UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

VERTIV CORPORATION

Petitioner

v.

VALTRUS INNOVATIONS LTD. and KEY PATENT INNOVATIONS LTD.

Patent Owners

Patent No. 6,854,287
Original Issue Date: February 15, 2005

Title: COOLING SYSTEM

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, 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. 6,854,287 ("the '287 patent") (Ex. 1001). The '287 patent is titled, "Cooling System," and lists Chandrakant D. Patel and Cullen E. Bash as the inventors. The '287 patent issued with twenty-two claims. Claims 1–9 are challenged (the "Challenged Claims").

5. The ’287 patent issued on February 15, 2005, from U.S. Application Serial No. 10/697,697, filed on October 31, 2003 (the “’697 application”), which claims priority to an earlier application No. 10/210,040 (the “’040 application) filed on August 2, 2002. Exhibit 1001, cover.

6. For purposes of this *Inter Partes* Review, I have been instructed to assume that the effective filing date of the Challenged Claims is the earliest possible filing date, *i.e.*, the August 2, 2002 filing date of the ’040 application.

7. I understand that according to the USPTO, the ’287 patent is currently assigned to Valtrus Innovations Limited (“Valtrus” or “Patent Owner”).

8. The ’287 patent is directed to a system and method for cooling a room configured to house computer systems. Ex. 1001, Abstract. The disclosed system includes heat exchanger units configured to receive air from the room and to deliver air to the room. Ex. 1001, Abstract. Cooling fluid is supplied to the heat exchanger units to cool the received air. Ex. 1001, Abstract. A cooling device controller can adjust the temperature of the cooling fluid supplied to the heat exchanger units in response to temperatures sensed at locations in the room. Ex. 1001, Abstract; 8:51–59. Adjusting the temperature of cooling fluid supplied to the heat exchanger units can in turn adjust the temperature of cooled air supplied to computer racks. Ex. 1001, 11:24–27. The system also includes a heat exchanger unit controller that can adjust the speed of fans to vary the cooling air flow rate. Ex. 1001, 9:37–43, 11:21–

24. I am familiar with the technology described in the ’287 patent as of the earliest possible priority date of August 2, 2002.

9. In preparing this Declaration, I have reviewed the ’287 patent (Ex. 1001), the file history of the ’287 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 August 2, 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 of buildings and rooms containing computer equipment as of August 2, 2002.

10. I have been asked to provide my technical expertise, analysis, insights, and opinions regarding the ’287 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 ’287 patent. As described in detail, I offer the following opinions in this Declaration.

11. In summary, and as will be explained in further detail below, a person of ordinary skill in the art (“POSITA”) would have recognized that the methods of the Challenged Claims were disclosed in multiple prior art references. Also, it would have been obvious to a POSITA to implement processes for controlling temperature conditions within a building that houses computers that are the same as the methods of the Challenged Claims. A POSITA would have done so with a

reasonable expectation of success by combining teachings of the prior art references that address the same problems using techniques that were predictable and well-known in the art, and the results of combining or modifying these well-known technologies were predictable in view of that knowledge.

II. MY BACKGROUND AND QUALIFICATIONS

12. Throughout the remainder of this Declaration, I will refer to the field of cooling buildings and rooms containing computer equipment 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 relevant art publications for at least the last 20 years.

13. 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 involves 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. I have performed research and consulted for numerous companies on issues related to heat transfer and flow and

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

14. 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 areas 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.

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

16. 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. During my doctoral program I served as a Teaching Assistant, then as a Graduate Teaching Fellow, and then as adjunct faculty.

17. In 2002, I joined the faculty of 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 topics associated with thermodynamics, heat transfer, and fluid mechanics, including the following classes: Heat Transfer (ENGR 384), Fluid Mechanics (ENGR 383), Advanced Thermal Design (ETLS 591), and Finite Element Analysis (ETLS 777). I have also 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.

18. 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.

19. 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.

20. 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), Remmele Engineering and Northrup Grumman (2002–2005). I have also performed my own studies of cooling of electronics, including computer systems and Central

Processing Units ("CPUs") as well as on cabinets 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 including heat transfer, fluid flow, thermodynamics and analysis of the structures that convey fluids for heating and cooling. I am also a named inventor on multiple patents that deal with flow and heat transfer.

22. I have served as 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. 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,

as well as software tools for modeling heat transfer and fluid flow. 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 I have published in include the *International Journal of Heat and Mass Transfer*, the *International Journal of Heat and Fluid Flow*, *Numerical Heat Transfer*, *Advances in Heat Transfer*, the *Journal of Thermal Science and Engineering Applications*, *Frontiers in Heat Transfer*, *Applied Thermal Engineering*, the *Journal of Fluids Engineering*, the *Journal of Heat Transfer*, and the *Journal of Heat Transfer Engineering*.

25. I have also authored multiple publications on computational fluid dynamics (CFD), which involves mathematical modeling of heat transfer and fluid flow systems. I served as the principal investigator on a project dedicated to performing CFD studies for the Supercomputing Institute from 2002–2012 and 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 ’287 patent concerns monitoring temperatures within a room containing computer systems and controlling an air conditioning system for providing conditioned air to cool the room. 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 ’287 patent fully. I believe my expertise and education in this field qualify me to explain this technology and to address the 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 atmospheric control technology, as well as other materials discussed in this declaration in forming my opinions.

29. For this work, I have been asked to review the ’287 patent including the specification and claims, and the ’287 patent’s prosecution history (file history). In developing my opinions related to the ’287 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. 6,854,287 (“the ’287 patent”)
Ex. 1003	Prosecution History of the ’287 patent
Ex. 1004	SL 16700 (DataCool Brochure.pdf)
Ex. 1005	U.S. Patent No. 6,557,624 (“Stahl”)
Ex. 1006	U.S. Patent Publication No. 2003/0067745A1 (“Patel”)
Ex. 1007	U.S. Patent No. 3,384,155 (“Newton”)
Ex. 1008	U.S. Patent No. 5,317,907 (“Shimizu”)
Ex. 1009	U.S. Patent No. 5,467,609 (“Feeney”)
Ex. 1010	U.S. Patent No. 6,006,528 (“Arima”)
Ex. 1011	U.S. Patent Publication No. 2001/0042616A1 (“Baer”)
Ex. 1012	Declaration of Tanya Zeif

32. 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

30. I have been asked to address the issues from the perspective of a person of ordinary skill in the art (POSITA) at the priority date of the ’287 patent. The field of the invention of the ’287 patent relates to measuring and controlling temperature conditions within a building environment containing heat generating

sources such as computer equipment; thermodynamics; fluid dynamics; thermal management of heat generating systems; building cooling systems involving heat exchangers, cooling air, chilled water, refrigerants or other fluids, piping, pumps, condensers, valves, compressors, fans, HVAC systems and other equipment used in building air conditioning and electronics cooling systems.

31. 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 the line of conventional wisdom in the art, and is a person of ordinary creativity.

32. 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 ’287 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 operation of cooling 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 design and/or operations of temperature management systems for buildings or electronics or computer systems.

33. At all relevant times, I have had a level of skill that was at least 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 August 2, 2002 priority date of the ’287 patent.

V. RELEVANT LEGAL STANDARDS

34. I have been asked to provide my opinions regarding whether the claims of the ’287 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.

35. 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 opinions expressed herein.

A. Claim Construction

36. 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 of the requirements of the claim but refers to another claim and incorporates all of the requirements of the claim to which it refers.

37. I have been informed and understand that in order to properly evaluate the validity of the ’287 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 for a person skilled in the art at the time of the invention. I have also 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 meanings to some terms by defining those terms or by otherwise incorporating such meanings in these documents.

38. I have followed these principles in my analysis throughout this declaration. In order to construe the claims, I have reviewed the entirety of the ’287 patent and its prosecution history.

B. Prior Art

39. 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 before the applicable filing date of a particular patent claim in the United States 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 a 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

40. 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.

41. 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

42. 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.

43. 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.

44. 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.

45. 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 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.

46. 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.

47. 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.

48. I understand that secondary considerations that may indicated 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 of that can suggest that a claimed invention *was* obviousness is the independent simultaneous invention by others.

49. 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 ’287 PATENT

A. Overview of the ’287 Patent

50. The ’287 patent relates to managing heat and controlling temperature throughout the environment of a building having rooms that house computer systems, one of many examples being data centers. The specification mentions known challenges associated with removing heat generated by the computer racks of a data center. Ex. 1001, 1:42–62. The specification acknowledges that data centers have conventionally been cooled using air conditions systems that include multiple air conditioning units and other components such as condensers, air movers (fans), etc. Ex. 1001, 1:63–2:3. According to the ‘287 patent, “conventional cooling systems often incur greater amounts of operating expenses than may be necessary to sufficiently cool the heat generating components contained in the racks of data centers.” Ex. 1001, 2:26–29. The ’287 patent asserts, for example, that

conventional air conditioning systems for data centers were not able to vary cooling fluid output based on the cooling needs at locations distributed throughout the data center, and that it was supposedly typical to operate the refrigerant compressor in such systems at maximum capacity regardless of the head loads being generated by the computer racks. Ex. 1001, 2:10–14.

51. As discussed more fully below, those assertions are at best overstated. It was well-known and conventional to those having ordinary skill in the art to control the operation of air conditioning systems in a manner responsive to localized heat profiles and cooling requirements so that sufficient amounts of cooling air are provided at low enough temperatures to the locations where cooling is needed and without wasting energy by overusing the air condition system.

52. The ’287 patent includes Figure 1 to illustrate the layout of a typical data center housing computer equipment in a series of racks 12.

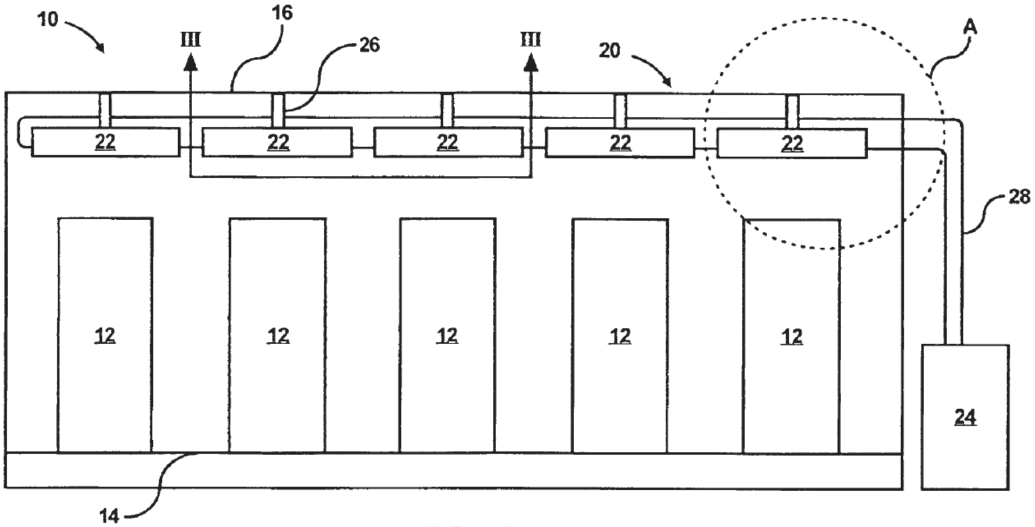


FIG. 1

Ex. 1001, FIG. 1. The disclosed data center cooling system 20 includes heat exchange units (HEUs) 22 and a cooling device 24. Ex. 1001, 4:46–47. The HEUs 22 are supported above the racks 12 and are designed to take in warm air and output cooled air. Ex. 1001, 4:19–23; 4:46–49. The disclosed HEUs 22 include fans 30 for directing air to flow through the unit. Ex. 1001, 5:56–59. A fluid line runs through each HEU below the fans and circulates cooling fluid through the HEU. As air flows over the fluid line, heat is transferred from the air to the cooling fluid lowering the temperature of air delivered by the HEU back to the room. Ex. 1001, 5:66–6:5.

53. These types of units were well-known and common components of data center and other building cooling systems before the August 2, 2002 priority date of the ’287 patent, as discussed more fully below. The ’287 patent acknowledges that the disclosed HEUs implement conventional technology already in use for data center cooling systems, and mentions a DataCool™ environmental control system provided by Liebert as one commercially available example. Ex. 1001, 4:49–53.

54. A 2001 Liebert product brochure (Ex. 1004) provides an overview of this commercially available DataCool™ system. The Liebert DataCool™ system uses a coolant distribution unit to distribute cooling fluid to heat exchangers equipped with adjustable fans. Ex. 1004, 4. These fans direct cooling to the

locations most in need. Ex. 1004, 4. The DataCool™ system is made with redundancy so that it can continue to function even after a failure of a component. Ex. 1004, 4. Coolant from the Coolant Distribution Units (CDUs) is sent to the fan coil heat exchangers through pipes. Ex. 1004, 4. The CDU can be positioned as an interface with a building's chilled water system. Ex. 1004, 4.

55. The '287 patent specification indicates that the HEUs should be positioned near the heat-generating racks, considering the fact that racks operating at higher capacities typically generate more heat. Ex. 1001, 4:64–5:63. The specification thus recommends operating HEUs positioned near racks that generate greater amounts of heat to provide higher cooling air flow rates and/or lower temperature air as compared to racks that generate less heat. Ex. 1001, 5:3–10. Operating data center cooling systems so that the volume and temperature of cooling air supplied to particular regions meets the cooling needs of those regions was not a new concept. For example, that was one of the primary operating principles of the commercially available DataCool™ system, which was referenced in the specification of the '287 patent. Ex. 1001, 4:49–53.

56. The '287 patent also acknowledges that cooling devices for removing heat from the cooling fluid returned from air cooling heat exchange units, such as the device 24 depicted in Figure 1, were also well-known. The specification indicates that "any reasonably suitable type of cooling device designed to

adequately cool the cooling fluid" may be used. Ex. 1001, 5:28–30. As examples of suitable cooling devices, the specification mentions those that include heat exchangers, heat pumps, variable capacity chillers, or evaporative cooling, as well as cooling devices that implement a closed-loop refrigeration cycle for transferring heat from the cooling fluid to the refrigerant. Ex. 1001, 5:32–40.

57. The specification mentions the capability of suitable cooling devices to adjust the temperature of the cooling fluid supplied to the HEUs. Ex. 1001, 5:30–32. Cooling fluid temperature control was also conventional as of the priority date of the '287 patent and known to those skilled in the art. This capability was present, for example, in the commercially available DataCool™ system. That system included coolant distribution units (CDUs) that operated to absorb heat from the cooling fluid into a building chilled water loop to maintain the cooling fluid temperature. Ex. 1004, 5. A controller operated each CDU to maintain the cooling fluid at a desired temperature, and it could adjust the cooling fluid temperature based on temperature and humidity conditions in the data center. Ex. 1004, 3–4.

58. Figure 3 of the '287 patent provides a schematic overhead illustration of a closed-loop cooling system in which cooling fluid supplied from a cooling device flows through several HEUs 22 and then circulates back to the cooling device. Figure 3 is reproduced below.

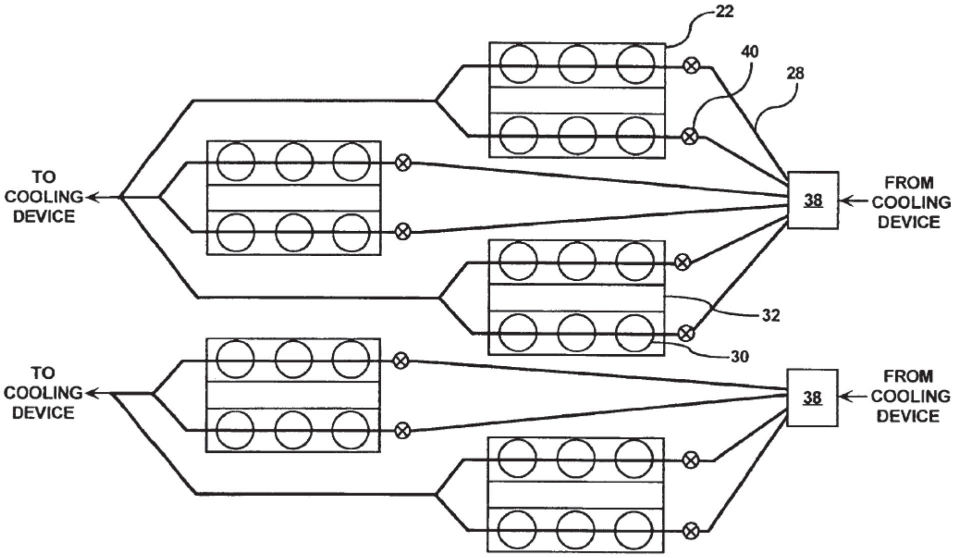


FIG. 3

Ex. 1001, FIG. 3. The cooling flows through fluid lines 28 extending from pumps 38. The HEUs 22 include fans 30 for circulating air over fluid lines positioned below the fans 30. The supply of cooling fluid flowing through fluid lines 28 to individual HEUs 22 is controllable by the pumps 38 and/or by flow control valves 40. Ex. 1001, 7:35–47. This arrangement allows independent control of the temperature of air flowing out of each of the HEUs 22. Ex. 1001, 7:48–51. For example, the flow of cooling fluid through HEUs 22 positioned near racks whose computer systems are idle may be restricted or halted. Ex. 1001, 7:52–55.

59. Figure 4, reproduced below, is a block diagram showing controllers used to operate the system.

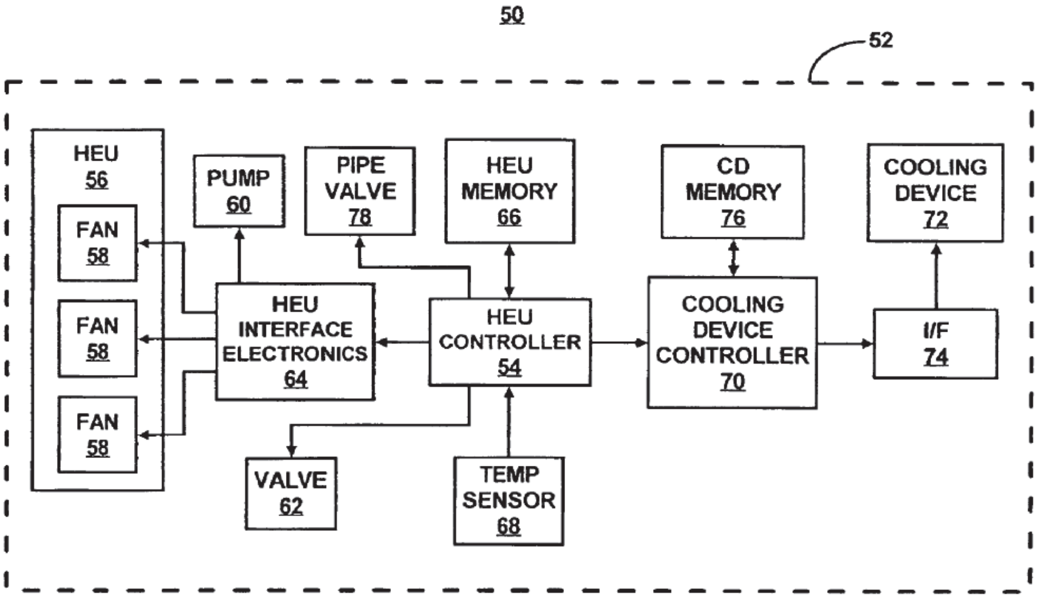


FIG. 4

Ex. 1001, FIG. 4. In this figure, the HEUs are designated 56 having fans 58. A cooling device 72 supplies cooling fluid via pump 60 through fluid lines equipped with valves 78 and 62. The system also includes a temperature sensor 68, as shown. Ex. 1001, 8:8–65.

60. The HEU controller 54 operates the fans 58, pump 60, and valves 78 and 62 in response to temperature measurements by temperature sensor 68. Ex. 1001, 8:24–37. For example, the HEU controller 54 may operate to manipulate the corresponding HEU 56 and/or fans 58 to change the volume flow rate, velocity, and other characteristic of the air flow, for the change in temperature. Ex. 1001, 9:37–43. The HEU controller 54 may also interact with a cooling device controller 70 to cause the cooling device controller 70 to manipulate the temperature of the cooling

fluid by controlling the operation of the cooling device 72. Ex. 1001, 9:43–45. Depending on the type of cooling device, this may involve controlling a variable speed compressor, a heat exchanger, a chilled water heat exchanger, a centrifugal chiller, etc. to manage the heat transferred out of the cooling fluid to vary the cooling fluid temperature. Ex. 1001, 8:38–59.

