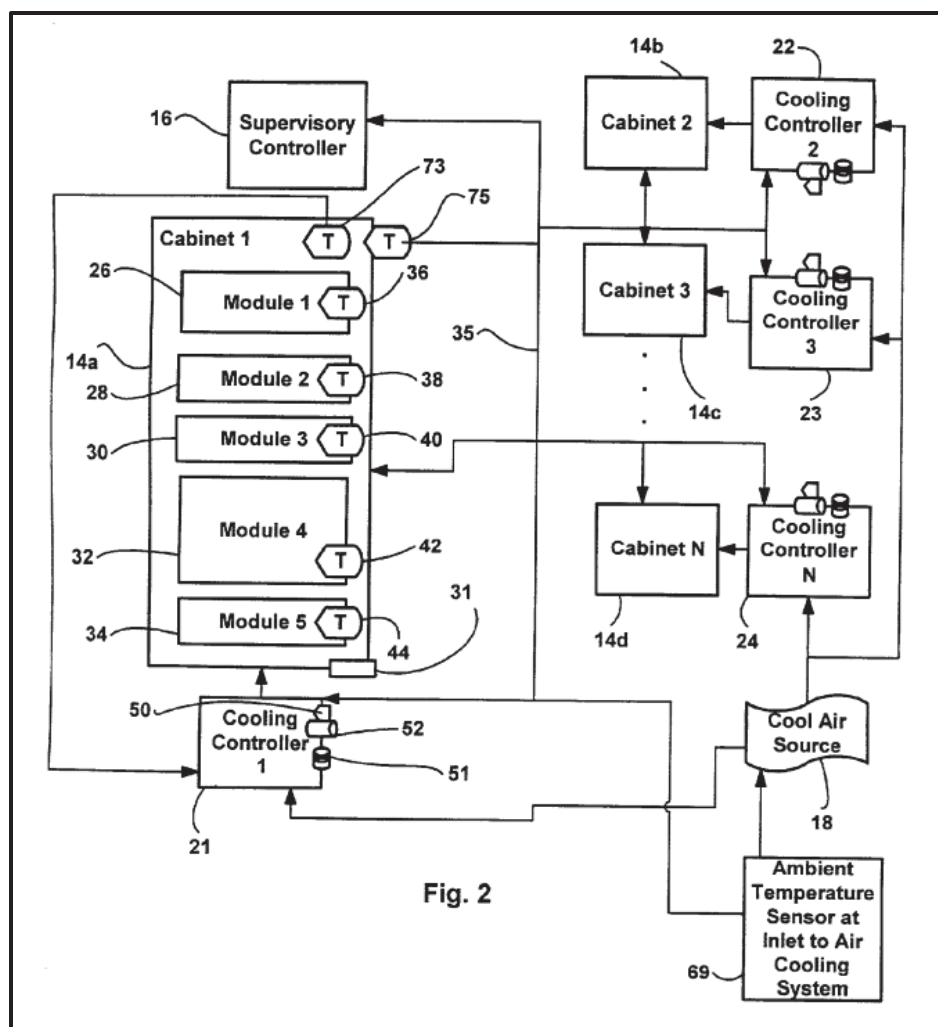


Ex. 1008, FIG. 8.

129. Bishop explains that varying the effective size of the openings through the positioning of the baffle **144** is useful to “deliver[] cool air from a cool air source directly to the position relative to heat generating electronic modules that is most efficient for use.” Ex. 1008, [0080].

130. As another example of how Bishop varies the delivery of cool air to heat generating electronic modules in a cabinet assembly (e.g., **14a**), Bishop discloses a method that utilizes the cooling controller **21**, which is best explained with reference to Figures 2 and 11 of Bishop.

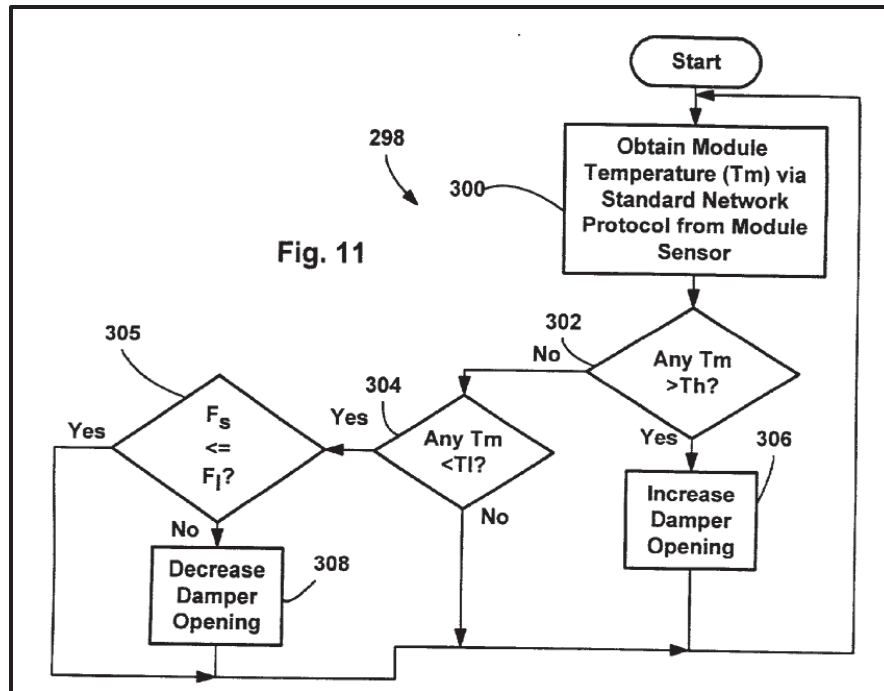
131. Figure 2, reproduced below, provides a schematic diagram of many of the components of Figure 1—including the cooling controller **21** and a cabinet assembly (e.g., **14a**). Ex. 1008, [0046]. As shown in Figure 2, “the temperature sensors in [the electronic]modules **26, 28, 30, 32** and **34** are identified by numerals **36, 38, 40, 42** and **44**, respectively.” Ex. 1008, [0081]. Since each module has its own temperature sensor, “each module is capable of determining its own internal temperature and communicating that temperature to supervising controller **16**” so that the “supervisory controller **16** may control controller **21** based on the temperature.” Ex. 1008, [0081]–[0082].



Ex. 1008, FIG. 2.

132. An exemplary method 298 of how the supervisory controller 16 may control cooling controller 21 is illustrated in Figure 11, provided below. Bishop further teaches that this “method 298 could also be performed via controller 21.”

Ex. 1008, [0082].



Ex. 1008, FIG. 11.

133. As shown in Figure 11, at block **300**, either the supervisory controller **16** or the cooling controller **21** “receives temperature readings from each module.” Ex. 1008, [0082]. Then, at block **302**, “supervising controller **16** compares each module temperature T_m to a threshold temperature that is at the high end of an acceptable temperature range” (T_h). Ex. 1008, [0083]. “[W]here any module temperature [does not] exceed[] the threshold temperature T_h , control passes to block **304** where supervising controller **16** determines if any temperature is less than a low threshold temperature T_l .” Ex. 1008, [0083].

134. “[W]here any module temperature is below the low threshold[,], control passes to block **305** where controller **16** compares [flow rates].” Ex. 1008, [0084]. If “the sensed rate F_s is greater than the minimum flow rate F_l , control passes

to block **308** where supervising controller **16** decreases the damper opening to reduce cooling air flow to the corresponding cabinet.” Ex. 1008, [0084]. And as discussed above, the damper is part of the cooling controller **21**. Ex. 1008, [0065].

135. Bishop further teaches that at “block **302**, where any module temperature is above the high threshold temperature[,] control passes to block **306** where supervising controller **16** [] increases the damper opening to increase cooling air flow to the corresponding cabinet.” Ex. 1008, [0085].

136. Bishop also explains that temperature sensor **73** inside each cabinet **14a** is also linked to controller **21** “to provide redundancy for sensors **36**, **38**, etc., or may supplant the module sensors **36**, **38**, etc. so that controller **21** operates independent of controller **16**.” Ex. 1008, [0105]. Sensor 75 on the outside of each cabinet is also linked to controller 16 to provide ambient temperature readings at the cabinet location. Ex. 1008, [0106].

137. Additional details about the disclosures of Bishop are set forth in Section IX below.

D. Kochavi

138. U.S. Patent No. 5,979,167 (“Kochavi”) issued on November 9, 1999, and the underlying Patent Application (No. 08/783,761) was filed on January 15, 1997. Ex. 1011, cover. Kochavi is directed to an air conditioning system that is

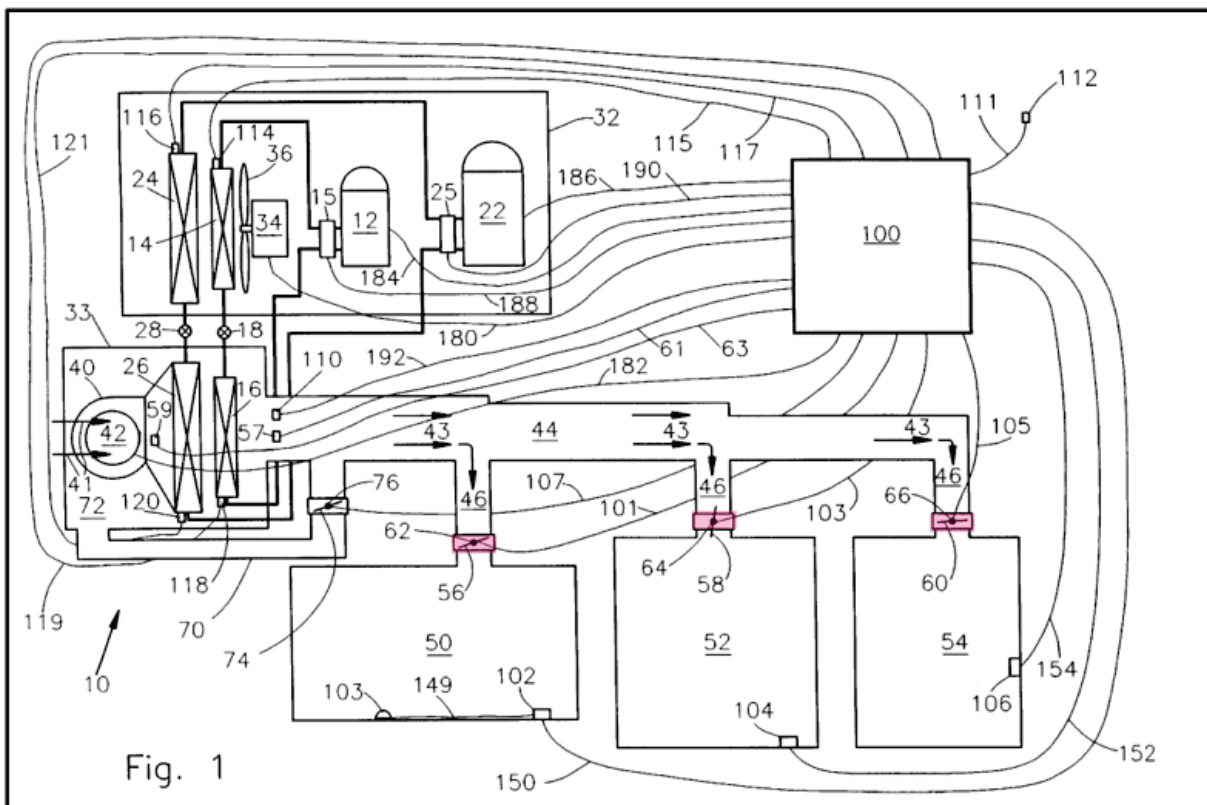
capable of heating and cooling multiple rooms simultaneously, where the rooms have different heating and cooling requirements.

139. Kochavi explains that “[v]arious central air conditioning systems are known in the art which provide conditioned air to a plurality of rooms wherein the temperature of each of the rooms may be controlled independently.” Ex. 1011, 1:10–13. Kochavi mentions one commercially available system that “divides the rooms to be air conditioned into a number of zones and controls the amount of conditioned air entering each zone by means of controllable dampers operating in response to the temperature in each of the zones.” Ex. 1011, 1:14–21.

140. Another prior art central air conditioning system described by Kochavi is the prior art device “described in U.S. Pat. No. 4,635,4[4]5 to Otsuka et al. The Otsuka prior art device measures the heat load in each room by means of temperature sensors and controls the quantity of air to be directed to each room by means of variable dampers. The pressure in the main air duct is also measured and the speed of the blower adjusted accordingly. Under part load conditions, the speed of the compressor is reduced so as to conserve energy.” Ex. 1011, 1:36–43.

141. Kochavi explains that these prior art solutions often have a compressor operating “at reduced speeds [that] results in inefficient operation of the compressor as well as requiring an expensive speed controller for controlling the speed of the electric motor which drives the compressor.” Ex. 1011, 1:44–51. In Kochavi’s

improved approach, shown in Figure 1, an annotated version of which is provided below, the air conditioning system **10** includes a first compressor **12**, a second compressor **22**, a blower **40**, a main duct **44**, and a control system **100**. Ex. 1011, 3:61–4:67. The blower **40** directs a flow of air through heat exchangers **16**, **26** to condition the air and then the conditioned air **43** flows through the main duct **44** and “through a plurality of branch ducts **46** to a plurality of rooms **50**, **52** and **54** via variable dampers **56**, **58** and **60** [(annotated in pink)] respectively.” Ex. 1011, 4:38–47.



Ex. 1011, FIG. 1 (annotated).

142. “The air conditioning system **10** also comprises an air flow pressure sensor **110** which may be located at the entrance to the main duct **44**. . . . The air flow sensor **110** is operative to send a duct pressure signal to the control system **100** which is substantially proportional to the air pressure at the entrance to the main duct **44**.” Ex. 1011, 4:58–67.

143. The air conditioning system **10** of Kochavi also has a “bypass duct **70** . . . to provide a flow path for the conditioned air from the main duct **44** and return it to an entrance region **72** located in proximity to the upstream end of the blower **40**.” Ex. 1011, 5:1–5. A bypass damper **74** in the bypass duct **70** “is operative, in response to signals from the control system **100**, to return some or all of the conditioned air to the entrance region **72** if the pressure sensed by air flow pressure sensor **110** exceeds a value which may be in the region of 16 to 19 psi and is preferably about 17 psi.” Ex. 1011, 5:5–12.

144. Kochavi also discloses that the control system **100** communicates with the compressors **12** and **22**, the blower motor **42** (of the blower **40**), the damper motors **62**, **64**, and **66** (of the dampers **56**, **58**, and **60**), the bypass damper motor **76** (of the bypass damper **74**), room temperature controllers **102**, **104** and **106** (in each of the rooms **50**, **52** and **54**), and the air flow pressure sensor **110**. Ex. 1011, 5:16–57.

145. Kochavi further discloses that the compressors **12** and **22** are able to allow operation of “the air conditioning system **10** for ‘summer operation’ and ‘winter operation’ as is known in the art.” Ex. 1011, 3:63–67. In other words, a POSITA would understand that the “air conditioning system **10** [] provid[es] cooling air during ‘summer operation’ and . . . provide[s] heated air during ‘winter operation.’” Ex. 1011, 6:53–59.

146. There is a room temperature controller **102**, **104**, **106** for each room. Ex. 1011, FIGs. 1 and 2, 6:60–65. Each room temperature controller **102** includes a first microprocessor **130** and a room temperature sensor **132** which are communicatively connected. Ex. 1011, 6:65–7:24. The first microprocessor **130** sends sensed temperature values and a desired room temperature to the control system **100**. Ex. 1011, 7:50–62, 8:24–27.

147. Figure 4, reproduced below, shows a flow chart of several procedures that the main control program can execute to control the compressors, dampers, bypass damper, blowers, and external blowers. Ex. 1011, 15:34–37.

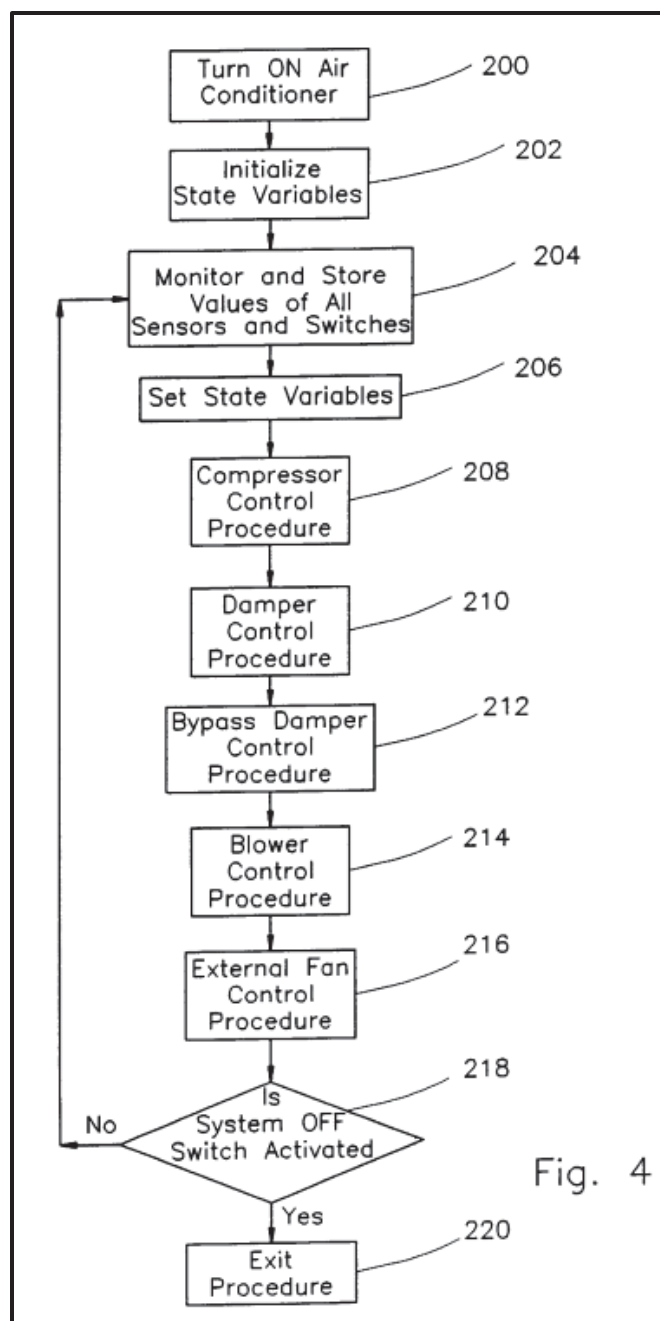


Fig. 4

Ex. 1011, FIG. 4.

148. The control system **100** can control the fraction opening of dampers **56**, **58** and **60**. Ex. 1011, 13:21–27. The “[o]peration of the control system **100** . . . for each of the rooms is [] described in terms of heating for ‘winter operation’. It is apparent to one normally skilled in the art that the teachings of the present invention

are equally applicable to cooling in ‘summer operation’.” Ex. 1011, 13:28–33. In winter operation, for example, if the measured temperate of room **50** is below a desire temperature range, the controller will be set to fully open to allow heated air into the room. Ex. 1011, FIG. 8, 13:44–53. When the temperature reaches the upper limit of the range, the controller **100** is operative to close the damper to prevent additional air from entering the room **50**. Ex. 1011, FIG. 8, 13:54–14:8.

149. A Compressor Control Procedure is operative to turn the first compressor **12** ON if the total thermal load of all the rooms is low, to turn the second compressor **22** ON if the total thermal load is at an intermediate value, and to turn both compressors ON if the total thermal load of all the rooms is at a high value. Ex. 1011, 19:32–40.

150. Depending on the pressure in the main duct **44**, the Bypass Damper Procedure is operative to increase or decrease the fraction opening of the bypass damper **74**, thereby maintaining a substantially constant pressure in the main duct **44**.” Ex. 1011, 15:61–65.

151. In the Blower Control Procedure, “the total air flow requirement for all of the rooms, RoomVolume, is calculated by summing up the individual air flow requirement of all of the rooms.” Ex. 1011, 20:7–10. “[T]he Blow[er] Control Procedure . . . is operative to adjust the speed of the blower motor **42**” in response to the total air flow requirement of all of the rooms. Ex. 1011, 20:15–29.

152. Additional details about the disclosures of Kochavi are set forth in Section IX below.

E. Feeney

153. U.S. Patent No. 5,467,609 to Feeney (Ex. 1013, “Feeney”) issued on November 21, 1995, from an application filed on March 3, 1994. Feeney discloses a raised floor system for supporting rack mounted computer equipment in facilities such as data centers. Ex. 1013, 1:17–36, 2:27–31. The disclosed system is made up of connectable floor modules, including modules providing operational support for use by the computer components.

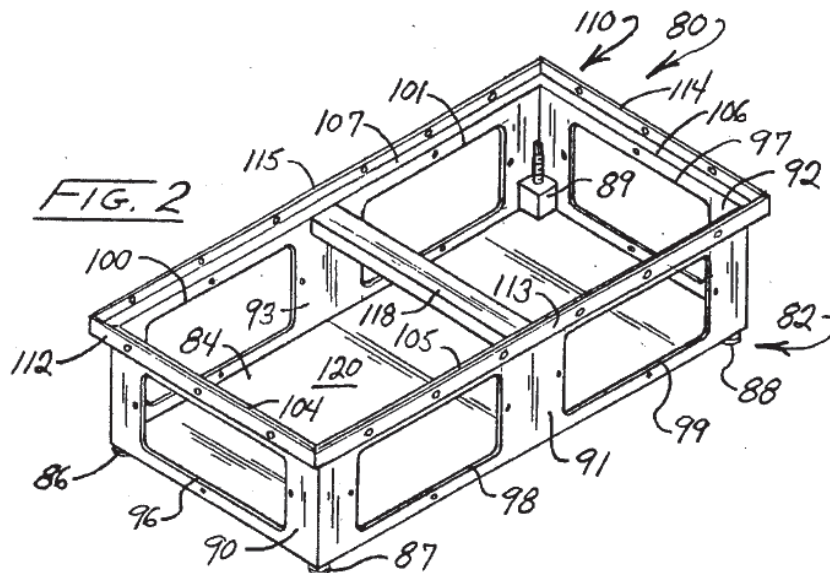
154. An embodiment of Feeney’s disclosed raised floor system is illustrated in Figure 1, reproduced below.



155. The computer racks 12 and 12' are supported on an elevated floor 32 which is formed of eight individual floor modules labeled 34 to 41 which each support two rigid floor tiles. Ex. 1013, 5:53–65. Certain modules, for example modules 37 and 38, contain chilled water air conditioning coils and floor tiles 50 and 51 contain air entry holes for supplying air to the cooling coils. Ex. 1013, 5:56–60; 6:2–7. Floor module 38 also houses an air blower fan 148. Ex. 1013, 8:1–3. Uninterruptable power supply (UPS) devices are located within modules 36 and 39.

Ex. 1009, 5:56–62, 6:7–16. The adjacent tile 54 within floor module 52 contains an air outlet 56 through which cooled air may flow into the base region of computer component 12'. Ex. 1013, 6:16–19.

156. Figure 2 shows an individual floor module.

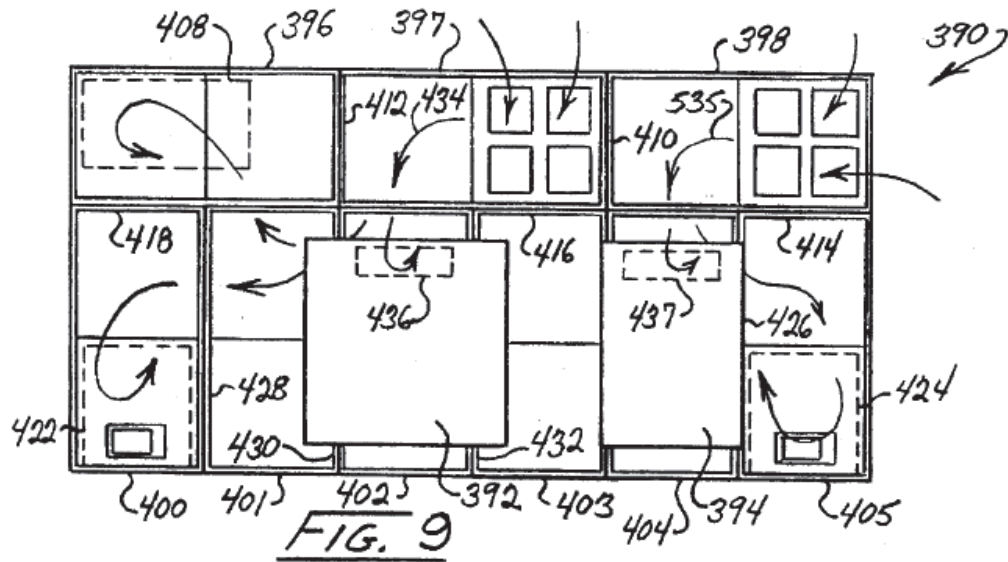


Ex. 1013, FIG. 2.

157. The illustrated module 82 has a rectangular frame 80 with bottom portion 84 and side panels 90–93. The shorter side panels 90 and 92 each include a single opening and the long panels 91 and 93 include two spaced-apart openings 98 and 99. Ex. 1013, 6:58–7:9. Feeney teaches that the user can define airflow paths in the plenum space under the raised floor by selective closure of these air transfer openings. Ex. 1013, 10:20–22. For example, with reference to Figure 1 above, an air blower fan 148 in floor module 38 forces cooling air through the system. By positioning blocking panels and gasketing to block certain of the air transfer

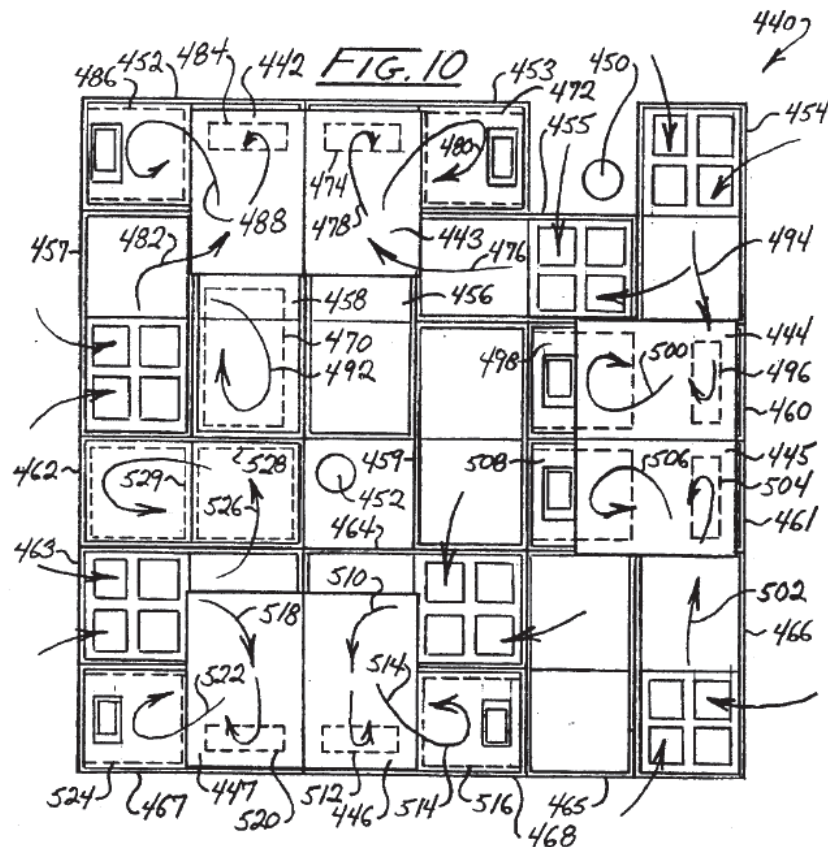
openings, an air flow path is established from the openings in floor tile 51, then through chilled water-cooling coil 124 to the input of the blower, and then from the blower output to the adjacent module 36 and exiting through an opening 56 in floor tile 54. Ex. 1013, 8:1–17.

158. Feeney emphasizes the advantageous capability for reconfiguring the floor modules “depending upon changing processing requirements and/or changes in the geometry of the floor region available for the data center function.” Ex. 1013, 11:48–52. Feeney teaches numerous exemplary arrangements of blocking panels to define alternative airflow paths to supply cooling air to the data center zones in a targeted manner. Figure 9, for example, shows an overhead view of one configuration in which module openings are selectively closed or left open to direct cooling air from air circulation blowers within modules 397 and 398 to computer components 392 and 394 and to UPS devices 422 and 424. Ex. 1013, 13:3–43; FIG. 9. In this arrangement, the panel openings are blocked at 410, 412 and 432. Ex. 1013, 13:22–24, 13:35–37.



Ex. 1013, FIG. 9.

159. Another example illustrating the flexibility of the system to direct multiple supplies of cooling air to the heat-generating equipment in multiple zones of a data center appears in Figure 10.



Ex. 1013, FIG. 10, 13:53–15:10.

IX. ANALYSIS OF THE PRIOR ART AND THE '179 PATENT CLAIMS

A. GROUND 1: CLAIMS 1–15 ARE ANTICIPATED BY BASH

160. It is my opinion that, under the construction of “partition” reflected in Patent Owner’s infringement assertions, Bash discloses all of the limitations of claims 1–15 of the ’179 patent. The reasons underlying my opinion are set forth below.

1. Claim 1

161. I discuss each limitation of claim 1 in turn below, in conjunction with the relevant disclosures of each claim limitation by Bash.

a. 1[pre] – “A method of cooling a plurality of racks in a data center, said method comprising:”

162. The preamble of claim 1 recites, “[a] *method of cooling a plurality of racks in a data center, said method comprising.*”

163. I have been informed that claim preambles are generally not limiting. In any case, even if the preamble here were a limitation, I believe that Bash discloses this recitation.

164. For example, Bash discloses “[a] method of cooling a plurality of racks in a data center, said method comprising.” Ex. 1005, Claim 12.

165. As another example, Bash discloses “a cooling system for cooling racks in a data center” and methods of using the same. Ex. 1005, Abstract.