61. The ’287 patent specification indicates that by controlling the flow of air from individual HEUs and/or controlling the temperature of cooling fluid circulating through individual HEUs in the manner disclosed, the operation of the cooling system 52 may be optimized while lowering energy costs required to cool the computer systems in the racks. Ex. 1001, 9:46–57.

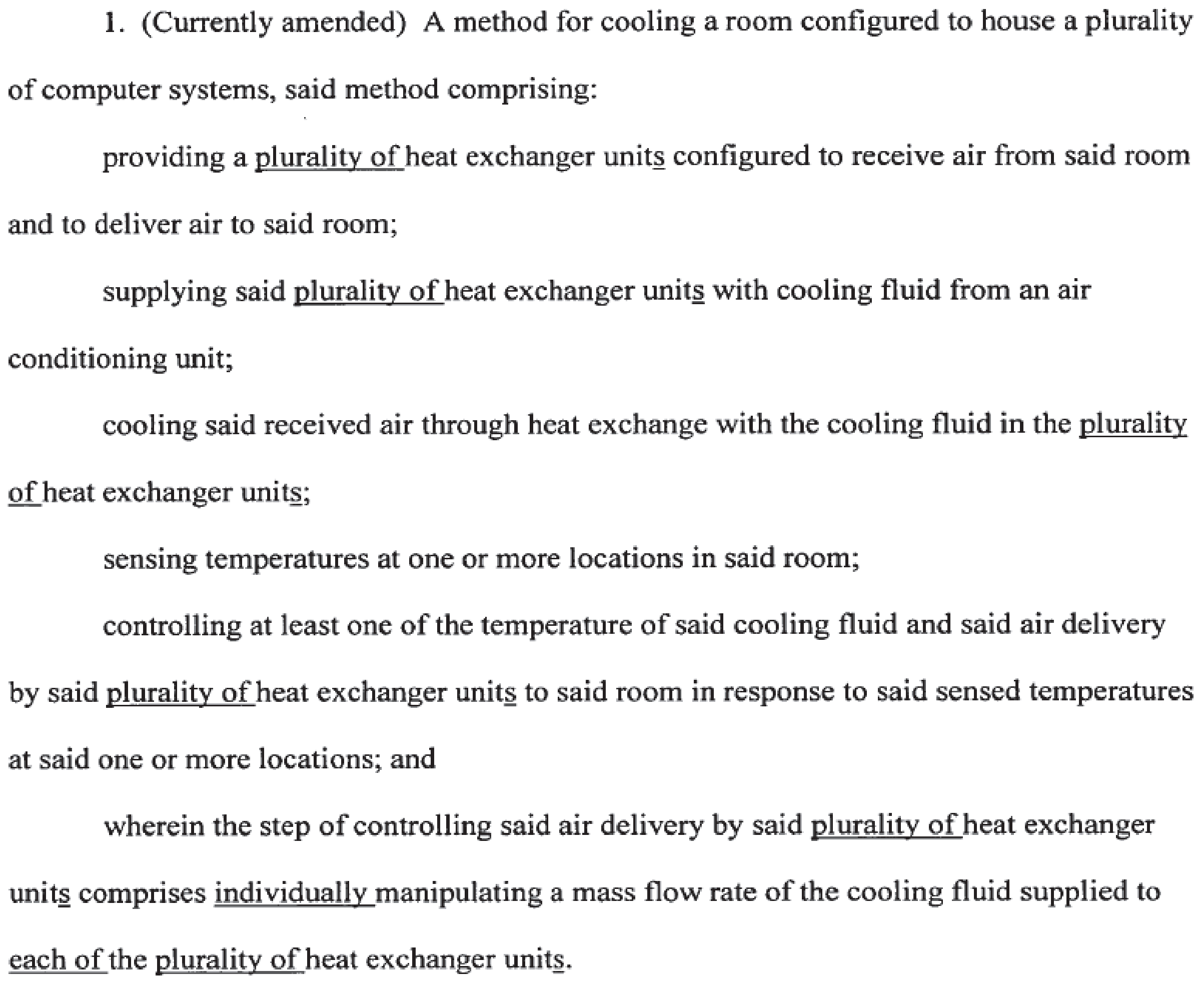
B. Prosecution History of the ’287 Patent

62. I have reviewed the prosecution history record of the ’287 patent to understand the interactions between the applicant and the Patent Office examiner that led to allowance of the patent.

63. The application was filed on October 31, 2003 claiming priority back to a related application filed on August 2, 2002. Ex. 1001, cover. A Non-Final Rejection was issued by the Office on May 4, 2004, rejecting all pending claims; there were twenty-one pending claims at this time. Ex. 1003, 299–300. Claims 1, 2, 30, 31 and 39 were rejected under 35 U.S.C. § 102(e) as being anticipated by U.S. Patent No. 6,557,624 (Ex. 1005, “Stahl”), claims 22–24 and 32–41 were rejected

under 35 U.S.C. § 103(a) over Stahl in view of U.S. Patent No. 5,946,926 ("Hartman"), claims 5 and 9–11 were rejected under 35 U.S.C. § 103(a) over Stahl in view of U.S. Patent No. 6,283,380 ("Nakanishi"), and claim 19 was rejected under 35 U.S.C. § 103(a) over Stahl in view of Hartman and Nakanishi. Ex. 1003, 301–04.

64. In a Response submitted on October 4, 2004, the applicant, Hewlett-Packard Company ("Applicant"), amended the pending claims so that they each recite a cooling system, cooling method, or computer readable storage medium for implementing a cooling method that involves cooling air through a plurality of heat exchanger units supplied with cooling fluid and controlling certain aspects of the operation of the plurality of heat exchanger units in response to sensed temperatures at one more locations in a room. Ex. 1003, 279–87. For example, the Applicant amended claim 1 as follows:



1. (Currently amended) A method for cooling a room configured to house a plurality of computer systems, said method comprising:

providing a plurality of heat exchanger units configured to receive air from said room and to deliver air to said room;

supplying said plurality of heat exchanger units with cooling fluid from an air conditioning unit;

cooling said received air through heat exchange with the cooling fluid in the plurality of heat exchanger units;

sensing temperatures at one or more locations in said room;

controlling at least one of the temperature of said cooling fluid and said air delivery by said plurality of heat exchanger units to said room in response to said sensed temperatures at said one or more locations; and

wherein the step of controlling said air delivery by said plurality of heat exchanger units comprises individually manipulating a mass flow rate of the cooling fluid supplied to each of the plurality of heat exchanger units.

Ex. 1003, 280.

65. In the accompanying remarks, the Applicant acknowledged that Stahl describes a cooling system that includes a heat exchanger through which coolant fluid flows and fan units for blowing air over the heat exchanger to cool the air supplied into a room. Ex. 1003, 289. The Applicant characterized the relevant heat exchanger 110 of Stahl as "a continuous tube through which coolant fluid flows in the vicinities of the fan units 120." Ex. 1003, 289.

66. For context, Figure 2 of Stahl is reproduced below showing an overhead view of fan units 120 containing fans 130 and cooling fluid flowing through a circuitous heat exchanger 110 beneath the fan units.

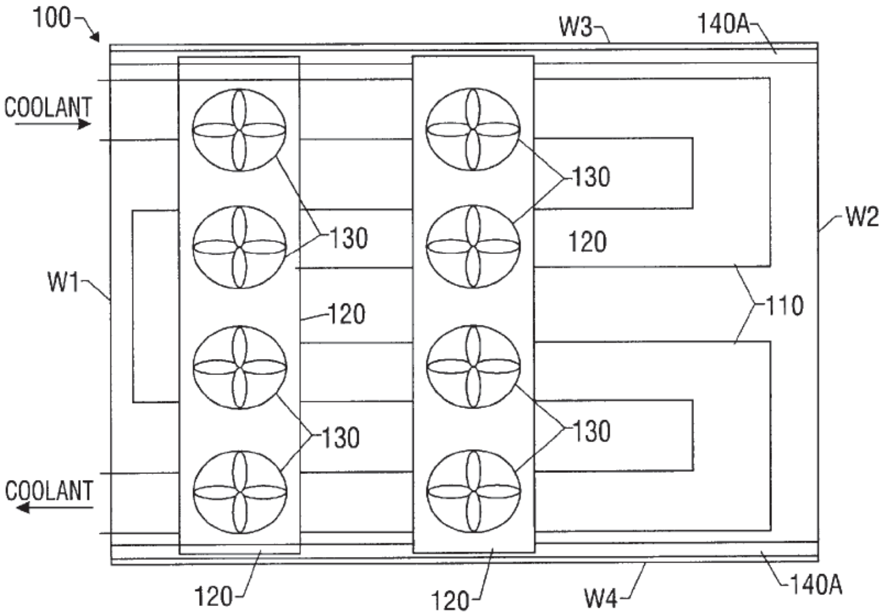


FIG. 2

Ex 1005, Figure 2. The Applicant argued that this cooling system differed from that of the claim because “Stahl [] does not disclose that a mass flow rate of the coolant fluid supplied into each of a plurality of heat exchangers is manipulated.” Ex. 1003, 289. The Applicant emphasized that “the cooling fluid flow in the vicinities of the fan units 120 is the same for each fan unit 120.” Ex. 1003, 290.

67. On October 26, 2004, the Office issued a Notice of Allowance, which allowed all of the pending claims as amended. Ex. 1003, 265–71. In the Reasons for Allowance, the Examiner indicated that independent claim 1 was patentable

because Stahl does not teach the method/system of cooling a room wherein the mass flow rate of the cooling fluid supplied to each of the heat exchangers is individually manipulated. Ex. 1003, 270.

VII. CLAIM CONSTRUCTION

68. 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 upon reviewing the patent claims, specification, and file history. As explained above, I was at least a person of ordinary skill in the art as of the August 2, 2002 priority date of the ’287 patent.

69. Based on the above, I provide here my opinion as to how a POSITA would have understood the claim terms “cooling fluid” and “air conditioning unit.” The first two steps of the method for cooling a room recited in independent claim 1 are:

> providing a plurality of heat exchanger units configured to receive air from said room and to deliver air to said room;
>
> supplying said plurality of heat exchanger units with cooling fluid from an air conditioning unit.

Ex. 1001, 14:17–23.

70. The specification states that chilled water, R134a refrigerant, and ethylene glycol mixture are examples of the types of cooling fluid supplied to the

heat exchanger units in embodiments of the ’287 patent. Ex. 1001, 3:34–37. The output of an air conditioner, however, is cooled air. The claim language describing cooling fluid being supplied to the heat exchanger units “from an air conditioning unit” would therefore seem odd to a POSITA.

71. The specification of the ’287 patent consistently refers to the component that supplies cooling fluid to heat exchanger units as a “cooling device” rather than as an “air conditioning unit.” For example, the specification explains:

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

Ex. 1001, 5:44–49, *see also* 3:41–48.

72. In my opinion, a POSITA would have resolved the potential ambiguity resulting from this inconsistent use of terminology by focusing on the claim language itself. The claim language would have led a POSITA to understand that “air conditioning unit” in the claims refers to any device that supplies cooling fluid to a plurality of heat exchanger units. A POSITA would also understand that the claims use the term “cooling fluid” to include any suitable heat transfer fluid, examples of which are chilled water, R134a refrigerant, and ethylene glycol solutions.

VIII. OVERVIEW OF THE PRIOR ART

A. Technical Background

73. As recognized in the background section of the ’287 patent, data centers typically contain racks housing a variety of computer systems including components such as printed circuit boards, storage devices, power supplies, processors, micro-controllers, semi-conductor devices, etc. Ex. 1001, 1:24–37. These devices generate and dissipate significant amounts of heat during operation which raises the temperature of the surrounding area. Ex. 1001, 1:36–41. The ’287 patent further recognizes that “[c]onventional data centers are typically cooled by operation of one or more air conditioning units.” Ex. 1001, 1:63–64.

74. The specification discusses the conventional practice of cooling data centers using air conditions systems. Ex. 1001, 1:63–2:3. POSITAs were very familiar with basic thermodynamic principles associated with air conditioning systems and managing heat emanating from computer equipment. For example, POSITAs understood that greater amounts of heat can be removed by increasing the mass flow of the cooling air and/or reducing the temperature of the cooling air flowing past the equipment. POSITAs further understood how to adjust cooling air flow by controlling variable speed fans or by manipulating devices in the air flow path such as vents, louvers, and return registers. POSITAs also understood that the

temperature of the cooling air can be manipulated by controlling the mass flow rate and/or the temperature of the cooling fluid circulating through the air cooling coils.

75. Contrary to the suggestions in the '287 patent specification, POSITAs were also well-aware as of the August 2, 2002 priority date '287 patent of available systems and conventional practices that applied these thermodynamic principles to operate cooling systems for data centers and other buildings efficiently and effectively based on localized cooling needs throughout the facility.

76. The commercially available DataCool™ environmental control system mentioned in the patent specification provides one example. Ex. 1001, 4:49–53. The DataCool™ system addressed the problem that "heat is not evenly distributed within the room . . . creating hot spots at various locations" and was designed to "remove[] heat where it's produced." Ex. 1004, 2. The system distributed cooling fluid such as chilled water through multiple heat exchanger coils positioned above the racks. Ex. 1004, 3, 7. The heat exchanger coils were equipped with adjustable fans for directing room air over the coils and distributing the cooled air to the racks that required cooling. Ex. 1004, 4. An automated cooling distribution unit controlled the flow of liquid cooling fluid to the heat exchanger units and controlled the temperature of the cooling fluid according to sensed room temperature and humidity conditions. Ex. 1004, 4–5.

77. The Stahl patent addressed during prosecution describes a similar cooling system that includes heat exchangers through which coolant fluid flows and fan units for blowing air around the heat exchangers to cool the air supplied into a room. Ex. 1005, Abstract. The Stahl patent is assigned to the same company, Liebert Corporation, that developed the DataCool™ system and it appears to generally correspond to that system. I understand that Liebert is a predecessor entity of Petitioner.

78. Figure 2 of Stahl is reproduced below showing an overhead view of fan units 120 containing fans 130 and cooling fluid flowing through a circuitous heat exchanger 110 beneath the fan units.

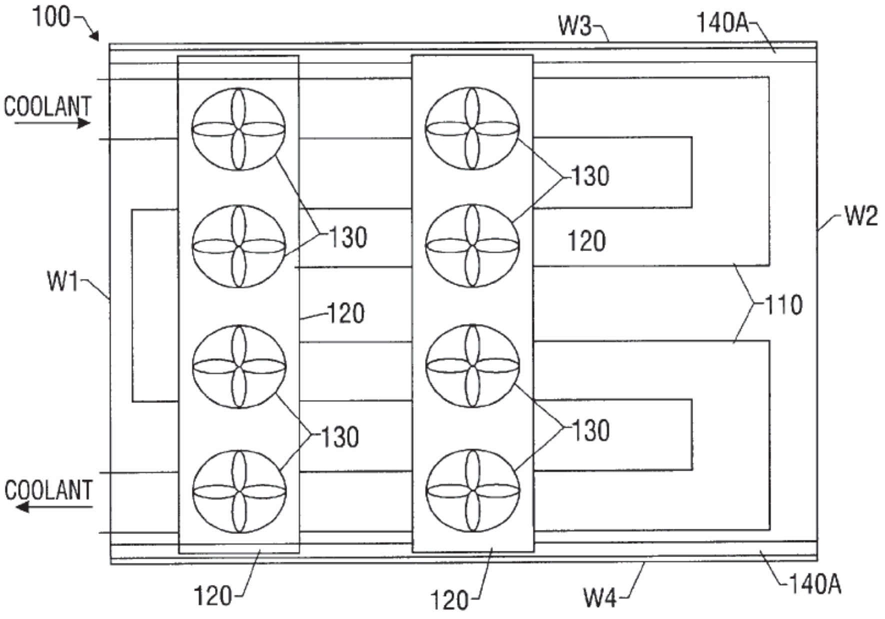


FIG. 2

Ex. 1005, Figure 2; 1:55–2:10.

79. Stahl teaches that the operating speed of the fans 130 may be "automatically varied to provide the desired cooling capacity." Ex. 1005, 3:66–4:2. In relation to another embodiment, Stahl also describes:

> Fan units 520A and 520B are activated to run at a desired speed, under manual or automatic control, as described. Alternatively, the speed of the fan units 520A and 520B are individually set. Heat exchangers 510A and 510B, which may be interconnected, and fan units 520A and 520B maintain room R at the desired temperature with the desired temperature gradient.

Ex. 1005, 5:64–6:3. Thus, there was nothing new about automatically controlling the amount of cooled air distributed to individual racks to maintain desired temperatures throughout a data center.

80. Stahl also teaches that "[c]oolant temperature and flow rate within the heat exchanger 110 may be controlled manually or automatically, as is understood in the art." Ex. 1005, 3:52–54; *see also* 5:42–45 ("The coolant is maintained at the desired temperature and flow rate, under manual or automatic control, as described."). Thus, automatically controlling the temperature and flow rate of the cooling fluid supplied to air cooling heat exchanger coils of data center cooling systems was also conventional as of the priority date of the '287 patent.

81. As discussed above, the Applicant distinguished the system of Stahl as being different from that of the '287 patent by characterizing the system as having only a single cooling coil 110 such that it did not involve manipulating the flow of coolant fluid supplied to each of a *plurality* of heat exchangers. Ex. 1003, 289. That

assertion did not account for Stahl's "combined cooling system" embodiment illustrated in Figures 5 and 6. Ex 1005, 5:34–36. Figure 5 is reproduced below.

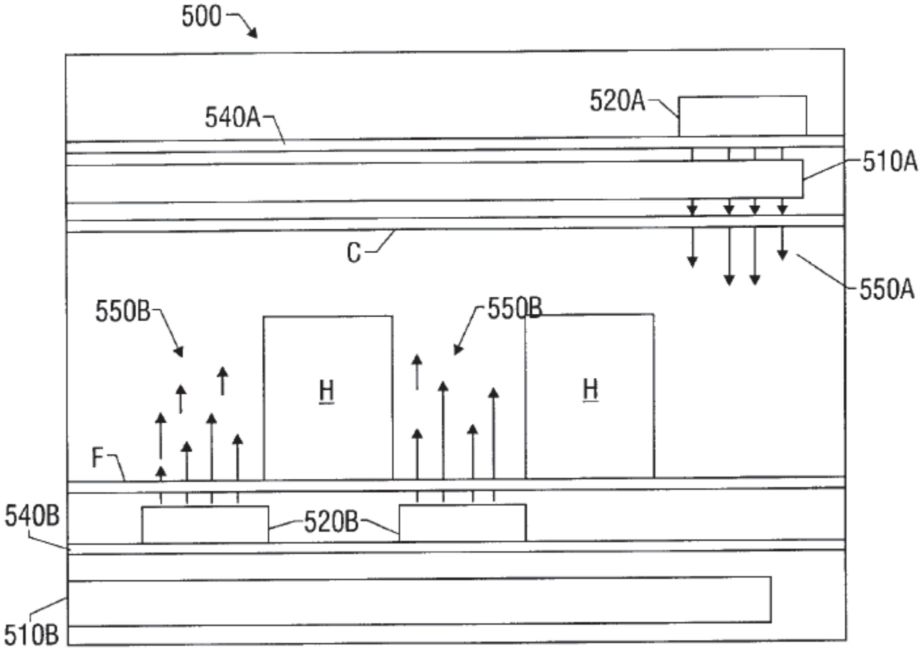


FIG. 5

As is shown, upper fan unit 520A is positioned along ceiling C and coolant flows through a heat exchanger 510A to cool air near the ceiling. Ex. 1005, 5:36–44. "The coolant is maintained at the desired temperature and flow rate, under manual or automatic control, as described." Ex. 1005, 5:44–46. Fan units 520B are positioned along the floor F and coolant flows through another heat exchanger 510B. Ex. 1005, 5:52–60.

82. Thus, Stahl *does* disclose embodiments having multiple heat exchanger units and individually controlling the fan speed and the coolant flow for each heat exchanger unit in order to adjust the flow rate and temperature of cooling

air in response to varying local heat loads. Those and many other conventional cooling system capabilities and operational practices were known to a POSITA as of the August 2, 2002 priority date.

83. The ’287 patent provides another example of a known cooling system for data centers, a system disclosed in an earlier filed application, U.S. Patent Application No. 09/970,707, which is incorporated by reference. Ex. 1001, 4:14–18. That application was filed on October 5, 2001, and published as U.S. Patent Publication No. 2003/0067745 A1 (Ex. 1006, “Patel”). Patel provides additional insight into the state of the relevant art as of the August 2, 2002 priority date of the ’287 patent.

84. Patel illustrates a conventional data center cooling system by reference to its Figure 1, reproduced below:

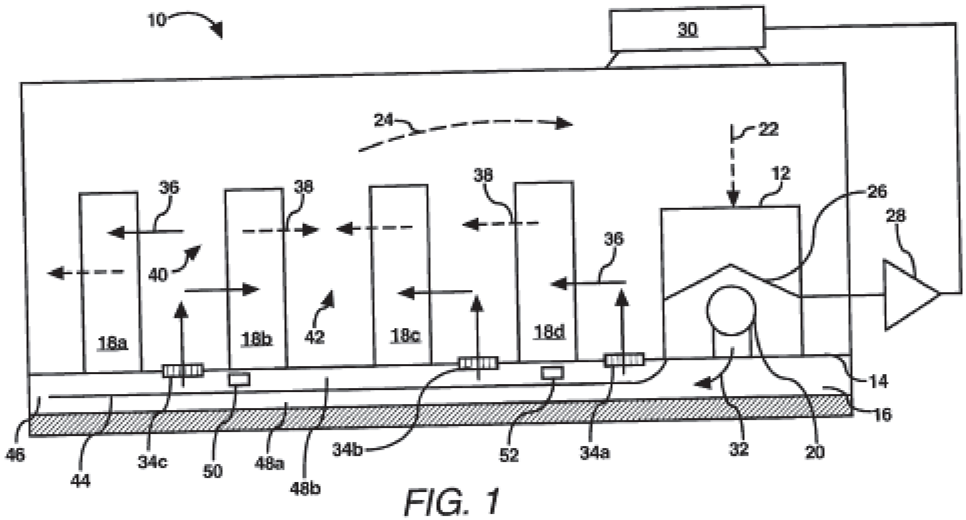


FIG. 1

Ex. 1006, FIG. 1.

85. The data center 10 includes a raised floor 14 with the space 16 beneath the floor serving as a plenum to deliver cooled air from cooling system 12 to racks 18 *a*-18 *d*. Ex. 1006, [0017]. A fan 20 supplies cooled air into the space 16. Ex. 1006, [0018]. Heated air in the data center enters the cooling system by arrow 22 and is cooled by a conventional refrigeration unit including a cooling coil 26, a compressor 28, and a condenser 30. Ex. 1006, [0018]. The cooling system 12 may be operated at various levels based on the heat loads in the racks 18 *a*-18 *d*. Ex. 1006, [0018]. For example, the capacity (e.g., the amount of work exerted on the refrigerant) of the compressor 28 and the speed of the fan 20 can each be modified to control the temperature and the amount of cooled air flow delivered to the racks 18 *a*-18 *d*. Ex. 1006, [0018]. The cooled air flows out of the raised floor 14 through vents 34 *a*-34 *c* that control the velocity and the volume flow rate of the cooled air to the racks. Ex. 1006, [0019].

86. Patel's disclosure reflects that, at the time of the filing of the '287 patent, it was known to take temperature measurements via temperature sensors located at various positions throughout the data center and determine whether the measured temperatures are within a desired range. Ex. 1006, [0042]–[0043]. Patel discloses that if a measured temperature of some locations is outside of the predetermined range, the cooling system would decrease or increase the flow of cooling air accordingly. Ex. 1006, [0045]–[0046]. Patel also explains that because

the temperatures of various racks and locations in the data center may differ, the cooling air flow should be adjusted responsive to the individual needs of each rack or other monitored location in the data center. Ex. 1006, [0051]. Thus, Patel reflects the conventional practice, known at the time the ’287 patent was filed, of varying the supply of cooling air to specific locations in a data center based on localized cooling needs rather than running the cooling system at or near full capacity all of the time.

87. POSITAs were aware of other approaches for supplying targeted cooling to computer equipment in data centers as of August 2, 2002. For example, U.S. Patent No. 5,467,609 to Feeney (Ex. 1009, “Feeney”), issued on November 21, 1995, describes a raised floor system made up of individual modules. Ex. 1009, 1:17–36; 2:27–31. Air cooling coils and associated motor driven blower fans are installed in some floor modules to accommodate the heat load of a corresponding computer component. Ex. 1009, 2:38–45.

88. An embodiment of Feeney’s disclosed raised floor system is illustrated in the annotated version of Figure 1, provided below.

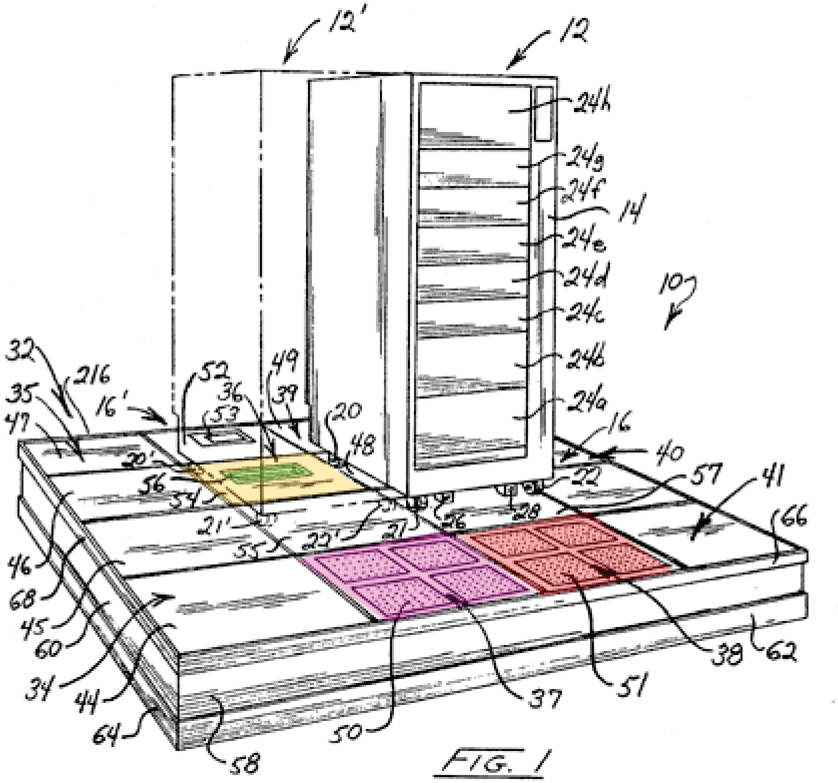


FIG. 1

Ex. 1009, FIG. 1 (annotated). The raised floor system 10 supports computer rack 12 and adjacent computer rack 12' on an elevated floor 32 which is formed of eight individual floor modules labeled 34 to 41. Certain modules, for example modules 37 and 38 (annotated in pink and red, respectively), contain chilled water air conditioning coils and carry patterns of air entry holes 50 and 51 for supplying air to the cooling coils. Ex. 1009, 5:56–60, 6:2–7. The adjacent tile 54 (annotated in orange) within floor module 52 contains an air outlet 56 (annotated in green) through which cooled air may flow into the base region of computer component 12'. Ex. 1009, 6:16–19. A blower fan 148 located within module 38 drives the air circulation. Ex. 1009, 8:1–17.

89. Figure 3, an annotated version of which is provided below, illustrates an overhead view of the system 10 with floor tiles 51 and 57 removed to reveal the integral air cooling system. Ex. 1009, 7:34–37

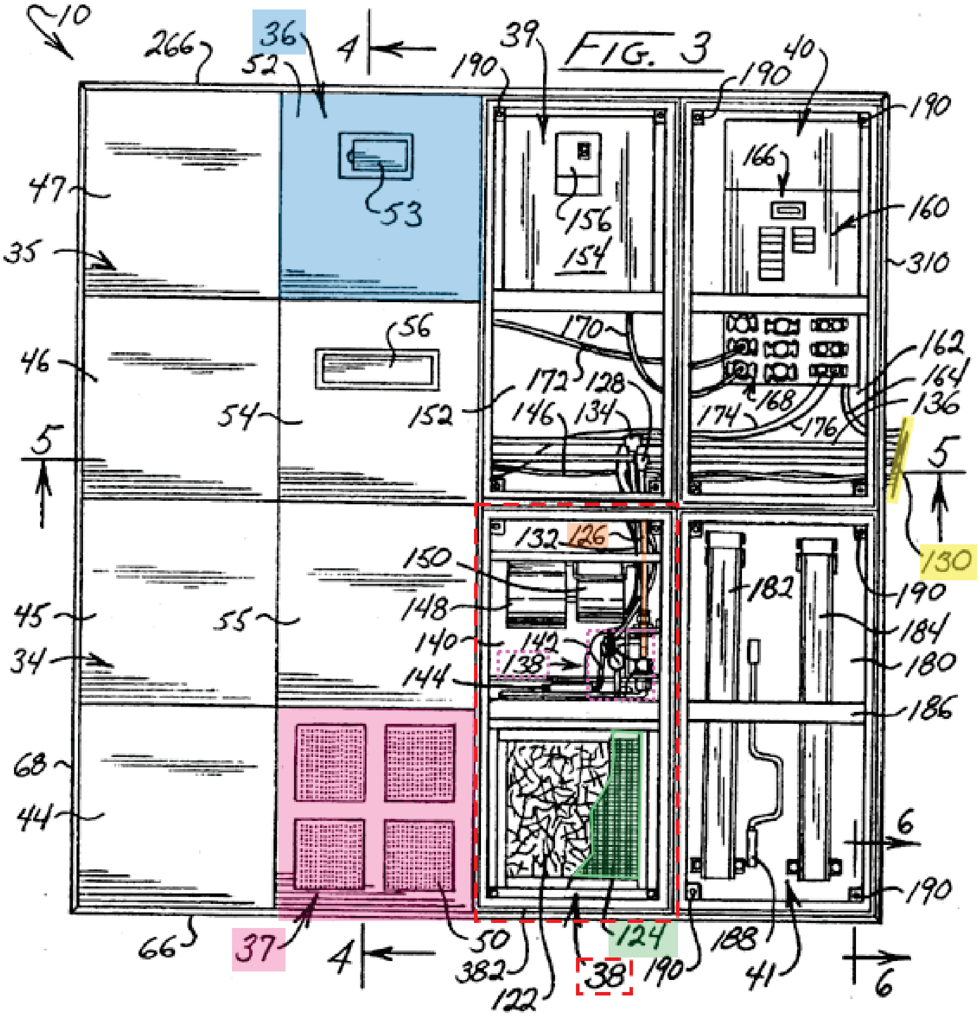


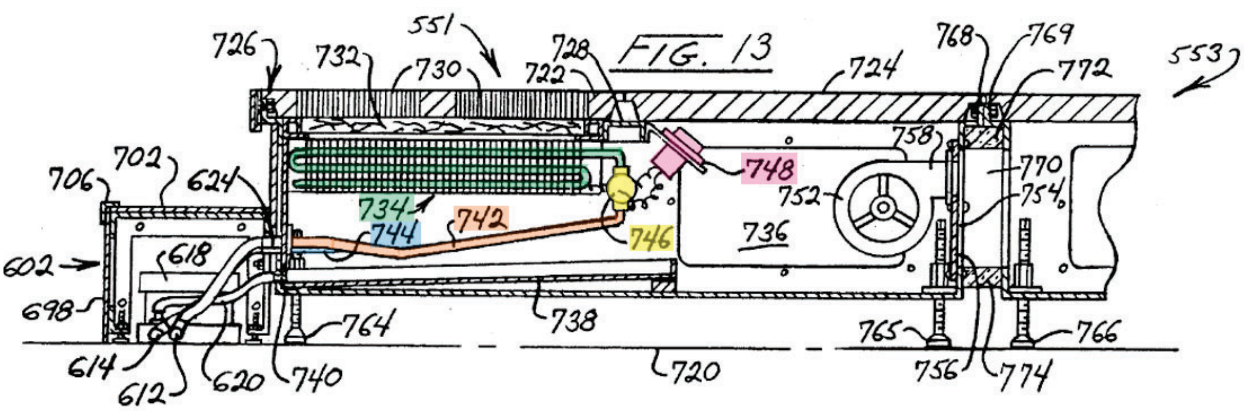
FIG. 3

Ex. 1009, Figure 3 (annotated).

90. A cooling coil 124 (annotated in green) is mounted within module 38 (outlined in red dashed lines) beneath air filter 122 (shown partially broken away). Ex. 1009, 7:37–39. Chilled water from a chiller unit flows through main feeder input 130 (annotated in yellow) and conduit 126 (annotated in orange) to the coil

124. Ex. 1009, 7:42–46. The line 130 also extends into floor module 36 (annotated in blue) to provide chilled water to another air cooling coil within adjacent floor module 37 (annotated in pink). Ex. 1009, 7:46–54. Control over chilled water input to each cooling coil is provided by a valve such as valve 138 (outlined in purple dashed lines) located within module 38 adjacent the coil 124. Ex. 1009, 7:54–59.

91. Figure 13, an annotated version of which is provided below, shows more detail regarding the design of the air cooling coil modules.



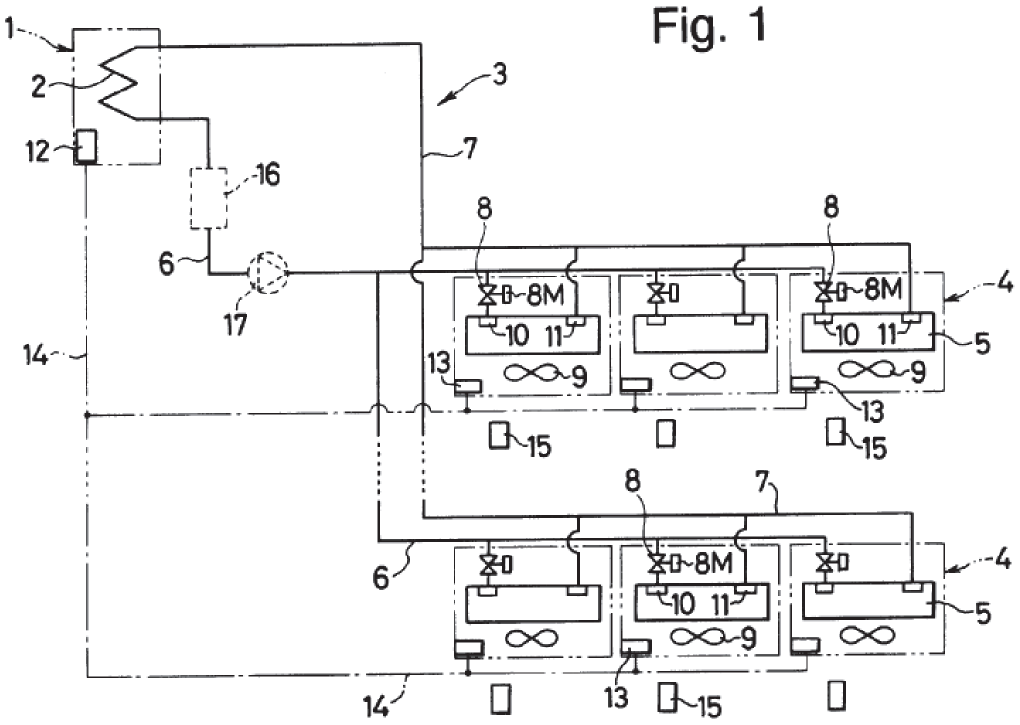
Ex. 1009, FIG. 13 (annotated).

92. The chilled water coil in this embodiment is labeled 734 (annotated in green) located within the cavity 736 of module 551. Ex. 1009, 17:25–27. Chilled water is supplied to the coil 734 through feed tube 742 (annotated in orange) and returns through tube 744 (annotated in blue). Ex. 1009, 17:33–36. Feeney further indicates that "[a] pneumatically actuated valve 746 [(annotated in yellow)] provides for temperature control in combination with a temperature sensing bulb-type actuator 748" (annotated in pink). Ex. 1009, 17:36–38.

93. Feeney therefore reflects the known approach of distributing multiple air cooling heat exchangers throughout the data center environment, supplying the coils with chilled water from a central unit, and automatically manipulating the flow of water to each coil based on sensed air temperature near the coil. This conventional way of managing varying localized heat loads generated by the computer systems was available and well-known to POSITAs as of August 2, 2002.

94. The concept of independently manipulating the coolant flow to individual air cooling heat exchangers based on sensed local temperature conditions was also well-established in building air conditioning systems that use evaporating two-phase refrigerant to absorb heat from the air. One example is provided by U.S. Patent No. 6,006,528 (Ex. 1010, "Arima") issued on December 28, 1999. Arima describes a building air conditioning system that supplies two-phase refrigerant to multiple air cooling heat exchanger units and automatically manipulates the refrigerant flow rate to each unit in response to varying temperature conditions in the room. Ex. 1010, Abstract.

95. One embodiment of an air conditioning system disclosed in Arima is illustrated in its Figure 1, shown below.



Ex. 1010, FIG. 1.

96. A heat source machine 1 absorbs heat as the refrigerant circulates through a heat exchanger 2. Ex. 1010, 6:29–48. User side machines 4 located throughout a building each include a heat exchanger 5 connected to the heat source side machine 1 by a liquid phase pipe 6 for supplying liquid phase refrigerant. Ex. 1010, 6:42–48. The liquid refrigerant supplied to the user side machines and absorbs heat from the warm air forced across each heat exchanger causing an evaporative cooling effect. Ex. 1010, 7:12–24. The gas phase refrigerant returns to the heat source side machine through the gas phase pipe 7. Ex. 1010, 7:25–29. A blower 9

associated with each heat exchanger causes room air to flow over the heat exchanger coil and return to the room. Ex. 1010, 6:49–51.

97. Flow control valves 8 controls the flow of refrigerant to each heat exchanger. Ex. 1010, 6:42–48. Temperature sensors 10 and 11 detect the temperature of the refrigerant at the inlet end and the outlet end of the heat exchanger 5 as an indication of the air conditioning load. Ex. 1010, 6:49–58. A control apparatus 12 receives temperature values detected by the temperature sensors 10 and 11 and provides a control signal back to user side machine to control the flow rate of refrigerant through control valve 8 based on the cooling demand indicated by the sensed temperatures. Ex. 1010, 7:63–8:9.