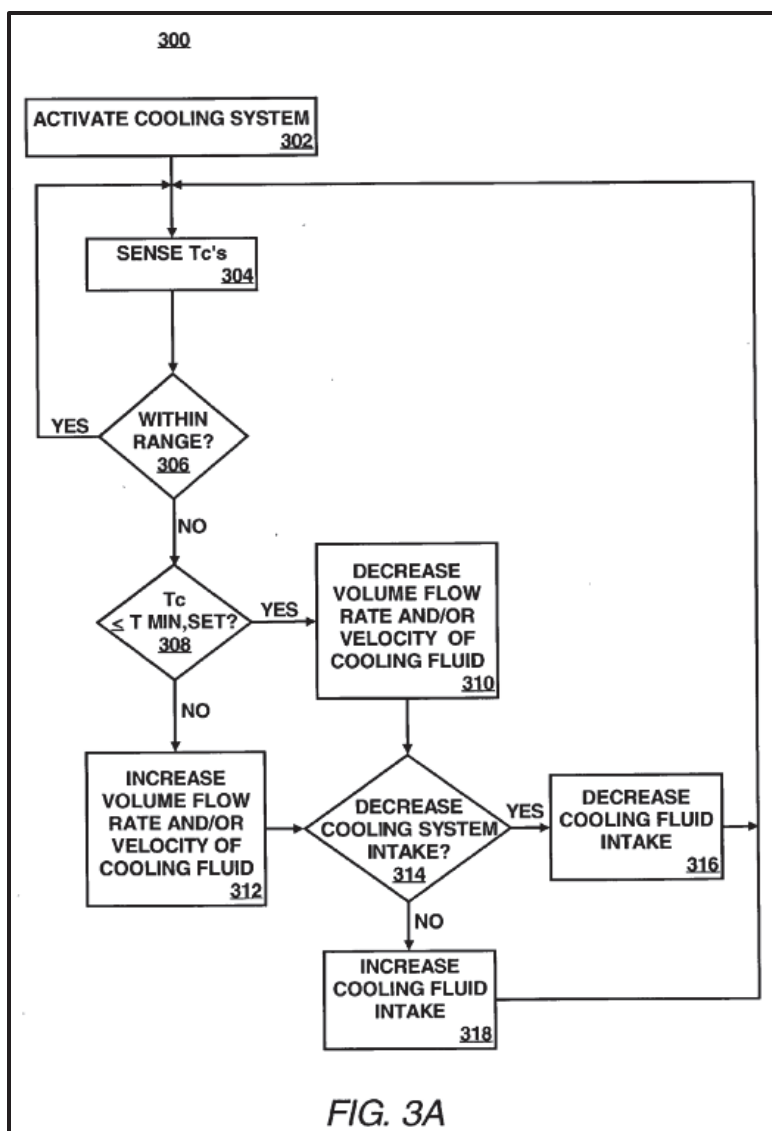
166. Thus, Bash discloses limitation 1[pre].

b. 1[a] – “activating a cooling device and opening a controllable partition configured to vary a supply of cooling fluid within a zone of said data center, said zone including at least one associated rack of said plurality of racks;”

167. Claim 1 further recites “*activating a cooling device and opening a controllable partition configured to vary a supply of cooling fluid within a zone of said data center, said zone including at least one associated rack of said plurality of racks.*” In my opinion, under Patent Owner’s construction of “partition” Bash discloses this limitation.

169. Bash further discloses the cooling fluid, i.e. cooling air, being delivered to the plurality of racks **18a–18d** (annotated in pink) by “flow[ing] out of the raised floor **14** through a plurality of dynamically controllable vents **36a–36c** [(annotated in orange)] that generally operate to control the velocity and the volume flow rate of the cooling fluid therethrough” and into the zone above the raised floor **14** where the plurality of racks **18a–18d** are located. Ex. 1005, [0018].

170. Bash also teaches a method of operating the cooling system **202** in the flow diagram **300** of Figure 3A of Bash, reproduced below. In the first step **302** of this method, “the cooling system **202** is activated and the vents **36a-36c** . . . are opened.” Ex. 1005, [0048].



Ex. 1005, FIG. 3A.

171. Since the cooling system of Bash includes a cooling device, a POSITA would understand that activating the cooling system also activates the cooling device. Thus, Bash teaches activating a cooling device as recited in limitation 1[a].

172. In my opinion, Bash also discloses opening a controllable partition configured to vary a supply of cooling fluid within a zone of said data center as recited in limitation 1[a].

173. With regard to “cooling fluid” in limitation 1[a], Bash discloses supplying cooling fluid under both Petitioner’s proposed construction of “cooling fluid” and Patent Owner’s expected construction, which each include cooling air. Bash teaches that “cooling fluid (e.g., *air*)” is delivered “from the cooling system **12** to a plurality of racks **18a-18d**.” Ex. 1005, [0012] (emphasis added).

174. Bash also discloses the “controllable partition” recited in this claim limitation under Patent Owner’s expected construction of “partition.” Specifically, the controllable vents **36a-36c** of Bash disclose the controllable partition under Patent Owner’s expected construction encompassing any device capable of manipulating the flow of cooling fluid.

175. Bash teaches that “cooling fluid flows out of the raised floor **14** through a plurality of dynamically *controllable* vents **36a-36c** that generally operate to control the velocity and the volume flow rate of the cooling fluid therethrough.” Ex. 1005, [0018] (emphasis added). Since the vents of Bash are controllable and are capable of manipulating the flow (e.g., velocity and volume flow rate) of cooling fluid, the vents **36a-36c** of Bash disclose the controllable partition under Patent Owner’s expected construction of “partition.”

176. Therefore, it is my opinion that the vents **36a-36c** of Bash disclose the controllable partition recited in claim 1 under Patent Owner’s expected construction of “partition.”

177. Bash also discloses that the vents **36a-36c** are configured to vary a supply of cooling fluid within a zone of the data center: “[t]he cooling fluid flows out of the raised floor **14** through a plurality of dynamically controllable vents **36a-36c** that generally operate to control the velocity and the volume flow rate of the cooling fluid therethrough.” Ex. 1005, [0018].

178. Bash further discloses that the zone of said data center includes at least one associated rack of said plurality of racks. For example, Bash teaches that the “cool aisles **44** are those aisles that include the vents **36a-36c** and thus receive cooling fluid for delivery to the racks **18a-18d**.” Ex. 1005, [0020].

179. Therefore, Bash teaches activating a cooling device and opening a controllable partition configured to vary a supply of cooling fluid within a zone of said data center, said zone including at least one associated rack of said plurality of racks, as recited in limitation 1[a].

c. 1[b] – “sensing the temperature of said at least one associated rack;”

180. Claim 1 recites “*sensing the temperature of said at least one associated rack*.” In my opinion, Bash discloses this limitation.

181. Bash teaches detecting temperatures via “a plurality of temperature sensors **48a-48c**, e.g., thermocouples, [that] may be positioned at various positions around the subsystems and/or the racks **18a-18d**.” Ex. 1005, [0030]. All of the temperature sensors disclosed in Bash (*e.g.*, **48a-48c**, **50**, **52**, **236-230**) may be

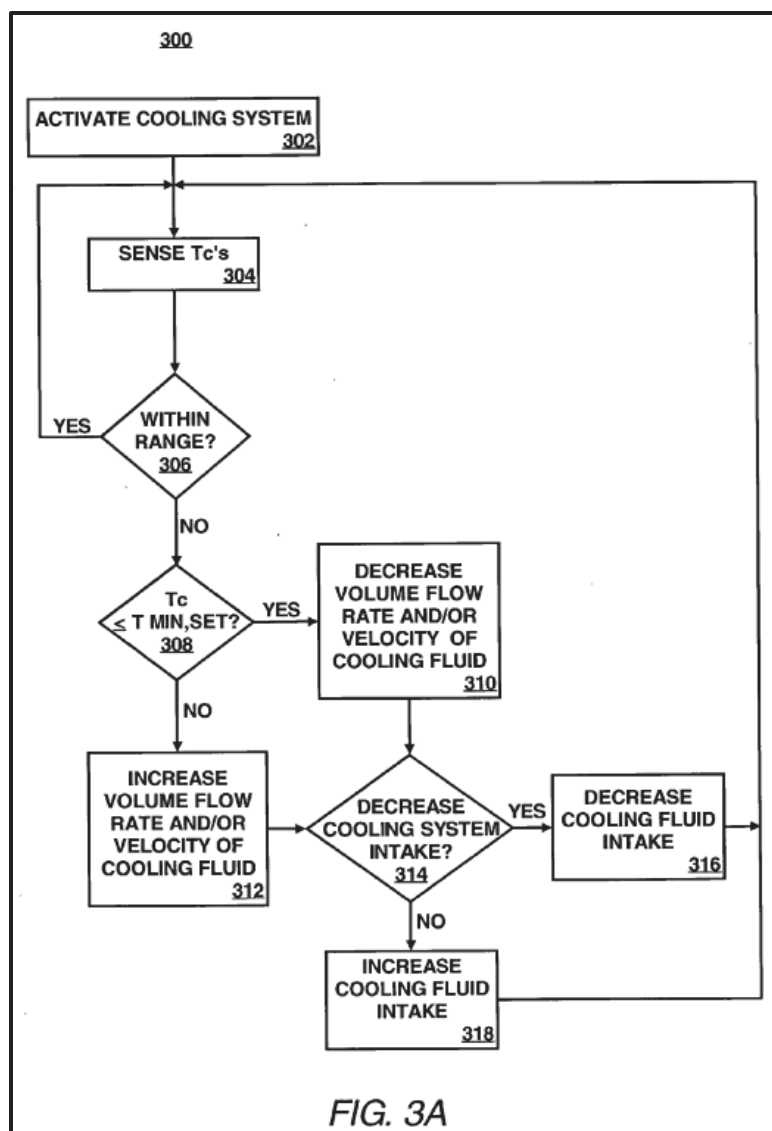
employed to sense temperatures (T_C 's) "in the general vicinity of the racks and/or sections of the racks." Ex. 1005, [0048]. Moreover, Bash teaches that the cooling system "may include any reasonably suitable number of temperature sensors to thus measure the temperatures of any reasonably suitable number of racks **18a-18d** or portions thereof." Ex. 1005, [0032].

182. Thus, Bash teaches sensing the temperature of said at least one associated rack, as recited in limitation 1[b].

d. 1[c] – “determining whether said sensed temperature is within a predetermined temperature range; and”

183. Claim 1 recites “*determining whether said sensed temperature is within a predetermined temperature range.*” In my opinion, Bash discloses this limitation.

184. As shown in the flow diagram **300** in Figure 3A of Bash, reproduced below, “[a]t step **304**, the temperatures of the components (T_C 's) are individually sensed by the temperature sensors. . . . At step **306**, it is determined whether each of the measured temperatures are individually 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 ($T_{\min, \text{set}}$).” Ex. 1005, [0049]; *see also* Ex. 1005, FIG. 3B.



Ex. 1005, FIG. 3A.

185. Thus, Bash teaches determining whether said sensed temperature is within a predetermined temperature range, as recited in claim 1.

e. 1[d] – “manipulating said controllable partition to vary said supply of said cooling fluid to said zone in response to said sensed temperature being outside said predetermined temperature range.”

186. Claim 1 recites “*manipulating said controllable partition to vary said supply of said cooling fluid to said zone in response to said sensed temperature*

being outside said predetermined temperature range.” In my opinion, Bash discloses this limitation.

187. Bash discloses that the “the shape and/or opening size of the vents **36a-36c**” are manipulable to vary the “velocity and the volume flow rate of the cooling fluid” that passes through the vents **36a-36c** from the plenum **16** below the raised floor **14** and into the zone where the racks **18a-18d** are located. Ex. 1005, [0019]. Bash also discloses that this manipulation of the vents is in response to said sensed temperature being outside said predetermined temperature range. Ex. 1005, [0050]–[0053].

188. As shown in Figure 3A of Bash, “[f]or 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 $T_{\max, \text{set}}$, it is determined whether the sensed temperature equals or falls below the $T_{\min, \text{set}}$ at step **308**. 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 fluid delivered to the racks.” Ex. 1005, [0050].

189. Bash further teaches that “[i]f the T_C ’s of some of the racks are below or equal to the $T_{\min, \text{set}}$, . . . the vent controller **228** may operate to decrease the volume flow rate and/or the velocity of cooling fluid circulating about those racks at step **310**. The determination of whether to decrease either or both the volume flow rate and the velocity of the cooling fluid may be based upon the detected temperature of

the racks.” Ex. 1005, [0051]. Likewise, “[i]f the T_c ’s of some of the racks exceed the $T_{\min, \text{set}}$ (i.e., also exceed the $T_{\max, \text{set}}$), . . . the vent controller **228** may operate to increase the volume flow rate and/or the velocity of cooling fluid circulating about those racks at step **312**.” Ex. 1005, [0052].

190. Thus, Bash teaches manipulating said controllable partition to vary said supply of said cooling fluid to said zone in response to said sensed temperature being outside said predetermined temperature range, as recited in limitation 1[d].

2. Claim 2

191. I discuss each limitation of claim 2 in turn below, in conjunction with the relevant disclosures of each claim limitation by Bash.

a. 2[a] – “The method according to claim 1, further comprising: determining whether the measured temperature of said at least one associated rack is below or equal to a predetermined minimum set point temperature; and”

192. Claim 2 recites “[t]he method according to claim 1, further comprising: determining whether the measured temperature of said at least one associated rack is below or equal to a predetermined minimum set point temperature.” In my opinion, Bash discloses this limitation.

193. As explained above, Bash discloses the method of claim 1 under Patent Owner’s expected construction of “partition.”

194. As shown in Figure 3A, reproduced below, Bash teaches that “[f]or 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 $T_{\max, \text{set}}$, it is determined whether the sensed temperature equals or falls below the $T_{\min, \text{set}}$ at step **308**.” Ex. 1005, [0050]. Bash also defines a minimum set point temperature [as] ($T_{\min, \text{set}}$).” Ex. 1005, FIG 3A, [0049]; *see also* Ex. 1005, FIG. 3B.

195. Limitation 2[a] of the ’179 patent is therefore disclosed by Bash.

- b. 2[b] – “decreasing the supply of said cooling fluid to said zone in response to said at least one associated rack having a measured temperature that falls below or equal said predetermined minimum set point temperature.”**

196. Claim 2 recites “*decreasing the supply of said cooling fluid to said zone in response to said at least one associated rack having a measured temperature that falls below or equal said predetermined minimum set point temperature.*” In my opinion, Bash discloses this limitation.

197. Bash discloses that “[i]f the T_C ’s of some of the racks are below or equal to the $T_{\min, \text{set}}$, . . . the vent controller **228** may operate to decrease the volume flow rate and/or the velocity of cooling fluid circulating about those racks at step **310**.” Ex. 1005, FIG. 3A, [0051]; *see also* Ex. 1005, [0022].

198. Limitation 2[b] of the ’179 patent is therefore disclosed by Bash.

3. Claim 3

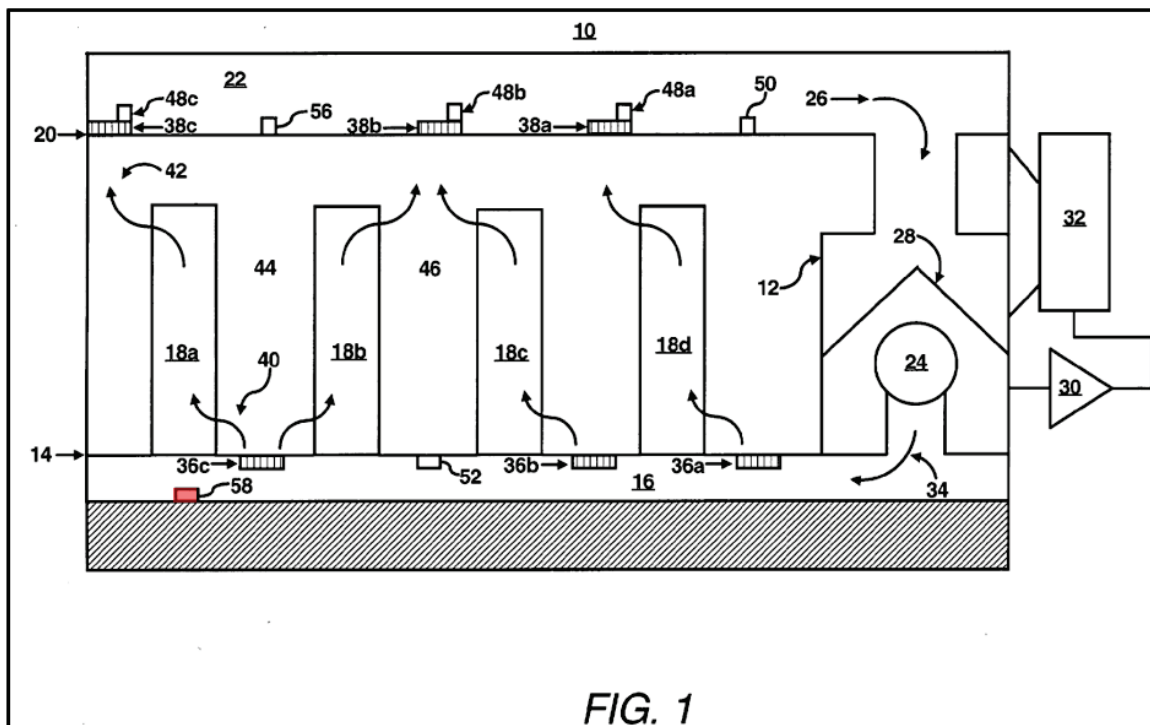
199. I discuss each limitation of claim 3 in turn below, in conjunction with the relevant disclosures of each claim limitation by Bash.

a. 3[a] – “The method according to claim 1, further comprising: sensing a pressure of a supply of said cooling fluid;”

200. Claim 3 recites “[t]he method according to claim 1, further comprising: sensing a pressure of a supply of said cooling fluid.” In my opinion, Bash discloses this limitation.

201. As explained above, Bash discloses the method of claim 1 under Patent Owner’s expected construction of “partition.”

202. As shown in Figure 1 of Bash, reproduced and annotated below, Bash discloses further that “a pressure sensor 58 [(annotated in red)] may be configured to measure the pressure of the cooling fluid in the space 16” below the floor from which cooling fluid is supplied. Ex. 1005, [0027].



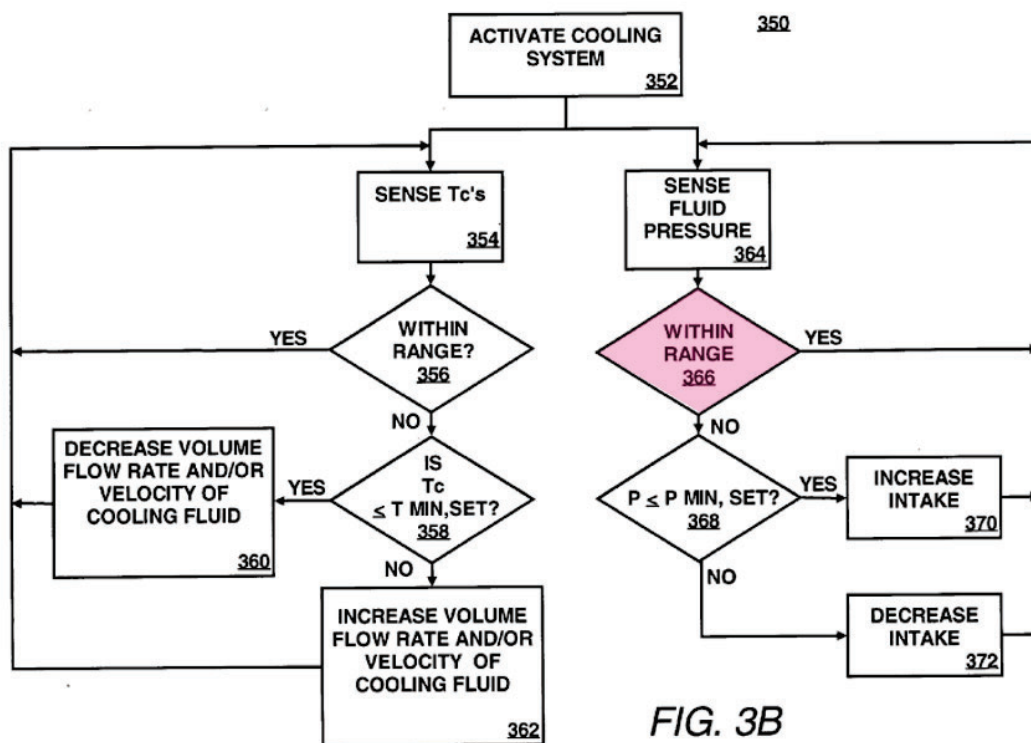
Ex. 1005, FIG. 1 (annotated).

203. Limitation 3[a] of the '179 patent is therefore disclosed by Bash.

b. 3[b] – “determining whether said sensed pressure is within a predetermined pressure range; and”

204. Claim 3 recites “*determining whether said sensed pressure is within a predetermined pressure range.*” In my opinion, Bash discloses this limitation.

205. As shown in Figure 3B of Bash, reproduced and annotated below, Bash teaches “determin[ing] whether the measured pressure is within a predetermined pressure range, e.g., a predetermined minimum set point pressure ($P_{\min, \text{set}}$) and a predetermined maximum set point pressure ($P_{\max, \text{set}}$), at step 366” (annotated in pink). Ex. 1005, [0060].



Ex. 1006, FIG. 3B (annotated).

206. Limitation 3[b] of the '179 patent is therefore disclosed by Bash.

c. 3[c] – “varying an output of said cooling device in response to said sensed pressure falling outside of said predetermined pressure range.”

207. Claim 3 recites “*varying an output of said cooling device in response to said sensed pressure falling outside of said predetermined pressure range.*” In my opinion, Bash discloses this limitation.

208. Bash teaches establishing a “predetermined pressure range” of “threshold pressures to determine whether to increase or decrease the movement of cooling fluid, e.g., in the space **16**.” Ex. 1005, [0061].

209. For example, as shown in Figure 3B of Bash, provided above, “[i]f the absolute value of the [measured pressure] P is determined to be below or equal to the $P_{\min, \text{set}}$, the cooling system controller **246** may operate to increase the cooling fluid intake, e.g., by increasing the speed of the fan **24** at step **370**. Otherwise, if the absolute value of the [measured pressure] P is determined to exceed the $P_{\min, \text{set}}$, and thereby exceed the $P_{\max, \text{set}}$, the cooling system controller **246** may operate to decrease the intake of the cooling fluid, e.g., by decreasing the compressor capacity and/or the fan speed, at step **372**.” Ex. 1005, [0062].

210. And because the “cooling device ha[s] a fan,” a POSITA would readily understand that varying the speed of the fan varies the output of the cooling device. Ex. 1005, [0005].

211. Limitation 3[c] of the '179 patent is therefore disclosed by Bash.

4. Claim 4 – “The method according to claim 2, further comprising: increasing the supply of said cooling fluid to said zone in response to said at least one associated rack having a measured temperature that exceed said predetermined minimum set point temperature.”

212. Claim 4 recites “[t]he method according to claim 2, further comprising: increasing the supply of said cooling fluid to said zone in response to said at least one associated rack having a measured temperature that exceed said predetermined minimum set point temperature.” In my opinion, Bash discloses this claim.

213. As explained above, Bash discloses the method of claim 2, which requires decreasing the cooling fluid supplied to a zone in response to a measured rack temperature being below or equal to a minimum set point temperature. Thus, based on its dependency from that claim, claim 4 requires decreasing the cooling fluid flow to a zone at one time and increasing the cooling fluid flow at another time.

214. Bash’s system is capable of both decreasing and increasing the cooling fluid flow to a zone as the sensed temperature conditions dictate. Bash discloses that “[i]f the T_C ’s of some of the racks exceed the $T_{\min, \text{set}}$ (i.e., also exceed the $T_{\max, \text{set}}$), . . . the vent controller **228** may operate to increase the volume flow rate and/or the velocity of cooling fluid circulating about those racks at step **312**.” Ex. 1005, [0052]. And as explained previously, T_C is a measured temperature of a rack

and $T_{\min, \text{set}}$ is the minimum set point temperature of the predetermined range of operating temperatures. Ex. 1005, [0049]; *see also* Ex. 1005, FIG. 3B.

215. Claim 4 of the '179 patent is therefore anticipated by Bash.

5. Claim 5 – “The method according to claim 3, wherein said step of varying said cooling device output includes determining whether said measured pressure falls below or equals a predetermined minimum set point pressure.”

216. Claim 5 recites “[t]he method according to claim 3, wherein said step of varying said cooling device output includes determining whether said measured pressure falls below or equals a predetermined minimum set point pressure.” In my opinion, Bash discloses this claim.

217. As explained above, Bash discloses the method of claim 3.

218. Bash expressly teaches “determin[ing] whether an absolute value of the measured pressure (P) is below or equal to a minimum pressure set point ($P_{\min, \text{set}}$) at step **368**” and varying the cooling device output at step **370**. Ex. 1005, FIG. 3B, [0061]–[0062].

219. Claim 5 of the '179 patent is therefore anticipated by Bash.

6. Claim 6 – “The method according to claim 4, further comprising: decreasing an output of said cooling fluid from said cooling device in response to said decrease in cooling fluid supply to said zone exceeding said increase in cooling fluid supply to said zone.”

220. Claim 6 recites, “[t]he method according to claim 4, further comprising: decreasing an output of said cooling fluid from said cooling device in

response to said decrease in cooling fluid supply to said zone exceeding said increase in cooling fluid supply to said zone.” In my opinion, Bash discloses this claim.

221. Claim 6 depends directly from claim 4 and indirectly from claim 2. A POSITA would understand that this claim requires decreasing the cooling fluid output from the cooling device if the decrease in cooling fluid to the zone (per claim 2) exceeds the increase in cooling fluid to the zone (per claim 4). Bash discloses that if the total amount of decreases in the volume flow rates of the cooling fluid exceeds the total amount of increases in the volume flow rates flow of the cooling fluid, the cooling system controller **246** may decrease the cooling fluid intake at step **316** by decreasing the speed of the fan **24**. Ex. 1005, [0054]. A POSITA understands that the intake and the output of cooling fluid by the cooling system of Bash are correlated. Decreasing the fan speed decreases the output of cooling fluid from the cooling device because the “cooling fluid is circulated in the data center by a cooling device having a fan.” Ex. 1005, FIG. 1, [0005].

222. Claim 6 of the '179 patent is therefore anticipated by Bash.

- 7. Claim 7 – “The method according to claim 4, further comprising: opening a plurality of vents, said vents being configured to supply cooling fluid to said racks; controlling one or more of said plurality vents to decrease the supply of said cooling fluid to said at least one associated rack having a measured temperature that fall below or equal said predetermined minimum set point temperature; and controlling said one or more vents to increase the supply of said cooling fluid to said at least one associated rack having a measured temperature that exceed said predetermined minimum set point temperature.”**

223. Claim 7 recites “[t]he method according to claim 4, further comprising: opening a plurality of vents, said vents being configured to supply cooling fluid to said racks; controlling one or more of said plurality vents to decrease the supply of said cooling fluid to said at least one associated rack having a measured temperature that fall below or equal said predetermined minimum set point temperature; and controlling said one or more vents to increase the supply of said cooling fluid to said at least one associated rack having a measured temperature that exceed said predetermined minimum set point temperature.” In my opinion, Bash discloses this claim.

224. Claim 7 depends directly from claim 4 and indirectly from claim 2. As explained above, Bash discloses the methods of those claims if analyzed according to Patent Owner’s apparent contention that a “partition” can be any device capable of manipulating cooling fluid flow. That construction would essentially make claim 7 redundant to claims 2 and 4 since Patent Owner’s construction would include a

vent as one type of partition. Therefore, my opinions stated above for claims 2 and 4 also apply to claim 7.

225. As discussed above, Bash discloses opening a plurality of dynamically controllable vents **36a–36c** that are configured to supply cooling fluid to the plurality of racks **18a–18d**. Ex. 1005, [0018], [0048]. Bash further discloses controlling the vents **36a–36c** to decrease the supply of cooling fluid delivered to racks having a measured temperature (T_C) that falls below or equal to a predetermined minimum set point temperature ($T_{\min, \text{set}}$); and to increase the supply of cooling fluid delivered to racks having a measured temperature (T_C) that exceeds the predetermined minimum set point temperature ($T_{\min, \text{set}}$). Ex. 1005, [0050]–[0052].

226. Claim 7 of the '179 patent is therefore anticipated by Bash.

8. **Claim 8 – “The method according to claim 4, further comprising: opening a plurality of returns, said returns being configured to remove cooling fluid from various locations of said data center; and controlling one or more of said plurality of returns to decrease the removal of said cooling fluid from around said at least one associated rack having a measured temperature that fall below or equal said predetermined minimum set point temperature; and controlling said one or more returns to increase the removal of said cooling fluid from around said at least one associated rack having a measured temperature that exceed said predetermined minimum set point temperature.”**

227. Claim 8 recites “[t]he method according to claim 4, further comprising: opening a plurality of returns, said returns being configured to remove cooling fluid from various locations of said data center; and controlling one or

more of said plurality of returns to decrease the removal of said cooling fluid from around said at least one associated rack having a measured temperature that fall below or equal said predetermined minimum set point temperature; and controlling said one or more returns to increase the removal of said cooling fluid from around said at least one associated rack having a measured temperature that exceed said predetermined minimum set point temperature.” In my opinion, Bash discloses this claim.

228. As explained above, Bash discloses the method of claim 4.

229. Bash further discloses opening a plurality of returns **38a–38c** that are configured to remove cooling fluid from the vicinity of racks in a data center. Ex. 1005, [0048]. [0067]. Bash also discloses controlling the returns **38a–38c** to decrease the removal of cooling fluid from the vicinity of the racks having a measured temperature (T_C) that falls below or equal to a predetermined minimum set point temperature ($T_{\min, \text{set}}$); and to increase the removal of cooling fluid from the vicinity of the racks having a measured temperature (T_C) that exceeds the predetermined minimum set point temperature ($T_{\min, \text{set}}$). Ex. 1005, [0050]–[0052].

230. Claim 8 of the '179 patent is therefore anticipated by Bash.

9. Claim 9

231. I discuss each limitation of claim 9 in turn below, in conjunction with the relevant disclosures of each claim limitation by Bash.

- a. 9[a] – “The method according to claim 4, further comprising: receiving temperatures from a movable device configured to detect at least one environmental condition at various locations of said data center; ”**

232. Claim 9 recites “[t]he method according to claim 4, further comprising: receiving temperatures from a movable device configured to detect at least one environmental condition at various locations of said data center.” In my opinion, Bash discloses this limitation.