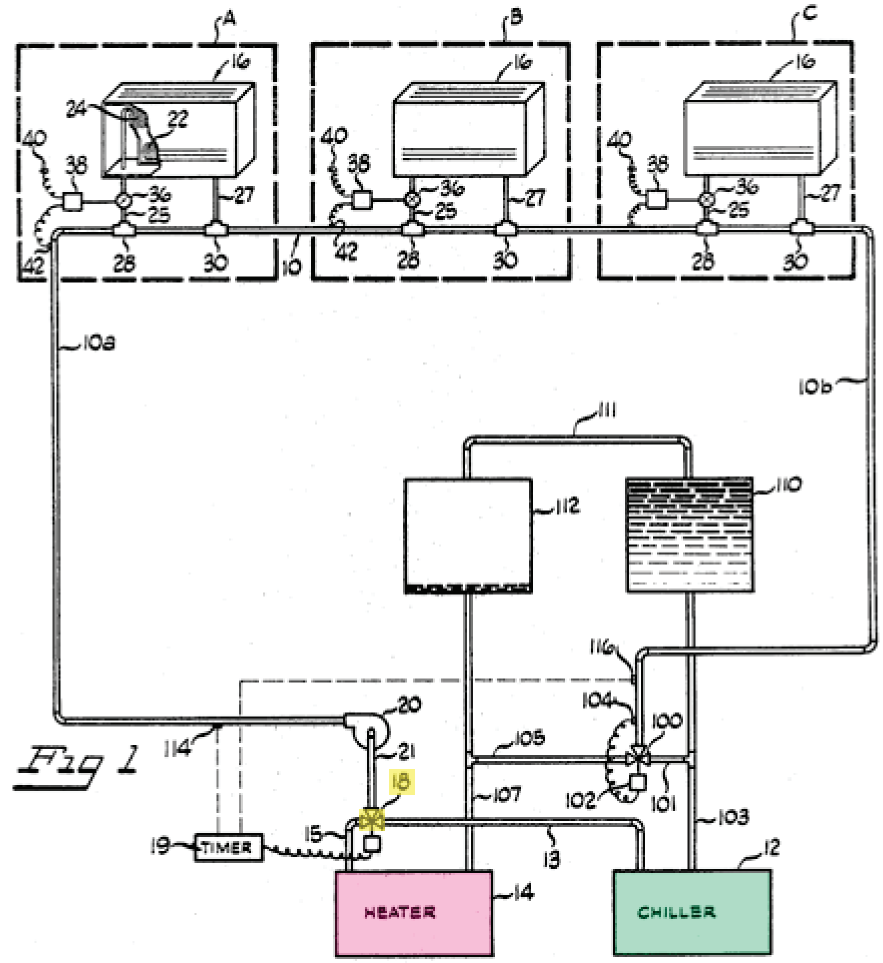
B. Newton

98. U.S. Patent No. 3,384,155 (Ex. 1007, "Newton") issued on May 21, 1968 based on an application filed on January 24, 1966. Ex. 1007, cover. Newton relates to air conditioning systems for multi-room buildings, in particular those having "interior zones, where the thermal loads are due almost entirely to lighting, office equipment and people, may require cooling all year long." Ex. 1007, 1:21–40. As discussed below, Newton reflects that automated coolant fluid flow control based on temperature conditions in locally managed zones was a conventional practice decades before the priority date of the '287 patent. Newton also teaches

automated fan speed control for greater temperature control within each managed zone.

99. The disclosed system can supply either heating or cooling water to heat exchangers dedicated to particular zones of a building. Ex. 1007, 1:10–13. A control system monitors ambient temperature sensed by temperature sensors in each zone and controls the supply of the water to the heat exchangers based on the heating or cooling needs of individual zones. Ex. 1007, 1:12–18, 2:5–26.

100. Figure 1, an annotated version of which is provided below, illustrates an embodiment of Newton's disclosed multi-zone heating and air conditioning system.



Ex. 1007, FIG. 1 (annotated).

101. Water circulates through a closed circuit conduit system 10 including a supply riser 10a and a return riser 10b. Conduit 10 interconnects a liquid chiller 12 (annotated in green), a heater or boiler 14 (annotated in pink), and multiple air conditioning units 16. Each air conditioning unit is located in one of zones A, B, and C to be conditioned. Ex. 1007, 2:58–64. The outlet line 13 from the chiller 12 and outlet line 15 from the water heater 14 are each connected to a three-way valve 18 (annotated in yellow), which selectively supplies cold or hot water to the

inlet side of a liquid pump by way of line 21. Ex. 1007, 2:65–70. Newton indicates that the depicted arrangement of room units and zones is "merely representative of a large number of such units and zones in a typical multi-room installation." Ex. 1007, 2:71–3:3.

102. The disclosed system is capable of cycling between supplying hot and cold water to the room units via a timing mechanism 19 which actuates the three-way supply valve 18. Ex. 1007, 5:16–19. When conditions are such that none of the zones require cooling, valve 18 is set to continuously supply hot water from heater 14 to all room units 16. Ex. 1007, 5:43–47. When conditions require heating in some zones and cooling in other zones, timer 19 causes valve 18 to alternate between supplying hot water through heater 14 and cold water through chiller 12 at regular time intervals. Ex. 1007, 5:53–6:1. When heating is no longer required in any zone, valve 18 supplies chilled water continuously. Ex. 1007, 6:1–5.

103. As shown in Figure 1 above, the inlet line 25 to each air conditioning unit includes a valve 36 actuated by a control 38. A temperature sensing bulb 40 measures the air temperature in the zone. The control 38 adjusts valve 36 in response to "the temperature of the air in the zones to be conditioned as sensed by temperature responsive bulbs 40 (or other suitable means) . . . ." Ex. 1007, 3:25–28; FIG. 4. The control 38 also checks the temperature of water available to the

room unit heat exchangers as sensed by temperature responsive bulbs 42. Ex. 1007, 3:29–32. "When any of the bulbs 40 senses a temperature above the desired temperature level thereby calling for cooling, valves 36 will open only if cold water is circulating through conduit 10; and, if bulbs 40 sense a temperature below the desired temperature level, thereby calling for heating, valves 36 will open only if hot water is circulating through conduit 10." Ex. 1007, 3:32–39.

104. The room air conditioning units of Newton's system each include a fan 22 or other suitable air circulating means. For example, item 22 in unit 16 located in Zone A in Figure 1. Ex. 1007, 3:4–7. Newton teaches implementing the disclosed system with automatic control of the fan speed of each room air conditioning unit to achieve more accurate temperature control. Such a control scheme is illustrated in Figure 5, which augments the water flow control valve operation discussed above. Ex. 1007, 3:66–71.

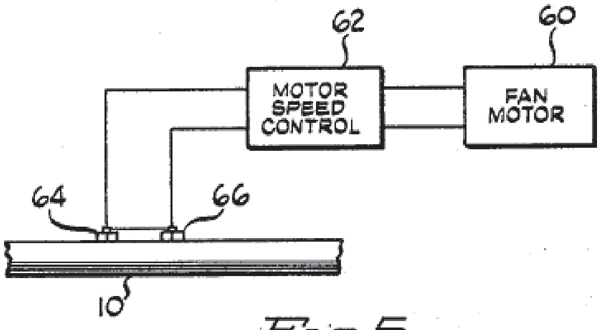


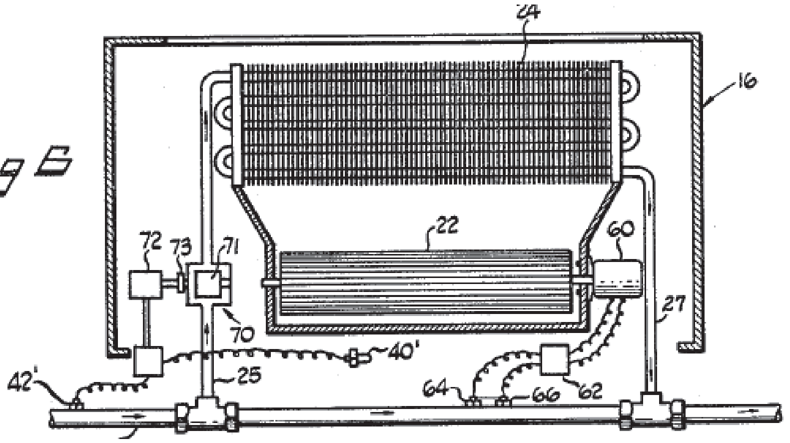
Fig 5

Ex. 1007, FIG. 5.

105. A controller 62 controls the speed of the fan motor 60. The signal to controller 62 is produced by two thermistors 64 and 66 coupled in series and located in thermal relation with liquid conduit 10. The thermistors are designed so that their combined resistance is at a minimum when the temperature of water flowing through line 10 is within a preset range, such as 65 F and 75 F. The resistance will increase in proportion to the water temperature varying above or below this range, resulting in the motor speed control 62 producing a signal that increases the fan speed as the water available to the room unit heat exchanger gets colder or hotter. Ex. 1007, 3:71–4:16.

106. Another embodiment of Newton's system is illustrated in Figure 6, provided below.

Fig 6



Ex. 1007, FIG. 6. This embodiment replaces the water flow control valve 36 at the inlet of each room air conditioning unit with a pump 70. Ex. 1007, 4:17–25. Newton teaches that the control circuitry 38' works similarly to that described for control 38 in relation to flow valve 36, except that controller 38' controls the motor 72 of the pump to manipulate the water flow in response to sensed temperature conditions in the zone. Ex. 1007, 4:26–35.

107. Newton teaches that automated fan speed control can also be used in embodiments using pumps to control the water flow to the room air conditioning units. Ex. 1007, 4:35–38.

C. Shimizu

108. U.S. Patent No. 5,317,907 (Ex. 1008, "Shimizu") issued on June 7, 1994 based on an application filed on April 24, 1992. Ex. 1008, cover. Shimizu describes an air conditioning system having an ambient air-conditioning unit and multiple personal air-conditioning units. Ex. 1008, Abstract. An outdoor compressor unit provides compressed refrigerant and an outdoor heat exchanger discharges heat absorbed by the refrigerant into external air. Ex. 1008, 2:15–23.The refrigerant circulates through the ambient indoor heat exchanger and through the heat exchangers in the personal air-conditioning units for absorbing heat from the internal air. Ex. 1008, 2:23–28.

109. Figure 1, an annotated version of which is provided below, illustrates an embodiment of the system disclosed in Shimizu.

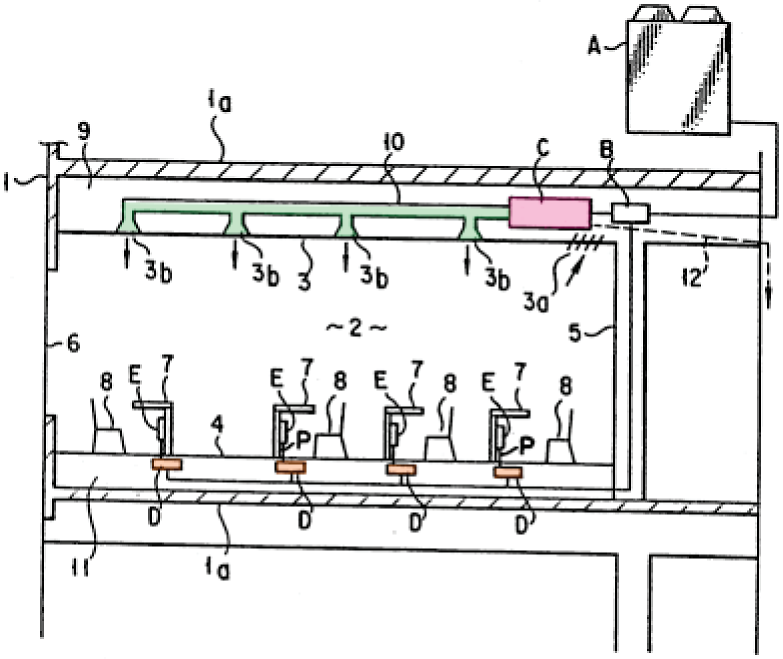
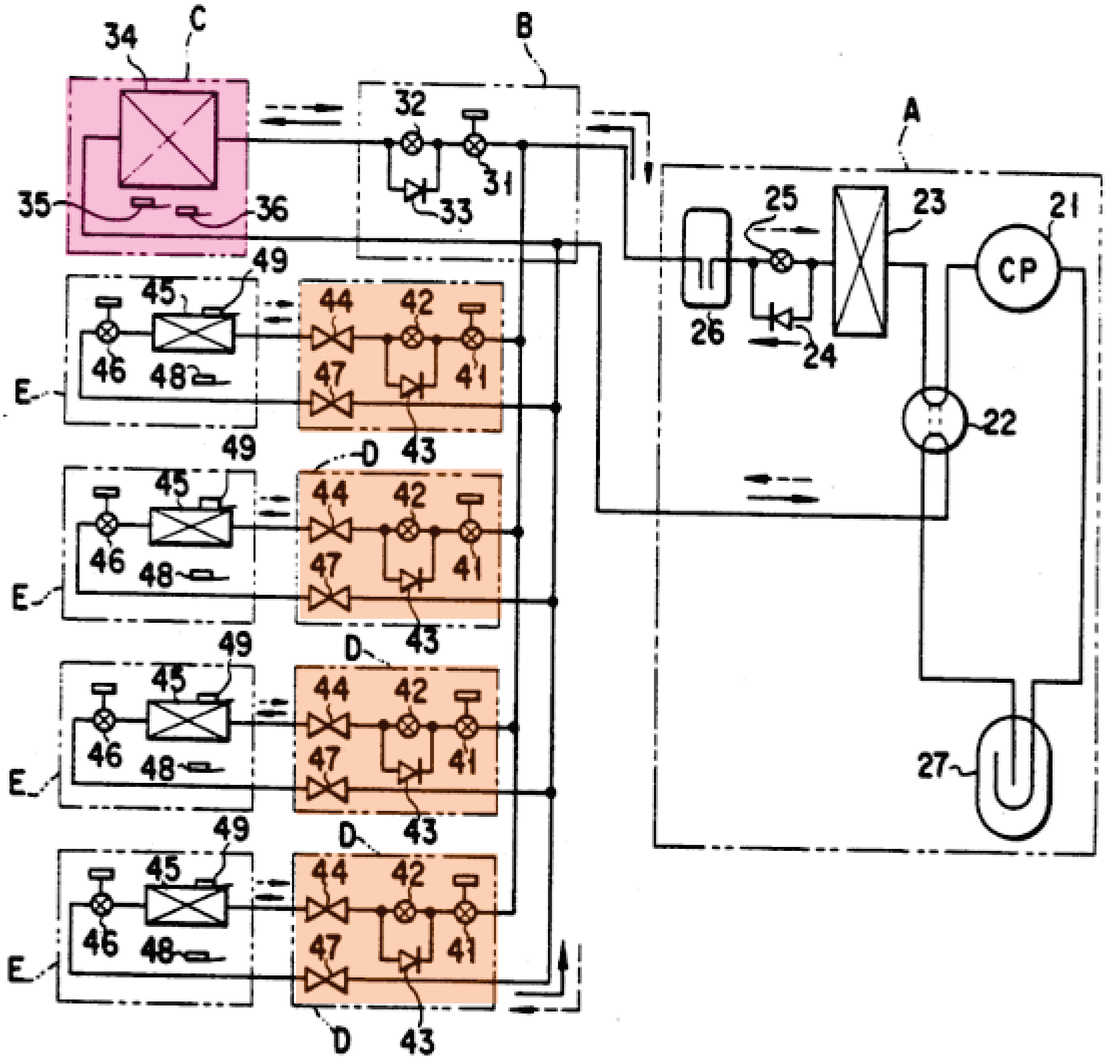


FIG. 1

Ex. 1008, FIG. 1 (annotated). As shown in FIG. 1, an ambient air-conditioning unit C (annotated in pink) is used for air-conditioning the whole space of the room and distributes cooled air through outlet ports 3b of a duct 10 (annotated in green). Ex. 1008, 3:61–64. An outdoor unit A is connected to distribution unit B via a refrigerant pipe. Ex. 1008, 4:18–20. The system also includes personal air-conditioning units E for separately air-conditioning spaces around the desks 7. Ex. 1008, 3:65–68.

110. Figure 2, an annotated version of which is provided below, shows additional details of the overall refrigerant cycle.



F I G. 2

Ex. 1008, FIG. 2 (annotated). As shown, the distribution unit B is connected to the ambient air-conditioning unit C (annotated in pink) and to flow dividing units D (annotated in orange) for connecting each personal air-conditioning unit to the outdoor unit A. Ex. 1008, 4:7–17. Each of the flow dividing units D includes a flow control valve 41 and expansion valve 42 for cooling. Ex. 1008, 4:44–47.

111. The ambient air-conditioning unit C includes an indoor heat exchanger 34 and an air temperature sensor 35 for sensing temperature of air in the room. Ex. 1008, 4:38–43. A "control unit 55 is connected to the air temperature sensor 35," and to an "indoor fan 56 [that] feeds internal air into the indoor heat exchanger 34." Ex. 1008, 5:32–38.

112. Each personal air-conditioning units E includes an evaporative pressure regulator 46, air temperature sensor 48 and heat exchanger temperature sensor 49 disposed on an indoor heat exchanger 45. Ex. 1008, 4:48–55. A control unit 60 is connected to the evaporative pressure regulator 46, air temperature sensor 48, heat exchanger temperature sensor 49, and indoor fan 61 that feeds internal air into the indoor heat exchanger 45. Ex. 1008, 5:43–50.

113. A portion of the refrigerant passing from the outdoor heat exchanger 23 through the liquid receiver 26 flows into the indoor heat exchanger 34 of ambient unit C via the flow control valve 31 and expansion valve 32. The refrigerant evaporates in the indoor heat exchanger 34 to cool the whole space in the room 2. Ex. 1008, 7:52–62. The refrigerant flow to the ambient air-conditioning unit C is regulated based on sensed temperature in the room. In particular, the temperature of the internal air in the room 2 is detected by the air temperature sensor 35, a difference between the detected temperature and the preset temperature is detected to determine an air-conditioning load, and then the opening of the flow control valve

31 is controlled so that refrigerant of an amount corresponding to the air-conditioning load flows into the ambient air-conditioning unit C. Ex. 1008, 8:44–56.

114. With regard to each personal air conditioning unit E, refrigerant from outdoor heat exchanger 23 flows into the indoor heat exchanger 45 through flow control valve 41 corresponding to the personal air-conditioning unit E. The refrigerant evaporates in the indoor heat exchanger 45 to provide a cooling effect. Ex. 1008, 7:32–38. The refrigerant flow to each personalized air conditioning unit C is also regulated in response to sensed temperature. First, the temperature of the air around the unit is detected by the corresponding air temperature sensor 48, a difference between the detected temperature and a preset temperature is detected, and then flow control valve 41 is controlled to manipulate refrigerant flow corresponding to the air-conditioning load in the vicinity of the personal air-conditioning unit. Ex. 1008, 7:63–8:7.

115. The Shimizu reference also teaches automated monitoring and control of the refrigerant temperature to prevent condensation. In particular, the control unit 60 of each personal air conditioning unit determines the dew point temperature of the internal air based on the measured air temperature and humidity. If the detected temperature of heat exchanger 45 is below the dew point temperature, the opening of the evaporative pressure regulator 46 is narrowed to raise the refrigerant

temperature so that the detected heat exchanger temperature is above the dew point temperature. Ex. 1008, 8:8–25.

D. Baer

116. U.S. Patent Application Publication No. 2001/0042616A1 (Ex. 1011, "Baer") was published on November 22, 2001 and is based on an application filed March 21, 2001. Ex. 1011, cover. Baer is directed to air conditioning systems adapted to cool electronics enclosures. Ex. 1011, Abstract. Baer addresses the need for stable temperature and humidity control of facilities containing dense arrangements of electronics equipment. Ex. 1011, [0002]. Baer explains the known challenges of removing large amounts of heat generated by the electronic equipment in such installations using conventional room air conditioners alone, which created a need to develop additional localized cooling solutions for enclosures containing electronic equipment. Ex. 1011, [0003].

117. Baer provides a high-level summary of his solution to this problem as follows:

> The principle of operation of the present system is as follows: Air from the computer room at the ambient temperature and humidity is taken into the enclosure and heated by the electronic equipment. The air is then expelled through a heat exchanger, which cools the air back to the ambient temperature. The exiting air is cooled using an external source of chilled water, glycol or a suitable dielectric fluid, which is typically readily available in commercial installations. By returning the air exiting the enclosure to the ambient temperature in the room, the load on the room air conditioning is reduced or eliminated. Furthermore, the cooling fluid provides a more efficient heat transfer medium for

> removing heat from the room than the room air, as would be the case with a conventional prior art cooling system.

Ex. 1011, [0005].

118. Figure 1, an annotated version of which is provided below, illustrates an embodiment of Baer's disclosed computer cabinet cooling system.