233. As explained above, Bash discloses the method of claim 4.

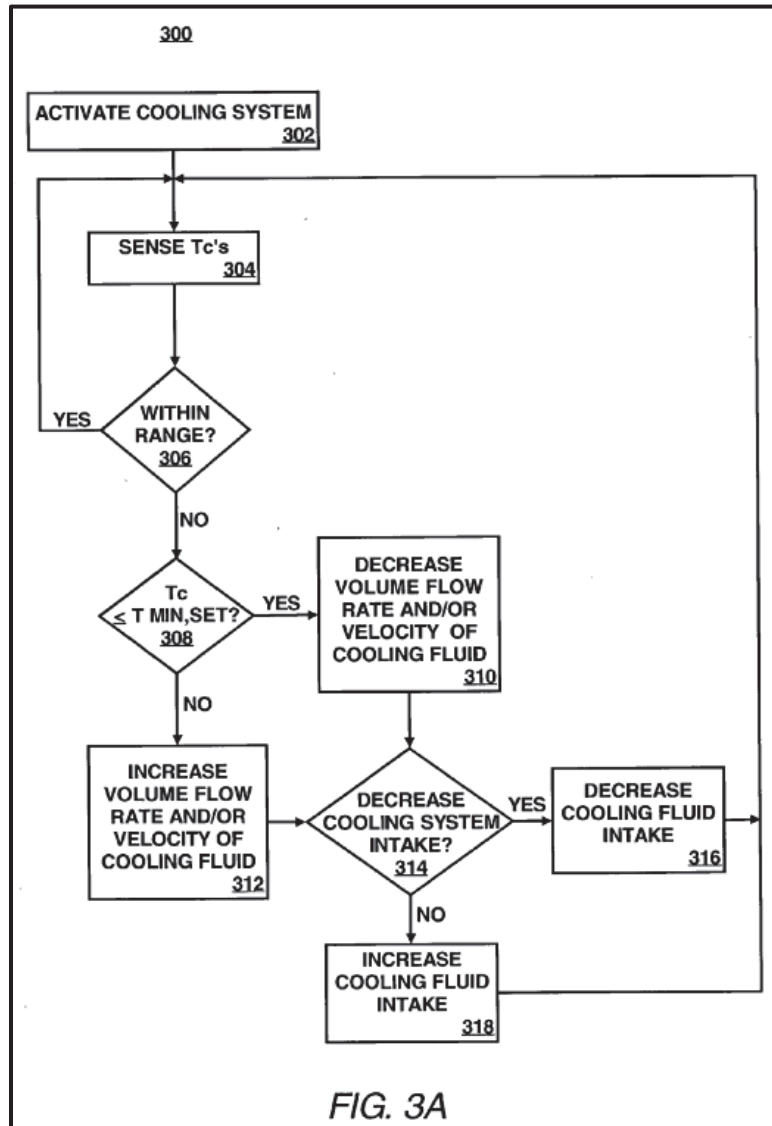
234. Bash further discloses that “a mobile device” may be used “to gather or measure at least one local environmental condition (e.g., temperature, pressure, air flow, humidity, etc.) in the data center **10**. More particularly, the mobile device is configured to travel around the racks to determine the one or more environmental conditions at various locations throughout the data center. . . . The information gathered by the mobile device may be transmitted to the cooling system **202**.” Ex. 1005, [0032].

235. Limitation 9[a] of the ’179 patent is therefore disclosed by Bash.

- b. 9[b] – “determining whether at least one of said sensed temperatures and received temperatures are within a predetermined temperature range; and”**

236. Claim 9 recites “*determining whether at least one of said sensed temperatures and received temperatures are within a predetermined temperature range.*” In my opinion, Bash discloses this limitation.

237. As shown in Figure 3A, provided below, Bash discloses determining whether each of the measured temperatures are within a predetermined range of operating temperatures. Ex. 1005, [0049].



Ex. 1005, FIG. 3A.

238. Bash further discloses that the cooling system **202** that receives measured temperatures from the mobile device (Ex. 1005, [0032]) is capable of

performing the method shown in the flow diagram **300** in Figure 3A of Bash (Ex. 1005, [0048]). *See also* Ex. 1005, FIG. 3B; [0060].

239. Limitation 9[b] of the '179 patent is therefore disclosed by Bash.

- c. 9[c] – **“manipulating said controllable partition to vary said supply of said cooling fluid to said zone in response to at least one of said sensed and received temperatures being outside of said predetermined temperature range.”**

240. Claim 9 recites *“manipulating said controllable partition to vary said supply of said cooling fluid to said zone in response to at least one of said sensed and received temperatures being outside of said predetermined temperature range.”* In my opinion, Bash discloses this limitation.

241. As discussed above with respect to limitation 1[a], the vents **36a-36c** of Bash disclose the controllable partition of the '179 patent under Patent Owner's expected construction of “partition.”

242. Bash discloses that the “the shape and/or opening size of the vents **36a-36c**” are manipulable to vary the “velocity and the volume flow rate of the cooling fluid” that passes through the vents and into the zone. Ex. 1005, [0019]. As discussed above, Bash also discloses manipulating the vents in response to sensed temperature being outside of a predetermined temperature range. Ex. 1005, FIG. 3A, [0050]–[0052].

243. Limitation 9[c] of the '179 patent is therefore disclosed by Bash.

10.Claim 10 – “The method according to claim 4, further comprising: performing a numerical modeling of a temperature distribution and flow characteristics of the data center; and manipulating said cooling device in response to said numerical modeling.”

244. Claim 10 recites, “[t]he method according to claim 4, further comprising: performing a numerical modeling of a temperature distribution and flow characteristics of the data center; and manipulating said cooling device in response to said numerical modeling.” In my opinion, Bash discloses this claim.

245. As explained above, Bash discloses the method of claim 4.

246. Bash discloses a “method . . . comprising: performing a numerical modeling of a temperature distribution and flow characteristics of the data center; and manipulating said cooling system in response to said numerical modeling.” Ex. 1005, Claim 20.

247. Bash also discloses that the cooling system includes a “cooling device having a fan,” so a POSITA would understand that manipulating the cooling system is synonymous with manipulating the cooling device. Ex. 1005, [0005].

248. Moreover, Bash discloses inputting velocity of the cooling fluid flowing through various sections of the data center and the distribution of temperature and pressure of the cooling fluid into a computational fluid dynamics (CFD) tool. Bash teaches using “a numerical model of the data center [produced by the CFD tool] to thus determine an optimized cooling distribution of the data center.” Ex. 1005, [0066]. Bash also teaches incorporating the numerical model into

the control logic summarized in Figure 3A “to determine whether the cooling system intake should be decreased based upon the heat loads and the fluid flow throughout the data center.” Ex. 1005, [0067].

249. Thus, Bash teaches using CFD tools to generate a numerical model of cooling fluid flow, temperature, and/or pressure in a data center. Bash also teaches using that numerical model to manipulate the operation of the air conditioning units (i.e. cooling devices).

250. Claim 10 of the '179 patent is therefore anticipated by Bash.

11.Claim 11 – “The method according to claim 5, further comprising: increasing the output of said cooling device in response to said measured pressure falling below or equaling said predetermined minimum set point pressure.”

251. Claim 11 recites, “[t]he method according to claim 5, further comprising: increasing the output of said cooling device in response to said measured pressure falling below or equaling said predetermined minimum set point pressure.” In my opinion, Bash discloses this claim.

252. As explained above, Bash discloses the method of claim 5.

253. Bash discloses that if the absolute value of the measured supply air pressure is “below or equal to the $P_{\min, \text{set}}$, the cooling system controller **246** may operate to increase the cooling fluid intake, e.g., by increasing the speed of the fan **24** at step **370**.” Ex. 1005, [0062].

254. And because Bash discloses that the “cooling fluid is circulated in the data center by a cooling device having a fan,” a POSITA would understand that increasing the speed of the fan **24** increases the output of cooling fluid from the cooling device. Ex. 1005, [0005].

255. Claim 11 of the '179 patent is therefore anticipated by Bash.

12.Claim 12 – “The method according to claim 5, further comprising: decreasing the output of said cooling device in response to said measured pressure exceeding said predetermined minimum set point pressure.”

256. Claim 12 recites, “[t]he method according to claim 5, further comprising: decreasing the output of said cooling device in response to said measured pressure exceeding said predetermined minimum set point pressure.” In my opinion, Bash discloses this claim.

257. As explained above, Bash discloses the method of claim 5.

258. Bash discloses that if the measured supply air pressure exceeds the $P_{\min, \text{set}}$, and thereby exceeds the $P_{\max, \text{set}}$, the cooling system controller **246** may decrease the intake of the cooling fluid by decreasing the fan speed. Ex. 1005, [0062]; *see also* Ex. 1005, FIG. 3B. Bash also explains that $P_{\min, \text{set}}$ is a minimum pressure set point of a predetermined pressure range. Ex. 1005, [0061]. Thus, $P_{\min, \text{set}}$ discloses the predetermined minimum set point pressure of claim 12 of the '179 patent.

259. And because Bash discloses that the “cooling fluid is circulated in the data center by a cooling device having a fan,” a POSITA would understand that decreasing the speed of the fan **24** decreases the output of cooling fluid from the cooling device. Ex. 1005, [0005].

260. Claim 12 of the '179 patent is therefore anticipated by Bash.

13.Claim 13 – “The method according to claim 6, further comprising: increasing an output of said cooling fluid from said cooling device in response to said decrease in cooling fluid supply to said zone falling below said increase in cooling fluid supply to said zone.”

261. Claim 13 recites, “[t]he method according to claim 6, further comprising: increasing an output of said cooling fluid from said cooling device in response to said decrease in cooling fluid supply to said zone falling below said increase in cooling fluid supply to said zone.” In my opinion, Bash discloses this claim.

262. As explained above, Bash discloses the method of claim 6.

263. Bash further discloses that “if the total amount of increases in the volume flow rates of the cooling fluid exceeds the total amount of decreases, the cooling system controller **246** may operate to increase the cooling system intake at step **318**.” Ex. 1005, [0054]. Bash explains that “increas[ing] the cooling fluid intake” may be accomplished “by increasing the speed of the fan **24**.” Ex. 1005, [0062]. As previously explained, the intake of cooling fluid by the cooling system of Bash correlates to the output of cooling fluid by the cooling system. And because

Bash discloses that the “cooling fluid is circulated in the data center by a cooling device having a fan,” increasing the speed of the fan **24** increases the output of cooling fluid from the cooling device.

264. Claim 13 of the '179 patent is therefore anticipated by Bash.

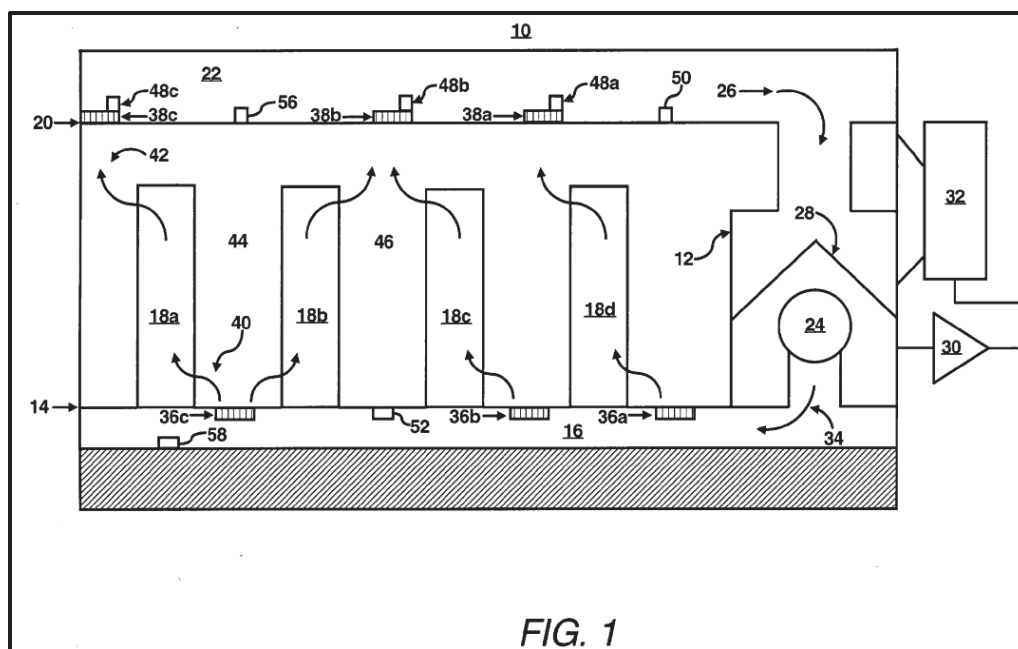
14.Claim 14 – “The method according to claim 7, further comprising: determining whether said at least one associated rack having a measured temperature that exceeds said predetermined minimum set point temperature is relatively downstream of the supply of said cooling fluid from said at least one associated rack having a measured temperature that fall below or equal said predetermined minimum set point temperature; and controlling said one or more vents to decrease the supply of said cooling fluid to said at least one associated rack being relatively upstream of the supply of said cooling fluid and controlling said one or more vents to increase the supply of said cooling fluid to said at least one associated rack being relatively downstream of the supply of said cooling fluid in response to determining said at least one associated rack having a measured temperature that exceeds said predetermined minimum set point temperature is relatively downstream of the supply of said cooling fluid from said at least one associated rack having a measured temperature that fall below or equal said predetermined minimum set point temperature.”

265. Claim 14 recites “[t]he method according to claim 7, further comprising: determining whether said at least one associated rack having a measured temperature that exceeds said predetermined minimum set point temperature is relatively downstream of the supply of said cooling fluid from said at least one associated rack having a measured temperature that fall below or equal said predetermined minimum set point temperature; and controlling said one or more vents to decrease the supply of said cooling fluid to said at least one

associated rack being relatively upstream of the supply of said cooling fluid and controlling said one or more vents to increase the supply of said cooling fluid to said at least one associated rack being relatively downstream of the supply of said cooling fluid in response to determining said at least one associated rack having a measured temperature that exceeds said predetermined minimum set point temperature is relatively downstream of the supply of said cooling fluid from said at least one associated rack having a measured temperature that fall below or equal said predetermined minimum set point temperature.” In my opinion, Bash discloses this claim.

266. As explained above, Bash discloses the method of claim 7.

267. Bash discloses controlling the vents **36a–36c** so as to selectively vary the supply of cooling fluid to data center zones based on sensed temperatures associated with the racks in each zone. Bash’s disclosed cooling system is adapted for a typical data center layout having racks arranged in cold aisles that include floor vents to supply cooling air and hot aisles having returns to remove air. Ex. 1005, FIG. 1, [0020]. Figure 1 illustrates this arrangement and shows cooling air supplied by fan 24 flowing under a raised floor plenum towards adjacent aisles (e.g. **44, 46**) in the direction of arrow **34**.



Ex. 1005, FIG. 1.

268. Racks **18a**, **18b** and associated vent **36c** are downstream of racks **18c**, **18d** and associated vents **36b**, **36a** relative to the location of the cooling air source. It follows directly from Bash's teachings that the controller is operable to increase cooling air flow through vent **36c** in response to a high temperature condition sensed at relatively downstream racks **18a** and/or **18b**, and to decrease cooling air flow through vents **36a** and/or **36b** in response to a low temperature condition sensed at relatively upstream racks **18c** and/or **18d**.

269. Claim 14 of the '179 patent is therefore anticipated by Bash.

15.Claim 15 – “The method according to claim 10, further comprising: implementing said numerical modeling to correlate at least two of temperature, velocity and pressure of said cooling fluid and power draw of at least one of said zone and said racks within said data center to thereby infer a thermal condition throughout said data center, wherein said manipulating step further comprises manipulating said cooling device in response to said inferred thermal condition.”

270. Claim 15 recites, “[t]he method according to claim 10, further comprising: implementing said numerical modeling to correlate at least two of temperature, velocity and pressure of said cooling fluid and power draw of at least one of said zone and said racks within said data center to thereby infer a thermal condition throughout said data center, wherein said manipulating step further comprises manipulating said cooling device in response to said inferred thermal condition.” In my opinion, Bash discloses this claim.

271. As explained above, Bash discloses the method of claim 10.

272. Bash teaches “[a] correlation of one or more of the following properties: velocity of the cooling fluid flowing through various sections of the data center, distribution of temperature and pressure of the cooling fluid in the data center, 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 data center when only a minimum number of sensors are available during operation of the cooling system.” Ex. 1005, [0066]. Bash teaches that the numerical model

may be incorporated into the control logic to determine whether the cooling system intake should be adjusted. Ex. 1005, [0067].

273. Bash also recites this technique in its claims: “implementing said numerical modeling to correlate at least two of temperature, velocity and pressure of said cooling fluid and power draw of said racks within said data center to thereby infer a thermal condition throughout said data center, wherein said manipulating step further comprises manipulating said cooling system in response to said inferred thermal condition.” Ex. 1005, Claim 21. Bash discloses that the cooling system includes a “cooling device having a fan,” so a POSITA would understand that manipulating the cooling system is synonymous with manipulating the cooling device. Ex. 1005, [0005].

274. Claim 15 of the ’179 patent is therefore anticipated by Bash.

B. GROUND 2: CLAIMS 1–7 AND 10–15 ARE ANTICIPATED BY PATEL

275. For the reasons set forth below, it is my opinion that Patel discloses all of the limitations of claims 1–7 and 10–15 of the ’179 patent if the claims are construed according to Patent Owner’s broad litigation assertions regarding the meaning of “partition.”

1. Claim 1

276. I discuss each limitation of claim 1 in turn below, in conjunction with the relevant disclosures of each claim limitation by Patel.

a. 1[pre] – “A method of cooling a plurality of racks in a data center, said method comprising:”

277. The preamble of claim 1 recites, “[a] *method of cooling a plurality of racks in a data center, said method comprising.*”

278. I have been informed that claim preambles are generally not limiting. In any case, I believe that Patel discloses the preamble.

279. For example, Patel discloses “a method of cooling a plurality of racks in a data center.” Ex. 1006, 2:27–29; Claim 14.

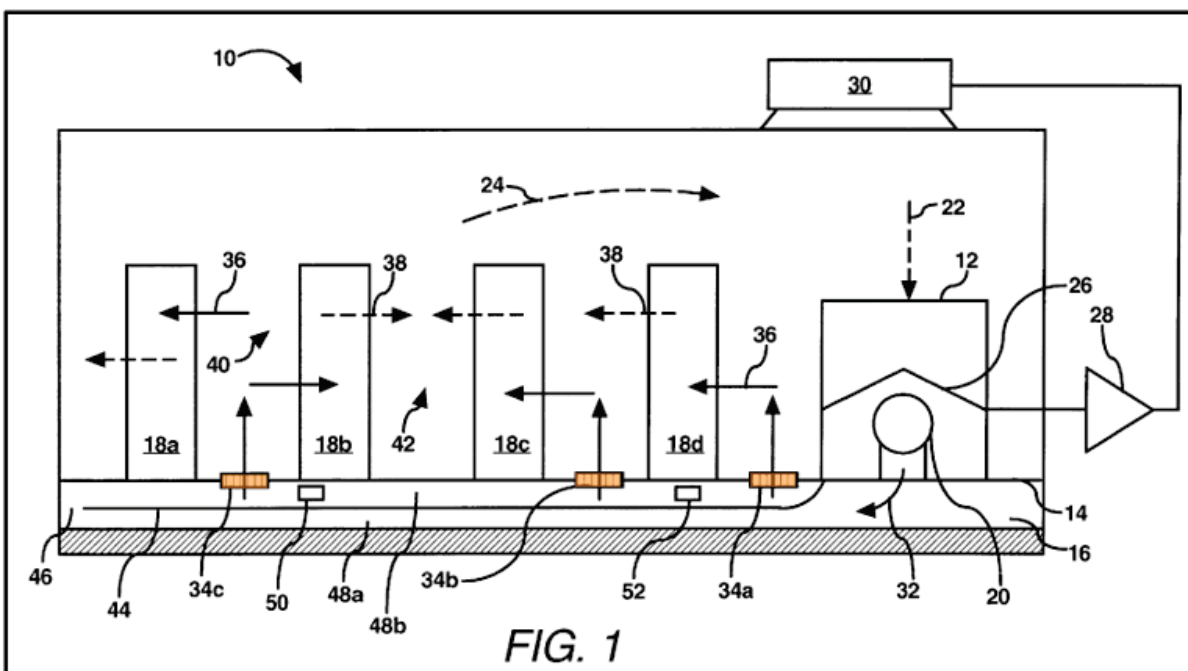
280. Thus, if the preamble is a limitation of claim 1, Patel discloses limitation 1[pre].

b. 1[a] – “activating a cooling device and opening a controllable partition configured to vary a supply of cooling fluid within a zone of said data center, said zone including at least one associated rack of said plurality of racks;”

281. Claim 1 further recites “*activating a cooling device and opening a controllable partition configured to vary a supply of cooling fluid within a zone of said data center, said zone including at least one associated rack of said plurality of racks.*” In my opinion, Patel discloses this limitation.

282. Patel discloses a data center **10** containing a cooling system **12**, a zone above a raised floor **14** with a plurality of racks **18a–18d** that house a plurality of electronic components, and a space **16** beneath the raised floor **14** that may function as a plenum to deliver cooling fluid (e.g., air) from the cooling system **12** to the

plurality of racks **18a–18d**. Ex. 1006, 3:48–54; 4:7–44; Figure 1 (reproduced and annotated below). “The cooling system **12** generally includes a fan **20** for supplying cooling fluid into the space **16** (e.g., plenum)” as indicated by arrow **32**. Ex. 1006, 4:44–45; 5:6–27; Figure 1. “Air is supplied into the fan **20** from the heated air in the data center **10** as indicated by arrows **22** and **24**” that is cooled by the cooling system **12** before being delivered into the space **16** (e.g., plenum). Ex. 1006, 4:45–52; 5:6–27.

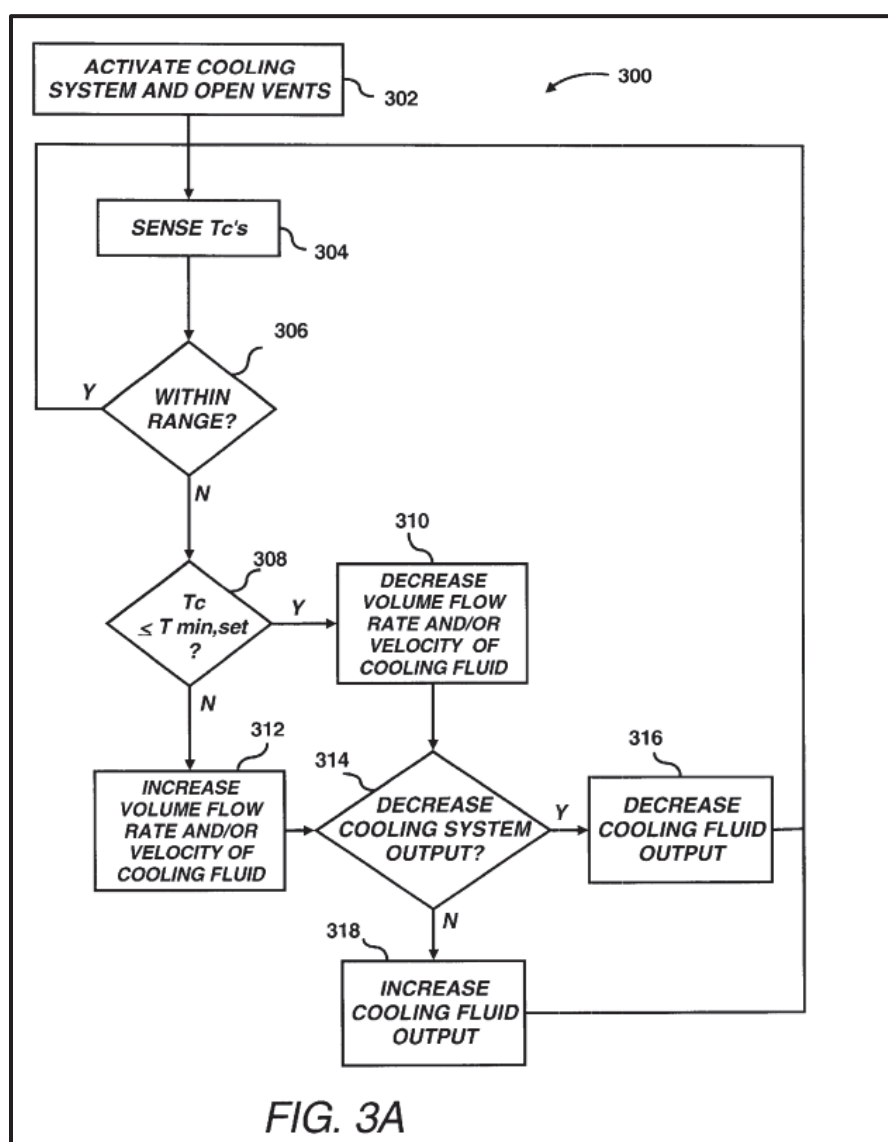


Ex. 1006, FIG. 1 (annotated).

283. Patel further discloses the cooling fluid being delivered to the plurality of racks **18a–18d** by “flow[ing] out of the raised floor **14** through a plurality of dynamically controllable vents **34a–34c** [(annotated in orange)] that generally operate to control the velocity and the volume flow rate of the cooling fluid

therethrough” and into the zone above the raised floor **14** where the plurality of racks **18a–18d** are located. Ex. 1006, 5:6–28.

284. Patel also teaches a method of operating the cooling system in the flow diagram **300** of Figure 3A of Patel, provided below. In the first step **302** of this method, “the cooling system **202** is activated and the vents **206–210** . . . are opened.” Ex. 1006, 10:16–17.



Ex. 1006, FIG. 3A.

285. Patel also discloses that the “smart cooling system for cooling racks in a data center . . . includes a cooling device for supplying cooling fluid to the racks. The cooling device includes a variable output fan and a variable capacity compressor.” Ex. 1006, 2:16–19.

286. Patel discloses the cooling fluid of the ’179 patent under both Petitioner’s proposed construction of “cooling fluid” and Patent Owner’s expected construction, which each include cooling air. Patel teaches that “cooling fluid (e.g., *air*)” is delivered “to various areas of a data center” Ex. 1006, 1:6–8 (emphasis added). Thus, Patel discloses the cooling fluid recited in claim 1 of the ’179 patent under Petitioner’s proposed construction (i.e. air).

287. With regard to a “controllable partition,” Patel’s controllable vents (e.g., **34a-34c**) disclose the controllable partition under Patent Owner’s expected construction of “partition” to encompass any device capable of manipulating the flow of cooling fluid. As discussed above, the dynamically controllable vents **34a-34c** operate to control the velocity and the volume flow rate of the cooling air into aisles of the data center containing racks. Ex. 1006, 5:8–11. For example, Patel teaches that the “cool aisles **40** are those aisles that include the vents **3[4]a-3[4]c** and thus receive cooling fluid for delivery to the racks **18a-18d**.” Ex. 1006, 5:23–26.

288. I have therefore concluded that Patel discloses limitation 1[a] under Patent Owner’s expected construction of “partition.”

c. 1[b] – “sensing the temperature of said at least one associated rack;”

289. Claim 1 recites “*sensing the temperature of said at least one associated rack.*” In my opinion, Patel discloses this limitation.

290. Patel teaches detecting temperatures via “a plurality of temperature sensors **212-216**, e.g., thermocouples, [that] may be positioned at various positions around the subsystems and/or the racks **18a-18d**.” Ex. 1006, 7:16–19. Patel also teaches that the cooling system “may include any reasonably suitable number of temperature sensors to thus measure the temperatures of any reasonably suitable number of racks **18a-18d** or portions thereof.” 1006, 7:37–41.

291. Thus, Patel teaches sensing the temperature of said at least one associated rack, as recited in limitation 1[b].

d. 1[c] – “determining whether said sensed temperature is within a predetermined temperature range; and”

292. Claim 1 recites “*determining whether said sensed temperature is within a predetermined temperature range.*” In my opinion, Patel discloses this limitation.

293. Patel discloses that the temperatures of the components (T_C ’s) are individually sensed by the temperature sensors and then it is determined whether each measured temperature is within a predetermined range of operating

temperatures, e.g., between $T_{\max, \text{set}}$ and $T_{\min, \text{set}}$. Ex. 1006, 10:35–43; *see also* Ex. 1006, FIGS. 3A and 3B.

294. Thus, Patel teaches determining whether said sensed temperature is within a predetermined temperature range, as recited in claim 1.

e. 1[d] – “**manipulating said controllable partition to vary said supply of said cooling fluid to said zone in response to said sensed temperature being outside said predetermined temperature range.**”

295. Claim 1 recites “*manipulating said controllable partition to vary said supply of said cooling fluid to said zone in response to said sensed temperature being outside said predetermined temperature range.*” In my opinion, Patel discloses this limitation.

296. As discussed above with respect to limitation 1[a], the vents of Patel disclose the controllable partition Patent Owner’s expected construction of “partition.”

297. Patel further discloses that the “the shape and/or opening size of the vents **34a-34c**” are manipulable to vary the “velocity and the volume flow rate of the cooling fluid” that passes through the vents and into the zone containing racks **18a-18d**. Ex. 1006, 5:7–17. Patel also discloses manipulating the vents in response to said sensed temperature being outside said predetermined temperature range. Thus, “[i]f the T_C ’s of some of the racks are below or equal to the $T_{\min, \text{set}}$, the vent controller **204** may operate to decrease the volume flow rate and/or the velocity of

cooling fluid to those racks at step **310**.” Ex. 1006, 11:6–0. Likewise, “[i]f the T_C ’s of some of the racks exceed the $T_{\min, \text{set}}$ (i.e., also exceed the $T_{\max, \text{set}}$), the vent controller **204** may operate to increase the volume flow rate and/or the velocity of cooling fluid to those racks at step **312**.” Ex. 1006, 11:20–23.

298. Thus, Patel teaches manipulating said controllable partition to vary said supply of said cooling fluid to said zone in response to said sensed temperature being outside said predetermined temperature range, as recited in limitation 1[d].

2. Claim 2

299. I discuss each limitation of claim 2 in turn below, in conjunction with the relevant disclosures of each claim limitation by Patel.

- a. 2[a] – **“The method according to claim 1, further comprising: determining whether the measured temperature of said at least one associated rack is below or equal to a predetermined minimum set point temperature; and”**

300. Claim 2 recites “[t]he method according to claim 1, further comprising: determining whether the measured temperature of said at least one associated rack is below or equal to a predetermined minimum set point temperature.” In my opinion, Patel discloses this limitation.

301. As explained above, Patel discloses the method of claim 1 under Patent Owner’s expected construction of “partition.”

302. As explained in relation to claim 1, Patel’s vent controller determines whether sensed rack temperatures are below a preset temperature range. Ex. 1006, 10:38–43, 10:53–61.

303. Limitation 2[a] of the ’179 patent is therefore disclosed by Patel.

b. 2[b] – “decreasing the supply of said cooling fluid to said zone in response to said at least one associated rack having a measured temperature that falls below or equal said predetermined minimum set point temperature.”

304. Claim 2 recites “*decreasing the supply of said cooling fluid to said zone in response to said at least one associated rack having a measured temperature that falls below or equal said predetermined minimum set point temperature.*” In my opinion, Patel discloses this limitation.

305. Referring again to Figure 3A, shown above, Patel discloses that “[i]f the T_C ’s of some of the racks are below or equal to the $T_{min, set}$, the vent controller **204** may operate to decrease the volume flow rate and/or the velocity of cooling fluid to those racks at step **310**.” Ex. 1006, 11:6–9.