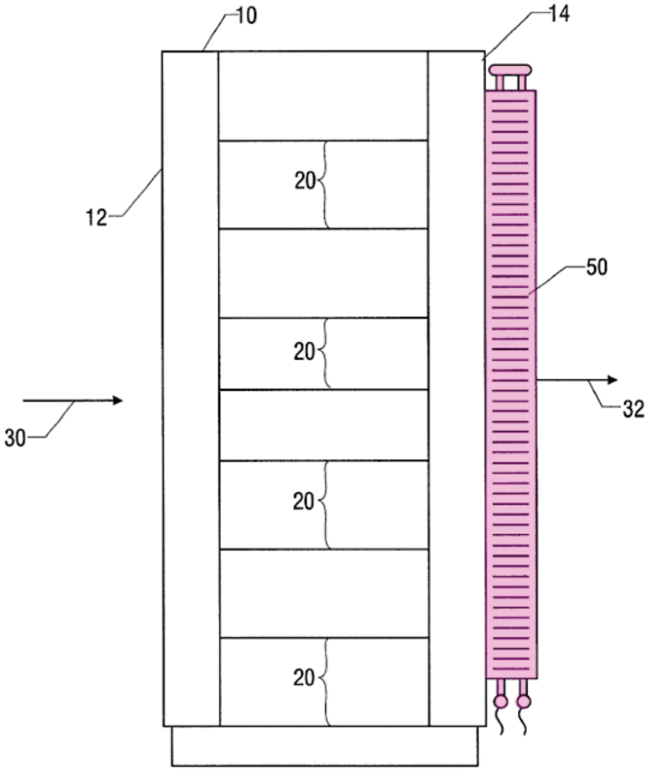


FIG. 1

Ex. 1011, FIG. 1 (annotated). As shown Figure 1, rack 10 houses electronic equipment such as computer devices supported on mounting racks 20. Cooling fans integral to the computer equipment draw air 30 from the room through the front 12 of enclosure 10 so that the air passes over the equipment and absorbs heat generated by the electronics. Ex. 1011, [0021]. Heat exchanger 50 (annotated in pink) mounted on the rear 40 of rack enclosure 10 absorbs the heat added to the air by the electronic equipment. The cooled air 32 flows out the back 14 of the enclosure 10 and returns to the computer room without contributing additional heat load to the room air conditioning system. Ex. 1011, [0021]–[0023].

119. Figure 2 provides more detail regarding the design of the heat exchanger 50 (annotated in pink in the annotated version of Figure 1, above) and coolant flow through the heat exchanger.

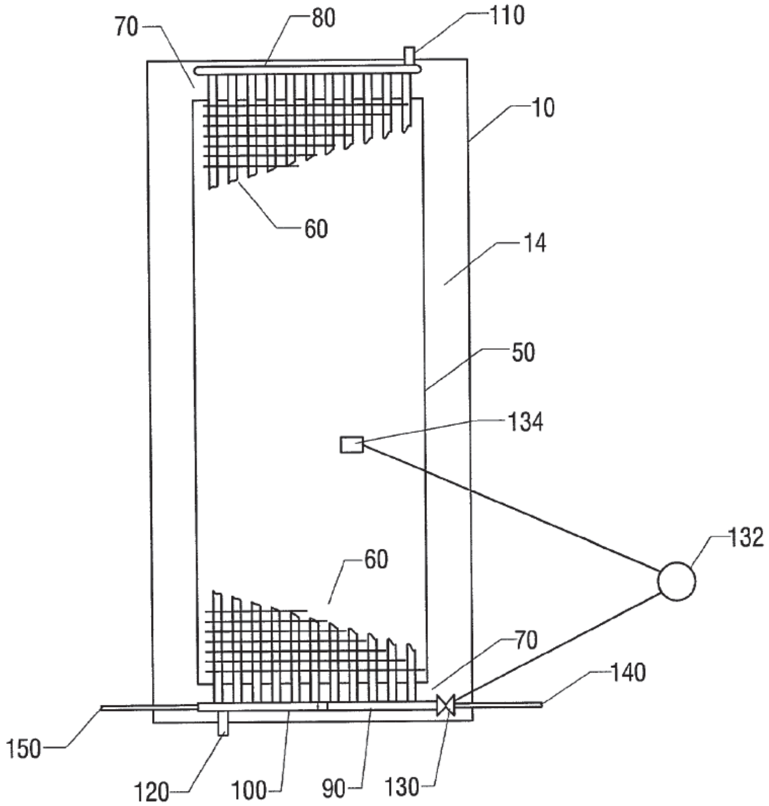


FIG. 2

Ex. 1011, FIG. 2. Figure 2 shows a fin-and-tube heat exchanger with cooling tubes 70 that pass through cooling fins 60. Baer indicates that chilled water, glycol, dielectric fluid or another cooling fluid from source 140 enters the heat exchanger through modulating valve 130. Ex. 1011, [0027].

120. Temperature controller 132 receives input from a temperature sensor 134 on the back of heat exchanger 50 which measures the temperature of the air leaving the heat exchanger. The temperature controller 132 operates the modulating valve 130 "to ensure that the air exiting the heat exchanger is at the same temperature as the room temperature of the computer room in which the equipment is housed." Ex. 1011, [0027]. After passing into inlet 90 and through the cooling tubes 70 and absorbing heat from the airflow across the electronic components, the cooling fluid is returned through line 150 to an external cooling source such as chiller or heat exchanger that rejects the heat. Ex. 1011, [0028].

121. An exemplary cooling fluid control valve 130 is illustrated in Figure 4, provided below, which shows a bottom view of the heat exchanger 50.

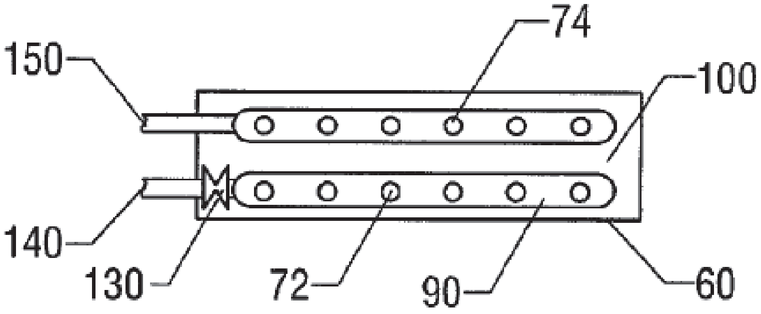


FIG. 4

Ex. 1011, FIG. 4. The cooling fluid enters the heat exchanger from cooling fluid source 140. "The flow of cooling fluid is modulated by valve 130 to regulate the amount of cooling fluid passing through the exchanger, which in turn controls the amount of heat absorbed and the temperature of the exiting air. The cooling fluid then enters inlet header 90 and passes upward through cooling tubes 72." Ex. 1011, [0030].

122. Baer's system may also be equipped with a variety of types of blowers or fans to supplement the amount of air flow generated by the electronic equipment's integral fans. Ex. 1011, [0036]–[0037]. Figure 6B, provided below, illustrates one design example.

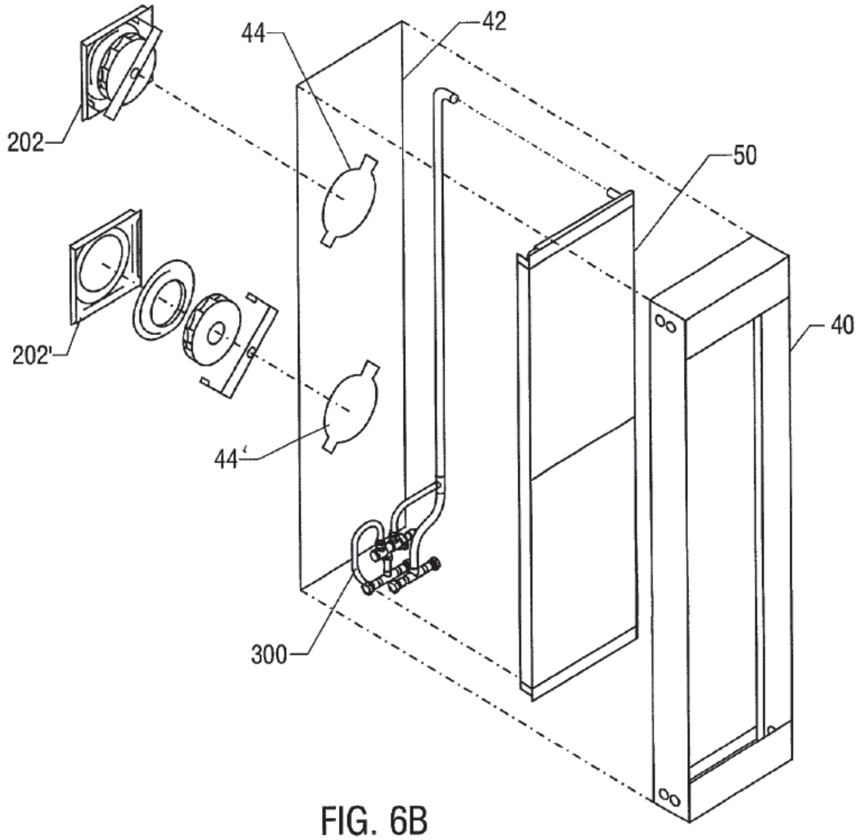


FIG. 6B

Ex. 1001, FIG. 6B. Panel 42 has openings 44, 44′ to receive fans 202, 202′ for distributing air across heat exchanger 50. Ex. 1011, [0039].

123. A more detailed illustration of cooling fluid valve and piping arrangement 300 appears in Figure 7, provided below.

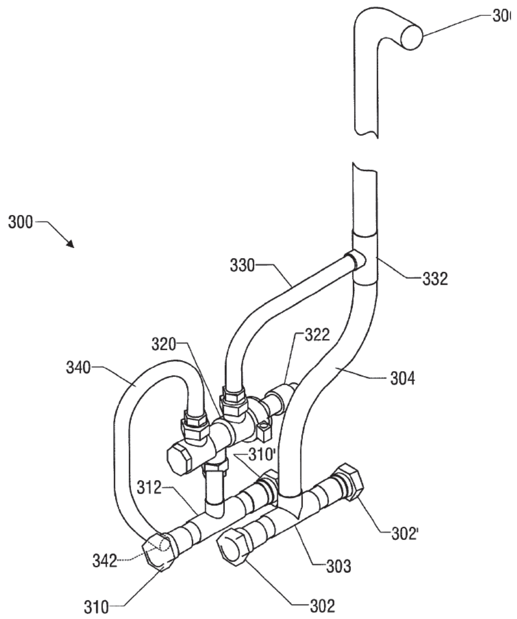


FIG. 7

Ex. 1007, FIG. 7. This arrangement includes thermostatic valve 320 coupled to coolant supply pipe 330. The valve 320 has a thermostatic operator 322 that changes the valve position according to temperature control. "The valve controls the flow of cooling fluid in the heat exchanger and ensures that the air exiting the heat exchanger is at the same temperature as the room temperature of the computer room in which the enclosure is housed." Ex. 1011, [0041]–[0042].

124. Several of the claims appearing at the end of Baer's disclosure also describe systems and methods in which refrigerated liquid flow through an air cooling heat exchanger is automatically regulated by a controller to maintain a

desired temperature of air existing the heat exchanger. Ex. 1011, claims 6, 7, 11, 12, 16 and 17.

IX. ANALYSIS OF THE PRIOR ART AND THE ’287 PATENT CLAIMS

A. GROUND 1: CLAIMS 1–4 AND 7–9 ARE ANTICIPATED BY NEWTON

125. For the reasons set forth below, it is my opinion that Newton discloses all of the limitations of claims 1–4 and 7–9 of the ’287 patent.

1. Claim 1

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

a. 1[pre] – “A method for cooling a room configured to house a plurality of computer systems, said method comprising:”

127. The preamble of claim 1 recites, “*[a] method for cooling a room configured to house a plurality of computer systems, said method comprising:*”

128. I have been informed that claim preambles are generally not limiting. Even if the preamble here were a limitation, it introduces the subject matter of claim 1 in very broad terms. The plain meaning of “a room configured to house a plurality of computer systems” would apply to any room equipped with a power source for operating computer equipment. The preamble language is not limited to methods of cooling data centers or other specialized facilities, does not mention any required features of the room beyond the capability to house computer systems, and does not

specify any type or arrangement of the computer systems (such as rack mounted system, etc.).

129. As discussed above, Newton discloses air conditioning systems for buildings such as office buildings having "interior zones, where the thermal loads are due almost entirely to lighting, office equipment and people, may require cooling all year long." Ex. 1007, 1:21–40. A POSITA reviewing Newton in the timeframe of the '287 patent priority date would understand the reference to "office equipment" generating "thermal loads" as including computer systems. Additionally, a POSITA would understand that the components and operating principles of the type of air conditioning system disclosed in Newton are applicable to cool any type of room that requires cooling, including rooms that house computer systems. Thus, Newton discloses limitation 1[pre].

b. 1[a] – "providing a plurality of heat exchanger units configured to receive air from said room and to deliver air to said room;"

130. Claim 1 further recites "*providing a plurality of heat exchanger units configured to receive air from said room and to deliver air to said room.*" In my opinion, Newton discloses this limitation.

131. As illustrated in the annotated version of Figure 1, provided below, Newton's disclosed cooling system and method involves multiple air conditioning units 16 each having a heat exchanger 24 (annotated in orange).

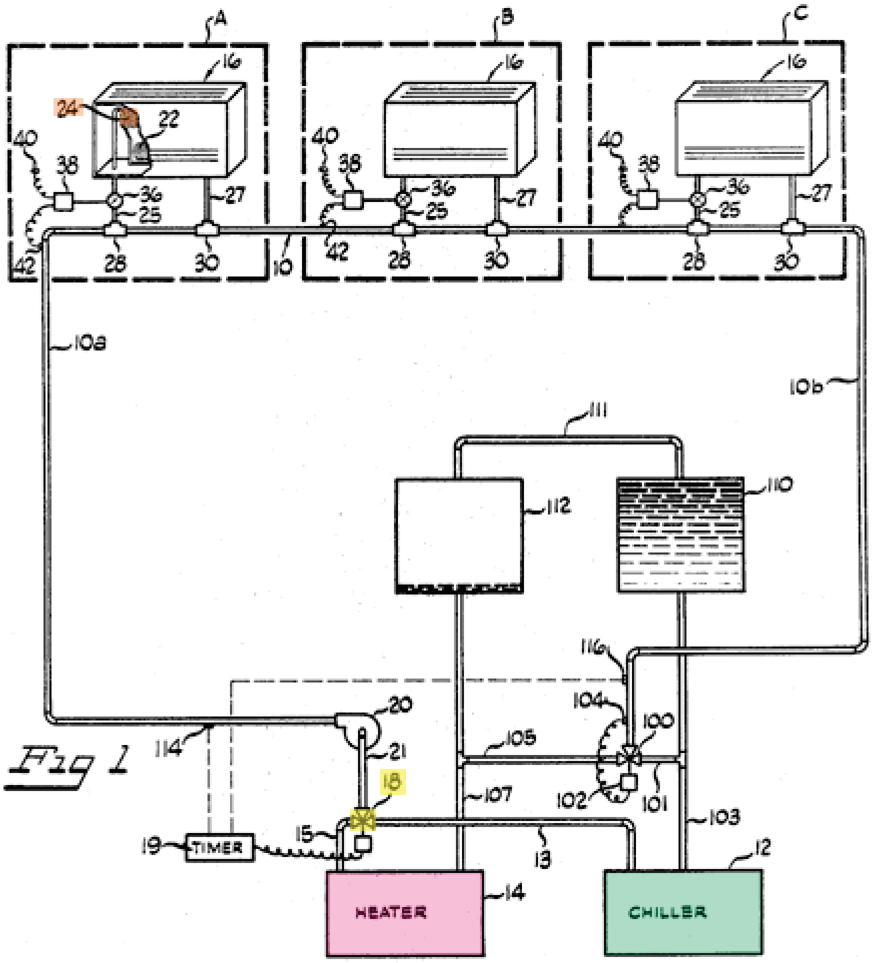


Fig 1

Ex. 1007, FIG. 1 (annotated). Each room air conditioning unit 16 is dedicated to a "zone" to be conditioned (e.g., zones A, B, and C). Ex. 1007, 2:58–64. According to Newton's teachings, a zone is a region where varying thermal loads are generated. *See, e.g.*, Ex. 1007, 1:24–40, 6:73–75. Newton also indicates that the depicted arrangement of room units and zones is "merely representative of a large number of such units and zones in a typical multi-room installation." Ex. 1007, 2:71–3:3. Thus, a POSITA understands the disclosure of Newton to include multiple (i.e., a plurality of) air conditioning units in a single room.

132. The room air conditioning units of Newton's system each include a fan 22 or other suitable air circulating means. For example, item 22 in unit 16 located in Zone A in Figure 1. Ex. 1007, 3:4–7. A POSITA understands that each fan functions to cause room air to circulate through the air conditioning unit, i.e., to be received by the unit and then discharged back into the room. Indeed, Newton's claims, specifically mention that the air conditioning units of the disclosed system include "air circulating means for circulating room air over the heat exchanger." Ex. 1007, 6:72–7:3.

133. Newton therefore discloses providing a plurality of heat exchanger units configured to receive air from said room and to deliver air to said room, as recited in claim 1.

c. 1[b] – "supplying said plurality of heat exchanger units with cooling fluid from an air conditioning unit;"

134. Claim 1 recites "*supplying said plurality of heat exchanger units with cooling fluid from an air conditioning unit.*" In my opinion, Newton discloses this limitation.

135. As explained in Section VII above, a POSITA would understand that "air conditioning unit" in the claims refers to a device that supplies cooling fluid to a plurality of heat exchanger units, and that the term "cooling fluid" includes any suitable heat transfer fluid.

136. In Newton's disclosed system and method, water circulates through a closed circuit conduit system 10 that interconnects a liquid chiller 12, a heater or boiler 14, and multiple air conditioning units 16. Ex. 1007, 2:58–64. The circulating water is supplied to the heat exchanger 24 of each unit through an inlet line 25 and leaves the heat exchanger through an outlet line 27. Ex. 1007, FIG. 1, 3:4–9. When operating in a cooling mode, the liquid circulating in conduit 10 and through the heat exchangers is cold water from a chiller 12 of the disclosed air conditioning system. Ex. 1007, 5:53–6:5.

137. Thus, Newton discloses supplying said plurality of heat exchanger units with cooling fluid from an air conditioning unit.

d. 1[c] – "cooling said received air through heat exchange with the cooling fluid in the plurality of heat exchanger units;"

138. Claim 1 recites "*cooling said received air through heat exchange with the cooling fluid in the plurality of heat exchanger units*." In my opinion, Newton discloses this limitation.

139. A POSITA would understand that when operating in the cooling mode, heat from the room air flowing through the room air conditioning units 16 is transferred to the chilled water circulating in the unit's heat exchanger 14 to cool the air. Newton expressly describes this in his claim 1, which recites: "temperature control means associated with each of said room units, said control means being operative to effect heat transfer between the circulating heat exchange medium and

the air in said zones . . . .” Ex. 1007, 7:18–24; *see also* Ex. 1007, 1:10–12; 3:4–9; 5:70–6:6.

140. Limitation 1[c] is therefore disclosed by Newton.

e. 1[d] – “sensing temperatures at one or more locations in said room;”

141. Claim 1 recites “*sensing temperatures at one or more locations in said room*.” In my opinion, Newton discloses this limitation.

142. In relation to the embodiment of Figure 1, Newton discloses measuring the air temperature in each zone with temperature sensing bulbs 40. Ex. 1007, 3:25–28, FIGs. 1 and 4. In relation to the embodiment of Figure 6, in which the flow of water to the heat exchangers 24 is controlled by a pump 70 instead of a flow control valve, Newton discloses sensing the air stream on the inlet side of fan 22 using temperature sensing bulb 40'. Ex. 1007, FIGs. 4 and 6, 4:26–29.

143. Newton also senses temperature of the available water using temperatures sensors 42 or 42'. Ex.1007, 3:25–32; 4:29–35. In relation to fan speed control, Newton’s system also includes thermistors 64 and 66 for determining whether the temperature of water circulating through the heat exchangers is within a preset range. Ex. 1007, FIG. 5, 3:71–4:16. These additional temperature sensors are also in the room and sense temperatures in the room. *See, e.g.*, Ex. 1007, 3:32–35, 3:40–46; 4:26–29.

144. Limitation 1[d] is therefore disclosed by Newton.

f. 1[e] – "controlling at least one of the temperature of said cooling fluid and said air delivery by said plurality of heat exchanger units to said room in response to said sensed temperatures at said one or more locations; and"

145. Claim 1 recites "*controlling at least one of the temperature of said cooling fluid and said air delivery by said plurality of heat exchanger units to said room in response to said sensed temperatures at said one or more locations*." In my opinion, Newton discloses this limitation.