306. Limitation 2[b] of the ’179 patent is therefore disclosed by Patel.

3. Claim 3

307. I discuss each limitation of claim 3 in turn below, in conjunction with the relevant disclosures of each claim limitation by Patel.

a. 3[a] – “The method according to claim 1, further comprising: sensing a pressure of a supply of said cooling fluid;”

308. Claim 3 recites “[t]he method according to claim 1, further comprising: sensing a pressure of a supply of said cooling fluid.” In my opinion, Patel discloses this limitation.

309. As explained above, Patel discloses the method of claim 1.

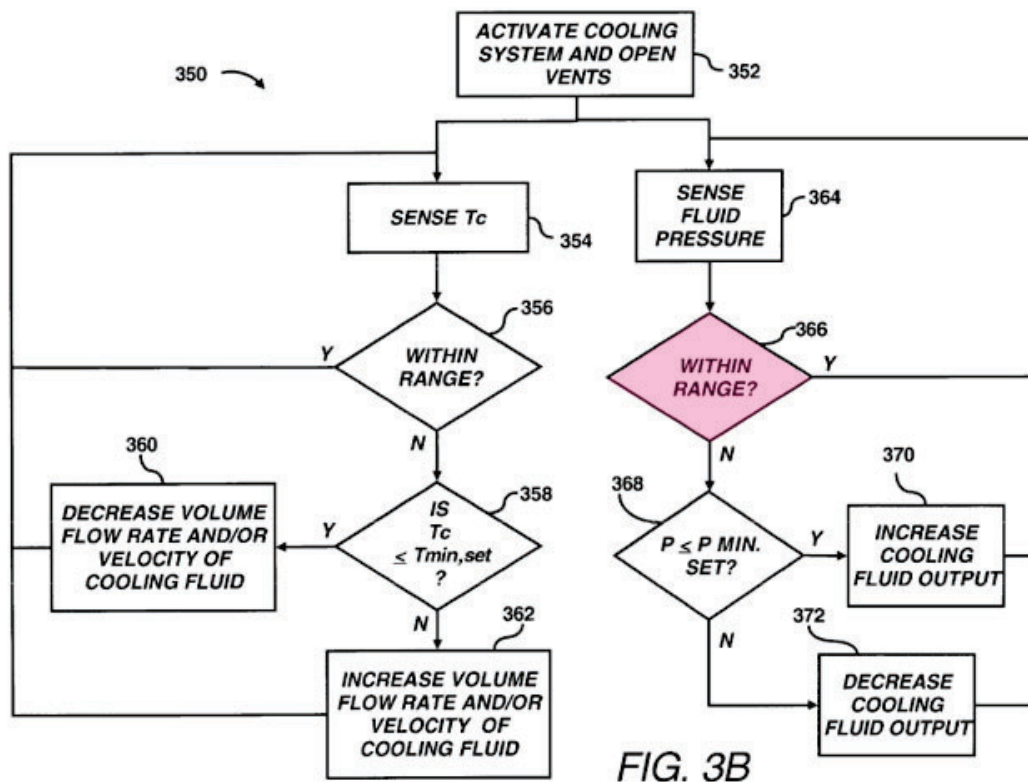
310. Patel also teaches that “the pressure of the cooling fluid supplying the vents **206-210** may be measured by a pressure sensor **232**.” Ex. 1006, 12:52–54.

311. Limitation 3[a] of the ’179 patent is therefore disclosed by Patel.

b. 3[b] – “determining whether said sensed pressure is within a predetermined pressure range; and”

312. Claim 3 recites “*determining whether said sensed pressure is within a predetermined pressure range.*” In my opinion, Patel discloses this limitation.

313. As shown in Figure 3B of Patel, reproduced and annotated below, Patel teaches “determin[ing] whether the measured pressure is within a predetermined pressure range, e.g., a predetermined minimum set point pressure ($P_{\min, \text{set}}$) and a predetermined maximum set point pressure ($P_{\max, \text{set}}$), at step **366**” (annotated in pink). Ex. 1006, 12:56–60.



Ex. 1006, FIG. 3B (annotated).

314. Limitation 3[b] of the '179 patent is therefore anticipated by Patel.

c. 3[c] – “varying an output of said cooling device in response to said sensed pressure falling outside of said predetermined pressure range.”

315. Claim 3 recites “*varying an output of said cooling device in response to said sensed pressure falling outside of said predetermined pressure range.*” In my opinion, Patel discloses this limitation.

316. Patel teaches that “the predetermined pressure range pertains to the threshold pressures to determine whether to increase or decrease the supply of fluid, e.g., in the second chamber **48b**” of the space (plenum) **16** below the raised floor **14** of the data center. Ex. 1006, 13:4–7.

317. For example, as shown in Figure 3B of Patel, provided above, “[i]f the [measured] P[ressure] is determined to be below or equal to the $P_{\min, \text{set}}$, the cooling system controller **222** may operate to increase the cooling fluid output, e.g., by increasing the compressor capacity and/or the fan output, at step **370**. Otherwise, if the [measured] P[ressure] is determined to exceed the $P_{\min, \text{set}}$, and thereby exceed the $P_{\max, \text{set}}$, the cooling system controller **222** may operate to decrease cooling fluid output, e.g., by decreasing the compressor capacity and/or the fan output, at step **372**.” Ex. 1006, 13:13–20. Varying the fan output varies the cooling air output of the cooling device.

318. Limitation 3[c] of the ’179 patent is therefore disclosed by Patel.

4. Claim 4 – “The method according to claim 2, further comprising: increasing the supply of said cooling fluid to said zone in response to said at least one associated rack having a measured temperature that exceed said predetermined minimum set point temperature.”

319. Claim 4 recites “[t]he method according to claim 2, further comprising: increasing the supply of said cooling fluid to said zone in response to said at least one associated rack having a measured temperature that exceed said predetermined minimum set point temperature.” In my opinion, Patel discloses this claim.

320. As explained above, Patel discloses the method of claim 2, which requires decreasing the cooling fluid supplied to a zone in response to a measured rack temperature being below or equal to a minimum set point temperature. Thus,

based on its dependency from that claim, claim 4 requires decreasing the cooling fluid flow to a zone at one time and increasing the cooling fluid flow at another time.

321. Patel's system is capable of both decreasing and increasing the cooling fluid flow to a zone as the sensed temperature conditions dictate. Patel teaches that "[i]f the T_C 's of some of the racks exceed the $T_{\min, \text{set}}$ (i.e., also exceed the $T_{\max, \text{set}}$), the vent controller **204** may operate to increase the volume flow rate and/or the velocity of cooling fluid to those racks at step **312**." Ex. 1006, 11:20–23. Patel also defines T_C as a measured temperature of a component (such as a rack) and $T_{\min, \text{set}}$ as the "minimum set point temperature" of the "predetermined range of operating temperatures." Ex. 1006, 10:35–43.

322. Claim 4 of the '179 patent is therefore disclosed by Patel.

5. Claim 5 – “The method according to claim 3, wherein said step of varying said cooling device output includes determining whether said measured pressure falls below or equals a predetermined minimum set point pressure.”

323. Claim 5 recites “[t]he method according to claim 3, wherein said step of varying said cooling device output includes determining whether said measured pressure falls below or equals a predetermined minimum set point pressure.” In my opinion, Patel discloses this claim.

324. As explained above, Patel discloses the method of claim 3.

325. Patel teaches “determin[ing] whether the measured pressure (P) is below or equal to a minimum pressure set point ($P_{\min, \text{set}}$) at step **368**.” Ex. 1006, FIG. 3B; 13:2–4.

326. Claim 5 of the ’179 patent is therefore anticipated by Patel.

6. Claim 6 – “The method according to claim 4, further comprising: decreasing an output of said cooling fluid from said cooling device in response to said decrease in cooling fluid supply to said zone exceeding said increase in cooling fluid supply to said zone.”

327. Claim 6 recites, “[t]he method according to claim 4, further comprising: decreasing an output of said cooling fluid from said cooling device in response to said decrease in cooling fluid supply to said zone exceeding said increase in cooling fluid supply to said zone.” In my opinion, Patel discloses this claim.

328. As explained above, Patel discloses the method of claim 4.

329. Patel discloses that “if the total amount of decreases in the volume flow rates of the cooling fluid exceeds the total amount of increases in the volume flow rates flow of the cooling fluid, the cooling system controller **222** may operate to decrease the cooling fluid output at step **316**.” Ex. 1006, 11:57–61. Patel indicates that the cooling fluid output may be decreased by decreasing the output of the fan **226**. Ex. 1006, 11:51–53.

330. Patel also describes the additional step of claim 6 of the ’179 patent in its own claims. Claim 16 of Patel recites: “[t]he method according to claim 15,

further comprising: decreasing an output of said cooling fluid from said cooling system in response to said decrease in cooling fluid supply to said racks exceeding said increase in cooling fluid supply to said racks.” Ex. 1006, 17:45–50.

331. Therefore, claim 6 of the ’179 patent is anticipated by Patel for at least these reasons.

7. Claim 7 – “The method according to claim 4, further comprising: opening a plurality of vents, said vents being configured to supply cooling fluid to said racks; controlling one or more of said plurality vents to decrease the supply of said cooling fluid to said at least one associated rack having a measured temperature that fall below or equal said predetermined minimum set point temperature; and controlling said one or more vents to increase the supply of said cooling fluid to said at least one associated rack having a measured temperature that exceed said predetermined minimum set point temperature.”

332. Claim 7 recites “[t]he method according to claim 4, further comprising: opening a plurality of vents, said vents being configured to supply cooling fluid to said racks; controlling one or more of said plurality vents to decrease the supply of said cooling fluid to said at least one associated rack having a measured temperature that fall below or equal said predetermined minimum set point temperature; and controlling said one or more vents to increase the supply of said cooling fluid to said at least one associated rack having a measured temperature that exceed said predetermined minimum set point temperature.” In my opinion, Patel discloses this claim.

333. As explained above, claim 7 is redundant to claims 2 and 4 under Patent Owner's broad application of the term "partition," which includes any device that can manipulate cooling fluid flow and therefore would treat a vent as a type of partition. Therefore, my opinions stated above for claims 2 and 4 also apply to claim 7.

334. As explained above, Patel discloses the methods of claims 4 and 2.

335. Patel discloses opening a plurality of dynamically controllable vents **34a–34c** that are configured to supply cooling fluid to the plurality of racks **18a–18d**. Ex. 1006, 5:6–28. Patel further discloses controlling the vents **34a–34c** to decrease the supply of cooling fluid delivered to racks having a measured temperature (T_C) that falls below or equal to a predetermined minimum set point temperature ($T_{\min, \text{set}}$); and to increase the supply of cooling fluid delivered to racks having a measured temperature (T_C) that exceeds the predetermined minimum set point temperature ($T_{\min, \text{set}}$). Ex. 1006, 5:11–17; 11:6–23.

336. Claim 7 of the '179 patent is therefore anticipated by Patel.

8. Claim 10 – “The method according to claim 4, further comprising: performing a numerical modeling of a temperature distribution and flow characteristics of the data center; and manipulating said cooling device in response to said numerical modeling.”

337. Claim 10 recites, “[t]he method according to claim 4, further comprising: performing a numerical modeling of a temperature distribution and

flow characteristics of the data center; and manipulating said cooling device in response to said numerical modeling.” In my opinion, Patel discloses this claim.

338. As explained above, Patel discloses the method of claim 4.

339. Patel discloses inputting cooling fluid flow velocities and temperature and pressure distribution data into a computational fluid dynamics (CFD) tool and generating a numerical model of the data center “to determine an optimal manner in which the air conditioning units may be operated as well as the flow of the cooling fluid through the vents to adequately cool the racks based upon an analysis of the data center layout and the heat loads.” Ex. 1006, 14:27–40.

340. Thus, Patel teaches using CFD tools to generate a numerical model of cooling fluid flow, temperature, and/or pressure in a data center. Patel also teaches using that numerical model to manipulate the operation of the air conditioning units (i.e., cooling devices), for example to determine whether the cooling fluid output should be decreased based on heat loads and fluid flows throughout the data center. Ex. 1006, 14:52–62.

341. Patel also discloses this step in Patel’s claim 21 which recites: “performing a numerical modeling of a temperature distribution and flow characteristics of the data center; and manipulating said cooling system in response to said numerical modeling.” Ex. 1006, 18:4–9.

342. Claim 10 of the ’179 patent is therefore anticipated by Patel.

9. Claim 11 – “The method according to claim 5, further comprising: increasing the output of said cooling device in response to said measured pressure falling below or equaling said predetermined minimum set point pressure.”

343. Claim 11 recites, “[t]he method according to claim 5, further comprising: increasing the output of said cooling device in response to said measured pressure falling below or equaling said predetermined minimum set point pressure.” In my opinion, Patel discloses this claim.

344. As explained above, Patel discloses the method of claim 5.

345. Patel discloses that the “cooling device [] suppl[ies] cooling fluid to the racks” and “includes a variable output fan and a variable capacity compressor.” Ex. 1006, 2:16–19. Patel’s system measures pressure of cooling air in the raised floor supply plenum, and “[i]f the [measured pressure] P is determined to be below or equal to the $P_{\min, \text{set}}$, the cooling system controller **222** may operate to increase the cooling fluid output, e.g., by increasing the compressor capacity and/or the fan output, at step **370**.” Ex. 1006, 13:13–16.

346. Claim 11 of the ’179 patent is therefore anticipated by Patel.

10. Claim 12 – “The method according to claim 5, further comprising: decreasing the output of said cooling device in response to said measured pressure exceeding said predetermined minimum set point pressure.”

347. Claim 12 recites, “[t]he method according to claim 5, further comprising: decreasing the output of said cooling device in response to said

measured pressure exceeding said predetermined minimum set point pressure.” In my opinion, Patel discloses this claim.

348. As explained above, Patel discloses the method of claim 5.

349. In Patel’s system, “if the [measured] P[ressure] is determined to exceed the $P_{\min, \text{set}}$, and thereby exceed the $P_{\max, \text{set}}$, the cooling system controller **222** may operate to decrease cooling fluid output, e.g., by decreasing the compressor capacity and/or the fan output, at step **372**.” Ex. 1006, 13:13–20. Patel also explains that $P_{\min, \text{set}}$ is a “predetermined minimum set point pressure.” Ex. 1006, 12:58.

350. And because the cooling device in Patel outputs cooling fluid and includes a compressor and a fan, decreasing the cooling fluid output in Patel is synonymous with decreasing the output of the cooling device. Ex. 1006, 2:17–19.

351. Claim 12 of the ’179 patent is therefore anticipated by Patel.

11.Claim 13 – “The method according to claim 6, further comprising: increasing an output of said cooling fluid from said cooling device in response to said decrease in cooling fluid supply to said zone falling below said increase in cooling fluid supply to said zone.”

352. Claim 13 recites, “[t]he method according to claim 6, further comprising: increasing an output of said cooling fluid from said cooling device in response to said decrease in cooling fluid supply to said zone falling below said increase in cooling fluid supply to said zone.” In my opinion, Patel discloses this claim.

353. As explained above, Patel discloses the method of claim 6.

354. Patel's cooling system controller 222 can determine whether to adjust the cooling fluid output of the cooling device, such as by varying the fan speed. Ex. 1006, 11:51–53. Patel discloses that “if the total amount of increases in the volume flow rates of the cooling fluid exceeds the total amount of decreases, the cooling system controller **222** may operate to increase the cooling system output at step **318**.” Ex. 1006, 11:61–65.

355. Also, claim 17 of Patel recites: “increasing an output of said cooling fluid from said cooling system in response to said decrease in cooling fluid supply to said racks falling below said increase in cooling fluid supply to said racks.” Ex. 1006, 17:51–56.

356. For at least these reasons, claim 13 of the '179 patent is anticipated by Patel.

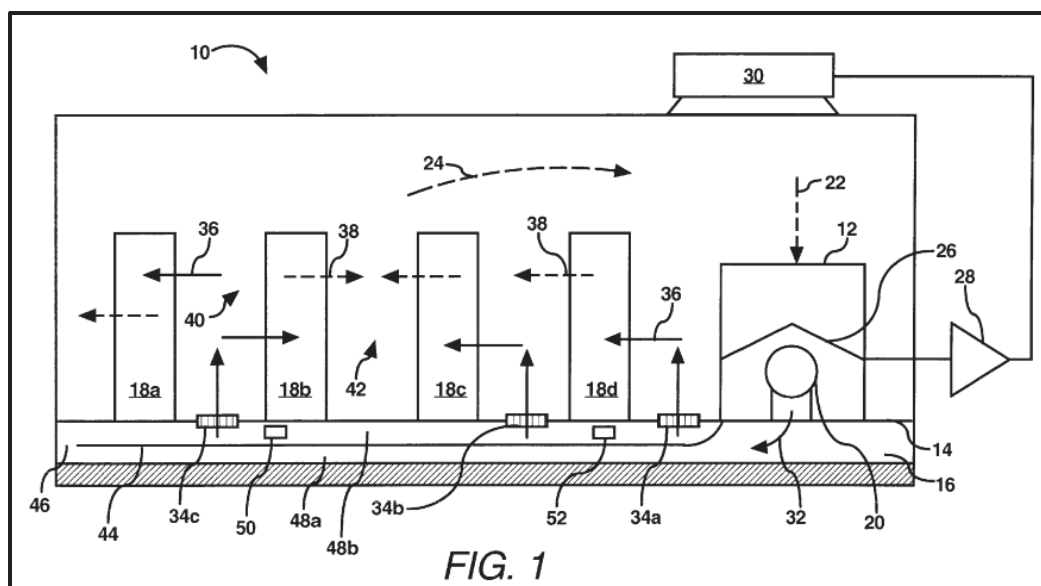
12.Claim 14 – “The method according to claim 7, further comprising: determining whether said at least one associated rack having a measured temperature that exceeds said predetermined minimum set point temperature is relatively downstream of the supply of said cooling fluid from said at least one associated rack having a measured temperature that fall below or equal said predetermined minimum set point temperature; and controlling said one or more vents to decrease the supply of said cooling fluid to said at least one associated rack being relatively upstream of the supply of said cooling fluid and controlling said one or more vents to increase the supply of said cooling fluid to said at least one associated rack being relatively downstream of the supply of said cooling fluid in response to determining said at least one associated rack having a measured temperature that exceeds said predetermined minimum set point temperature is relatively downstream of the supply of said cooling fluid from said at least one associated rack having a measured temperature that fall below or equal said predetermined minimum set point temperature.”

357. Claim 14 recites “[t]he method according to claim 7, further comprising: determining whether said at least one associated rack having a measured temperature that exceeds said predetermined minimum set point temperature is relatively downstream of the supply of said cooling fluid from said at least one associated rack having a measured temperature that fall below or equal said predetermined minimum set point temperature; and controlling said one or more vents to decrease the supply of said cooling fluid to said at least one associated rack being relatively upstream of the supply of said cooling fluid and controlling said one or more vents to increase the supply of said cooling fluid to said at least one associated rack being relatively downstream of the supply of said cooling fluid in response to determining said at least one associated rack having a

measured temperature that exceeds said predetermined minimum set point temperature is relatively downstream of the supply of said cooling fluid from said at least one associated rack having a measured temperature that fall below or equal said predetermined minimum set point temperature.” In my opinion, Patel discloses this claim.

358. As explained above, Patel discloses the method of claim 7.

359. Patel discloses controlling the vents **34a–34c** to selectively vary the supply of cooling fluid to data center zones based on sensed temperatures associated with the racks in each zone. Ex. 1006, 5:8–17. Patel’s disclosed cooling system is adapted for a typical data center layout having racks arranged in cold aisles that include floor vents to supply cooling air and hot aisles that receive air heated by the computer equipment. Ex. 1006, FIG. 1, 5:21–28. Figure 1 illustrates this arrangement and shows cooling air supplied by fan 20 flowing under a raised floor plenum towards adjacent aisles (e.g. **40, 42**) in the direction of arrow **32**.



Ex. 1006, FIG. 1.

360. Racks **18a**, **18b** and associated vent **34c** are downstream of racks **18c**, **18d** and associated vent **34b**, **34a** relative to the location of the cooling air source. It follows directly from Patel's teachings that the controller is operable to increase cooling air flow through vent **34c** in response to a high temperature condition sensed at relatively downstream racks **18a** and/or **18b**, and to decrease cooling air flow through vents **34a** and/or **34b** in response to a low temperature condition sensed at relatively upstream racks **18c** and/or **18d**.

361. Claim 14 of the '179 patent is therefore anticipated by Patel.

13.Claim 15 – “The method according to claim 10, further comprising: implementing said numerical modeling to correlate at least two of temperature, velocity and pressure of said cooling fluid and power draw of at least one of said zone and said racks within said data center to thereby infer a thermal condition throughout said data center, wherein said manipulating step further comprises manipulating said cooling device in response to said inferred thermal condition.”

362. Claim 15 recites, “[t]he method according to claim 10, further comprising: implementing said numerical modeling to correlate at least two of temperature, velocity and pressure of said cooling fluid and power draw of at least one of said zone and said racks within said data center to thereby infer a thermal condition throughout said data center, wherein said manipulating step further comprises manipulating said cooling device in response to said inferred thermal condition.” In my opinion, Patel discloses this claim.

363. As explained above, Patel discloses the method of claim 10.

364. Bash teaches that “[a] correlation of one or more of the following properties: velocity of the cooling fluid flowing through various sections of the data center, distribution of temperature and pressure of the cooling fluid in the data center, 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 data center when only a minimum number of sensors are available during operation of the cooling system.” Ex. 1006, 14:40–48. Patel also teaches that the numerical

model may be incorporated into the control logic to determine whether the cooling system intake should be adjusted. Ex. 1006, 14:52–56.

365. Patel’s claim 22 also describes the step of “implementing said numerical modeling to correlate at least two of temperature, velocity and pressure of said cooling fluid and power draw of said racks within said data center to thereby infer a thermal condition throughout said data center, wherein said manipulating step further comprises manipulating said cooling system in response to said inferred thermal condition.” Ex. 1006, 18:10–18.

366. Claim 15 of the ’179 patent is therefore anticipated by Patel.

C. GROUND 3: CLAIMS 1–6 and 11–13 ARE OBVIOUS OVER BISHOP IN VIEW OF FEENEY AND KOCHAVI

367. For the reasons set forth below, it is my opinion that claims 1–6 and 11–13 of the ’179 patent are rendered obvious by Bishop in view of Feeney and Kochavi.

368. In particular, as discussed in Section V.A. above, I have concluded that the plain meaning of the term “partition” as recited in the claims and used throughout the ’179 patent refers to “a barrier or wall that subdivides a space.” The only structures identified in the ’179 patent as being “partitions” are the vertical barriers **22a–22j** beneath the raised floor platform that subdivide the pressurized enclosure into zones. Ex. 1001, FIG. 1; 4:13–16. Some barriers are controllable by

a motorized mechanism, such as controllable partition 26f, which also divides the space into zones (i.e., zones **20g** and **20h**). Ex. 1001, FIG. 5, 16:9–10; 16:21–23.

369. If independent claim 1 is interpreted such that the controllable partitions are barriers that subdivide the plenum space, it is my opinion that a POSITA familiar with Bishop's teachings and Feeney's teachings would have been motivated to modify a preferred embodiment of Bishop by providing cooling air flow control dampers in the form of barriers that subdivide the space beneath Bishop's raised floor platform.

370. It would have been obvious to a skilled artisan to modify the system and methods of Bishop based on Feeney in view of their collective teachings, and based on a POSITA's knowledge of the art. Bishop and Feeney are closely analogous references directed to cooling of data center environments. Both references were directed to solving a similar problem – i.e., to provide cooling air for varying heat loads generated by computer equipment to maintain the temperature distribution throughout the environment within an acceptable range. Both offer a similar solution. They each describe a cooling system that distributes cooling air from a central source through a plenum beneath a raised floor platform. They each involve directing the cooling air to exit through specialized floor tiles near the heat-generating computer equipment positioned on the floor. Feeney directs the air flow by selectively opening or closing openings in vertically oriented side panels of

individual modules within the plenum space, and by providing vents in certain floor tiles through which the cooling air exits into the desired zones. Bishop accomplishes this through a similar approach of specialized floor tiles through which cooling air can exit through controllable air flow dampers and then flow through a computer cabinet.

371. Bishop does not expressly describe dampers or cooling air flow control devices that subdivide the space beneath its raised floor platform into zones. However, the closely related systems and methods disclosed in both references confirm that a POSITA would look to modify Bishop based on Feeney, or combine the interrelated teachings of the two references to arrive at the claimed invention. The similarities between the two references would have suggested to a POSITA following the ordinary process design to combine their teachings. It further confirms that it would have been obvious for a POSITA to try to combine the teachings, choosing from a finite number of predictable solutions, and to modify the controllable damper mechanism described in Bishop so that it forms a controllable barrier that subdivides the under-floor plenum space into zones, in addition to allowing for controlling cooling air flow to desired zones, and with a reasonable expectation of success.

372. A POSITA would understand that there are a limited number of ways to direct cooling air flow beneath a pressurized raised floor platform and cause the

cooling air to exit through the floor and into the above-floor environment at locations where cooling is needed. Bishop's approach of providing a vertically oriented supply conduit and associated controllable damper for directing cooling airflow upwards to exit through select floor tiles represents one known way to accomplish this. Bishop's disclosed system automatically adjusts the damper position in response to air temperatures sensed near the equipment to optimize the cooling fluid distribution. However, continually adjusting the amount of cooling air flowing through individual controllable dampers can cause the plenum air pressure to vary appreciably and create undesirable pressure imbalances. Bishop specifically acknowledges that disparate pressures in the space beneath the platform can cause operational challenges and should be avoided. Ex. 1008, [0088].

373. The '179 patent recognizes the benefits of subdividing the plenum of a pressurized raised floor enclosure into zones and controlling the flow of cooling air from one zone to another in order to better control the amount of cooling air delivered to the racks based on their respective heat loads. Ex. 1001, 4:11–31. It further shows the flexibility of such a system when operating multiple cooling devices to provide cooling air to a large number of racks, such as the four cooling systems 12a–12d for cooling sixteen racks illustrated in Figure 1. Ex. 1001, FIG. 1, 3:41–56. However, a POSITA would have already appreciated these benefits from the teachings of Feeney, which similarly provide a subdivided pressurized plenum

space to distribute cooling air output from multiple cooling devices (i.e. chilled water coils equipped with air blower fans) and teaches a POSITA to use adjustable vertical barriers to create subzones and flow paths within the plenum for directing sufficient cooling air to particular data center zones. Ex. 1013, 5:47–6:10.

374. It would have been obvious from a POSITA's knowledge of the art to look to another analogous reference such as Feeney in the same field that specifically teaches a plenum space subdivided by barriers that are adjustable to properly balance the supply of cooling fluid from multiple sources to multiple destinations within the data center.

375. In my opinion and based on my knowledge and experience, modifying Bishop's system to include subdividing barriers in the plenum space that are controllable to adjust air flow to different areas of the data center would have been exceedingly straightforward using the existing features of Bishop's system and the capabilities of a POSITA. Bishop includes vertically-oriented beams 76 supporting the raised floor support assembly 74. Ex. 1008, FIG. 5. It would have been straightforward for a POSITA to insert panels spanning adjacent beams and mechanically connect them to the beams to subdivide the plenum space into zones. A POSITA would have also been able to readily integrate Bishop's controllable dampers into such vertically-oriented panels. Cooling air supplied through a damper

into a zone would then flow upward through one or more of the existing openings in floor tile(s) of the zone.

376. The '179 patent recognizes that cooling fluid flow through a vertically-oriented, subdividing partition can be regulated by varying the size of an opening in the partition (Ex. 1001, 5:5:3–8), which is the same basic function of Bishop's controllable dampers. Furthermore, this approach would have predictably resulted in a greater ability to direct cooling air flow within the plenum space while maintaining stable pressure equilibrium. It would also have provided a more flexible and customizable system by permitting the data center heat loads to be managed in sub-zones, including through the use of multiple cooling devices, each device responsible for supplying cooling air to one or more particular zones. Furthermore, this approach would have predictably resulted in more consistent and reliable control of cooling air flow to locations where it is needed as well as more efficient operation of the entire cooling system.

377. Thus, in my opinion, ample motivation existed for a POSITA to make the above modifications to Bishop's system and methodology based on Feeney's teachings in order to arrive at the methods of the Bishop/Feeney Combination (the modifications and combinations discussed regarding Bishop and Feeney shall be referred to herein as the "Bishop/Feeney Combination"). I further explain in the following discussion my reasons for concluding that if interpreted to require the

“controllable partition” to be a controllable wall or barrier that subdivides a space (i.e., the plenum space), the Bishop/Feeney Combination renders obvious claim 1.

378. In the below discussion, I also provide and explain my opinions that dependent claims 2 and 4 also would have been obvious based on the Bishop/Feeney Combination and, that claims 3, 5, 6, and 11–13 would have been obvious further in view of Kochavi.

379. I should also note that under Patent Owner’s apparent construction of “partition” to include any device that can control gas or liquid flow, which is broader than Petitioner’s construction of that term, these claims would also have been obvious based on the combinations of references discussed below.

1. Claim 1

380. As explained below, Bishop discloses all limitations of independent claim 1 under Patent Owner’s broad construction and discloses most limitations under a narrower construction requiring “partition” to be a wall or barrier that subdivides a space. The Bishop/Feeney Combination discloses all limitations under either construction and renders claim 1 invalid for obviousness.

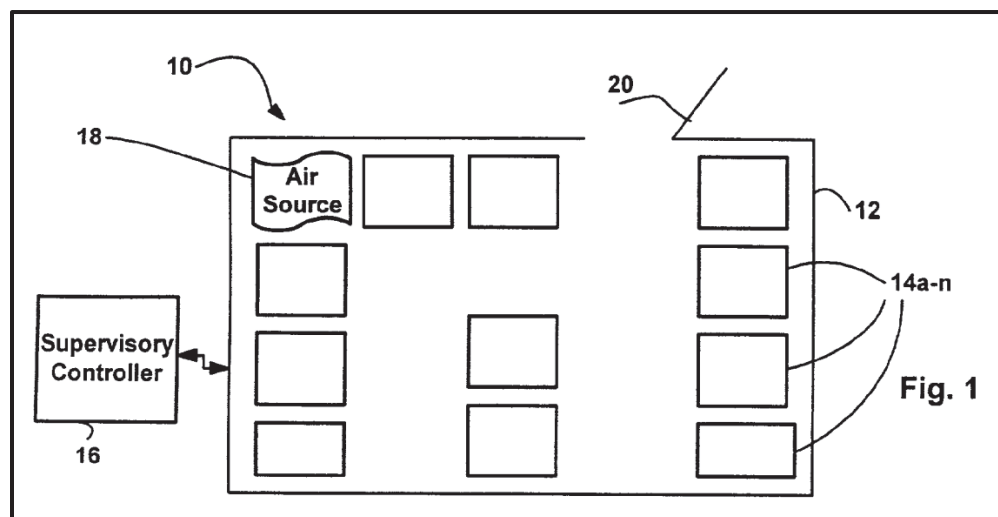
a. 1[pre] – “A method of cooling a plurality of racks in a data center, said method comprising:”

381. The preamble of claim 1 recites, “[a] *method of cooling a plurality of racks in a data center, said method comprising.*”

382. I have been informed that claim preambles are generally not limiting. In any case, I believe that the Bishop/Feeney Combination discloses this recitation.

383. Bishop is directed to “cooling at least one electronic module inside a module cabinet.” Ex. 1008, [0043]. Bishop further discloses that each cabinet “is typically constructed about each rack” (Ex. 1008, [0007]), with each rack including “computer servers and other electronic modules” (Ex. 1008, [0005]). Thus, Bishop is directed to cooling electronic module cabinets that enclose racks.

384. Bishop also discloses a plurality of electronic module cabinet assemblies **14a–n** arranged in a spaced format within a critical environment room **10**, as shown in Figure 1, reproduced below. Ex. 1008, [0062]. An air source **18** is located inside the critical environment **10** and provides cooling air to the environment. Ex. 1008, [0062]. Since the critical environment room **10** houses a number of racks, a POSITA would understand that the critical environment room **10** is synonymous with a data center.



Ex. 1008, FIG. 1.

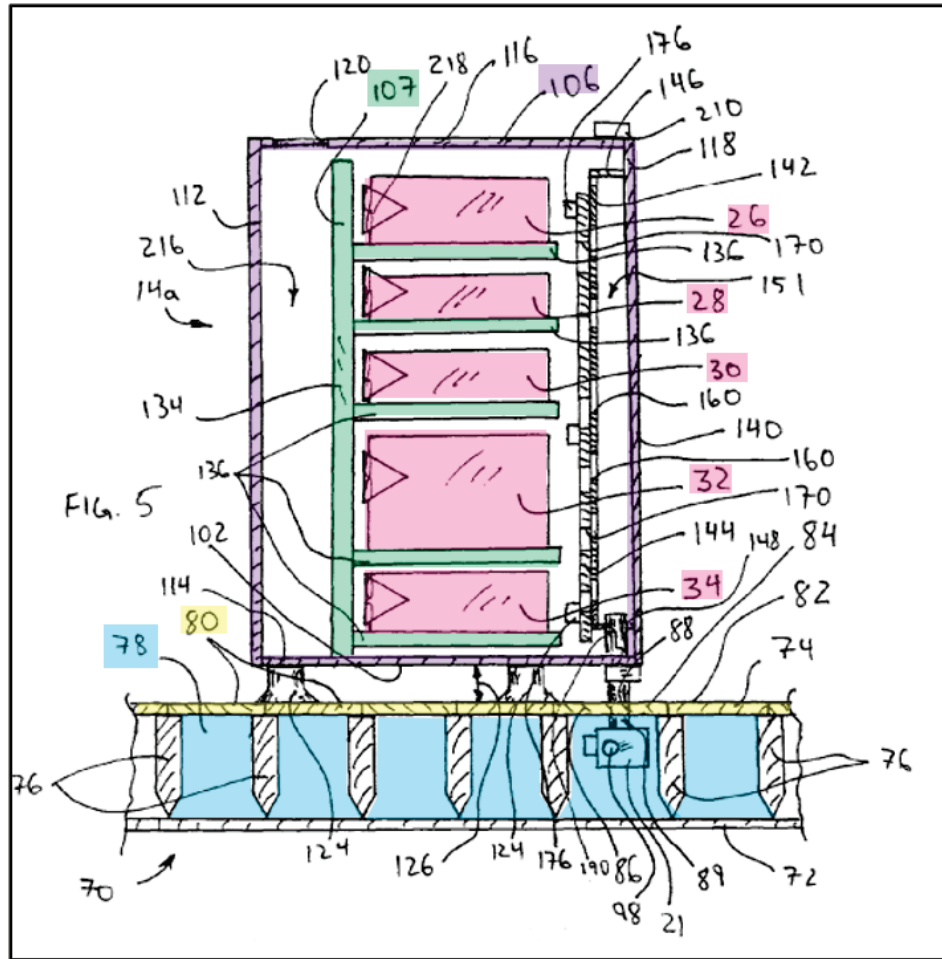
385. Thus, Bishop discloses limitation 1[pre].

386. Feeney is also directed to cooling rack mounted computer equipment within a data center. Ex. 1013, 1:17–36, 2:27–31.

b. 1[a] – “activating a cooling device and opening a controllable partition configured to vary a supply of cooling fluid within a zone of said data center, said zone including at least one associated rack of said plurality of racks;”

387. Claim 1 further recites “*activating a cooling device and opening a controllable partition configured to vary a supply of cooling fluid within a zone of said data center, said zone including at least one associated rack of said plurality of racks.*”

388. Bishop provides further details regarding an exemplary cabinet assembly **14a** shown in Figure 1, which was discussed with respect to limitation 1[pre]. As shown in Figure 5, provided and annotated below, Bishop discloses that the “cabinet assembly **14a** includes . . . five electronic modules **26, 28, 30, 32** and **34**” (annotated in pink). Ex. 1008, [0067].



Ex. 1008, FIG. 5 (annotated).

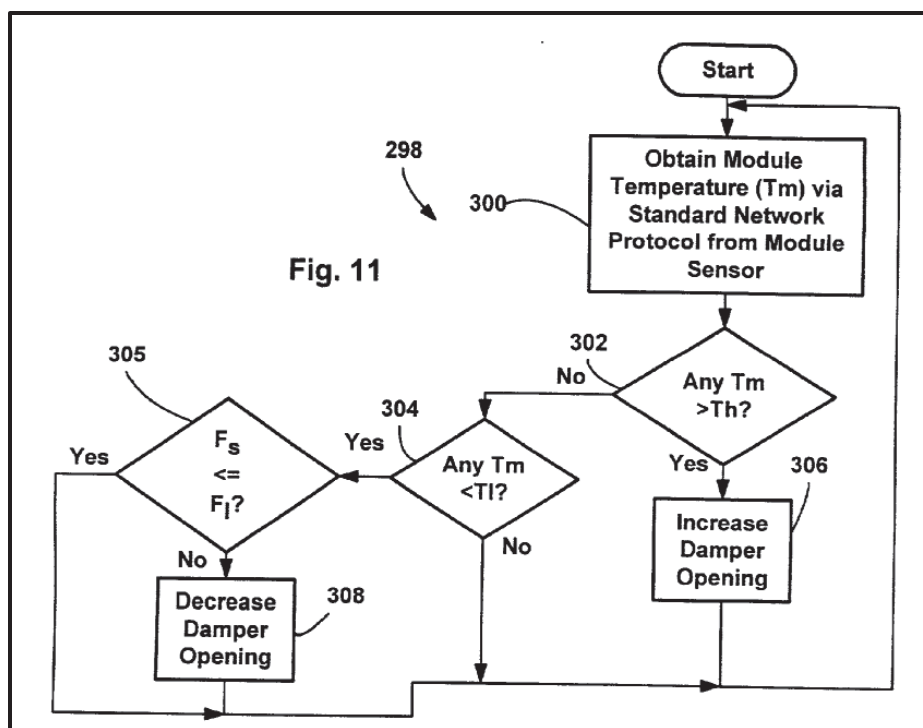
389. Still referring to Figure 5 of Bishop, “[t]he cooling air source **18** provides cool air within space **78**” below the support tiles **80** that serve as a floor on which the cabinet assembly **14a** sits. Ex. 1008, [0063]. “Some of the tiles are . . . special control tiles (e.g., **84**)” that “facilitate delivery of cool air from space **78** directly into cabinet assemblies (e.g., **14a**) thereabove.” Ex. 1008, [0064]. The “control tile **84** also includes a cooling controller unit **21**” that “includes a damper and a processor (not separately illustrated).” Ex. 1008, [0065].

390. Thus, Bishop discloses activating a cooling device (i.e. cooling air source **18**) in order to provide cool air to the cabinet assemblies.

391. Bishop teaches pulling “cool air . . . through each entire electronic module and over heat generating components therein” to cool cabinet assemblies. Ex. 1008, [0080]; *see also* Ex. 1008, [0088]. The ’179 patent teaches that air is a permissible cooling fluid. Thus, Bishop discloses the cooling fluid recited in claim 1.

392. With regard to the “controllable partition” in limitation 1[a], Bishop discloses controlling the damper of each cooling controller unit **21** to vary the supply of cooling fluid within zones of a data center containing computer racks (i.e. cabinet assemblies). Bishop’s system is operable to vary a supply of cooling fluid to the cabinet assemblies supported above special control tiles (such as tile **84**) that include a cooling controller unit **21**. Ex. 1008, [0064]–[0065]. Thus, Bishop discloses opening a controllable partition (i.e., damper) configured to vary a supply of cooling fluid within a zone of said data center containing a cabinet or rack.

393. As shown in Figure 11, the cooling controller **21** may “decrease[] the damper opening to reduce cooling air flow to the corresponding cabinet” at block **308** and may “increase[] the damper opening to increase cooling air flow to the corresponding cabinet” at block **306**. Ex. 1008, [0084]–[0085].



Ex. 1008, FIG. 11.

394. Bishop teaches that the damper is a part of the cooling controller unit **21**. Ex. 1008, [0065]. As shown in Figure 5 above, the cooling controller unit **21**, and therefore its damper, is positioned between the under-floor space **78** and the cabinet assemblies (e.g., **14a**) above the floor. Ex. 1008, [0064]–[0065].

395. However, Bishop does not expressly describe dampers that are associated with barriers that subdivide the space **78** below the raised floor **74**. To the extent that limitation 1[a] is interpreted to require a controllable wall or barrier that subdivides the plenum space, this would have been obvious to a POSITA based on the combined teachings of Bishop and Feeney and a POSITA's knowledge of conventional technologies, tools, and practices.

396. As discussed above, Feeney describes a subdivided pressurized plenum space to distribute cooling air from multiple cooling devices. Feeney teaches that the user can define the paths for cooling air flow under the raised floor and through vented floor tiles by selective closure of air transfer openings in vertically oriented walls that subdivide the plenum space. Ex. 1013, 10:20–22. Feeney encourages the practice of reconfiguring the air flow paths “depending upon changing processing requirements and/or changes in the geometry of the floor region available for the data center function” as being advantageous. Ex. 1013, 11:48–52. Feeney teaches numerous exemplary arrangements of blocking panels to prevent or permit flow through the vertical subdividing walls so as to define airflow paths for targeting the supply of cooling air to the data center zones.

397. It would have been obvious to a POSITA familiar with Bishop’s system and Feeney’s additional teachings to modify Bishop to provide controllable dampers within barriers that subdivide plenum space 78 into sections or zones. A POSITA would have recognized that breaking up the plenum space into smaller regions would help avoid undesirable pressure imbalances, a concern that Bishop specifically acknowledges. Ex. 1008, [0088]. A POSITA would further appreciate that this would provide other similar benefits to those stated in the ’179 patent, such as assuring that sufficient cooling air is distributed from one zone to another in order to better control the amount of cooling air delivered to the racks in each zone. Ex.

1001, 4:11–31. The additional benefits in terms of flexibility to adjust the system to accommodate operating multiple cooling systems to provide cooling air to a large number of racks, is also suggested by Feeney. The system of Feeney has a subdivided pressurized plenum space to distribute cooling air from multiple cooling devices along optimized plenum flow paths using partitions to properly balance the supply of cooling fluid between cooling devices and heat loads.

398. Modifying Bishop's system to include subdividing barriers in the plenum space would improve both Bishop's and Feeney's systems because the vertical barriers would be controllable in response to changing temperature conditions. Bishop is already equipped with controller 21 and a control logic for automatically manipulating airflow dampers based on sensed temperature conditions associated with the computer racks. The modifications would require only routine implementation of mechanical components to add subdividing barriers having associated dampers and connect them to controllers 21. The damper positions would then be automatically adjustable to vary cooling flow rates based on sensed temperature conditions.

399. For these reasons and the additional reasons provided above, it would have been obvious to implement Bishop's air flow control dampers as controllable partitions that subdivide the plenum space so as to provide greater control over the distribution of cooling air within the plenum space, while maintaining stable

pressure conditions regardless of the number of cooling devices deployed, the size of the data center, or the number of computer racks in the data center.

400. Therefore, even under a more restrictive construction of “partition,” the Bishop/Feeney Combination discloses activating a cooling device and opening a controllable partition configured to vary a supply of cooling fluid within a zone of a data center that includes at least one computer rack, as recited in limitation 1[a].

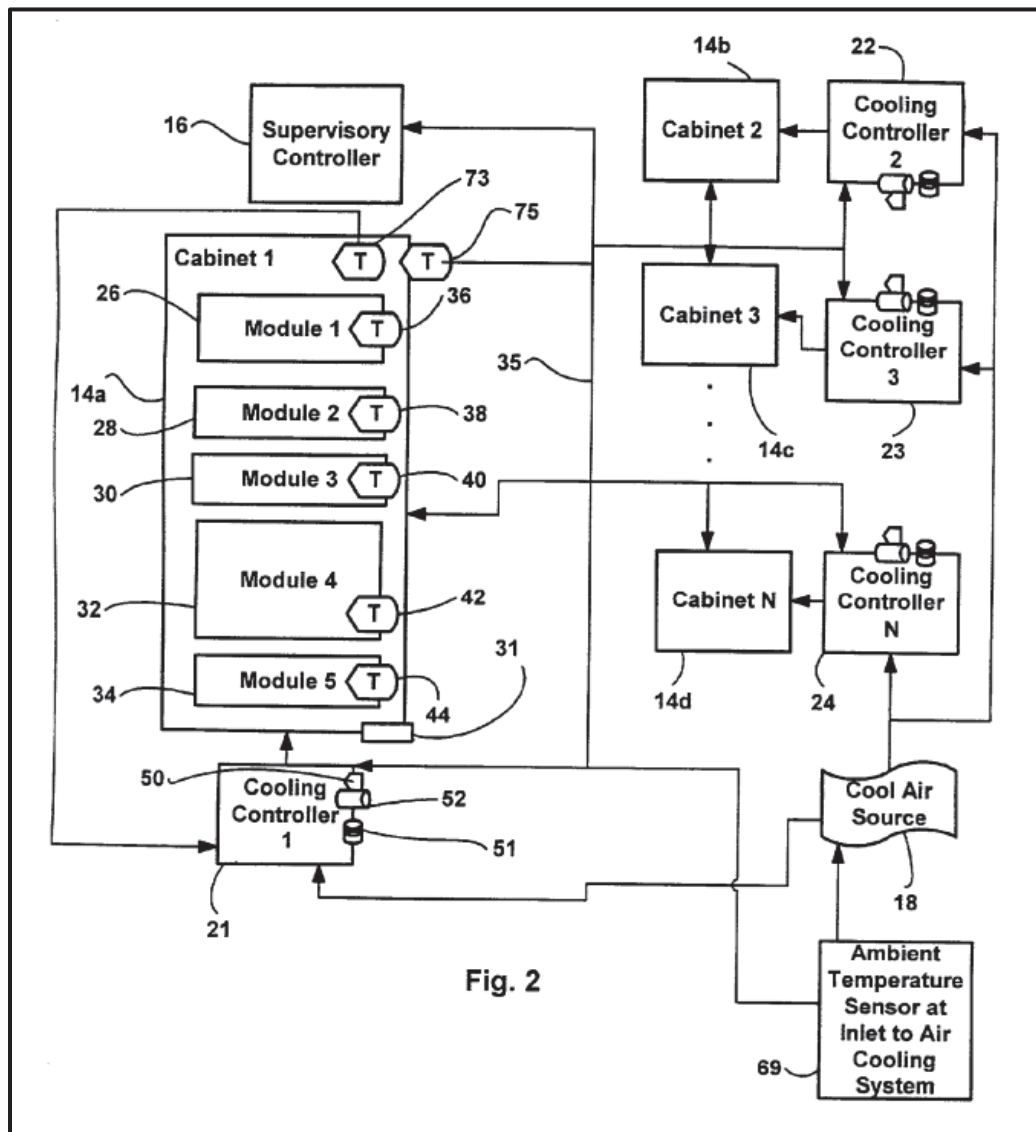
401. Because Bishop’s disclosed damper is configurable to control the supply of cooling air to a particular region of a data center, the Bishop/Feeney Combination also discloses this limitation under the Patent Owner’s broader construction of “partition.”

c. 1[b] – “sensing the temperature of said at least one associated rack;”

402. Claim 1 recites “*sensing the temperature of said at least one associated rack.*”

403. Bishop discloses the “cabinet assembly **14a** includes a housing **106**, a shelving unit **107**, five electronic modules **26**, **28**, **30**, **32** and **34**, an internal temperature sensor **73** and an external temperature sensor **77.**” Ex. 1008, [0067]. Since each “cabinet is typically constructed about each rack,” the cabinet assembly’s **14a** internal temperature sensor **73** senses the temperature of a rack. Ex. 1008, [0007].

404. Additionally, and as shown in Figure 2, reproduced below, Bishop discloses “temperature sensors in [or on the electronic]modules **26, 28, 30, 32** and **34** [] identified by numerals **36, 38, 40, 42** and **44**, respectively.” Ex. 1008, [0081]; *see also* Ex. 1008, [0106].



Ex. 1008, FIG. 2.

405. Bishop discloses sensing temperatures via the temperature sensors of the modules **36, 38, 40, 42** and **44** to provide the “temperature readings from

modules **26, 28, 30, 32** and **34**, [to the] supervising controller **16**” and the cooling controller **21**. Ex. 1008, [0082].

406. Thus, Bishop’s disclosure of sensing temperatures of the modules within a rack and other temperatures associated with the racks discloses sensing the temperature of said at least one associated rack, as recited in limitation 1[b].

d. 1[c] – “determining whether said sensed temperature is within a predetermined temperature range; and”

407. Claim 1 recites “*determining whether said sensed temperature is within a predetermined temperature range.*”

408. Bishop teaches “compar[ing] each module temperature T_m to a threshold temperature that is at the high end of an acceptable temperature range” (T_h). Ex. 1008, [0083]. “[W]here any module temperature [does not] exceed[] the threshold temperature T_h , control passes to block **304** where supervising controller **16** determines if any temperature is less than a low threshold temperature T_l .” Ex. 1008, FIG. 11, [0083]. The temperature sensor **73** inside each cabinet **14a** is also linked to controller **21** and may be assessed against the acceptable temperature range as an alternative to the sensed module temperatures. Ex. 1008, [0105].

409. Thus, the Bishop/Feeney Combination teaches determining whether said sensed temperature is within a predetermined temperature range, as recited in limitation 1[c].

- e. 1[d] – “manipulating said controllable partition to vary said supply of said cooling fluid to said zone in response to said sensed temperature being outside said predetermined temperature range.”

410. Claim 1 recites “*manipulating said controllable partition to vary said supply of said cooling fluid to said zone in response to said sensed temperature being outside said predetermined temperature range.*”

411. Bishop discloses that if the sensed temperature is above the high threshold temperature, the controller increases the damper opening to increase cooling air flow to the corresponding cabinet. Ex. 1008, [0085]. If the sensed temperature is below the low threshold, the controller is operable to decrease the damper opening to reduce cooling air flow to the corresponding cabinet. Ex. 1008, [0084].

412. Thus, the Bishop/Feeney Combination discloses limitation 1[d].

2. Claim 2

413. As I explain below, the Bishop/Feeney Combination renders claim 2 obvious.

- a. 2[a] – “The method according to claim 1, further comprising: determining whether the measured temperature of said at least one associated rack is below or equal to a predetermined minimum set point temperature; and”

414. Claim 2 recites “[t]he method according to claim 1, further comprising: determining whether the measured temperature of said at least one

associated rack is below or equal to a predetermined minimum set point temperature.”

415. As explained above in Section IX.C.1.d, Bishop discloses determining whether sensed temperatures associated with the racks or the modules in the racks are below a minimum threshold temperature.

416. Thus, the Bishop/Feeney Combination discloses limitation 2[a].

b. 2[b] – “decreasing the supply of said cooling fluid to said zone in response to said at least one associated rack having a measured temperature that falls below or equal said predetermined minimum set point temperature.”

417. Claim 2 recites “*decreasing the supply of said cooling fluid to said zone in response to said at least one associated rack having a measured temperature that falls below or equal said predetermined minimum set point temperature.”*

418. As discussed in relation to claim 1, Bishop discloses that the controller decreases the damper opening to reduce cooling air flow to the corresponding cabinet when the sensed temperature is below a minimum threshold. Ex. 1008, [0084].

419. Thus, the Bishop/Feeney Combination discloses limitation 2[b].

420. Thus, it is my opinion that the Bishop/Feeney Combination discloses each limitation of claim 2 and renders claim 2 unpatentable as obvious.

3. Claim 3

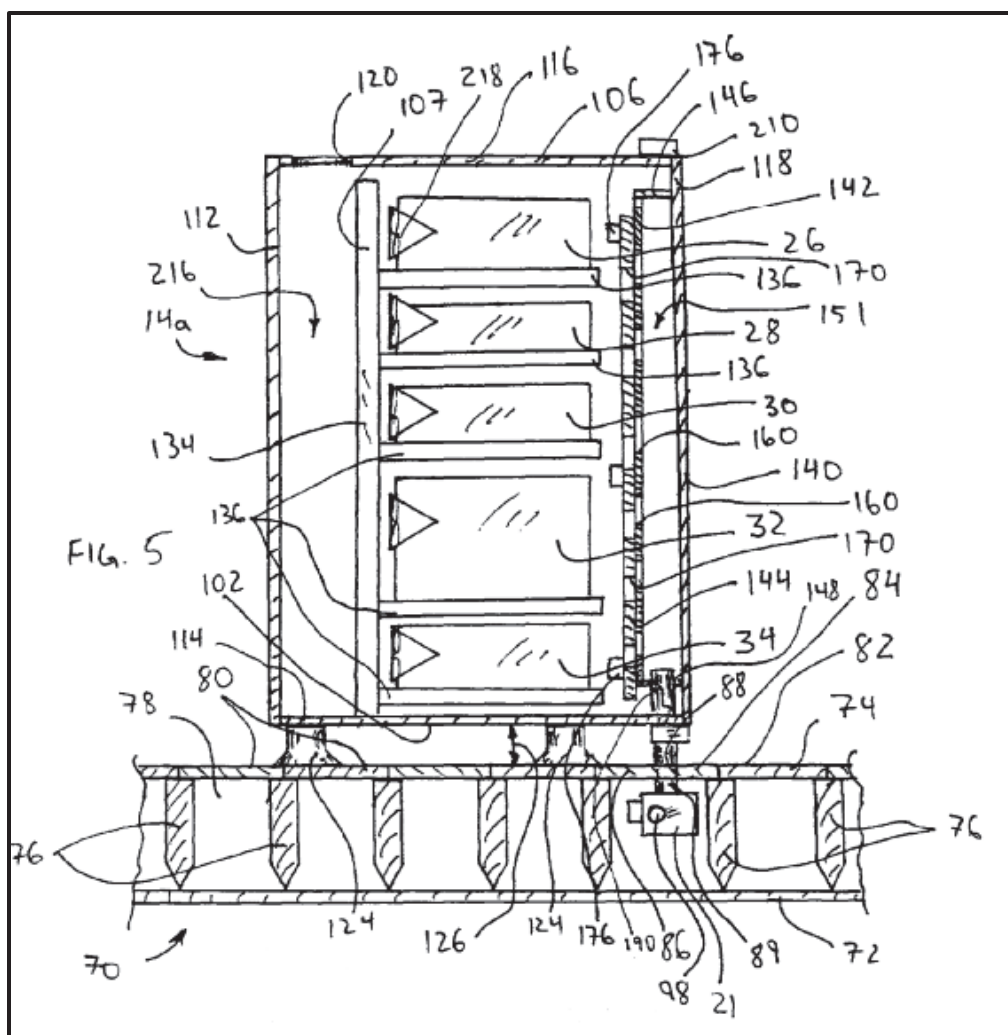
421. As I explain below, Bishop in combination with Feeney and further in view of Kochavi renders obvious claim 3. I discuss each limitation of claim 3 in turn below, and then explain why it would have been obvious to a POSITA to further modify the Bishop/Feeney combination in view of the cooling methods of Kochavi based on their collective teachings and based on a POSITA's knowledge of the art.

a. 3[a] – “The method according to claim 1, further comprising: sensing a pressure of a supply of said cooling fluid;”

422. Claim 3 recites “[t]he method according to claim 1, further comprising: sensing a pressure of a supply of said cooling fluid.”

423. As explained above, Bishop discloses the method of claim 1.

424. Bishop discloses a pressure sensor sensing the static pressure within space **78** from which the cool air is supplied into cabinet assemblies. Ex. 1008, [0064], [0066]. The space **78** below the cabinet assembly **14a** can be seen in Figure 5 of Bishop, reproduced below.



Ex. 1008, FIG. 5.

425. Limitation 3[a] is therefore disclosed by Bishop.

426. As shown in Figure 1 of Kochavi, reproduced with annotations below, “[t]he air conditioning system **10** [] comprises an air flow pressure sensor **110** [(annotated in orange)] which may be located at the entrance to the main duct **44** The air flow sensor **110** is operative to send a duct pressure signal to the control system **100** which is substantially proportional to the air pressure at the entrance to the main duct **44**.” Ex. 1011, 4:58–67.

427. Kochavi further discloses that the main duct **44** supplies conditioned air (such as cool air) to a plurality of branch ducts **46** and into a plurality of rooms **50, 52** and **54**. Ex. 1011, Ex. 1011, 4:42–4:47. Thus, the air flow pressure sensor **110** of Kochavi senses a pressure of a supply of cool air.

b. 3[b] – “determining whether said sensed pressure is within a predetermined pressure range; and”

Vertiv Ex. 1002
Vertiv v. Valtrus

430. Kochavi discloses a bypass damper **74** in the bypass duct **70** that “is operative, in response to signals from the control system **100**, to return some or all of the conditioned air to the entrance region **72** if the pressure sensed by air flow pressure sensor **110** exceeds a value which may be in the region of 16 to 19 psi and is preferably about 17 psi.” Ex. 1011, 5:5–12. Thus, Kochavi teaches comparing a sensed pressure to a predetermined pressure range (i.e., 16 to 19 psi).

431. Limitation 3[b] is therefore disclosed by Kochavi.

c. 3[c] – “varying an output of said cooling device in response to said sensed pressure falling outside of said predetermined pressure range.”

432. Claim 3 recites “*varying an output of said cooling device in response to said sensed pressure falling outside of said predetermined pressure range.*”

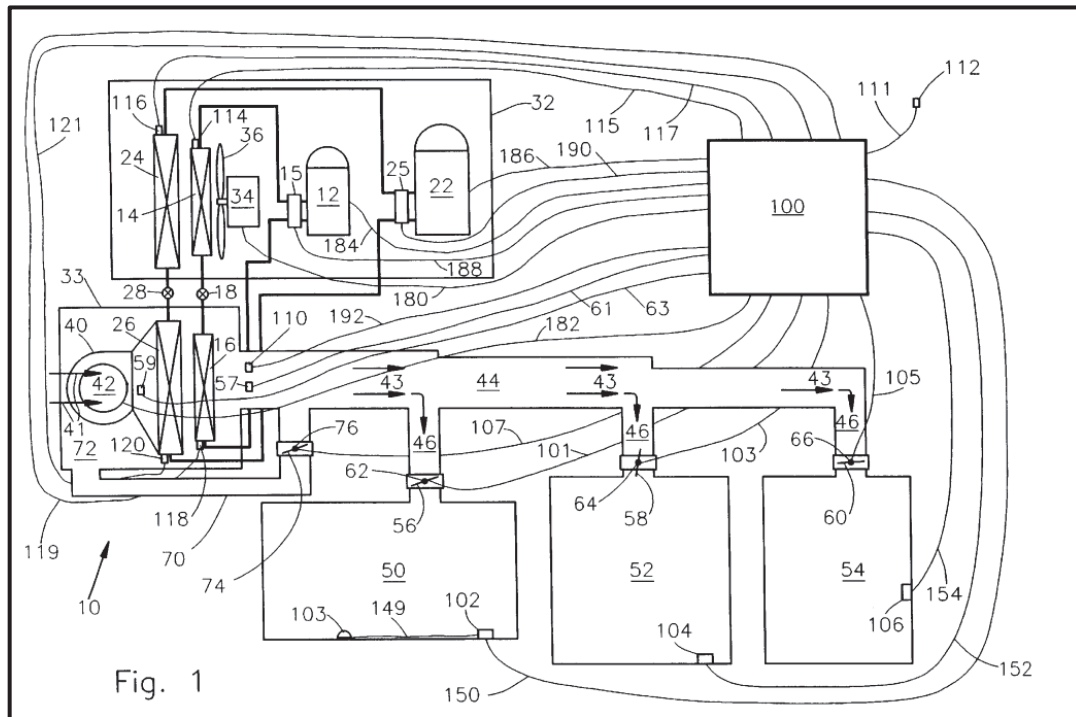
433. Bishop does not expressly disclose varying the output of its cooling device in response to sensed pressure being out of range. However, Kochavi discloses this.

434. In particular, Kochavi discloses a bypass damper **74** in the bypass duct **70** that “is operative, in response to signals from the control system **100**, to return some or all of the conditioned air to the entrance region **72** if the pressure sensed by air flow pressure sensor **110** exceeds a value which may be in the region of 16 to 19 psi and is preferably about 17 psi.” Ex. 1011, 5:5–12. Kochavi further discloses that depending on the pressure in the main duct **44** sensed by the air flow pressure sensor **110**, the system increases or decreases the fraction opening of the

bypass damper 74 to maintain a substantially constant pressure in the main duct 44.

Ex. 1011, 15:61–65.

435. Figure 1 below shows the position of the bypass damper 74 in the air duct system.



Ex. 1011, FIG. 1.

436. A POSITA reviewing this diagram would understand that decreasing the opening of the bypass damper 74 when the sensed pressure is below the predetermined range leads to more airflow to main duct 44 thereby increasing the pressure of the supply of conditioned air. Conversely, increasing the opening of the bypass damper results in decreasing the airflow and pressure in main duct 44.

437. It would have been obvious to a POSITA, using the system of the Bishop/Feeney Combination, to modify the system to add a capability of adjusting

the cooling device when the pressure of the cooling air supply to the zones is outside of a desired pressure range.

d. A POSITA Would Have Been Motivated to Modify the Bishop/Feeney Combination Based on Kochavi to Arrive at Claim 3 and Would Have Had a Reasonable Expectation of Success

438. It would have been obvious to incorporate Kochavi's supply air pressure regulation feature into the system and method of the Bishop/Feeney Combination.