146. This claim limitation requires controlling *at least one* of the temperature of the cooling fluid or the air delivery by the heat exchangers. Newton's disclosed system performs *both* of these control operations.

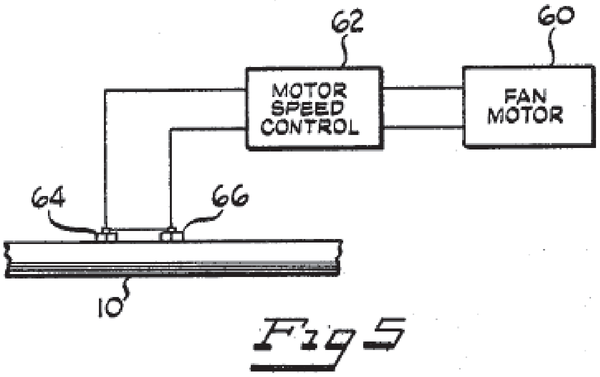
147. With regard to controlling cooling fluid temperature, Newton's system includes a heater 14 and a chiller 12 and can vary the temperature of the water circulating in the closed-loop conduit 10 between hot and cold by operation of three-way valve 18 on the inlet side of pump 20. Ex. 1007, 2:58–70. When sensed temperature conditions are such that none of the zones require cooling, valve 18 is set to continuously supply hot water from heater 14 to all room units 16. Ex. 1007, 5:43–47. When conditions are such as to require heating in some zones and cooling in other zones, timer 19 causes valve 18 to alternate between supplying hot water through heater 14 and cold water through chiller 12 at regular time intervals. Ex. 1007, 5:53–6:1. When heating is no longer required in any zone, valve 18 supplies

chilled water continuously. Ex. 1007, 6:1–5; *see also* Ex. 1007, 4:39–43; 4:60–69; 5:1–40; 5:70–6:10.

148. Individual room air conditioning units 16 sense the air temperature in their zone using temperature sensing bulbs 40. Ex. 1007, 3:25–28, FIG. 4. "When any of the bulbs 40 senses a temperature above the desired temperature level thereby calling for cooling, valves 36 will open only if cold water is circulating through conduit 10; and, if bulbs 40 sense a temperature below the desired temperature level, thereby calling for heating, valves 36 will open only if hot water is circulating through conduit 10." Ex. 1007, 3:32–39.

149. Therefore, Newton's system and control method disclose adjusting the temperature of the water supplied to the heat exchangers of individual room air conditioning units in response to sensed air temperature in the associated zones indicating a need for cooling.

150. With regard to controlling air delivery, the room air conditioning units each include a fan, such as item 22 in the unit 16 located in Zone A in Figure 1. Ex. 1007, 3:4–7. Newton teaches automatic control of the fan speed per the control scheme depicted in Figure 5, provided below, which augments the water flow control valve operation discussed above for better temperature control. Ex. 1007, 3:65–71; *see also* Ex. 1007, 3:25–35; 4:12–16; 4:32–39.



Ex. 1007, FIG. 5.

151. As discussed above, controller 62 controls the speed of the fan motor 60 based on a signal produced from two thermistors 64 and 66 that increases in proportion to how much the sensed water temperature is outside of a preset range, such as 65 F to 75 F. The motor control 62 produces a signal that increases the fan speed as the water available to the room unit heat exchanger gets colder or hotter. Ex. 1007, 3:71–4:16. Thus, Newton also discloses controlling the air delivery in response to sensed temperatures in the room, i.e., the temperature of the water circulating through the heat exchanger unit.

152. Newton also controls air delivery by individually manipulating the flow of chilled water to each heat exchanger in response to a measured temperature of the corresponding zone, as discussed in relation to limitation 1[f] below.

153. Limitation 1[e] is therefore disclosed by Newton.

g. 1[f] – "wherein the step of controlling said air delivery by said plurality of heat exchanger units comprises individually manipulating a mass flow rate of the cooling fluid supplied to each of the plurality of heat exchanger units."

154. Claim 1 recites "*wherein the step of controlling said air delivery by said plurality of heat exchanger units comprises individually manipulating a mass flow rate of the cooling fluid supplied to each of the plurality of heat exchanger units*." In my opinion, Newton discloses this limitation.

155. According to this claim limitation, one way to control "air delivery" as that term is used in claim 1 is by individually manipulating the mass flow rate of cooling fluid supplied to each of the plurality of heat exchanger units. In Newton's system, a control system monitors ambient temperature sensed by temperature sensors in each zone and controls the supply of water to the heat exchangers based on the cooling needs of individual zones. Ex. 1007, 1:12–18, 2:5–26.

156. As discussed in relation to limitation 1[e], each of Newton's room air conditioning units 16 senses the air temperature of its zone with temperature sensing bulbs 40. Ex. 1007, 3:25–28, FIG. 4. When the temperature sensed by a given unit exceeds the desired temperature for the zone, and chilled water is circulating in the closed-loop conduit 10, a control 38 opens water control valve 36 to allow the chilled water to flow through the unit's heat exchanger. Ex. 1007, 3:25–39. Conversely, as a POSITA would readily understand, whenever the sensed temperature falls within the desired range, the valve will be closed and prevent

water flow through the heat exchanger. Each room air conditioning unit has its own water control valve 36, temperature sensors 40 and 42, and control 38 such that the flow of water through each unit is manipulated independently. *See, e.g.*, Ex. 1007, FIG. 1.

157. Newton's alternative embodiment of Figure 6 also discloses individually manipulating the flow of chilled water to each heat exchanger unit in response to sensed temperatures, albeit by controlling a water pump (e.g., 70) instead of a control valve. Ex. 1007, 4:17–35.

158. Limitation 1[f] is therefore disclosed by Newton.

2. Claim 2 – "The method according to claim 1, wherein said step of controlling at least one of a temperature of said cooling fluid and said air delivery to said room comprises varying an output of said air conditioning unit to control the temperature of said cooling fluid."

159. Claim 2 recites "*[t]he method according to claim 1, wherein said step of controlling at least one of a temperature of said cooling fluid and said air delivery to said room comprises varying an output of said air conditioning unit to control the temperature of said cooling fluid*." In my opinion, Newton discloses this claim.

160. As explained above, Newton discloses the method of claim 1.

161. As discussed above, to remain consistent with claim limitation 1[b], the "air conditioning system" refers to the system that supplies cooling fluid to the heat exchanger units. Newton discloses a chiller 12 and heater 14 and three-way

valve 18 for controlling temperature of water supplied to the inlet of pump 20 for circulation to the heat exchanger units. Ex. 1007, FIG. 1; 2:65–70. The valve 18 varies the temperature of circulating water and it does so in response to sensed temperatures in the zones. Ex. 1007, 5:16–41. As explained above, Newton teaches that if sensed temperatures are such that some zones require cooling, the control will cause chilled water to circulate at set time intervals. If all zones require cooling, the control will cause chilled water to circulate continuously. Ex. 1007, 5:53–6:5.

162. Claim 2 of the ’287 patent is therefore anticipated by Newton.

3. Claim 3 – “The method according to claim 1, further comprising: determining whether the sensed temperatures at one or more locations in said room are within a predetermined range.”

163. Claim 3 recites “*[t]he method according to claim 1, further comprising: determining whether the sensed temperatures at one or more locations in said room are within a predetermined range*.” In my opinion, Newton discloses this claim.

164. As explained above, Newton discloses the method of claim 1.

165. The control 38 for each room air conditioning unit determines when the unit’s temperature sensing bulb 40 “senses a temperature above the desired temperature level thereby calling for cooling . . . .” Ex. 1007, 3:32–39. The control 38' of the embodiment shown in Figure 6 works the same way but manipulates a water pump instead of a water flow valve. Ex. 1007, 4:26–38.

166. Claim 3 of the ’287 patent is therefore disclosed by Newton.

4. Claim 4 – “The method according to claim 3, further comprising: varying the cooling fluid temperature in response to the sensed temperatures at one or more locations in said room being outside of said predetermined range.”

167. Claim 4 recites “*[t]he method according to claim 3, further comprising: varying the cooling fluid temperature in response to the sensed temperatures at one or more locations in said room being outside of said predetermined range*.” In my opinion, Newton discloses this claim.

168. As explained above, Newton discloses the method of claim 3.

169. As discussed above, Newton’s disclosed system automatically adjusts its operations in response to changing conditions in one or more zones being managed. For example, when cooling is not required in any zone, the system will continuously circulate hot water through conduit 10 for use by room unit heat exchangers in zones that require heating. Ex. 1007, 5:43–47. However, when the sensed temperature of a zone subsequently exceeds the desired range, the control system will adjust three-way valve 18 to so that chilled water is circulated, either periodically or continuously (if no zones require additional heating). Ex. 1007, 5:53–6:5. Thus, Newton discloses varying the fluid temperature in response to one or more sensed temperatures being outside of a predetermined range.

170. Claim 4 of the ’287 patent is therefore disclosed by Newton.

5. Claim 7 – "The method according to claim 1, wherein the step of manipulating a mass flow rate of the cooling fluid supplied to each of the plurality of heat exchanger units further comprises metering the flow of cooling fluid through each of said plurality of heat exchanger units with a plurality of valves positioned along respective cooling fluid lines configured to channel cooling fluid from the air conditioning unit to the plurality of heat exchanger units."

171. Claim 7 recites "*[t]he method according to claim 1, wherein the step of manipulating a mass flow rate of the cooling fluid supplied to each of the plurality of heat exchanger units further comprises metering the flow of cooling fluid through each of said plurality of heat exchanger units with a plurality of valves positioned along respective cooling fluid lines configured to channel cooling fluid from the air conditioning unit to the plurality of heat exchanger units*." In my opinion, Newton discloses this claim.

172. As explained above, Newton discloses the method of claim 1.

173. The flow control valves 36 at the inlet of each heat exchanger disclose the plurality of valves positioned along respective cooling fluid lines recited in this limitation. As shown in Figure 1, the valves 36 are each positioned along a respective inlet line 25 extending from inlet fittings 28 installed in the closed-loop water conduit 10. The water chiller 12 connects to the conduit 10 through line 13, valve 18 and pump 20. Ex. 1007, FIG. 1, 3:25–32. Each control valve 36 functions to meter the flow of cooling water to the associated heat exchanger 24. Ex. 1007, 3:25–40. Additionally, Newton discloses an embodiment in Figure 6 that includes

a small pump 70 associated with each of the individual heat exchangers 24 for controlling coolant flow. Ex. 1007, 4:17–25.

174. Claim 7 of the ’287 patent is therefore disclosed by Newton.

6. Claim 8 – “The method according to claim 1, wherein the step of manipulating a mass flow rate of the cooling fluid supplied to each of the plurality of heat exchanger units further comprises metering the flow of cooling fluid through said plurality of heat exchanger units with a plurality of pumps positioned along respective cooling fluid lines configured to channel cooling fluid from the air conditioning unit to the plurality of heat exchanger units.”

175. Claim 8 recites “*[t]he method according to claim 1, wherein the step of manipulating a mass flow rate of the cooling fluid supplied to each of the plurality of heat exchanger units further comprises metering the flow of cooling fluid through said plurality of heat exchanger units with a plurality of pumps positioned along respective cooling fluid lines configured to channel cooling fluid from the air conditioning unit to the plurality of heat exchanger units*.” In my opinion, Newton discloses this claim.

176. As explained above, Newton discloses the method of claim 1.

177. As explained above, the embodiment shown in Newton’s Figure 6 meters the water flow into each heat exchanger by controlling the motor of pump 70 in response to sensed temperatures conditions in the zone. Ex. 1007, 4:17–35.

178. Claim 8 of the ’287 patent is therefore disclosed by Newton.

7. Claim 9 – “The method according to claim 1, further comprising: manipulating a mass flow rate of the cooling fluid supplied to the plurality of heat exchanger units in substantially independent manners with respect to each of the plurality of heat exchanger units.”

179. Claim 9 recites “*[t]he method according to claim 1, further comprising: manipulating a mass flow rate of the cooling fluid supplied to the plurality of heat exchanger units in substantially independent manners with respect to each of the plurality of heat exchanger units*.” In my opinion, Newton discloses this claim.

180. As explained above, Newton discloses the method of claim 1.

181. Newton’s system architecture and control method are designed to handle the varying heat loads associated with different zones of a building. Newton mentions, for example, that at any given time, some zone may require heating while others require cooling. Ex. 1007, 5:53–6:1. Newton’s system can automatically adjust to the varying needs because it controls each unit independent of the other units.

182. As discussed in relation to limitation 1[f], each room air conditioning unit of Newton’s system has its own water control valve 36, temperature sensors 40 and 42, and control 38 such that the flow of water through each unit is manipulated independently. Ex. 1007, 3:25–39. Newton’s alternative embodiment of Figure 6 discloses individually manipulating a pump at the inlet of each heat exchanger to

control the flow of chilled water to the heat exchanger unit in response to sensed temperatures. Ex. 1007, 4:17–38.

183. Claim 9 of the ’287 patent is therefore disclosed by Newton.

B. GROUND 2: CLAIMS 5 AND 6 ARE OBVIOUS OVER NEWTON AND THE KNOWLEDGE OF A PERSON OF ORDINARY SKILL IN THE ART

184. A set forth above, it is my opinion that all limitations of at least claims 1–4 and 7–9 are disclosed in Newton.

1. Claim 5 – “The method according to claim 4, further comprising: increasing said cooling fluid temperature in response to a sum of the sensed temperatures at one or more locations being below said predetermined range.”

185. Claim 5 depends from claim 4. The added limitation recites: “increasing said cooling fluid temperature in response to a sum of the sensed temperatures at one or more locations being below said predetermined range.” Newton does not explicitly disclose computing a sum of temperatures or increasing the cooling fluid temperature if the sum is below a predetermined range. However, this would have been obvious to a POSITA.

186. Like the ’287 patent, Newton is directed to cooling environments within buildings containing computer equipment. Newton solves a similar problem—i.e., to provide cooling for varying heat loads generated by equipment such as computers to maintain a desired temperature distribution throughout the environment. Like the ’287 patent, Newton’s cooling system includes air cooling

heat exchangers at various locations supplied with water from a central source, with the temperature and flow rate of the water circulating through individual heat exchangers being adjustable based on air temperature conditions near the heat exchanger.

187. Most limitations of claims 1–9 are disclosed in Newton. This confirms how close the reference is to the ‘287 patent and confirms that a POSITA would look to Newton as a starting point when facing problems similar to those addressed in the ’287 patent. Like the ’287 patent, Newton teaches comparing data representing current air temperature conditions to desired air temperature conditions to identify locations that need cooling. And like the ’287 patent, Newton provides for changing the circulating water temperature to achieve the desired heat transfer with the air and recognized the benefits of this capability when managing varying heat loads of different regions of a building.

188. A POSITA would understand that there are a limited number of ways to assess the cooling needs of a particular location within a building. The method of claim 5 involves determining whether the sum of sensed temperatures at one or more locations is below a predetermined range. A POSITA would understand that assessing a sum of multiple temperature measurements could provide additional insight into local air temperature conditions for use in determining whether to adjust the cooling fluid temperature. For example, a sum of temperatures measured at

different times could reflect whether an out-of-range temperature condition is persisting and could also reflect the total magnitude of the required heating or cooling. Alternatively, a sum of temperatures measured near different heat exchange units within a location could correlate to the size of the out-of-range temperature region.

189. Newton similarly teaches assessing cooling and heating demands associated with each of multiple heat exchanger locations for determining whether to increase or decrease the temperature of the circulating water. The demand at each unit is assessed by comparing sensed air temperature at each heat exchange unit to a desired temperature level. Ex. 1007, 3:25–39. When conditions require heating by some heat exchangers and cooling by others, the system changes the circulating water temperature between hot and cold. Ex. 1007, 5:16–6:1. Newton further teaches performing the temperature cycling operation "[d]epending on the relative demand for heating or cooling . . . ." Ex. 1007, 5:70–6:1. For example "if the cooling loads are above some predetermined level (approximately 75% of the maximum load for the entire building), valve 18 will be positioned . . . so as to continuously circulate chilled fluid from chiller 12." Ex. 1007, 5:24–29.

190. Thus, Newton teaches evaluating the total cooling and heating demands, determined by measuring air temperatures at multiple heat exchanger locations, to determine whether to change the temperature of circulating water—

akin to using a temperature summation. It would have been obvious from a POSITA's knowledge to assess the total cooling or heating demand by determining whether the sum of temperatures sensed at multiple heat exchanger locations is above or below a predetermined range. Assessing a sum of temperatures is one of a limited number of ways of assessing an aggregate heating or cooling demand within a region—that is, the total magnitude of the heating or cooling demand.

191. In my opinion and based on my knowledge and experience, generating a sum of temperature values measured at multiple locations and comparing the sum to a predetermined range is a way to assess cooling needs within a building location; and adjusting the cooling fluid temperature as appropriate, would have been exceedingly straightforward using the existing features of Newton's system and the capabilities of a POSITA. Furthermore, this approach would have predictably resulted in a fast and reliable determination of regions where air temperatures are below optimal temperature conditions justifying increasing the water temperature. In fact, I have personal experience using temperature summations in this way, prior to the priority date of the '287 patent.

192. A POSITA would have had a reasonable expectation of success because it would have been a routine and obvious matter for a POSITA to modify Newton's system and methodology because the system already includes temperature sensors for each heat exchanger and a control system capable of

comparing measured temperatures to desired temperature level and to adjust the circulating water temperature based on the total cooling demand. The simple, routine and low-cost nature of modifying the control algorithms of Newton to determine whether a sum of measured temperatures is within a predetermined range as a means for assessing an aggregate cooling demand, which would have ensured a reasonable expectation of success, would have further motivated a person of ordinary skill in the art.

193. Thus, in my opinion, ample motivation existed for a POSITA to modify Newton's control methodology in order to arrive at the method of claim 5.

2. Claim 6 – "The method according to claim 4, further comprising: decreasing said cooling fluid temperature in response to a sum of the sensed temperatures at one or more locations being above said predetermined range."

194. Dependent claim 6 is analogous to claim 5 but requires decreasing the cooling fluid temperature when the computed sum of sensed temperatures is above the predetermined target temperature. This, too, would have been obvious to a POSITA for essentially the same reasons just explained.

195. It is, therefore, my opinion that the subject matter of dependent claims 5 and 6 would have been obvious in view of Newton and a POSITA's knowledge.

C. GROUND 3: CLAIMS 1–4, 7, AND 9 ARE ANTICIPATED BY SHIMIZU ET AL.

196. For the reasons set forth below, it is my opinion that Shimizu discloses all limitations of claims 1–4, 7, and 9 of the ’287 patent.

1. Claim 1

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

a. 1[pre] – “A method for cooling a room configured to house a plurality of computer systems, said method comprising:”

198. The preamble of claim 1 recites, “*[a] method for cooling a room configured to house a plurality of computer systems, said method comprising:*”

199. As discussed above in relation to Ground 1, a POSITA would understand the phrase “a room configured to house a plurality of computer systems” to apply to any room equipped with a power source for operating computer equipment. Although the ’287 patent specification mentions the cooling of data centers, the preamble language is not limited to methods of cooling data centers or other specialized facilities, does not mention any required features of the room beyond the capability to house computer systems, and does not specify any type or arrangement of the computer systems.