439. Bishop, Feeney, and Kochavi are closely analogous references that are each directed to the same field of endeavor, namely, meeting the localized air conditioning needs of individual zones (e.g., rooms, cabinets, etc.). Ex. 1008, [0032]; Ex. 1011, 1:54–57; Ex. 1013, 2:37–63. Each of these references offer similar solutions. *See, e.g.*, Sections VIII.C. – VIII.E., herein.

440. The similarities between the references would have suggested to a POSITA following the ordinary design process to combine their teachings. The similarities further confirm that it would have been obvious for a POSITA to try to combine the references (choosing from a finite number of identified, predictable solutions, with a reasonable expectation of success), and substitute the known elements of Kochavi to obtain predictable results.

441. For example, a POSITA would have been motivated to incorporate Kochavi's capability to vary the supply of cooled air when the air pressure falls

outside of a predetermined range because Bishop teaches measuring the pressure of a supply of cool air and providing pressure measurements to a supervising controller **16** (Ex. 1008, [0066]) so that the supervising controller **16** can “diagnose problems such as . . . inefficient pressure generation” (Ex. 1008, [0088]). Bishop cautions that air pressure in raised floor plenums such as Bishop’s space 78 “can vary appreciably despite the fact that equilibrium is ideal.” Ex. 1008, [0087]. A POSITA desiring to use a system made in accordance with the Bishop/Feeney Combination would have been motivated to solve this problem and would have looked to an analogous reference, such as Kochavi, for a solution.

442. Kochavi teaches varying the cooling device output as needed to return the supply air pressure to the desire range. It would have been a routine matter to modify Bishop’s controller to include the capability to vary the cooling air output of the cooling device when the pressure is out of range. Bishop’s system already has the capability to sense the supply pressure and provide the sensed values to the controller. Bishop’s disclosure allows for use of a variety of conventional cooling devices. A POSITA would have known how to implement a conventional cooling device equipped with a variable speed blower fan. Feeney, for example, discloses cooling devices having associated blower fans. Kochavi offers another easily implementable approach of a bypass damper to adjust the cooling flow output from the cooling device.

443. A POSITA would have had a reasonable expectation of success in implementing a suitable means for varying the supply of cool air in response to pressure fluctuations in the supply plenum. The results—improved pressure control and more stable operations—were both beneficial and predictable. The simple, routine, and low-cost nature of incorporating automatic pressure regulation in the Bishop/Feeney Combination, which would have ensured a reasonable expectation of success, would have further motivated a person of ordinary skill in the art.

444. Claim 3 is therefore rendered obvious by the Bishop/Feeney Combination in view of Kochavi.

4. Claim 4 – “The method according to claim 2, further comprising: increasing the supply of said cooling fluid to said zone in response to said at least one associated rack having a measured temperature that exceed said predetermined minimum set point temperature.”

445. Claim 4 recites “[t]he method according to claim 2, further comprising: increasing the supply of said cooling fluid to said zone in response to said at least one associated rack having a measured temperature that exceed said predetermined minimum set point temperature.”

446. As explained above, Bishop discloses the method of claim 2.

447. As previously discussed, Bishop’s system controller increases the damper opening to increase cooling air flow to the corresponding cabinet when the sensed temperature is above the desired range. Ex. 1008, FIG. 11, [0085].

448. Claim 4 of the '179 patent is therefore rendered obvious by the Bishop/Feeney combination in view of Kochavi.

5. Claim 5 – “The method according to claim 3, wherein said step of varying said cooling device output includes determining whether said measured pressure falls below or equals a predetermined minimum set point pressure.”

449. Claim 5 recites “[t]he method according to claim 3, wherein said step of varying said cooling device output includes determining whether said measured pressure falls below or equals a predetermined minimum set point pressure.”

450. Claim 5 depends from claim 3. Kochavi discloses the additional limitation of claim 5.

451. As discussed, Kochavi discloses increasing or decreasing the fraction opening of the bypass damper **74** to maintain a substantially constant pressure in the main duct **44**. Ex. 1011, 15:61–65. Thus, Kochavi’s air supply pressure control necessarily involves determining whether the sensed pressure is within the predetermined pressure range because Kochavi discloses that the bypass damper **74** returns some or all of the conditioned air to the entrance region **72** based on the outcome of that determination. A POSITA would understand that this control strategy includes determining when the sensed pressure is below the predetermined range such that the airflow to main duct **44** should be increased.

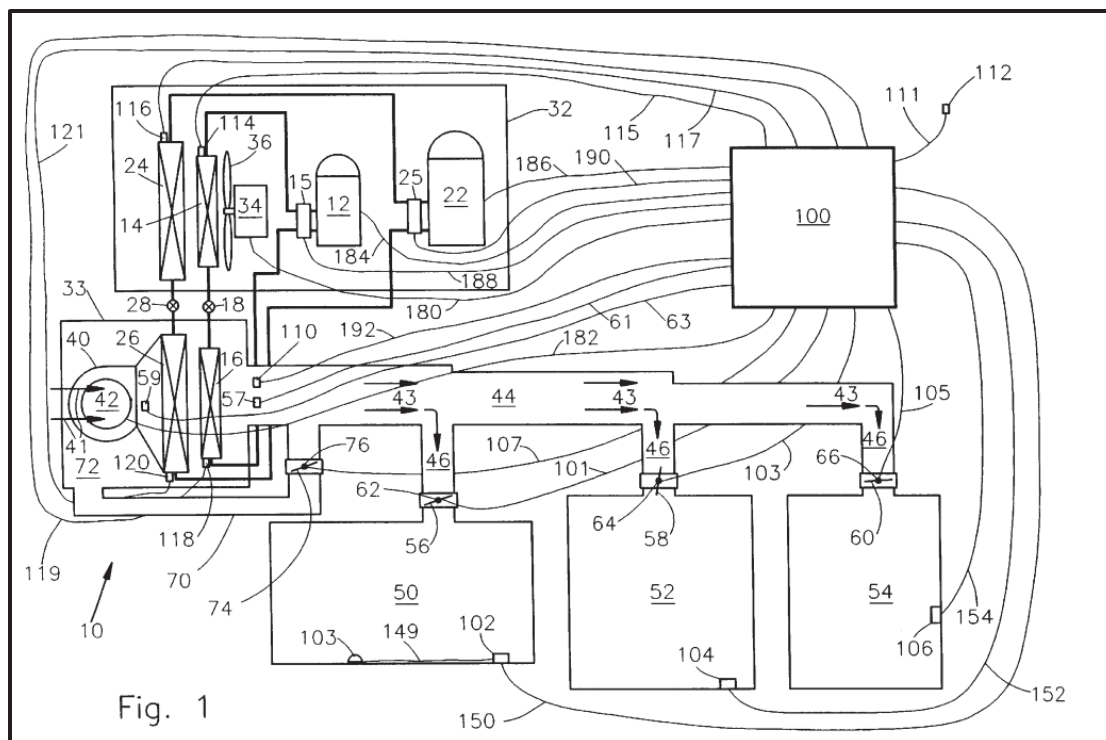
452. Claim 5 of the '179 patent is therefore rendered obvious by the Bishop/Feeney Combination in view of Kochavi.

6. Claim 6 – “The method according to claim 4, further comprising: decreasing an output of said cooling fluid from said cooling device in response to said decrease in cooling fluid supply to said zone exceeding said increase in cooling fluid supply to said zone.”

453. Claim 6 recites, “[t]he method according to claim 4, further comprising: decreasing an output of said cooling fluid from said cooling device in response to said decrease in cooling fluid supply to said zone exceeding said increase in cooling fluid supply to said zone.”

454. Claim 6 depends directly from claim 4 and indirectly from claim 2. A POSITA would understand that this claim requires decreasing the cooling fluid output from the cooling device if the decrease in cooling fluid to the zone (per claim 2) exceeds the increase in cooling fluid to the zone (per claim 4).

455. The additional step of claim 6 is inherent in Kochavi’s automatic pressure regulation methodology. As discussed above, Kochavi’s system allows for varying cooling air flow to individual rooms via controllable air dampers, as shown in Figure 1 below.



Ex. 1011, FIG. 1.

456. Kochavi's Damper Control Procedure is operable to increase or decrease the fraction open for the dampers in each of the rooms, thereby increasing or decreasing the flow of conditioned air to each of the rooms **50**, **52** and **54**. Ex. 1011, 15:55–60. In the operation state illustrated in Figure 1, the middle damper **64** is fully open, the left damper **62** is partially open, and the right damper **66** is closed. A POSITA would immediately envision other states, such as when the position of the middle damper is being adjusted periodically in response to conditions in room **52** during a time period when the remaining two dampers remained closed. A POSITA understands that in normal operational circumstances, the increases and decreases of cooling air flow to room **52** directly impact the air pressure in the main

duct **44**. When the increases in cooling air flow to room **52** exceed decreases for a period of time, the pressure in the duct will drop, and vice versa. Kochavi's pressure control feature, discussed above, results in decreasing the cooling air supplied to the duct in response to a pressure increase in the duct, i.e., when the decreases in cooling air supplied to room **52** exceed increases in the cooling air supplied to that zone during the time period.

457. Therefore, in my opinion, this feature is provided by the same pressure regulation feature of Kochavi discussed above, and the Bishop/Feeney Combination as modified in view of Kochavi discloses claim 6.

458. Claim 6 is therefore rendered obvious by the Bishop/Kochavi combination in view of Kochavi.

7. Claim 11 – “The method according to claim 5, further comprising: increasing the output of said cooling device in response to said measured pressure falling below or equaling said predetermined minimum set point pressure.”

459. Claim 11 recites, “[t]he method according to claim 5, further comprising: increasing the output of said cooling device in response to said measured pressure falling below or equaling said predetermined minimum set point pressure.”

460. As explained with respect to claim 5, Kochavi teaches comparing a sensed pressure to a predetermined pressure range (i.e. 16 to 19 psi). Kochavi indicates that depending on the pressure in the main duct **44** sensed by the air flow

pressure sensor **110**, Kochavi's system increases or decreases the fraction opening of the bypass damper **74** to maintain a substantially constant pressure in the main duct **44**. Ex. 1011, 15:61–65. Thus, Kochavi's pressure control necessarily involves increasing the cooling fluid output to the main duct 44 when the sensed pressure is below the predetermined pressure range.

461. Claim 11 of the '179 patent is therefore rendered obvious by the Bishop/Feeney Combination in view of Kochavi.

8. Claim 12 – “The method according to claim 5, further comprising: decreasing the output of said cooling device in response to said measured pressure exceeding said predetermined minimum set point pressure.”

462. Claim 12 recites, “[t]he method according to claim 5, further comprising: decreasing the output of said cooling device in response to said measured pressure exceeding said predetermined minimum set point pressure.”

463. Kochavi discloses comparing a sensed pressure to a predetermined pressure range and decreasing the fraction opening of the bypass damper **74** to maintain a substantially constant pressure in the main duct **44**. Ex. 1011, 15:61–65. Thus, Kochavi's pressure control necessarily involves decreasing the cooling fluid output to the main duct 44 when the sensed pressure exceeds the predetermined pressure range.

464. Claim 12 of the '179 patent is therefore rendered obvious by the Bishop/Feeney Combination in view of Kochavi.

9. Claim 13 – “The method according to claim 6, further comprising: increasing an output of said cooling fluid from said cooling device in response to said decrease in cooling fluid supply to said zone falling below said increase in cooling fluid supply to said zone.”

465. Claim 13 recites, “[t]he method according to claim 6, further comprising: increasing an output of said cooling fluid from said cooling device in response to said decrease in cooling fluid supply to said zone falling below said increase in cooling fluid supply to said zone.”

466. This claim is analogous to claim 6, but is directed to the circumstance in which decreases in cooling fluid supplied to a zone are less than increases in cooling fluid supplied to the zone. My analysis above for claim 6 applies here. In that circumstance, Kochavi’s pressure control logic would sense a reduction of pressure in main duct 44 and respond by increasing the cooling air supply to the duct. Therefore, the additional step of claim 13 is inherent in Kochavi’s disclosure.

467. Claim 13 of the ’179 patent is therefore rendered obvious by the Bishop/Feeney Combination in view of Kochavi.

X. CONCLUDING STATEMENTS

468. In my opinion, all limitations in claims 1–15 of the ’179 patent were well known and anticipated by the Bash and/or Patel prior art before the filing date of the application that issued as the ’179 patent under a broader interpretation of the recited “controllable partition.” I have also concluded that under a more confined interpretation of “controllable partition,” at least claims 1, 2, and 4 would have been

obvious based on the combination of Bishop and Feeney, and that at least claims 3, 5, 6, and 11–13 would have been obvious, based on Bishop and Feeney and further in view of Kochavi. As such, it is my opinion that claims 1–15 of the '179 patent should be found unpatentable.

469. I declare that all statements made herein of my own knowledge are true, and that all statements made on information and belief are believed to be true, and that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code.

Executed on February 26, 2025 in Minneapolis, Minnesota.

DocuSigned by:

7A860E4BA901415...

John P. Abraham, Ph.D.

SUMMARY

Thermal science expert with experience in all aspects of heat transfer and fluid mechanics. Produced approximately 500 publications, books, book chapters, conference presentations, and patents in areas including biological heat transfer and fluid flow, biomedical device design, energy, burn injuries, climate change, fundamental heat transfer and fluid mechanics, and manufacturing processes. Author of approximately 350 popular press articles and has been in approximately 400 radio and television appearances.

ACADEMIC APPOINTMENTS

University of St. Thomas, St Paul, MN

Professor	2013-Present
Associate Professor	2008-2013
Assistant Professor	2002-2008

OTHER EMPLOYMENT

WTS. LLC

Vice President of Research

2023-present

Responsible for directing solar-electrical-thermal research activities

EDUCATION

University of Minnesota - Twin Cities, Minneapolis, MN

Ph.D. , Mechanical Engineering (Thermal Sciences)	2002
M.S. , Mechanical Engineering, GPA 3.96/4.00	1999
B.S. , Mechanical Engineering, GPA 4.00/4.00, Minor : Mathematics	1997

PREVIOUS TEACHING EXPERIENCE

Adjunct Faculty, *University of St. Thomas, St Paul, MN*

2000-2002

Graduate Teaching Fellow, *University of Minnesota, Minneapolis, MN*

2001-2002

Teaching Assistant, *University of Minnesota, Minneapolis, MN*

1997-2001

Tutor, *University of Minnesota, Minneapolis, MN*

1993-1997

HONORS/AWARDS

- Advances in Atmospheric Sciences Notable paper award (2024).
- Journal of Forensic Sciences, Noteworthy paper award (2023).
- AAS Esteemed News and Views Paper Prize, (2023)
- Editor's Choice Award, Journal of Forensic Sciences, (2022).
- AAS Esteemed News and Views Paper Prize, (2022)
- Journal of Atmospheric and Oceanic Technology, Editor award (2020)
- National Center for Science Education, Friend of the Planet Award (2016)
- University of St. Thomas, Professor of the Year (2016)
- USA Green Deal of the Year business excellence award (2013)
- Composites Sustainability Award, American Composites Manufacturers Association Award for Composite Excellence, (2013)

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- Nominated, George Mason University, Center for Climate Change Communication, Climate Change Communicator of the Year (2011)
- University of St. Thomas, John Ireland Award (2009)
- University of St. Thomas, Distinguished Educator Award (2008)
- University of St. Thomas, Engineering Professor of the Year (2005)
- Graduate Teaching Fellowship (2001/2002)
- Institute of Technology Teaching Assistant of the Year, awarded by the Institute of Technology Student Board, University of Minnesota (1999/2000)
- Institute of Technology Teaching Assistant of the Year, awarded by the Institute of Technology Student Board, University of Minnesota (2000/2001)
- Institute of Technology Teaching Assistant of the Year, awarded by the Institute of Technology Student Board, University of Minnesota (2001/2002)
- Mechanical Engineering Teaching Assistant of the Year, Mechanical Engineering Department, University of Minnesota (1998/1999)
- Minnesota Professional Engineers Foundation Orion Buan Memorial Scholarship (1996)
- Walter and Margaret Pierce Endowment Fund Scholarship (1996)
- National Space Grant Consortium Scholarship (1996)
- Frank Louk Scholarship (1996)
- Citizens' Scholarship (1992-1995)
- Alfred O. Neir Scholarship (1994)
- Dean's List (1993-1997)

OTHER POSITIONS

Climate Blogger – Guardian Newspaper

2013-2020

Editorial Board Member – Handling Ethics Cases, Energies

2024-present

PUBLICATIONS

(26 edited works, 4 books, 45 book chapters, 320 journal publications, 149 presentations, 26 granted patents, 7 patent applications, 2 granted trademarks)

TOP PUBLICATIONS BY ALTMETRIC

L. Cheng, J.P. Abraham, K.E. Trenberth, T. Boyer, M.E. Mann, J. Zhu, F. Wang, R. Locarnini, J. Fasullo, Y. Li, B. Zhang, L. Wan, X. Chen, D. Wang, L. Feng, X. Song, Y. Liu, F. Reseghetti, S. Simoncelli, V. Gouretski, G. Chen, A. Mishonov, J. Reagan, K. von Schuckmann, Y. Pan, Z. Tan, Y. Zhu, W. Wei, G. Li, Q. Ren, L. Cao, and Y. Lu, New Record Ocean Temperatures and Related Climate Indicators in 2023, *Advances in Atmospheric Sciences*, 2025, doi: 10.1007/s00376-024-3378-5. **Altmetric score = 1064, top 1% in all journals, January 2024. This altmetric score places the paper in the top 1% (top 168 out of 205963 papers) in all journals, and within the top 1% of papers in the publishing journal.**

L. Cheng, J.P. Abraham, K.E. Trenberth, J.T. Fasullo, T. Boyer, M.E. Mann, J. Zhu, F. Wang, R. Locarnini, Y. Li, B. Zhang, F. Yu, L. Wan, X. Chen, X. Song, Y. Liu, F. Reseghetti, S. Simoncelli, V. Gouretski, G. Chen, A. Mishonov, J. Reagan, and G. Li, Another Year of Record Heat for the Oceans, *Advances in Atmospheric Sciences*, Vol. 40, pp. 963-974, 2023. **Altmetric score = 1438, top 1% in all journals, January 2023. This altmetric score places the paper in**

the top 1% (top 100 out of 214000 papers) in all journals, and within the top 1% of papers in the publishing journal.

L. Cheng, J.P. Abraham, K.E. Trenberth, J. Fasullo, T. Boyer, M.E. Mann, J. Zhu, F. Wang, R. Locarnini, Y. Li, B. Zhang, Z. Tan, F. Yu, L. Wan, X. Chen, X. Song, Y. Liu, F. Reseghetti, S. Simoncelli, V. Gouretski, G. Chen, A. Mishonov, J. Reagan, Another Record Ocean Warming Continues Through 2021 Despite La Nina Conditions, *Advances in Atmospheric Sciences*, Vol. 39, 373-385, 2022). **Altmetric score = 4686, top 1% in all journals, January 2022. This altmetric score places the paper in the top 0.02% (top 57 out of 287000 papers) in all journals, and within the top 1% of papers in the publishing journal.**

L. Cheng, J.P. Abraham, K.E. Trenberth, J.T. Fasullo, T.L. Boyer, R. Locarnini, B. Zhang, F. Yu, L. Wan, X. Chen, X. Song, Y. Liu, M.E. Mann, F. Reseghetti, S. Simoncelli, V. Gouretski, G. Chen, and J. Zhu, Upper Ocean Temperatures Hit Record High in 2020, *Advances in Atmospheric Sciences*, Vol. 38, pp. 523-530, 2021. **Altmetric score = 1439, top 1% in all journals, August 2021.**

G. Li, L. Cheng, J. Zhu, K.E. Trenberth, M.E. Mann and J.P. Abraham, Increasing Ocean Stratification Over the Past Half Century, *Nature Climate Change*, Vol. 10, pp. 1116-1123, 2020. **Altmetric score = 726, top 1%, July 2021.**

J.P. Abraham, B. D. Plourde, and L. Cheng, Using Heat to Kill SARS-CoV-2, *Reviews in Medical Virology*, Vol. 30, e2115, 2020. **Altmetric score = 392, top 1%, July, 2021.**

L. Cheng, J.P. Abraham, J. Zhu, K.E. Trenberth, J. Fasullo, T. Boyer, R. Locarnini, B. Zhang, F. Yu, L. Wan, X. Chen, X. Song, Y. Liu, and M.E. Mann, Record-Setting Ocean Warmth Continued in 2019, *Advances in Atmospheric Sciences*, Vol. 37, 1-6, 2020. **This paper was in the top 100 of all published scientific papers in the year 2020, ranked by Altmetric. Also, second of all 2020 papers in the subject area of climate. Altmetric score = 3957, top 1%, January 2021.**

L. Cheng, J. Zhu, J.P. Abraham, K. E. Trenberth, J. T. Fasullo, B. Zhang, F. Yu, L. Wan, Z. Chen, X. Song, 2018 Continues record global warming, *Advances in Atmospheric Sciences*, 36, pp. 249-252, 2019. **Altmetric score = 646, top 1%, January 2021.**

L. Cheng, J.P. Abraham, Z. Hausfather, and K.E. Trenberth, How fast are the oceans warming?, *Science*, Vol. 363, pp. 128-129, 2019. **Altmetric score = 2853, top 1%, January 2021.**

L.J. Cheng, K.E. Trenberth, T. Boyer, J. T. Fasullo, L. Zhu, J.P. Abraham, Improved Estimates of Ocean Heat Content from 1960-2015, *Science Advances*, Vol. 4, paper no. e1601545, 2017. **Altmetric Score = 753, top 1%, January 2021.**

J.P. Abraham, M. Baringer, N.L. Bindoff, T. Boyer, L.J. Cheng, J.A. Church, J.L. Conroy, C.M. Domingues, J.T. Fasullo, J. Gilson, G. Goni, S.A. Good, J. M. Gorman, V. Gouretski, M. Ishii, G.C. Johnson, S. Kizu, J.M. Lyman, A. M. Macdonald, W.J. Minkowycz, S.E. Moffitt, M.D. Palmer, A.R. Piola, F. Reseghetti, K. Schuckmann, K.E. Trenberth, I. Velicogna, and J.K. Willis, A Review of Global Ocean Temperature Observations: Implications for Ocean Heat Content

Estimates and Climate Change, *Reviews of Geophysics*, Vol. 51, pp 450-483, 2013. **Altmetric score = 178, top 5%, January 2024.**

Editing Activities (28 editorial activities)

1. Editor, *Advances in Heat Transfer*, Vol. 60, (Forthcoming, 2025).
2. Editor, *Advances in Heat Transfer*, Vol. 59, (Forthcoming, 2025).
3. Editor, *Advances in Heat Transfer*, Vol. 58, 2024.
4. Editor, *Advances in Heat Transfer*, Vol. 57, 2024.
5. Editor, *Advances in Numerical Heat Transfer – Artificial Intelligence Methods*, (forthcoming 2024)
6. Editor, Special edition in *Numerical Heat Transfer B – AI methods in heat transfer* (2023)
7. Editor, *Advances in Heat Transfer*, Vol. 56, 2023.
8. Editor, *Advances in Heat Transfer*, Vol. 55, 2023.
9. Editor in Chief, *Numerical Heat Transfer A* (2022-2024).
10. Editor in Chief, *Numerical Heat Transfer B* (2022-2024).
11. Editor, *Advances in Atmospheric Sciences (AAS)*, 2022.
12. Editor, *Advances in Heat Transfer*, Vol. 54, 2022.
13. Editor, *Advances in Heat Transfer*, Vol. 53, 2021.
14. Editor, *Advances in Heat Transfer*, Vol. 52, 2020.
15. Editor, *Advances in Heat Transfer*, Vol. 51, 2019.
16. Editor, *Advances in Heat Transfer*, Vol. 50, 2018.
17. Editor, *Advances in Heat Transfer*, Vol. 49, 2017.
18. Editor, *Advances in Heat Transfer*, Vol. 48, 2016.
19. Editor, *Advances in Heat Transfer*, Vol. 47, 2015.
20. Editor, *Advances in Heat Transfer*, Vol. 46, 2014.
21. Editor, *Advances in Numerical Heat Transfer Vol. 5: Numerical Models of Heat Exchangers*, Taylor and Francis, New York, 2017.
22. Editor, *Small-Scale Wind Power – Design, Analysis, and Economic Impacts*, Momentum Press, 2014.
23. Editor, *Advances in Heat Transfer*, Vol. 45, 2013.
24. Editor, *Advances in Heat Transfer*, Vol. 44, 2012.
25. Editor, *Advances in Numerical Heat Transfer Vol. 4: Nanoscale Heat Transfer and Fluid Flow*, Taylor and Francis, New York, 2012.
26. Guest Editor, *Advances in Numerical Heat Transfer Vol. 3: Numerical Implementation of Biological Models and Equations*, Taylor and Francis, New York, 2009.
27. Guest Editor, Special Edition of the *International Journal of Heat and Mass Transfer: Bioheat and Biofluid Flow*, Elsevier, Vol. 51, 23-24, November, 2008.
28. Assistant Editor, *Handbook of Numerical Heat Transfer*, 2nd Ed. Editors: Sparrow, Minkowycz, and Murthy, John-Wiley & Sons, Inc., New York, 2006.

Editorial Board Member

1. Water Eng. & Sciences, 2023-present
2. *Advances in Atmospheric Sciences*, 2022-present
3. *International Journal of Forensic Sciences*, 2023-present

4. International Society of Cardiovascular Translational Research, 2020-present
5. Energies, Thermal Management, 2019-present
6. Cardiovascular Revascularization Medicine, 2018-present
7. Stem Cell Biology and Transplantation, 2015-present
8. Associate Editor, National Center for Science Education, Climate Science, 2012-present
9. International Journal of Mechanics and Energy, 2012-present
10. Open Mechanical Engineering Journal, 2007-present
11. Open Mechanical Engineering Reviews, 2007-present
12. Open Mechanical Engineering Letters, 2007-present
13. Open Medical Devices Journal, 2008-present
14. Creative Engineering Journal, 2009-present
15. ISRN Applied Mathematics, 2011-present
16. International Journal of Sustainable Energy, 2012 - present
17. International Journal of Materials, Methods, and Technologies, 2012- present

Books

1. K. Vajravelu, J.P. Abraham, S. Mukhopadhyay, and P. Lakshminarayana, Advances in Nanofluid Flow, Heat, and Mass Transfer at Moving/Stretching Surfaces, CRC Press, (in preparation).
2. J.P. Abraham and B.D. Plourde, Small-Scale Wind Power – Design, Analysis, and Environmental Impacts, *Momentum Press*, 2014.
3. J.P. Abraham, P.S. Ellis, M.C. MacCracken, and G.M. Woodwell, Climate controversy 2013. New York, NY: *AuthorHouse*, 2013.
4. J.P. Abraham, E.M. Sparrow, W.J. Minkowycz, R.Ramazani-Rend, and J.C.K. Tong, All Fluid-Flow-Regimes Simulation Model for Internal Flows, *Nova Science Publishers, Inc.*, Hauppauge, NY, 2011.

Book Chapters (author of 43 book chapters)

1. F. Salmasi, J.P. Abraham, and B.O. Bakhshayesh, Numerical Study of Stability of Retaining Walls in the Presence of Horizontal and Chimney Drainage, *Engineering Research: Perspective on Recent Advances*, MDPI Publisher, 2025.
2. F. Salmasi and J.P. Abraham, Estimation of Energy Dissipation of Flow Over Stepped Spillways, *Energy Research: Perspectives on Recent Advances*, MPDI Publisher, 2025.
3. K. Vajravelu, J.P. Abraham, S. Mukhopadhyay, and P. Lakshminarayana, Advances in Nanofluid Flow, Heat, and Mass Transfer at a Moving/Stretching Surface, *Advances in Heat Transfer*, Vol. 58, 2024.
4. F. Salmasi and J.P. Abraham, New Perspectives on the Design of Stilling Basins, *Theory and Applications of Engineering Research*, 2024.

5. F. Salmasi and J.P. Abraham, Exploring Two-Phase Flow Dynamics: Experimental Investigations and Computational Modeling in Smooth and Stepped Chutes, *Theory and Applications of Engineering Research*, 2024.
6. F. Salmasi and J.P. Abraham, Ogee Crest Weir Head-Discharge Relationships, *Research Highlights in Science and Technology*, 2023.
7. F. Salmasi and J.P. Abraham, Hydraulic Performance of Sluice Gates: A Review of Head Loss Estimation and Discharge Coefficients for Optimal Flow Control and Design Considerations, *Dam Engineering – Design, Construction and Sustainability*, IntechOpen, 2023.
8. D.K. Vashwakarma, S. Bhattacharyya, M.L. Soni, and J.P. Abraham, Effect of Inlet Flat Obstruction on Thermohydraulic Characteristics in a Smooth Circular Tube in the Transitional Flow Regime, in Bhattacharya, Verma, Harikrishnan (eds), *Fluid Mechanics and Fluid Power, Vol. 3, Lecture Notes in Mechanical Engineering*, Springer, doi: 10.1007/978-981-19-6270-7_76.
9. F. Salmasi and J.P. Abraham, On the Finite Differences Method Using MS Excel, *Research Highlights in Mathematics and Computer Science* Vol. 6, pp 140-186, 2023.
10. F. Salmasi and J.P. Abraham, Boundary of Transition Flow Regime on Stepped Spillways by Physical Modeling, *Current Overview on Science and Technology Research*, (in press).
11. F. Salmasi and J.P. Abraham, Determination of Stilling Basin Invert Elevation and its Effect on Controlling Hydraulic Jumps, Chapter 5, *Techniques and Innovation in Engineering Research*, Vol. 2, 2022.
12. F. Salmasi and J.P. Abraham. Energy Loss at the Base of a Free Straight Drop Spillway, *Current Overview on Science and Technology Research*, Vol. 6, 2, 2022.
13. F. Salmasi and J.P. Abraham, Computation of Optimal Cross Section of Gravity Dams Using Genetic Algorithms, *Current Overview on Science and Technology Research*, Vol. 6, Chapter 1, 2022.
14. F. Salmasi and J.P. Abraham, Flow Characteristics of Skimming Regime Flow Over Stepped Spillways with Attention to Optimum Step Size, *Current Overview on Science and Technology Research*, Vol. 6, Chapter 3, 2022.
15. R. Daneshfaraz, E. Aminvash, and J.P. Abraham, Hydraulic Characteristics of Fish-Passes on Inclined Drops, *Research Developments in Science and Technology*, Vol. 4, pp. 108-123, 2022.