200. As discussed above, Shimizu discloses an air conditioning system for cooling the internal space of a room of a building containing desks 7 and chairs 8. Ex. 1008, 3:48–55. Shimizu illustrates the system in the context of a building having

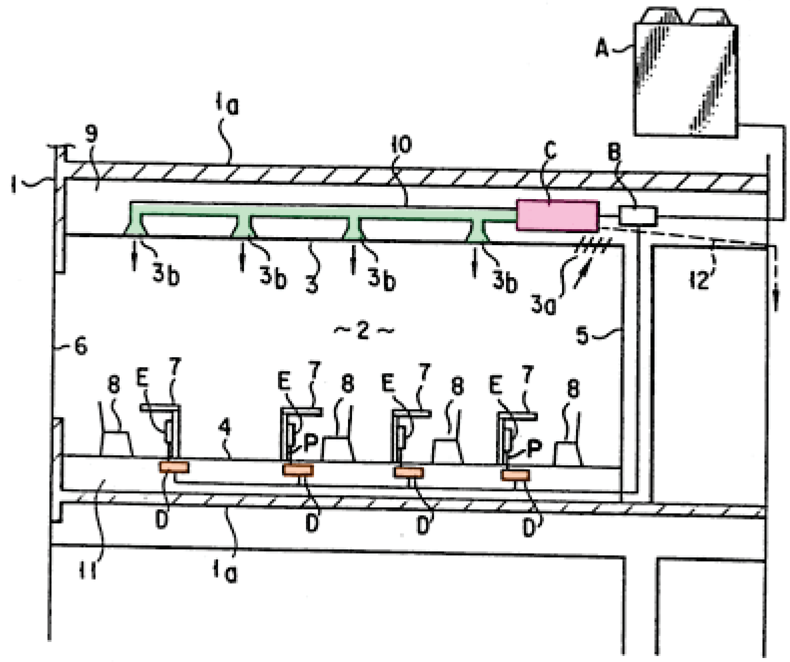
a space beneath a floor 4 "for accommodating the electrical wirings of computer and business machines." Ex. 1008, , 4:1–6. A POSITA would thus understand the disclosed system and methods to apply to buildings having rooms configured to house computer systems.

201. Thus, to the extent that the preamble is considered a claim limitation, Shimizu discloses limitation 1[pre].

b. 1[a] – "providing a plurality of heat exchanger units configured to receive air from said room and to deliver air to said room;"

202. Claim 1 further recites "*providing a plurality of heat exchanger units configured to receive air from said room and to deliver air to said room.*" In my opinion, Shimizu discloses this limitation.

203. Figure 1, an annotated version of which is provided below, illustrates an embodiment of the system disclosed in Shimizu.



F I G. 1

Ex. 1008, FIG. 1 (annotated).

204. An outdoor unit A includes a variable-capability compressor 21 that compresses the refrigerant, which then condenses to the liquid phase in an outdoor heat exchanger 23. Ex. 1008, 2:15–23, 4:29–34, 7:28–31.

205. An ambient air conditioning unit C (annotated in pink) provides air conditioning for the whole space of the room. It receives room air and distributes cooled air through outlet ports 3b of a duct 10 (annotated in green). Ex. 1008, 3:61–64. The ambient air conditioning unit C includes an indoor heat exchanger 34. Ex. 1008, 4:38–43.

206. The system also includes personal air conditioning units E for separately cooling spaces around the desks 7. Ex. 1008, 3:65–68. Each personal air conditioning unit E includes an indoor heat exchanger 45. Ex. 1008, 4:48–55. An indoor fan 61 feeds air into each indoor heat exchanger 45. Ex. 1008, 5:43–50.

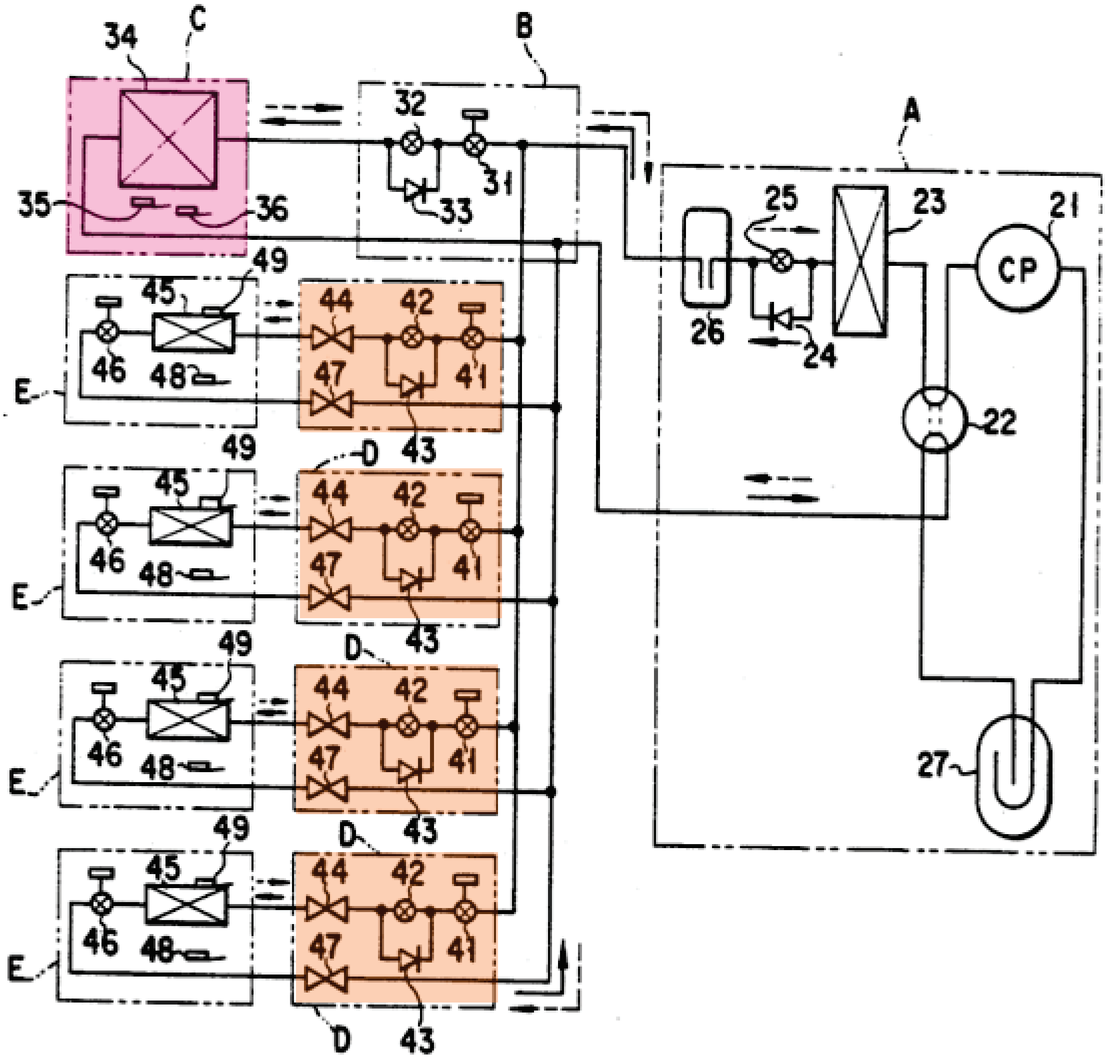
207. This discloses to a POSITA an air conditioning system that includes multiple heat exchanger units that receive warm air from the room and deliver cooled air to the room. Shimizu therefore discloses claim limitation 1[a].

c. 1[b] – "supplying said plurality of heat exchanger units with cooling fluid from an air conditioning unit;"

208. Claim 1 recites "*supplying said plurality of heat exchanger units with cooling fluid from an air conditioning unit.*" In my opinion, Shimizu discloses this limitation.

209. As I have explained, a POSITA would understand that "air conditioning unit" in claim 1 refers to a device that supplies cooling fluid to a plurality of heat exchanger units, and would also understand that the term "cooling fluid" includes any suitable heat transfer fluid. *Supra* Section VII.

210. Figure 2, an annotated version of which is provided below, shows additional details of the overall refrigerant cycle.



F I G. 2

Ex. 1008, FIG. 2 (annotated).

211. Outdoor unit A supplies refrigerant through distribution unit B to the ambient air conditioning unit C (annotated in pink). Ex. 1008, 4:14–17 and 4:24–28. The distribution unit B is also connected to dividing units D (annotated in

orange), which control the flow of refrigerant from outdoor unit A to personal air conditioning units E. Ex. 1008, 4:7–17 and 4:44–47.

212. Shimizu's disclosure of supplying two-phase refrigerant cooling fluid from outdoor unit A to a heat exchanger of the ambient indoor air conditioner as well as to the heat exchangers of multiple personal air conditioning units meets limitation 1[b].

d. 1[c] – "cooling said received air through heat exchange with the cooling fluid in the plurality of heat exchanger units;"

213. Claim 1 recites "*cooling said received air through heat exchange with the cooling fluid in the plurality of heat exchanger units*." In my opinion, Shimizu discloses this limitation.

214. Shimizu indicates that the heat exchangers of ambient air conditioning unit C and of the personal air conditioning units E are "for exchanging the heat of received refrigerant with the heat of internal air," resulting in "cooling the whole space in the room" and "separately cooling the discrete spaces in the room." Ex. 1008, 2:23–28, 2:34–35 and 2:41–42. Shimizu also describes this in the claims, such as claim 7, which describes the heat exchanger of an air conditioning unit for "cooling air in said room" and heat exchangers of personal air conditioners for "cooling air in said room predetermined locations." Ex. 1008, 16:24–31; *see also* Ex. 1008, 5:45–50; 13:13–14; 14:38–45; 14:64–65; 15:42–55.

215. Limitation 1[c] is therefore disclosed by Shimizu.

e. 1[d] – "sensing temperatures at one or more locations in said room;"

216. Claim 1 recites "*sensing temperatures at one or more locations in said room*." In my opinion, Shimizu discloses this limitation.

217. The ambient air conditioning unit C of Shimizu's system includes an air temperature sensor 35 for sensing temperature of air in the room. Ex. 1008, 4:38–43. Each personal air conditioning unit E includes temperature sensor 48 for sensing air temperature and temperature sensor 49 on an indoor heat exchanger 45 for sensing the heat exchanger temperature. Ex. 1008, 4:48–55; *see also* Ex. 1008, 5:46–47; 5:63–64; 7:67; 11:14–15; 11:66; FIG. 5.

218. Limitation 1[d] is therefore disclosed by Shimizu.

f. 1[e] – "controlling at least one of the temperature of said cooling fluid and said air delivery by said plurality of heat exchanger units to said room in response to said sensed temperatures at said one or more locations; and"

219. Claim 1 recites "*controlling at least one of the temperature of said cooling fluid and said air delivery by said plurality of heat exchanger units to said room in response to said sensed temperatures at said one or more locations*." In my opinion, Shimizu discloses this limitation.

220. This claim limitation requires controlling *at least one* of temperature of the cooling fluid or air delivery by the heat exchangers. As discussed below, Shimizu discloses performing *both* control operations.

221. With regard to controlling cooling fluid temperature, Shimizu's system controls the refrigerant temperature in two respects. The first relates to controlling the temperature at which the refrigerant evaporates in the air cooling heat exchangers of the personal air conditioning units. The control unit 60 of each personal air conditioning unit determines the dew point temperature of the internal air derived from the measured air temperature and humidity. Ex. 1008, 6:54–56; 6:67–7:5. If the detected temperature of heat exchanger 45 is below the dew point temperature (which would lead to condensation) the opening of the evaporative pressure regulator 46 is adjusted (i.e., narrowed) to raise the refrigerant temperature so that the detected heat exchanger temperature is above the dew point temperature. Ex. 1008, 8:8–25. As a POSITA understands, narrowing the flow passage through pressure regulator 46 increases the refrigerant pressure and thus its evaporation temperature. This control of refrigerant temperature is in response to measured air room air temperature.

222. Shimizu also controls refrigerant temperature output from the compressor 21 of outdoor unit A and does so in response to measured temperatures in the room. In particular, the ambient air conditioning unit C detects the room air temperature using sensor 35 and computes a difference from a preset desired temperature to determine an air conditioning load. Ex. 1008, 8:44–52. The air conditioning load for each personalized air conditioning unit E is computed as a

difference between the air temperature around the unit detected bytemperature sensor 48 and a preset temperature. Ex. 1008, 7:63–8:3. The total sum of the air conditioning loads is derived and a control unit 50 adjusts the frequency of the voltage signal driving the motor 21M of compressor 21 based on the total air conditioning load. Ex. 1008, FIGs. 4 and 7, 5:22–27, 9:6–12.

223. As a POSITA understands, adjusting the speed of the compressor motor changes how much the refrigerant vapor is compressed by the compressor, affecting its pressure and temperature. Therefore, this aspect of Shimizu's control system also discloses controlling the refrigerant temperature in response to temperatures measured at one or more locations in the room.

224. Therefore, Shimizu's system and control method disclose controlling the temperature at which the refrigerant evaporates in the heat exchangers of personal air conditioning units E and controlling the temperature of refrigerant supplied to the heat exchangers, in response to temperatures sensed at multiple locations in the room.

225. With regard to controlling "air delivery," the next limitation 1[f] indicates that this includes the technique of individually manipulating the mass flow rate of cooling fluid supplied to each of a plurality of heat exchanger units (which affects the temperature of the delivered air) in response to sensed temperature at

one or more locations. Shimizu also discloses this step, as discussed in relation to limitation 1[f] below.

226. Limitation 1[e] is therefore disclosed by Shimizu.

g. 1[f] – "wherein the step of controlling said air delivery by said plurality of heat exchanger units comprises individually manipulating a mass flow rate of the cooling fluid supplied to each of the plurality of heat exchanger units."

227. Claim 1 recites "*wherein the step of controlling said air delivery by said plurality of heat exchanger units comprises individually manipulating a mass flow rate of the cooling fluid supplied to each of the plurality of heat exchanger units*." In my opinion, Shimizu discloses this limitation.

228. A portion of the refrigerant passing from the outdoor heat exchanger 23 through the liquid receiver 26 flows into the indoor heat exchanger 34 of ambient unit C via the flow control valve 31 and expansion valve 32. Ex. 1008, FIG. 2, 7:52–62. The refrigerant flow to the heat exchanger is regulated based on sensed temperature in the room. In particular, the temperature of the internal air in the room 2 is detected by the air temperature sensor 35, a difference between the detected temperature and the preset temperature is computed to determine an air conditioning load, and then the opening of the flow control valve 31 is controlled so that refrigerant of an amount corresponding to the air conditioning load flows into the heat exchanger. Ex. 1008, 8:44–56.

229. Refrigerant from outdoor heat exchanger 23 flows into the indoor heat exchanger 45 of each personal air conditioning unit E through a corresponding flow control valve 41. Ex. 1008, FIG. 2, 7:32–38. The refrigerant flow to each heat exchanger 45 is regulated in response to the sensed temperature. The temperature of the air around the unit is detected by the corresponding air temperature sensor 48 and a difference between the detected temperature and a preset temperature is detected. Then flow control valve 41 is controlled to manipulate refrigerant flow corresponding to the air conditioning load in the vicinity of the personal air conditioning unit. Ex. 1008, FIG. 5, 7:63–8:7; *see also* Ex. 1008, 4:44–48; 6:31–33; 8:4; FIG. 5.

230. Limitation 1[f] is therefore disclosed by Shimizu.

2. Claim 2 – "The method according to claim 1, wherein said step of controlling at least one of a temperature of said cooling fluid and said air delivery to said room comprises varying an output of said air conditioning unit to control the temperature of said cooling fluid."

231. Claim 2 recites "*[t]he method according to claim 1, wherein said step of controlling at least one of a temperature of said cooling fluid and said air delivery to said room comprises varying an output of said air conditioning unit to control the temperature of said cooling fluid*." In my opinion, Shimizu discloses this claim.

232. As explained above, Shimizu discloses the method of claim 1.

233. As discussed above, Shimizu discloses varying the motor speed and thus the output of compressor 21 in response to the total air conditioning load determined by comparison of sensed room temperatures at multiple locations to preset temperatures. Ex. 1008, FIGs. 4 and 7, 5:22–27, 7:63–8:3, 8:44–52, 9:6–12. This affects the temperature and flow rate of the refrigerant supplied to the heat exchanger units.

234. Claim 2 of the ’287 patent is therefore anticipated by Shimizu.

3. Claim 3 – “The method according to claim 1, further comprising: determining whether the sensed temperatures at one or more locations in said room are within a predetermined range.”

235. Claim 3 recites “*[t]he method according to claim 1, further comprising: determining whether the sensed temperatures at one or more locations in said room are within a predetermined range*.” In my opinion, Shimizu discloses this claim.

236. As explained above, Shimizu discloses the method of claim 1.

237. The disclosed system regulates refrigerant flow to the heat exchangers of the ambient air conditioning unit and of the personal air conditioning units based on calculating differences between sensed air temperature and temperature preset by a user. Ex. 1008, FIG. 5, 7:63–8:7, 8:44–56. A POSITA would understand from Shimizu’s teachings that when a sensed temperature is above the preset temperature, Shimizu’s control system identifies this as an air conditioning load of

a magnitude proportional to the computed temperature difference. Thus, Shimizu discloses determining whether a sensed temperature at one or more locations is within a predetermined range, i.e., the range consisting of temperatures below the preset temperature.

238. Claim 3 of the ’287 patent is therefore anticipated by Shimizu.

4. Claim 4 – “The method according to claim 3, further comprising: varying the cooling fluid temperature in response to the sensed temperatures at one or more locations in said room being outside of said predetermined range.”

239. Claim 4 recites “*[t]he method according to claim 3, further comprising: varying the cooling fluid temperature in response to the sensed temperatures at one or more locations in said room being outside of said predetermined range*.” In my opinion, Shimizu discloses this claim.

240. As explained above, Shimizu discloses the method of claim 3.

241. Shimizu’s disclosed system automatically adjusts the compressor output in response to the total air conditioning load, and this directly affects the temperature of the refrigerant circulated to the heat exchanger units. Ex. 1008, FIGs. 4 and 7, 5:22–27, 7:63–8:3, 8:44–52, 9:6–12. The control system determines the air conditioning load for each unit based on sensed air temperature near the unit being outside of the predetermined range (i.e., being higher than the preset temperature). Ex. 1008, FIG. 5, 7:63–8:7, 8:44–56.

242. Claim 4 of the ’287 patent is therefore anticipated by Shimizu.

5. Claim 7 – "The method according to claim 1, wherein the step of manipulating a mass flow rate of the cooling fluid supplied to each of the plurality of heat exchanger units further comprises metering the flow of cooling fluid through each of said plurality of heat exchanger units with a plurality of valves positioned along respective cooling fluid lines configured to channel cooling fluid from the air conditioning unit to the plurality of heat exchanger units."

243. Claim 7 recites "*[t]he method according to claim 1, wherein the step of manipulating a mass flow rate of the cooling fluid supplied to each of the plurality of heat exchanger units further comprises metering the flow of cooling fluid through each of said plurality of heat exchanger units with a plurality of valves positioned along respective cooling fluid lines configured to channel cooling fluid from the air conditioning unit to the plurality of heat exchanger units*." In my opinion, Shimizu discloses this claim.

244. As explained above, Shimizu discloses the method of claim 1.

245. As shown in Figure 2, an annotated version of which is provided below, the flow control valve 31 at the inlet of indoor heat exchanger 34 is positioned along a fluid line extending through distribution unit B (annotated in blue, below) for metering the flow of refrigerant from outdoor unit A (annotated in yellow, below) to the heat exchanger 34. Each flow control valve 41 is positioned along fluid lines for metering the flow of refrigerant to a respective heat exchanger 45 of a personal air conditioning unit.