16. F. Salmasi, J.P. Abraham, and A. Salmasi, Design Considerations for Pumping Stations Using Variable Speed Pumps, *Novel Perspectives of Engineering Research*, Vol. 10, pp. 98-118, 2022.
17. F. Salmasi, J.P. Abraham, Drainage Gallery in Concrete Gravity Dams and its Effect on Reduction of Uplift Forces, *Novel Perspectives of Engineering Research*, Vol. 10 pp. 43-62, 2022.
18. F. Salmasi, and J.P. Abraham, Numerical Simulation Using the Finite Element Method to Investigate the Effect of Horizontal Drains and Cutoff Walls on Seepage and Uplift Pressure in Heterogeneous Earth Dams, *Novel Perspectives of Engineering Research*, Vol. 9, pp. 58-85, 2022.
19. F. Salmasi, J.P. Abraham, B. Nourani, Determining the Analysis of the Stability of Embankments Against Sliding and Prediction of Sliding and Critical Factor of Safety, *Novel Perspectives of Engineering Research*, pp. 98-125, 2022.
20. F. Salmasi and J.P. Abraham, Effect of Horizontal Drain Length and Cutoff Wall on Seepage and Uplift Pressure in Heterogeneous Earth Dam with Numerical Simulation, *Novel Perspectives of Engineering Research*, Vol. 9, pp. 58-85, 2022.
21. F. Salmasi and J.P. Abraham, Numerical Investigation of Reduction of Uplift Forces by Drain Pipes Under the Bed of a Canal, *Novel Perspectives in Engineering Research*, Vol. 7, pp. 117-139, 2022.
22. F. Salmasi and J.P. Abraham, A Case Study on the Weep Hole and Cutoff Wall Effect for Decreasing Uplift Pressure on Hydraulic Structures, *Innovations in Science and Technology*, Vol. 6, pp. 12-38, 2022.
23. F. Salmasi and J.P. Abraham, Comparison of Uplift Pressure and Hydraulic Gradient in Three Types of Dams: Concrete Gravity dams, Homogeneous, and Heterogeneous Earth-Filled Dams, *Innovations in Science and Technology*, Vol. 3, pp. 71-86, 2022.
24. F. Salmasi and J.P. Abraham, Geological Considerations in Dam Engineering, *Novel Perspectives of Engineering Research*, Vol. 6, pp. 97-125, 2022.
25. B.D. Plourde, J. Kilonzo, J. Kiplagat, J.P. Abraham, and L. Cheng, From Sunlight to Drinking Water – The Design and Validation of a Solar-Pasteurization System, Published in *Handbook of Research on Heat Transfer*, edited by S. Bhattacharyya and V. Goel, Chapter 16, 2022.
26. A. Salmasi, J.P. Abraham, and F. Salmasi, Prospects for Application of Nanotechnology in Marine Industries, *Innovations in Science and Technology*, Vol. 4, pp. 84-106, 2022.
27. F. Salmasi and J.P. Abraham, Validity of Schaffernak and Casangrande analytical solutions for Seepage Through a Homogeneous Earth Dam and Comparison with

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- Numerical Solutions Based on the Finite Element Method, in *Novel Perspectives of Engineering Research*, Vol. 4, pp. 79-93, 2021.
28. F. Salmasi and J.P. Abraham, Effect of Embankment Soil Layers on Stress-Strain Characteristics, *Recent Progress in Plant and Soil Research*, Vol. 4, pp. 68-84, 2021
 29. F. Salmasi and J.P. Abraham, Study on the Effect of Inclination of Cutoff Wall Beneath Gravity Dams on Uplift Force, in *Novel Perspectives of Engineering Research*, Vol. 1, pp. 38-57, 2021.
 30. J.P. Abraham, S. Bhattacharya, L. Cheng, and J.M. Gorman, A Brief History of and Introduction to Computational Fluid Dynamics, in *Computational Fluid Dynamics*, edited by: Suvarjan Bhattacharya, published by IntechOpen, 2021.
 31. F. Salmasi and J.P. Abraham, The Method of Characteristics Applied to the Sensitivity Analysis for Water Hammer Problems, *New Approaches in Engineering Research*, B.P. International, Vol. 9, pp. 50-63, 2021.
 32. J. Gorman, S. Bhattacharya, J.P. Abraham, L. Cheng, Turbulence Models Commonly used in CFD, in: *Computational Fluid Dynamics*, edited by: Suvarjan Bhattacharya, published by IntechOpen, 2021.
 33. J.M. Gorman, M. Regnier, and J.P. Abraham, Heat Exchange Between the Human Body and the Environment – A Comprehensive, Multi-Scale Numerical Simulation, in: *Advances in Heat Transfer*, Vol. 52, 2020.
 34. L.E. Olsen, J.P. Abraham, L.J. Cheng, J.M. Gorman, E.M. Sparrow, Summary of Forced-Convection Fluid Flow and Heat Transfer for Square Cylinders of Different Aspect Ratios Ranging from the Cube to a Two-Dimensional Cylinder, in: *Advances in Heat Transfer*, Vol. 51, pp. 351-457, 2019.
 35. E.M. Sparrow, J.M. Gorman, A. Ghosh, J.P. Abraham, Enhancement of Jet Impingement Heat Transfer by Means of Jet Axis Switching, in: *Advances in Heat Transfer*, Vol. 50, 2018.
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 38. J.P. Abraham, B.D. Plourde, L.J. Vallez, B.B. Nelson-Cheeseman, J.R. Stark, J.M. Gorman, E.M. Sparrow, Skin Burn, in: *Theory and Application of Heat Transfer in Humans*, edited by Devashish Shrivastava, Wiley, June 2018.

39. M.W. Dewhirst, J.P. Abraham, B.L. Viglianti, Evolution of Thermal Dosimetry for Application of Hyperthermia Treatment to Cancer, in: *Advances in Heat Transfer*, Vol. 47, 397-421, 2015.
40. B.D. Plourde, E.D. Taylor, P.O. Okaka, and J.P. Abraham, Financial and Implementation Considerations for Small-Scale Wind Power, in: *Small-Scale Wind Power – Design, Analysis, and Economic Impacts*, Momentum Press, 2014.
41. B.D. Plourde, E.D. Taylor, W.J. Minkowycz, and J.P. Abraham, Introduction to Small-Scale Wind Power, in: *Small-Scale Wind Power – Design, Analysis, and Economic Impacts*, Momentum Press, 2014.
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Conference Presentations and Public Lectures (148 presentations)

- 1. H. Zheng, L. Cheng, and J.P. Abraham, Sea Level Budget in Light of Recent Observational Advances Since 1960, EGU General Assembly, Vienna, Austria, April 27-May 2, 2025.

2. E. Wells, B.D. Plourde, J. Lyons, J.P. Abraham, G. Pauly, G. Riche, L. Purdum, C. Armstrong, K. Rice, T. Decker, K. Nowlan, M. Story, T. Solider Wolf, Electrification and Job Development for Rural Applications in the USA: Case Study – Wind River Reservation: Impacts on Tribal Capacity, Resiliency, Access to Power, and Jobs, *Microgrid Global Innovation Forum*, San Francisco, September 24-25, 2024.
3. J.P. Abraham, Heat Transfer in Forensics, VCU Forensics Seminar, December 6, 2022.
4. L. Cheng, and J.P. Abraham, Perspectives on Ocean sand Their Role in the Global Energy Budget and Water Cycle, *American Meteorological Society 102nd Annual Meeting, Houston, Kevin Trenberth Symposium*, January 23-27, 2022 (invited).
5. L. E. Olsen and J.P. Abraham, New correlations for convective coefficients over square and cubical bodies, *48th National Conference on fluid mechanics and fluid power*, December 27-29, 2021.
6. D. Vishwakarma, S. Bhattacharyya, M. Soni and J.P. Abraham, Effect of Inlet Flat Obstruction on Thermohydraulic Characteristics in a Smooth Circular Tube in the Transition Flow Regime, *48th National Conference on fluid mechanics and fluid power*, December 27-29, 2021.
7. J.P. Abraham, Introduction to the Computational Tools Available in Fluid Mechanics and Heat Transfer Research, *National Workshop on Research Methodology in Fluid Mechanics*, Pilani, India, June 7-9, 2021.
8. L. Cheng, K. Trenberth, N. Gruber, M.E. Mann, J.P. Abraham, and J. Fasullo, Improved Estimates of Changes in Upper Ocean Salinity and Water Cycle, *AGU Fall Meeting*, 2020.
9. J.P. Abraham, The Science of Global Warming – What do we really know? *Presented at New Mexico Tech. Lecture Series*, September 24, 2020.
10. L. Cheng, K. Trenberth, K. von Schuckmann, J.P. Abraham, V. Gouretski, Oceanic Responses to the Climate: Recognizing Changes and Extremes, *AAAS Annual Meeting*, February 11, 2021.
11. J.P. Abraham, Advanced Methods in Thermal Engineering, *International Workshop on Recent Advances in Thermal Engineering*, India, June 29-July 3, 2020.
12. J.P. Abraham, L. Cheng, Kevin Trenberth – A Life of Research and Impact, *Trenberth Symposium*, Denver, CO, March 16, 2020.
13. J.P. Abraham, Modern Climate Change, *Threats to the Worlds Oceans – World Ocean Day*, Minneapolis, MN June 8, 2020.

14. L. Cheng, K.E. Trenberth, N. Gruber, M.E. Mann, J.P. Abraham, J. Fasullo, G. Li, X. Zhao, and J. Zhu, Ocean Subsurface Salinity Changes Yield an Anthropogenic Climate Change Signal, *Ocean Sciences 2020*, San Diego, CA, February 16-21, 2020.
15. J.P. Abraham, Climate Science, Projections for the Next Two Decades, *Code Blue, Health Care Professionals for a Healthy Climate*, Minneapolis, MN, April 4, 2020.
16. L. Cheng, G. Foster, Z. Hausfather, K.E. Trenberth, J.P. Abraham, Increase in the Rate of Ocean Warming, *2019 AGU Fall Meeting*, San Francisco, December, 9-13, 2019.
17. J.P. Abraham, G. Foster, Z. Hausfather, L. Cheng, K.E. Trenberth, Earth's Energy Imbalance and Energy Flows Through the Climate System, *2019 AGU Fall Meeting*, San Francisco, December, 9-13, 2019.
18. L. E. Olsen and J.P. Abraham, Evaluation of CFD algorithms for solving a canonical problem of flow over a square cylinder, *4th Thermal and Fluids Engineering Conference*, Las Vegas, April 14-17, 2019.
19. S. A. Mandia, J.P. Abraham, M. Ashley, and J.W. Dash, The Climate Rapid Response Team – An Effective Model for Engaging Media and Policymakers, *2018 AGU Fall Meeting*, Washington, DC, December 2018.
20. J.P. Abraham, Climate Change, the Evidence is in the Oceans, *Presented at the National Laboratory for Marine Science and Technology*, Qingdao, China, October 25, 2018.
21. J.P. Abraham, Progress in XBT simulations, *Presented at the Institute of Atmospheric Physics*, Beijing, October 23, 2018.
22. J.P. Abraham, B.D. Plourde, J.R. Stark, Modeling Hemodynamics Through Lesions *Cardiovascular Research Technologies Conference 18*, Washington DC., March 3-6, 2018.
23. G. Wang, L. Cheng, J.P. Abraham, C. Li, and H. Du, Consensuses and discrepancies of basin-scale ocean heat content changes in different ocean analysis, *AOGS 15th Annual Meeting*, June 3-8, Hawaii, USA, 2018.
24. K.E. Trenberth, L. Cheng, P. Jacobs, and J.P. Abraham, Are recent hurricane (Harvey, Irma, and Maria) disasters Natural? *AGU Fall 2017 Meeting*, New Orleans, December 11-15, 2017.
25. P. Jacobs, S. Akella, K.E. Trenberth, L. Cheng, and J.P. Abraham, The Historical Context of the 2017 Hurricane Season's Ocean Warmth, *AGU Fall 2017 Meeting*, New Orleans, December 11-15, 2017.

26. J.P. Abraham, P. Jacobs, L. Cheng, K.E. Trenberth, Are recent hurricane (Harvey, Irma, and Maria) disasters Natural? *AGU Fall 2017 Meeting*, New Orleans, December 11-15, 2017.
27. J.P. Abraham and B.D. Plourde, Using ANSYS for Multiphysics Design of a Water Treatment System, *ANSYS Innovation Conference 2017*, Minneapolis, MN, November 8, 2017.
28. J.P. Abraham, L.J. Cheng, K.E. Trenberth, Improved Estimates of Ocean Heat Content from 1960-2015, *NOAA Presentation*, Washington DC, June 22, 2017.
29. J.P. Abraham, Use of Computational Fluid Dynamics to Improve Oceanographic Measurements, *NOAA Presentation*, Washington DC, January 12, 2017.
30. J.P. Abraham, B.D. Plourde, Use of Multi-lumen Catheters to Preserve Injected Stem Cell Viability, *Cardiovascular Research Technologies Conference 17*, Washington DC., February 18-21, 2017.
31. L. Cheng, J. Zhu, K. Trenberth, J. Fasullo, M. Palmer, T. Boyer, J. Abraham, Improved Ocean Heat Content Estimation Since 1960, *AGU Fall Meeting 2016*, San Francisco, CA, 2016.
32. J.P. Abraham, B. D. Plourde, John Stark, L.J. Vallez, Using ANSYS to Reduce Costs and Speed Development Process, *ANSYS Upper Midwest Innovation Conference*, Bloomington, Minnesota, November 17, 2016 (Keynote).
33. N. Langat, T. Thoruwa, J. Abraham, J. Wanyoko, Performance of an Improved Fluidized System for Processing Green Tea, *ICEE 18th International Conference on Energy Engineering*, Toronto, Canada, 2016.
34. L. Cheng, R. Cowley, J.P. Abraham, Cold Water Biases in XBT Descent, *5th XBT Science Workshop*, Tokyo, Japan, October 3-7, 2016 (Invited).
35. L. Cheng, K. Trenberth, M. Palmer, J.P. Abraham, Historical Ocean Heat Content Estimation and the Implications for Assessing Historical Earth's Energy Budget, *Clivar 2016*, Qingdao, China, 2016.
36. R. Cowley, J.P. Abraham, L. Cheng, The Effect of Water Temperature on XBT Fall Rate, *Clivar Third IQuOD Workshop*, Hamburg, Germany, December 3-4, 2015.
37. R. Cowley, L. Cheng, G. Goni, T. Boyer, J.P. Abraham, S. Wijffels, V. Gouretski, F. Reseghetti, S. Kizu, S. Dong, F. Bringas, M. Goes, L. Houpert, J. Sprintall, J. Zhu, Towards Reducing Uncertainty in Historical XBT Data: An International Effort from the XBT Science Team, *2016 Ocean Sciences Meeting*, New Orleans, LA, February 21-26, 2016.

38. J.P. Abraham and B.D. Plourde, Novel Cost-Effective Solution for Potable Water in All Environments, *The Food-Energy-Water Nexus, 16th National Conference and Global Forum on Science, Policy, and the Environment*, Washington DC, January 18-21, 2016.
39. J.P. Abraham and B.D. Plourde, Off-Grid Wind Power Systems for the Developing World, *The Food-Energy-Water Nexus, 16th National Conference and Global Forum on Science, Policy, and the Environment*, Washington DC, January 18-21, 2016.
40. L.Cheng, J. Zhu, J.P. Abraham, An Updated Historical (1970-2014) Upper OHC Estimates and Implication for the Global Energy Budget, *Climate and Ocean Variability and Change (CLIVAR) 8th Session of the Global Synthesis*, Exeter, UK, September 28, 2015.
41. J.P. Abraham, Our Changing Climate, *Citizens Climate Lobby Conference*, Red Wing, MN, November 6, 2015.
42. J.P. Abraham, J.R. Stark, Advances in XBT Measurement and Bias Reduction, *Chinese Academy of Sciences*, Beijing, October 10, 2015.
43. G. Foster and J.P. Abraham, Lack of Evidence for a Slowdown in Global Temperature, *American Geophysical Union Fall Meeting*, San Francisco, CA, December 14-18, 2015.
44. L. Cheng, J. Zhu, and J.P. Abraham, An Updated Estimate on Global Upper Ocean Heat Content Change and the Remaining Challenges, *American Geophysical Union Fall Meeting*, San Francisco, CA, December 14-18, 2015.
45. G. Foster and J.P. Abraham, Lack of Evidence for a Slowdown in Global Temperature, *US Climate Variability and Predictability Program (CLIVAR) Summit*, Tucson, AZ, August 4-6, 2015.
46. J.P. Abraham, Small-scale Wind Turbines: Design, Analysis and Applications, *Hong Kong University*, January 28, 2015 (invited).
47. J.P. Abraham, The Science of Climate Change, What Do We Really Know, *Hong Kong University of Science and Technology*, January 26, 2015 (invited).
48. J.P. Abraham et al., A Novel Multi Lumen Compliant Balloon Catheter (ND[®] Infusion Catheter) Preserves Stem Cell Viability and Improves Dispersion When Compared to a Standard Single Lumen Balloon Angioplasty Catheter, *European Society of Cardiology*, 2015, (submitted).
49. J.P. Abraham, T.M. Shepard, W.J. Minkowycz, J.R. Stark, J. M. Gorman, Quantification of Near-Surface Impact Forces on XBTs, *The 4th XBT Workshop: XBT Science and the Way Forward*, Beijing, China, November 11-13, 2014.

50. J.P. Abraham, B.D. Plourde, S.A. Mandia, and K.E. Trenberth, Closing the Earth Energy Imbalance, *3rd International Conference on Earth Science and Climate Change*, San Francisco, CA, July 28-30, 2014.
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52. J.P. Abraham, B.D. Plourde, J.R. Stark, W.J. Minkowycz, Cryosurgical Treatment of Cancer: The Importance of Modeling, *4th World Congress on Cancer Science and Therapy*, Chicago, October 20-22, 2014.
53. N. Dib, J.P. Abraham, B. D. Plourde, D.B. Schwalbach, D. Dana, L. Myers, K. Hunkler, T. Flower, and R.E. Kohler, A Novel Multi-lumen Compliant Balloon Catheter Preserves Stem Cell Viability and Decreases Cellular Clumping When Compared to a Standard Single-lumen Balloon Angioplasty Catheter, *Transcatheter Cardiovascular Therapeutics (TCT 2014)*, Washington, DC, September 13-17, 2014.
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55. J.P. Abraham, The Science of Climate Change (Keynote), *2014 Summer Institute for Climate Change and Energy Education*, Sandstone, MN, August 4-6, 2014.
56. J.P. Abraham, D. B. Schwalbach, T. M. Shepard, J. M. Gorman, Calculating forces of impact as objects travel from air into water at high velocity, *ANSYS Regional Conference*, Minneapolis, MN, June 10, 2014.
57. B.D. Plourde, D.B. Schwalbach, J.P. Abraham, R.E. Kohler, and N.N. Johnson, Intracoronary Injection of Medication from multi-lumen injection Catheters, *Design of Medical Devices 2014*, April 7-14, Minneapolis, MN.
58. N. Dib, J. Abraham, B.D. Plourde, D.S. Schwalbach, D. Dana, D. Lester, T. Flowers, and R.E. Kohler, Comparison of the Stem Cell Viability and Shear Stress of Single Lumen and Multi Lumen Balloon Infusion Catheter for Intra-Arterial Stem Cell Infusion, *American Cardiology Conference 2014*, Washington, DC, March 29-31.
59. J.P. Abraham, The Science of Global Warming, What Do We Really Know (Keynote), *Audubon Society National Meeting*, October 6, 2013.
60. J.P. Abraham, Thawing Out Climate Science, IEEE 2013 Awards Banquet, St. Paul, MN, February 23, 2013.

61. J.P. Abraham, Using ANSYS to Model Rotating Oceanographic Devices, *ANSYS Regional Conference*, Minneapolis, June 6, 2013.
62. N. Dib, J.P. Abraham, B. Plourde, D. Schwalbach, D. Dana, L. Myers, T. Flowers, and R. Kohler, Stem Cell Viability Significantly Reduced After Passing Through a Standard Single Lumen Over-the-wire 0.014 inch Balloon Angioplasty Catheter, *TCT 2013 Conference*, October 27-November 1, 2013, San Francisco, CA.
63. J.P. Abraham, Measurements of the Earth's Climate System, *IEEE Conference on Instrumentation and Measurement Technology Conference*, Minneapolis, MN, May 6, 2013.
64. J.P. Abraham, Numerical Simulations of Drug Deposition of Paclitaxel, *Design of Medical Devices Conference*, 2013, Minneapolis, MN, April 8-11, 2013.
65. J.P. Abraham, J. Stark, J. Gorman, E. Sparrow, R. Kohler, A Model of Drug Deposition Within Artery Walls, *Design of Medical Devices Conference*, 2013, Minneapolis, MN, April 8-11, 2013.
66. J.L. Conroy, S.A. Mandia, J.P. Abraham, S.E. Moffitt, G. Tootle, Environmental Litigation and the Role of Climate Scientists, *AGU Winter Meeting 2012*, December 3-7, San Francisco, 2012.
67. S.A. Mandia, J. Abraham, J. Dash, M. Ashley, Filling the Knowledge Gap that Exists Between the Public and Its Leaders and Climate Science Experts, *AGU Winter Meeting 2012*, December 3-7, San Francisco, 2012.
68. S.A. Mandia, J.P. Abraham, J. Dash, and M. Ashley, Navigating Negative Conversations in Climate Change, *AGU Winter Meeting 2012*, December 3-7, San Francisco, 2012.
69. M.J. Kallock, A. Yevzlin, M. Nelson, and J.P. Abraham, Numerical Modeling of Blood Flow in a New Percutaneously Delivered Hemodialysis Shunt, *BMES 2012 Annual Meeting*, Atlanta Georgia, October 24-27, 2012.
70. J.P. Abraham, Understanding Climate Change's Common Myths, *Minnesota Broadcast Meteorologists Climate Change Science Seminar*, St. Paul, MN, October 5-6, 2012.
71. N.P. Sullivan, J.E. Wentz, J.P. Abraham, Multi-Scale Modeling of Tubular Cross-Flow Microfiltration of Metalworking Fluids, *ASME International Mechanical Engineering Congress and Exposition*, Houston, TX, November 9-15, 2012.
72. J.P. Abraham, M. Nelson, J. Jeske, J. Gorman, Simulation Tools for Design and Testing Substitution in Medical Devices, *Lifescience Alley Research Conference, Research and Development 101*, Minneapolis, MN, May 22, 2012.

73. M.J. Kallock, M. E. Nelson, J. P. Abraham, and A. S. Yevzlin, Fluid Mechanic Modeling of a Percutaneously Delivered Vascular Access Device, *American Society of Diagnostic and Interventional Nephrology, 8th Annual Meeting*, New Orleans, LA, February 24-26, 2012.
74. D. Dana, J.P. Abraham, R. Kohler, A. Campbell, B. Baird, M. Olson, and N. Dib, A Novel Catheter Delivery System (CardioDib) That May Enable Intracoronary Stem Cell Infusion by Possibly Minimizing Cellular Clumping and Distal Embolization (DE) While Preserving Cellular Viability, *9th International Symposium on Stem Cell Therapy and Cardiovascular Innovations*, Madrid, Spain, June 7-8, 2012.
75. K.E. Trenberth, K. Emanuel, J.P. Abraham, Climate Science and Meteorology, *AMS National Broadcast Meteorology Conference*, Boston, MA, August 24, 2012
76. J.P. Abraham, J. Jeske, and M. Nelson, Thermal and Fluid Flow Simulations in Health Care: Product Development and Safety Improvement, *Design of Medical Devices Conference*, Minneapolis, MN April 10-12, 2012.
77. J.P. Abraham, Climate Myths, Misconceptions, and Their Creators, American Chemical Society, St. Paul, MN, November 13, 2012.
78. I. Enting, J.P. Abraham, Detailed Debunking of Denial, *AGU Winter Meeting 2012*, December 3-7, San Francisco, 2012.
79. B.D. Plourde, J.P. Abraham, G.S. Mowry, E.M. Sparrow, Experimental Test of Multi-Stage Vertical-Axis Turbines for Cellular Communication Applications, *ASME 6th International Conference on Energy Sustainability*, San Diego, CA, July 23-26, 2012.
80. M.N. Nelson and J.P. Abraham, Hemodynamics of AV Grafts for Hemodialysis Access, *Design of Medical Devices Conference*, Minneapolis, MN April 10-12, 2012.
81. J.P. Abraham and J.S. Jeske, Cryosurgical Simulations for Ablation of Kidney Tumors, *Design of Medical Devices Conference*, Minneapolis, MN April 10-12, 2012.
82. J.P. Abraham, J.R. Stark, and J.M. Gorman, Drag Calculations on Oceanographic Devices, *ANSYS Regional Conference*, Minneapolis, MN, October 20, 2011.
83. J.P. Abraham, B.D. Plourde, and G.S. Mowry, Fluid Dynamic Simulations of Wind Turbines, *ANSYS Regional Conference*, Minneapolis, MN, October 20, 2011.
84. S.A. Mandia, J.P. Abraham, R. Weymann, and M. Ashley, The Climate Science Rapid Response Team – A Model for Science Communication, *Geological Society of America Annual Meeting and Exposition*, Minneapolis, MN, October 9-12, 2011.

85. S.A. Mandia, J.P. Abraham, R.J. Weymann, and M. Ashley, The Climate Sciences Rapid Response Team – A Model for Science Communication, *American Geophysical Union Fall Meeting*, San Francisco, CA December 5-9, 2011.
86. J.P. Abraham, J. Stark, J. Gorman, F. Reseghetti, J. Willis, and J. Lyman, Preliminary Fluid Drag Calculations for Expendable Bathythermograph Devices, *American Geophysical Union Fall Meeting*, San Francisco, CA December 5-9, 2011.
87. S.A. Mandia, J.P. Abraham, R.A. Weymann, and M. Ashley, Scientists Shaping the Discussion, *American Geophysical Union Fall Meeting*, San Francisco, CA December 5-9, 2011.
88. J.P. Abraham, J.R. Stark, J.M. Gorman, F. Reseghetti, J. Willis, and J. Lyman, Computational Modeling of Probe Dynamics to Improve Ocean Heat Content Measurements, *American Geophysical Union Fall Meeting*, San Francisco, CA December 5-9, 2011.
89. B.M. Osende, J.P. Abraham, and G.S. Mowry, The Design, Installation, and Maintenance of a Village-Sized Solar Power System in Uganda, *Nanotech, Cleantech, Microtech 2011 Conference*, June 13-16, 2011, Boston, MA. Published in the Technical Proceedings of the 2011 NSTI Nanotechnology Conference and Expo, Vol. 3, pp. 755-758, 2011.
90. J.M. Gorman, E.M. Sparrow, G.S. Mowry, and J.P. Abraham, Simulation of Helically Wrapped, Compact Heat Exchangers, *ASME 2011 Energy Sustainability Conference*, Washington, DC, August 7-10, 2011.
91. B.D. Plourde, J.P. Abraham, G.S. Mowry, and W.J. Minkowycz, Vertical-Axis Wind Turbines for Powering Cellular Communication Towers, *Nanotech, Cleantech, Microtech 2011 Conference*, June 13-16, 2011, Boston, MA. Published in the Technical Proceedings of the 2011 NSTI Nanotechnology Conference and Expo, Vol. 3, pp. 750-753, 2011.
92. L. Tran, M.P. Hennessey, and J.P. Abraham, Simulation and Visualization of Dynamic Systems: Several Approaches and Comparisons, *ASME International Mechanical Engineering Congress and Expo*, Vancouver, Canada, November 12-18, 2011.
93. J.P. Abraham, Global Warming, What does the Science Tell Us?, *7th Annual Environmental Institute Conference* (KEYNOTE), Minneapolis, MN, April 21, 2010.
94. J.P. Abraham, G.S. Mowry, B.D. Plourde, and W.J. Minkowycz, Numerical Simulations of Vertical-Axis Wind Turbine Blades, *ASME 2011 Energy Sustainability Conference and Fuel Cell Conference*, Washington, DC, August 7-10, 2011.

95. J.P. Abraham, G.S. Mowry, B.D. Plourde, and W.J. Minkowycz, Wind Tunnel Tests of Vertical-Axis Wind Turbine Blades, *ASME 2011 Energy Sustainability Conference and Fuel Cell Conference*, Washington, DC, August 7-10, 2011.
96. R.D. Lovik, E.M. Sparrow, J.P. Abraham, C.L. Zelmer, S.K.S. Friend, and D.K. Smith, Effect of Component Misalignment on Human Tissue Temperatures Associated with Recharging Neuromodulation Devices, *Design of Medical Devices Conference*, Minneapolis, MN April 12-14, 2011.
97. N.N. Johnson, K. L. McCaffrey, K.M. Rose, and J.P. Abraham, Cryosurgical Treatments for Uterine Fibroids, *ASME 2010 International Congress and Expo*, Vancouver, CA, November 12-18, 2010.
98. R.D. Lovik, K. J. Kelly, E.M. Sparrow, and J.P. Abraham, Effect of Misalignment of Implant and Antenna on Heat Generation of Externally Recharged Neuromodulation Implants, *North American Neuromodulation Society 14th Annual Meeting*, Las Vegas, NV, December 2-5, 2010.
99. J.P. Abraham and S. Mandia, An Emerging Ethic of Responsibility: A Case Study for Engaging the Public, *American Geophysical Union Fall Meeting*, San Francisco, CA December 13-17, 2010.
100. J.P. Abraham and G.S. Mowry, B.D. Plourde, Analysis of Thermal and Fluid Flow Problems, *Thermal Packaging and Small Business Innovation Workshop*, Eagan, MN, October 5-6, 2010.
101. N.N. Johnson, J.P. Abraham, Z.I. Helgeson, and M.P. Hennessey, Numerical Simulation of Blood Flow in the Presence of Embolizing Agents, *ASME 2010 International Congress and Expo*, Vancouver, CA, November 12-18, 2010.
102. N.N. Johnson, J.P. Abraham, and Z.I. Helgeson, Calculations of Scald Burns: Effects of Water Temperature, Exposure Duration, and Clothing, *ASME 2010 International Congress and Expo*, Vancouver, CA, November 12-18, 2010.
103. N.N. Johnson, M.P. Hennessey, and J.P. Abraham, Swept Arc Length Measure of Abrasive Wear, *ASME 2010 International Congress and Expo*, Vancouver, CA, November 12-18, 2010.
104. K.L. McCaffrey, K.M. Rose, and J.P. Abraham, Numerical Simulation of Cryosurgery as a Potential Treatment for Uterine Fibroids, *14th International Heat Transfer Conference*, Washington, D.C., August 8-13, 2010.
105. J.P. Abraham, E.M. Sparrow, J.C.K. Tong, and W.J. Minkowycz, Intermittent Flow Modeling. Part 1: Hydrodynamic and thermal Modeling of Steady, Intermittent Flows in Constant Area Ducts, *14th International Heat Transfer Conference*, Washington, D.C., August 8-13, 2010.

106. J.P. Abraham, E.M. Sparrow, J.C.K. Tong, and W.J. Minkowycz, Intermittent Flow Modeling. Part 2: Time-Varying Flows and Flows in Variable Area Ducts, *14th International Heat Transfer Conference*, Washington, D.C., August 8-13, 2010.
107. K.L. McCaffrey, K.M. Rose, and J.P. Abraham, Cryosurgery as an Alternative Treatment for Menorrhagia and Uterine Fibroids, *ASME Summer Biomedical Engineering Conference*, Naples, FL, June 16-19, 2010.
108. J.M. Gorman, N.K. Sherrill, J.P. Abraham, Analysis of Drag-Reducing Techniques for Olympic Skeleton Helmets, *ANSYS Users Conference*, Minneapolis, MN, June 11, 2010.
109. B. D. Plourde, J.P. Abraham, G.S. Mowry, Numerical Simulation of Vertical Axis Wind Turbines, *ANSYS Users Conference*, Minneapolis, MN, June 11, 2010.
110. J.P. Abraham, Z.I. Helgeson, N.N. Johnson, G.S. Mowry, Numerical Simulations and Medical Device Design, *ANSYS Users Conference*, Minneapolis, MN, June 11, 2010.
111. J.M. Gorman, N.K. Sherrill, J.P. Abraham, Drag-Reducing Vortex Generators and Olympic Skeleton Helmet Design, *ANSYS Users Conference*, Chicago, IL, June 7, 2010.
112. J.P. Abraham, Z.I. Helgeson, N.N. Johnson, G.S. Mowry, (Keynote), Numerical Simulations in Biomedical Design, *ANSYS Users Conference*, Chicago, IL, June 7, 2010.
113. J.P. Abraham, E.M. Sparrow, Y. Bayazit, R.D. Lovik, and D.S. Smith, Numerical and Experimental Simulations as Symbiotic Tools for Solving Complex Bio-Thermal Problems, *Design of Medical Devices Conference*, Minneapolis, MN April 13-15, 2010.
114. E.M. Sparrow and J.P. Abraham, Numerical Solutions of Biological Heat Transfer, *Design of Medical Devices Conference*, Minneapolis, MN April 13-15, 2010.
115. J.P. Abraham, R.D. Lovik, D.S. Smith, E.M. Sparrow, and K.J. Kelly, Heat Generation Measurements of Revised Neuromodulation Devices and Calculations of Tissue Temperatures, *North American Neuromodulation Society 13th Annual Meeting*, Las Vegas, December 3-6, 2009.
116. J.P. Abraham and E.M. Sparrow, Numerical Simulation as a Tool for Assessing Thermal- and Fluid-Based Processes and Therapies, *Institute for Engineering in Medicine Innovation Showcase*, Minneapolis, MN, September 22, 2009.
117. J.P. Abraham, E.M. Sparrow, and R.D. Lovik, An Investigation of Tissue-Temperature Elevation Caused by Recharging of Transcutaneous Neuromodulation Devices, *31st Annual International Conference of the IEEE Engineering in Medicine in Biology Society*, Minneapolis, MN, September 2-7, 2009.

118. R.D. Lovik, J.P. Abraham, and E.P. Sparrow, Pulsating Fluid Flows Undergoing Transitions Between Laminar, Transitional, and Turbulent Regimes, *ASME 2009 Summer Bioengineering Conference*, Lake Tahoe, CA, June 17-21, 2009.
119. E.M. Sparrow, and J.P. Abraham, Case Studies on the Use of Numerical Simulation for design and Optimization of Medical Devices, *Design of Medical Devices Conference*, Minneapolis, MN April 14-16, 2009.
120. F. Hoover and J. Abraham Assessment of the Carbon Dioxide and Energy Balances of Biofuels, *Climate Change Technology Conference 2009*, Hamilton, Ontario, May 12-15, 2009.
121. J.P. Abraham, G.S. Mowry, and R.E. Erickson, Design and Analysis of a Small-Scale Vertical-Axis Wind Turbine for Rooftop Power Generation, *Climate Change Technology Conference 2009*, Hamilton, Ontario, May 12-15, 2009.
122. F. Hoover and J.P. Abraham, A review: Comprehensive Comparison of Corn-based and Cellulosic-based Ethanol as Biofuel Sources, *Clean Technology Conference and Expo 2009*, Houston, TX, May 3-7, 2009.
123. J.P. Abraham, G.S. Mowry, and R.E. Erickson, Design and Analysis of a Small-Scale Vertical-Axis Wind Turbine, *Clean Technology Conference and Expo 2009*, Houston, TX, May 3-7, 2009.
124. J.P. Abraham, R.D. Lovik, and E.M. Sparrow, Tissue Temperature Rises Due to Heat Generation in Neuromodulation Implants, North American Neuromodulation Society 12th Annual Meeting, Las Vegas, December 4-7, 2008.
125. G. Nelson, A. Majewicz, and J.P. Abraham, Numerical Simulation of Thermal Injury to the Artery Wall During Orbital Atherectomy, *ANSYS International*, Pittsburgh, PA, August 26-29, 2008.
126. J.P. Abraham, Integrating Integration of ANSYS/CFX into Classrooms, *ANSYS International*, Pittsburgh, PA, August 26-29, 2008.
127. J.P. Abraham, Pressure Drop and Heat Transfer Calculations for Laminar-Turbulent Intermittent Flows, *ANSYS International*, Pittsburgh, PA, August 26-29, 2008.
128. J.P. Abraham, J.C.K. Tong, and E.M. Sparrow, Prediction of Laminar-Turbulent Transition and Friction Factors in Transitional Flows, *ASME International Congress and Expo*, Boston, MA, October 31 – November 5, 2008.
129. R.D. Lovik, J.P. Abraham, and E.M. Sparrow, Assessment of Possible Thermal Damage of Tissue Due to Atherectomy by Means of a Mechanical Debulking Device, *ASME 2008 Summer Bioengineering Conference*, Marco-Island, FL, June 25-29, 2008.

130. J.P. Abraham and A.P. Thomas, Numerical Simulation of Induced Co-Flow and Laminar-to-Turbulent Transition Associated with Synthetic Jets, *Fluconome 2007*, Tallahassee, FL, September 16-19, 2007.
131. J.P. Abraham and C.M. George, An Investigation of Radiation Shields for Full-Building Cooling in Desert Climates, *Solar 2007*, Cleveland, OH July 7-12, 2007.
132. A. Marchese, J.P. Abraham, C.S. Greene, L. Kizenwether, and J. Ochs, Toward a Common Standard Rubric for Evaluating Capstone Design Projects, *National Capstone Design Course Conference*, Boulder, CO June, 13-15, 2007 (Best Paper Award).
133. John Abraham, Chris Greene, Anthony Marchese, External Assessment Through Peer-to-Peer Evaluation of Capstone Projects, *Frontiers in Education*, Milwaukee, WI, October, 10-13, 2007.
134. John Abraham, Computation Fluid Dynamics Using ANSYS CFX, presented at the University of Minnesota Digital Technology Center, Sept. 12 and 14, 2006.
135. John Abraham, Application of the Finite Element Method, *LifeSciences Conference*, Minneapolis, October 5, 2006.
136. John Kim and John Abraham, Design of Experiments in the Medical Device Industry, *LifeSciences Conference*, Minneapolis, October 5, 2006.
137. Ephraim Sparrow, Nick Whitehead, and John Abraham, Fluid Flow Dynamics in the Urinary Tract – Impact on Device Design, Presented to the Department of Urologic Surgery, April 17, 2006.
138. John Abraham, Nick Whitehead, and Ephraim Sparrow, Numerical Simulation of Thermal Therapies, Presented to the Department of Urologic Surgery, April 17, 2006.
139. John Abraham, Nick Whitehead, and Ephraim Sparrow, Biomedical Applications Simulations/Experimental Investigations, *Biomedical Focus 2006*, Brooklyn Center, MN, March 20-21, 2006.
140. Nick Whitehead, Ephraim Sparrow, and John Abraham, A Role for Engineering in Medical Simulations, *Simulation in Healthcare*, Minneapolis, MN, November 28, 2005.
141. Ronald Major and John Abraham, The Application of Thermal Analysis on a Disk Array, *Fluent's 2005 CFD Summit*, Detroit, MI, June 7-8, 2005.
142. Camille George and John Abraham, A Sustainable Low-Energy Cooling System for Hot Dry Climates, *Sustainability as Security*, Austin, TX, October 5-9, 2005.

143. John P. Abraham and Ephraim M. Sparrow, Irrelevance of the Relative Velocity as the Characteristic Velocity When Both a Fluid and its Bounding Surface are in Motion, *Lorenz G. Straub Award*, Minneapolis, MN, November 13, 2004.
144. John P. Abraham and Ephraim M. Sparrow, An Unexpected U-Turn After an Eckert Straight Start, *Eckert Symposium*, Minneapolis, MN, September 13-14, 2004.
145. John P. Abraham and Ephraim M. Sparrow, Methodologies to Enhance the Numerical Simulations of Electronic Cooling, *Semi-Therm Conference*, San Jose, CA, March 9-10, 2004.
146. Ephraim M. Sparrow, John P. Abraham, and Paul Chevalier, A DOS-Enhanced Numerical Simulation of Heat Transfer and Fluid Flow Through an Array of Offset Fins with Conjugate Heating in the Bounding Solid, *ASME International Mechanical Engineering Congress and R & D Expo*, Washington, DC, November, 2003.
147. J. P. Abraham, Ephraim M. Sparrow, Student-Related Research “Thermal Design Capstone Projects”, *ASME International Mechanical Engineering Congress and R & D Expo*, Washington, DC, November, 2003.
148. Sparrow, E.M., Martin, G.L., Abraham, J.P., and Tong, J.C., Air-to-Air Energy Exchanger Test Facility for Mass and Energy Transfer Performance. *American Society of Heating, Refrigeration, and Air-Conditioning Engineers Annual Meeting*, Inc., Cincinnati, OH, ASHRAE Symposium Paper, 2001.
149. Tamma, K.K., Zhou, X., Abraham, J., and Anderson, C.V.D.R., Constitutive Model Theories and Plausible Propositions/Challenges to Heat Transport Characterization. *ASME/JSME Joint Thermal Engineering Conference*, March, 1999.

Granted Patents (author of 26 patents)

1. Robert Monson and John Abraham, “Dual-phase thermal electricity generator”, U.S. Patent # 8,484,974.
2. Robert Monson and John Abraham, “Variable Orifice Valve”, U.S. Patent # 7,559,485
3. Robert Monson, John Abraham, Joseph Crimando, Joel Farley, Matthew Linder, and Joel Seipel, "Vehicle Energy Absorption Apparatus", US Patent # 8,118,255.
4. B.D. Plourde and J.P. Abraham, “Rotor Blade for Vertical Axis Wind Turbine”, US Patent # 9,482,204/ WO 2011150171.
5. B.D. Plourde, J.P. Abraham, D.R. Plourde, A. Gikling, R. Pakonen, “Dual-Axis Tracking Device”, US Patent # 10,168,412.
6. B. D. Plourde, J. P. Abraham, D.R. Plourde, R. Pakonen, “Control Valve Assembly for Fluid Heating System”, US Patent # 10,495,720.

7. B. D. Plourde, J. P. Abraham, D.R. Plourde, R. Pakonen, “Dual Axis Tracking Device”, China National Intellectual Property Administration, Patent number ZL201580075224.1, 2020.
8. B.R. Plourde, J. P. Abraham, D.R. Plourde, R. Pakonen, “Dual Axis Tracking Method”, U.S. Patent 10,890,645.
9. B.D. Plourde, A. Gikling, J.P. Abraham, R. Pakonen, “Digital Fluid Heating System”, U.S. Patent 10,989,420.
10. B.D Plourde, J.P. Abraham, D. Plourde, R. Pakonen, A. Gikling, N. Naughton, “Fluid Heating System”, European Patent, EP 3227618.
11. B. D. Plourde, J. P. Abraham, D.R. Plourde, R. Pakonen, “Method of Calculating Pathogen Inactivation for a Fluid Heating System”, US Patent, 11,255,804.
12. B.D. Plourde, A. Gikling, J.P. Abraham, R. Pakonen, “Digital Fluid Heating System”, China National Intellectual Property Administration, Chinese Application Number 201780083752.0
13. B.D. Plourde, A. Gikling, J.P. Abraham, R. Pakonen, “Digital Fluid Heating System”, African Regional Intellectual Property Organization (ARIPO), (patent granted, number forthcoming).
14. B.D. Plourde, A. Gikling, J.P. Abraham, R. Pakonen, “Digital Fluid Heating System”, European Union number EP 4,080,134.
15. B.D. Plourde, A. Gikling, J.P. Abraham, R. Pakonen, “Digital Fluid Heating System”, European Union number EP3,542,107.
16. B.D. Plourde, A. Gikling, J.P. Abraham, R. Pakonen, “Digital Fluid Heating System”, Columbia, Application number NC 2019/00006027, (*number to be issued*).
17. B.D. Plourde, A. Gikling, J.P. Abraham, R. Pakonen, and D. Plourde, Solar Heating for Refrigeration and Fluid Heating Devices, Colombian Application No. 2019/0011368, (*number to be issued*).
18. B.D. Plourde, A. Gikling, J.P. Abraham R. Pakonen, and D. Plourde, Digital Fluid Heating System, US Patent no. 11,920,801
19. B.D. Plourde, J.P. Abraham, D. Plourde, R. Pakonen, A. Gikling, N. Naughton, “Fluid Heating System”, US Patent no. 11,946,886.
20. B.D. Plourde, A. Gikling, J.P. Abraham, R. Pakonen, “Solar Heating for Refrigeration and Fluid Heating Devices”, filed March 2018. Brazil Application No. BR1120190190414, (patent number forthcoming).

21. B.D. Plourde, A. Gikling, J.P. Abraham, R. Pakonen, “Digital Fluid Heating System”, filed November 2017. Brazil Application No. BR112019009923-9, (patent number forthcoming).
22. B.D. Plourde, A. Gikling, J.P. Abraham, R. Pakonen, “Fluid Heating System”, Peru, Application Number 001011-2019 (patent number forthcoming).
23. B.D. Plourde, A. Gikling, J.P. Abraham, R. Pakonen, “Digital Fluid Heating System”, India, Patent no. 478824.
24. B.D. Plourde, A. Gikling, J.P. Abraham, R. Pakonen, “Dual-Axis Tracking Method”, India, 522,368, 2024.
25. B.D. Plourde, A. Gikling, J.P. Abraham, R. Pakonen, “Solar Heating for Refrigeration and Fluid Heating Devices”, Peru, (patent number forthcoming).
26. B.D. Plourde, A. Gikling, J.P. Abraham, R. Pakonen, “Dual Axis Tracking Device”, European Application, No. 15816974.8

Pending Patents

1. B.D. Plourde, J.P. Abraham, “Solar Heating System”, US Patent Application No. 62/423,814 (filed November 18, 2016).
2. B.D. Plourde, A. Gikling, J.P. Abraham, R. Pakonen, “Solar Heating for Refrigeration and Fluid Heating Devices”, filed March 2018. US Application number 20180266712.
3. B.D. Plourde, A. Gikling, J.P. Abraham, R. Pakonen, “Dual-Axis Tracking Method”, US Application number 2019/0107598, filed November 2018.
4. B.D. Plourde, A. Gikling, J.P. Abraham, R. Pakonen, “Digital Fluid Heating System”, US Application number 2018/0142905, filed November 2017.
5. B.D. Plourde, A. Gikling, J.P. Abraham, R. Pakonen, “Fluid Heating System”, Chinese National Intellectual Property Administration, Application number 2022105305045.8.
6. B.D. Plourde, A. Gikling, J.P. Abraham, R. Pakonen, “Fluid Heating System”, India, Application number 201737018679.
7. B.D. Plourde, A. Gikling, J.P. Abraham, R. Pakonen, “Digital Fluid Heating System”, Brazil, Application number BR112019009923-9.

Granted Trademarks

1. US Trademark Registration Number 5656322, assignee: WTS LLC, Minnesota, USA. Trademark granted, January 15, 2019.
2. US Trademark Registration Number 5656323, assignee: WTS LLC, Minnesota, USA. Trademark granted, January 15, 2019.

Editorial Board Member

18. International Society of Cardiovascular Translational Research, 2020-present
19. Energies, Thermal Management, 2019-present
20. Cardiovascular Revascularization Medicine, 2018-present
21. Stem Cell Biology and Transplantation, 2015-present
22. Associate Editor, NCSE, Climate Science, 2012-present
23. International Journal of Mechanics and Energy, 2012-present
24. Open Mechanical Engineering Journal, 2007-present
25. Open Mechanical Engineering Reviews, 2007-present
26. Open Mechanical Engineering Letters, 2007-present
27. Open Medical Devices Journal, 2008-present
28. Creative Engineering Journal, 2009-present
29. ISRN Applied Mathematics, 2011-present
30. International Journal of Sustainable Energy, 2012 - present
31. International Journal of Materials, Methods, and Technologies, 2012- present

CONSULTANTSHIPS

GRANTS (funding \$24.02 million)

<i>Bold Alliance</i>	2023-2024
<i>Varian Medical Systems</i>	2023
<i>Flotherm</i>	2021-2023
<i>LEMA, LLC, MN</i>	2016-2023
<i>HRST, Inc., MN</i>	2021
<i>Biotronik</i>	2021
<i>Starky</i>	2020
<i>Marvin Windows</i>	2020-2022
<i>Cardiovascular Systems, Inc.</i>	2019-2021
<i>ALS Consulting</i>	2019
<i>Medivator, MN</i>	2018-2019
<i>Medivators, MN</i>	2014-2015
<i>EKOS, MN</i>	2018
<i>Marcor</i>	2018
<i>Marvin Windows</i>	2018
<i>Medtronic, Fridley, MN</i>	2017-2020
<i>Orbital ATK</i>	2017-2018
<i>Pride Engineering, MN</i>	2017-2018
<i>Cargill, MN</i>	2016-2017
<i>EKOS, MN</i>	2016-2017
<i>Precision Air, MN</i>	2016

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3M, MN	2015-2017
Flourescence, Inc., MN	2015
Smiths Medical, MN	2014-2015
WTS LLC, MN	2014-2022
Somnetics, MN	2014
Lake Region Medical, MN	2013-2014
Amphora Medical, MN	2013-2014
ALS Consulting, MN	2013-2016
Medtronic, Fridley, MN	2013-2016
Devicix, MN	2012-2013
CriticCare, MN	2012
HRST, Inc., MN	2012-2015
QIG Group, OH	2011-2013
Phraxis, MN	2011-2012
Cardiovascular Systems, Inc., Roseville, MN	2007-2015
Translational Biologic Infusion, AZ	2011-2013
Galil Medical, Roseville, MN	2011
Imation, Oakdale, MN	2010
Medtronic, Fridley, MN	2008-2011
R4 Engineering, India	2008-2009
Horizontal Winds,	2008-2009
Lockheed Martin, Eagan, MN	2007-2009
St. Jude Medical, Minnetonka, MN	2007-2009
Arizant Medical, Eden Prairie, MN	2006
Johnson and Johnson, Newark, NJ	2004-2005
Cortron/XeteX, Fridley, MN	2005
MicroControl Company, MN	circa 2001
Donaldson Co., Bloomington, MN	1999-2003
Augustine Medical, Eden Prairie, MN	2000-2003
Midmac Systems Inc., St Paul, MN	2002
Remmele Engineering Inc., St Paul, MN	2002-2005
Urologix, Minneapolis, MN	circa 2004
Restore Medical, Minneapolis, MN	circa 2002
Jennio, Minnesota	circa 2001
Caterpillar, Minneapolis, MN	circa 2000
ADC telecom, Minneapolis, MN	circa 2000
Entropy Solutions	circa 2000
XeteX, Inc., Minneapolis, MN	1996-2000
Pneuseal, St. Paul, MN	1996-1998
Los Alamos National Laboratory, Los Alamos, NM	1994

GRANTS (funding \$24.783 million)

Energetics Technology Center

2025

\$477,000 Funding for development of solar-powered towers with sensors

Energetics Technology Center	2025
\$50,000 Funding for development of solar-powered towers with sensors	
USAID	2024
\$145,900 Funding through USAID's Health Electrification and Telecommunications Alliance (HETA program)	
Department of Interior	2024
\$130,000 Funding for electrification of Wind River Reservation	
Bold Alliance	2023
~\$12K For research on pollution plumes from a rupture pipeline	
Varian Medical Systems, Inc.	2023
Brain thermal transport, oncology applications	
LEMA, LLC	2016-2022
\$20m for development and deployment of solar-power off grid systems. Part of Consolidated Appropriations Act, 2023	
HRST, Inc.	2021
\$34,000 for analysis of flow patterns in power plants	
Biotronik	2021
\$44k for simulation of heating caused by implanted medical devices	
Flotherm (SBIR award FAIN 2034065)	2020-2023
\$20k for simulation of body-heating devices \$48k for simulation of body-heating devices SBIR funding, NSF Small Business Innovative Research project	
Starky	2019-2020
\$6k for thermal modeling of hearing aid batteries	
National Science Foundation (Co-PI, FAIN = 2018403)	2020-2021
\$424k for engineering PIV instrumentation	
Intertek	2019-2020
\$13k for study of tissue surrogates for biological heating	
Cardiovascular Systems, Inc.	2019-2021
\$13k for thermal model of blower impellor for a dialysis pump \$9k for thermal model of blower impellor for a dialysis pump \$4k for thermal model of blower impellor for a dialysis pump \$20k for flow model of blower impellor for a dialysis pump \$5k for flow model of blower impellor for a dialysis pump	

ALS Consulting	2019
\$15k for thermal model of power plant	
Medivators	2019
\$12k for thermal model of thermal sterilization	
Marvin Windows	2019-2022
\$4k for thermal analysis of a tiny home	
\$5k for thermal model of manufacturing line	
\$4k for thermal model of manufacturing line	
Medtronic	2019
\$22k for simulation of tissue temperatures during transcutaneous recharge	
\$25.5k for simulation of tissue temperatures during transcutaneous recharge	
Medivators	2018
\$18k to research airflow in medical sterilization equipment.	
Marvin Windows	2018-2020
\$6k to research thermal processes during window ventilation	
\$4k to research thermal processes of natural lighting	
\$4k to research thermal processes of natural lighting	
Medtronic	2018
\$3k to research battery heating rates	
\$8k to research thermal tolerance of brain tissue	
EKOS	2018
\$14k for analysis of flow distribution within stents	
Marcor	2018
\$10k for fluid and heat transfer analysis	
Pride Engineering	2017
\$3k to calculate a metal stamping machine process	
Orbital ATK	2017-2018
\$30k to simulate fluid flow	
\$12k to simulate fluid flow	
Medtronic	2017
\$5k to research thermal tolerance of brain tissue	
\$14k to calculate cranial temperature increases during transcranial recharge	
3M	2017
\$14k to simulate airflow in ultra-clean operating rooms.	

Zoll Engineering	2017
\$5.5k for design of flow through a ventilation medical device	
Cargill	2016-2017
\$14k for analysis of food frier	
\$15k for analysis of a food processing device	
EKOS	2017
\$14k for analysis of flow distribution within stents	
\$14k for analysis of flow distribution within stents	
\$12k for analysis of flow distribution within stents	
ALS Consulting	2016
\$15k for analysis of fluid flow in power plants	
Precision Air	2016
\$1600 for simulation of airflow in operating rooms	
Medtronic	2016
\$12k for simulation of tissue temperatures during transcutaneous recharge	
3M	2015
\$12k to simulate airflow in ultra-clean operating rooms.	
Cardiovascular Systems, Inc.	2015-2016
\$8,000 for the study of deformable arteries	
\$6,000 for biological flows and impellor design	
AF Energy	2015
\$3000 wind turbine calculations	
Intellectual Ventures Laboratory	2015
\$2000 wall condensation calculations	
Medivators	2015
\$4000 for flow and pressure calculations medical chamber.	
Flourescence, Inc.	2015
\$2,000 designing biological heater for cell environments	
Mador Technologies	2015
\$20,000 analyzing a liquid nitrogen water condensation device	
Koronis Biomedical Technologies	2015
\$5,000 simulation of fluid flow	

Mador Technologies	2014-2015
\$8,000 analyzing a liquid nitrogen water condensation device	
National Resources Defense Council	2015
\$10k for climate education work	
Medtronic	2014
\$12k for simulation of tissue temperatures during transcutaneous recharge	
Smiths Medical	2014
\$9.5k for design and optimization of medical warming blankets	
\$10k for the design and improvement of medical fans	
\$12k for the design and analysis of human thermal analogs	
WTS LLC	2014-present
\$1.5m for the design of solar pasteurization systems	
Medivators	2014
\$4000 for flow and pressure calculations medical chamber.	
\$3000 for flow and pressure calculations medical chamber.	
Somnetics	2014
\$6000 for flow and pressure calculations in CPAP devices.	
Lake Region Medical	2013-2014
\$4500 for simulations of a guidewire manufacturing oven	
Amphora Medical	2013-2014
\$55.5k for design of RF probes for ablation of bladder tissue	
ALS Consulting	2013-2014
\$17.5k for analysis of fluid flow in power plants	
Medtronic, Inc.	2012-2013
\$13k for analysis of subdermal heating associated with recharge of neuromodulation systems.	
Phraxis	2013
\$2,250 for the analysis of blood flow through an AV shunt	
Translational Biologic Infusion Catheter	2011-2013
\$21.5k for the study of flow and pressure drop in a stem-cell delivery catheter	
Advanced Circulatory Systems, Inc.	2013
\$4200 for fluid flow modeling of medical-device blowers	
HRST, Inc.	2012-2015

\$11,250 for analysis of flow patterns in manifolds		
Devicix		2012
\$2000 for the analysis of medical-fluid injection devices		
Helical		2012-2013
\$18,200 for the design and analysis of rooftop wind turbines		
QiG Group		2012
\$7000 for study of thermoelectric technologies to power implants		
HRST, Inc.		2012
\$4300 for analysis of perforated plates for flow uniformity		
Energy Foundation		2012-2013
\$30k developing climate-science communication strategies		
CriticCare		2012
\$4,275 for numerical modeling of accelerated aging of medical devices.		
HRST, Inc.		2012
\$5,540 for research study on mixing efficiency in heat recovery plants.		
Windstrip, LLC		2009-2013
\$1m for development of vertical axis wind turbines to power cellular communication equipment.		
QiG Group		2011-2012
\$20k for study of implant heating of biological tissue		
Phraxis		2011-2012
\$8,000 for the analysis of blood flow through an AV shunt		
Energy Foundation		2011-2012
\$71k developing climate-science communication strategies		
Cardiovascular Systems, Inc.		2011
\$23k for the study of paclitaxel distribution techniques.		
Cardiovascular Systems, Inc.		2011
\$5,000 for the study of temperature management in palleted products		
Galil Medical		2011
\$9,000 for the kidney tumor cryosurgical devices.		
Multiple groups		2010
\$13,000 for installation of solar panels in Uganda		

Imation	
\$10k for the design of a polymeric extrusion die	2010
Cypress Wind	
\$30.6k for the development of a vertical axis, small-footprint wind turbine.	2010
Cypress Wind	
\$27k for the development of a vertical axis, small-footprint wind turbine.	2009
Cardiovascular Systems, Inc.	2009
\$80k for the study of cavitation and bolus formation during orbital atherectomy procedures.	
Medtronic, Inc.	
\$65k for analysis of subdermal heating associated with recharge of neuromodulation systems.	2008-2011
University of St. Thomas Faculty Development Grant	2009
\$4,200 for the purchase of a high-performance computer for numerical simulations.	
CSUMS: A computational Training and Interdisciplinary Research Program for Undergraduates in the Mathematical Sciences at the University of St. Thomas	2008-2013
Served as Senior Personnel on a \$716,836 NSF award for the development of applied research projects for undergraduates in mathematics.	
Lockheed Martin Innovative Program - Advanced Cooling Technology grant	2009
\$19.5k for the improvements to avionics heat pipe applications.	
Horizontal Winds	2008-2009
\$11k for research on vertical-axis wind turbines	
R4 Engineering	2008-2009
\$10k for analysis of building-support insulation systems	
Lockheed Martin Innovative Program - Advanced Cooling Technology grant	2007
\$53k for the development of advanced electronic-cooling methodologies.	
Arizant Medical	2006
Characterization of a forced-air patient warming device	
Johnson and Johnson, Newark, NJ	2004-2005
Analysis of a uterine fibroid embolization device	
Urologix	2004
Design of thermoelectric device for heating/cooling of urological catheter fluids	

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Donaldson Co.	1999-2003
Analysis and characterization of a filter-manufacturing device	
Augustine Medical	2000-2003
Characterization of a forced-air patient warming device	
Midmac Systems Inc.	2002
Thermal analysis of a polymeric sealing machine	
Restore Medical	2002
Characterization of sleep apnea treatment	
Remmele Engineering Inc.	2002-2005
Thermal analysis of a polymeric sealing machine for insulin packaging	
Thermal analysis of liquid-based cold plates for cooling naval radar	
MicroControl Company	2001
Analysis of burn-in board devices	
Jenni-O	2001
Analyzed devices that handle, transport, and cool turkeys during processing.	
Caterpillar	2000
Analysis of a screed heating machine	
ADC Telecom	2000
Optimization of an AC/DC power converter	
Viracon Glass	2000
Design and analysis of glass thermal processing method	
Entropy Solutions	2000
Design and Analysis of insulation and phase change thermal management for shipping containers	
XeteX, Inc	1996-2000
Design of an air-to-air heat exchanger	
Creation of a film processing machine for coating heat exchangers	
Construction and operation of a full-sized HVAC test facility	
Pneuseal	1996-1998
Operation and optimization of a polymeric sealing device for medical packaging	
Principal Investigator – Supercomputing Institute	2002-2012
Served as PI for multi-year project dedicated to performing computational fluid dynamic studies. This grant awarded computing resources at the Supercomputing Institute for Digital Simulation and Advanced Computing.	

Principal Investigator – ASHRAE Project Grant Program **2003**

Awarded a \$5,000 grant funded by ASHRAE to investigate the efficacy of rotating-wheel heat and moisture exchangers.

Faculty Advisor – Bush Grant, Young Scholars Program **2002**

Faculty advisor for a \$3,000 grant for undergraduate research of air-jet heat transfer for surgical applications.

Faculty Advisor – Bush Grant, Young Scholars Program **2002**

Faculty advisor for a \$3,000 grant for undergraduate research to encourage American Indian students to pursue careers in science and technology.

**A Multi-Function Heat Exchanger for Control of Temperature, Moisture,
and Air Quality** **1997-2000**

Project Engineer for \$475K SBIR grants awarded by NSF, grant nos. 9660900 and 9801062