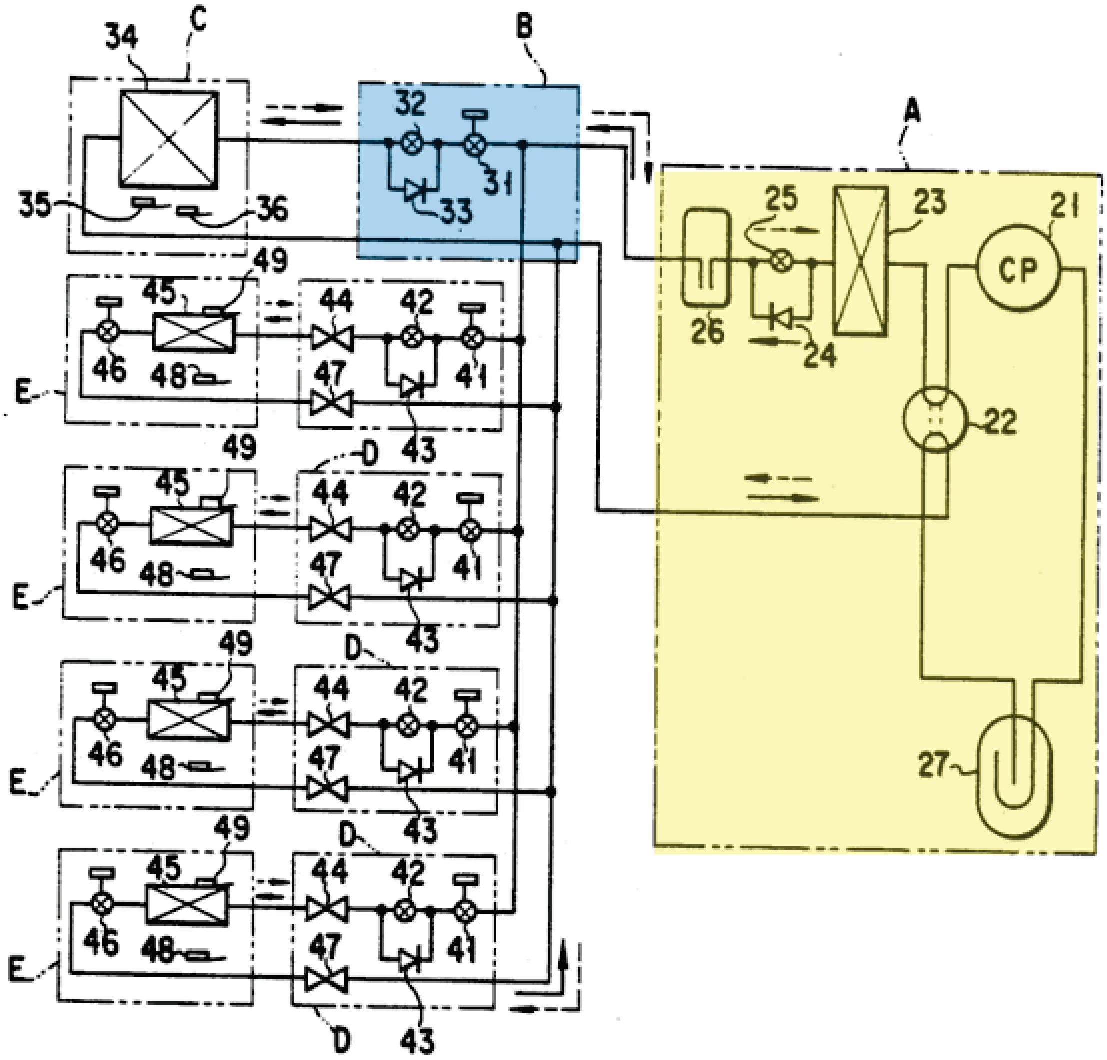


FIG. 2

Ex. 1008, FIG. 2 (annotated).

246. Claim 7 of the ’287 patent is therefore anticipated by Shimizu.

6. Claim 9 – "The method according to claim 1, further comprising: manipulating a mass flow rate of the cooling fluid supplied to the plurality of heat exchanger units in substantially independent manners with respect to each of the plurality of heat exchanger units."

247. Claim 9 recites "*[t]he method according to claim 1, further comprising: manipulating a mass flow rate of the cooling fluid supplied to the plurality of heat exchanger units in substantially independent manners with respect to each of the plurality of heat exchanger units*." In my opinion, Shimizu discloses this claim.

248. As explained above, Shimizu discloses the method of claim 1.

249. As discussed in relation to limitation 1[f], the ambient air conditioning unit and each personal air conditioning unit has its own refrigerant control valve and temperature sensor, and the control system disclosed in Shimizu manipulates each control valve independently of the others based on the computed air conditioning load of the individual unit. *See* Section IX.C.1.g.

250. Claim 9 of the '287 patent is therefore anticipated by Shimizu.

D. GROUND 4: CLAIMS 1, 3, 7, AND 9 ARE ANTICIPATED BY BAER

251. For the reasons set forth below, it is my opinion that Baer discloses all limitations of claims 1, 3, 7, and 9 of the '287 patent.

1. Claim 1

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

a. 1[pre] – "A method for cooling a room configured to house a plurality of computer systems, said method comprising:"

253. The preamble of claim 1 recites, "*[a] method for cooling a room configured to house a plurality of computer systems, said method comprising:*"

254. As discussed above in relation to Ground 1, a POSITA would understand the phrase "a room configured to house a plurality of computer systems" to apply to any room equipped with a power source for operating computer equipment.

255. Baer discloses an air conditioning system for cooling computer rooms. "The principle of operation of the present system is as follows: Air from the computer room at the ambient temperature and humidity is taken into the enclosure and heated by the electronic equipment. The air is then expelled through a heat exchanger, which cools the air back to the ambient temperature." Ex. 1011, [0005].

256. Thus, to the extent that the preamble is considered a claim limitation, Baer discloses limitation 1[pre].

b. 1[a] – "providing a plurality of heat exchanger units configured to receive air from said room and to deliver air to said room;"

257. Claim 1 further recites "*providing a plurality of heat exchanger units configured to receive air from said room and to deliver air to said room.*" In my opinion, Baer discloses this limitation.

258. Figure 1, an annotated version of which is provided below, illustrates an embodiment of Baer's disclosed computer cabinet cooling system.

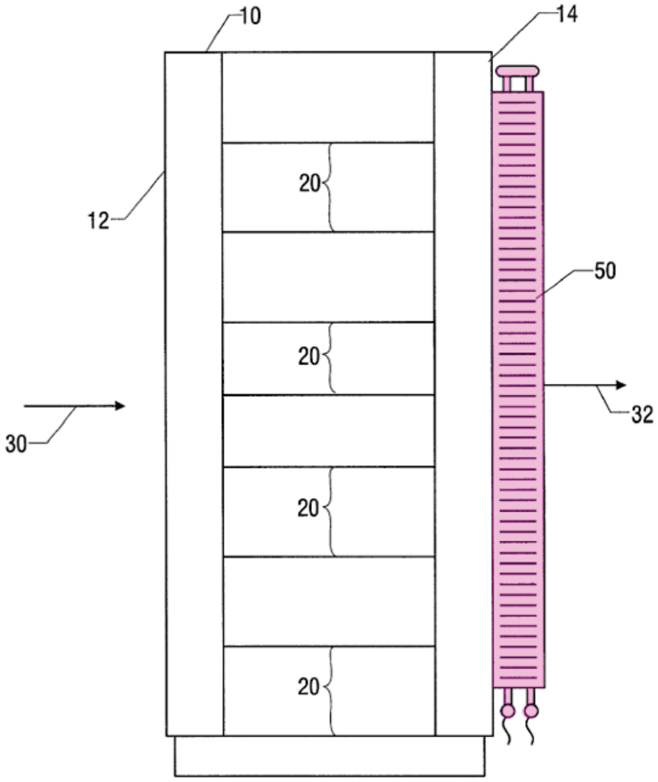


FIG. 1

Ex. 1011, FIG. 1 (annotated).

259. Rack 10 houses electronic equipment such as computer devices supported on mounting racks 20. Cooling fans integral to the computer equipment draw air 30 from the room through the front 12 of rack enclosure 10 so that the air passes over the equipment and absorbs heat generated by the electronics. Ex. 1011, [0021]. Heat exchanger 50 (annotated in pink) mounted on the rear 40 of rack enclosure 10 absorbs the heat added to the air by the electronic equipment. The cooled air 32 flows out the back 14 of rack enclosure 10 and returns to the computer

room without contributing additional heat load to the room air conditioning system. Ex. 1011, [0023].

260. As a POSITA would recognize, a typical computer room contains multiple rack enclosures. Baer indicates that his invention addresses a need "to install additional localized cooling for *enclosures* containing electronic equipment that will remove the heat generated by the electronic equipment from the room . . . ." Ex. 1008, [0003] (emphasis added). Therefore, Baer discloses providing multiple heat exchangers, each associated with one of multiple rack enclosures within a room, and each operating to receive warm air from the room and to return cooled air to the room. *See, e.g.*, Ex. 1008, [0004]–[0005]; [0008]–[0010]; [0022]–[0023]; [0030].

261. Baer therefore discloses providing a plurality of heat exchanger units configured to receive air from said room and to deliver air to said room, as recited in claim limitation 1[a].

c. 1[b] – "supplying said plurality of heat exchanger units with cooling fluid from an air conditioning unit;"

262. Claim 1 recites "*supplying said plurality of heat exchanger units with cooling fluid from an air conditioning unit.*" In my opinion, Baer discloses this limitation.

263. As I have explained, a POSITA would understand that "air conditioning unit" in claim 1 refers to a device that supplies cooling fluid to a

plurality of heat exchanger units, and would also understand that the term "cooling fluid" includes any suitable heat transfer fluid. *Supra* Section VII.

264. Figure 2 provides more detail regarding the disclosed fin-and-tube heat exchanger 50 associated with each rack enclosure and the coolant flow through the heat exchanger.

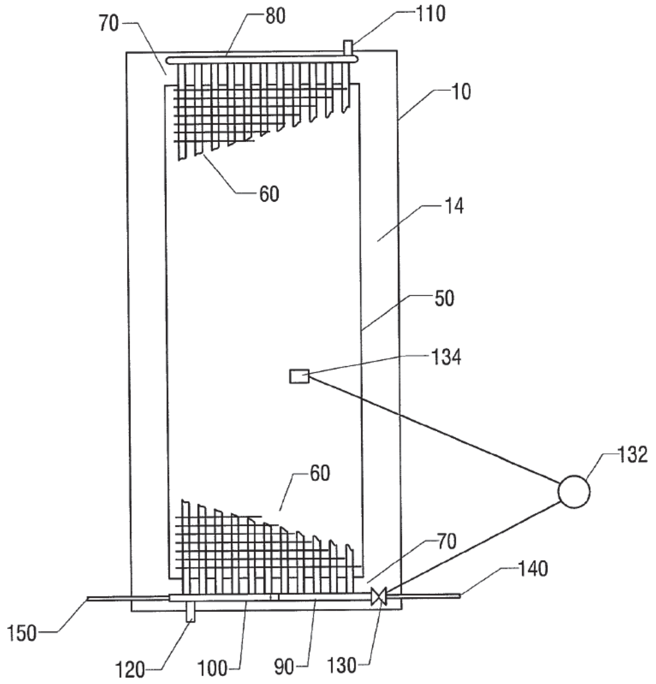


FIG. 2

Ex. 1011, FIG. 2.

265. Baer indicates that chilled water, glycol, dielectric fluid or another cooling fluid from source 140 enters the heat exchanger through modulating valve 130. Ex. 1011, [0027]. After passing into inlet 90, the cooling fluid flows through tubes 70 while absorbing heat from air exiting the enclosure and then returns through line 150 to an external cooling source, such as a chiller or heat

exchanger that rejects the heat. Ex. 1011, [0028]. Baer also explains that "[t]he chilled fluid is then returned to the inlet 140, operating the cycle continuously." Ex. 1011, [0028]. A POSITA would understand the described cooling flow circulation to apply to the heat exchangers mounted to other enclosure racks in the computer room as well, each receiving cooling fluid from the external cooling source and returning it to the external cooling source after absorbing heat from the air.

266. Therefore, Baer discloses supplying a plurality of heat exchanger units with cooling fluid from an air conditioning unit as recited in claim limitation 1[b].

d. 1[c] – "cooling said received air through heat exchange with the cooling fluid in the plurality of heat exchanger units;"

267. Claim 1 recites "*cooling said received air through heat exchange with the cooling fluid in the plurality of heat exchanger units*." In my opinion, Baer discloses this limitation.

268. For example, Baer indicates that each heat exchanger coupled to each enclosure rack receives air heated by the electronics equipment and "cools the air back to the ambient temperature." Ex. 1011, [0005]. For example, heat exchanger 50 mounted on rack enclosure 10 "absorbs the heat added to the air by the electronic equipment." Cooled air 32 flows out the back 14 of the enclosure 10 and "then returns to the computer room" without contributing additional heat load to the room air conditioning system. Ex. 1011, [0023].

269. Limitation 1[c] is therefore disclosed by Baer.

e. 1[d] – "sensing temperatures at one or more locations in said room;"

270. Claim 1 recites "*sensing temperatures at one or more locations in said room*." In my opinion, Baer discloses this limitation.

271. Baer discloses that temperature controller 132 receives input from "a temperature sensor 134 on the back of heat exchanger 50 to measure the temperature of the air leaving the heat exchanger." Ex. 1011, FIG. 2; [0027]. This teaches sensing temperature at the location of each enclosure rack. *See, e.g.*, Ex. 1011, FIG. 2; [0027]; [0042].

272. Limitation 1[d] is therefore disclosed by Baer.

f. 1[e] – "controlling at least one of the temperature of said cooling fluid and said air delivery by said plurality of heat exchanger units to said room in response to said sensed temperatures at said one or more locations; and"

273. Claim 1 recites "*controlling at least one of the temperature of said cooling fluid and said air delivery by said plurality of heat exchanger units to said room in response to said sensed temperatures at said one or more locations*." In my opinion, Baer discloses this limitation.

274. This claim limitation requires controlling *at least one* of temperature of the cooling fluid or air delivery by the heat exchangers. With regard to controlling "air delivery," the next limitation 1[f] indicates that this includes the technique of individually manipulating the mass flow rate of cooling fluid supplied to each of a plurality of heat exchanger units (which affects the temperature of the delivered air)

in response to the sensed temperature at one or more locations. Baer discloses this step, as discussed in relation to limitation 1[f] below. *See also* Ex. 1011, Claims 7; 12; 13; 17.

275. Limitation 1[e] is therefore disclosed by Baer.

g. 1[f] – "wherein the step of controlling said air delivery by said plurality of heat exchanger units comprises individually manipulating a mass flow rate of the cooling fluid supplied to each of the plurality of heat exchanger units."

276. Claim 1 recites "*wherein the step of controlling said air delivery by said plurality of heat exchanger units comprises individually manipulating a mass flow rate of the cooling fluid supplied to each of the plurality of heat exchanger units*." In my opinion, Baer discloses this limitation.

277. As discussed, cooling fluid flow into each heat exchanger is controlled by a modulating valve 130. Ex. 1011, FIG. 2, [0027]. Baer's disclosed temperature controller 132 receives input from a temperature sensor 134 on the back of heat exchanger 50 which measures the temperature of air leaving the heat exchanger. Temperature controller 132 operates the modulating valve 130 "to ensure that the air exiting the heat exchanger is at the same temperature as the room temperature of the computer room in which the equipment is housed." Ex. 1011, [0027]; *see also* Ex. 1011, [0042].

278. Figure 4 shows a bottom view of the heat exchanger 50.

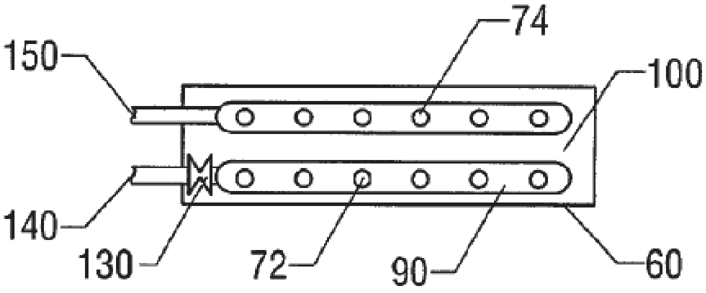


FIG. 4

Ex. 1011, FIG. 4. Baer indicates that "[t]he flow of cooling fluid is modulated by valve 130 to regulate the amount of cooling fluid passing through the exchanger, which in turn controls the amount of heat absorbed and the temperature of the exiting air." Ex. 1011, [0030].

279. Baer similarly describes a thermostatic valve 320 coupled to a coolant supply line and thermostatic operator 322 that changes the valve position according to sensed temperature. *See, e.g.*, Ex. 1011, FIG. 6B. "The valve controls the flow of cooling fluid in the heat exchanger and ensures that the air exiting the heat exchanger is at the same temperature as the room temperature of the computer room in which the enclosure is housed." Ex. 1011, FIG. 7, [0038]–[0039], [0042].

280. Therefore, Baer discloses individually manipulating a mass flow rate of cooling fluid supplied to each of the plurality of heat exchanger units in response to air temperature sensed at each enclosure rack. Limitation 1[f] is therefore disclosed by Baer.

2. Claim 3 – "The method according to claim 1, further comprising: determining whether the sensed temperatures at one or more locations in said room are within a predetermined range."

281. Claim 3 recites "*[t]he method according to claim 1, further comprising: determining whether the sensed temperatures at one or more locations in said room are within a predetermined range*." In my opinion, Baer discloses this claim.

282. As explained above, Baer discloses the method of claim 1.

283. Baer discloses that the temperature sensor 134 on the back of each heat exchanger 50 measures the temperature of the air leaving the heat exchanger. Ex. 1011, FIG. 2; [0027]. The controller 132 receives the sensed temperature values and manipulates the cooling fluid flow modulating valve 132 "to ensure that the air exiting the heat exchanger is at the same temperature as the room temperature of the computer room in which the equipment is housed." Ex. 1011, [0027]; *see also* Ex. 1011, [0042].

284. A POSITA would understand from these teachings that controller 132 has a target temperature range that reflects the desired room temperature and manipulates the cooling flow modulating valve 132 when the sensed temperature is not within the desired room temperature range. Thus, Baer discloses determining whether a sensed temperature at one or more locations is within a predetermined range, i.e., the desired room temperature range.

285. Claim 3 of the ’287 patent is therefore anticipated by Baer.

3. Claim 7 – “The method according to claim 1, wherein the step of manipulating a mass flow rate of the cooling fluid supplied to each of the plurality of heat exchanger units further comprises metering the flow of cooling fluid through each of said plurality of heat exchanger units with a plurality of valves positioned along respective cooling fluid lines configured to channel cooling fluid from the air conditioning unit to the plurality of heat exchanger units.”

286. Claim 7 recites “*[t]he method according to claim 1, wherein the step of manipulating a mass flow rate of the cooling fluid supplied to each of the plurality of heat exchanger units further comprises metering the flow of cooling fluid through each of said plurality of heat exchanger units with a plurality of valves positioned along respective cooling fluid lines configured to channel cooling fluid from the air conditioning unit to the plurality of heat exchanger units*.” In my opinion, Baer discloses this claim.

287. As explained above, Baer discloses the method of claim 1.

288. The coolant flow modulating valve 130 at the inlet of each heat exchanger is positioned along fluid line 140 for metering the flow of coolant from a chiller or other external source to the heat exchanger 50. Ex. 1011, FIG. 2; [0027]. The thermostatic valve 320 of Baer’s alternative embodiment is also coupled to a coolant supply line for controlling fluid in the heat exchanger. Ex. 1011, FIG. 7; *see also* Ex. 1011, [0041]–[0042].

289. Claim 7 of the ’287 patent is therefore anticipated by Baer.

4. Claim 9 – "The method according to claim 1, further comprising: manipulating a mass flow rate of the cooling fluid supplied to the plurality of heat exchanger units in substantially independent manners with respect to each of the plurality of heat exchanger units."

290. Claim 9 recites "*[t]he method according to claim 1, further comprising: manipulating a mass flow rate of the cooling fluid supplied to the plurality of heat exchanger units in substantially independent manners with respect to each of the plurality of heat exchanger units*." In my opinion, Baer discloses this claim.

291. As explained above, Baer discloses the method of claim 1.

292. As discussed in relation to limitation 1[f], each heat exchanger of Baer's system has a dedicated cooling fluid modulating valve and temperature sensor, and the disclosed control system manipulates each modulating valve independently of the others based on the sensed temperature of air exiting the heat exchanger. *See also* Ex. 1011, FIG. 7; [0027]; [0042].

293. Claim 9 of the '287 patent is therefore anticipated by Baer.

X. CONCLUDING STATEMENTS

294. In my opinion, all of the limitations in claims 1–9 of the '287 patent were well known before the filing data of the application that issued as the '287 patent. As such, it is my opinion that claims 1–9 of the '287 patent should be found unpatentable.

295. 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:
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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)

- 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: 10.1007s00376-024-3378-5. **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

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: Suvanjan 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: Suvanjan 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. Ghoash, J.P. Abraham, Enhancement of Jet Impingement Heat Transfer by Means of Jet Axis Switching, in: *Advances in Heat Transfer,* Vol. 50, 2018.

36. E.M. Sparrow, J.M. Gorman, J.P. Abraham, W.J. Minkowycz, Validation of Turbulence Models for Numerical Simulation of Fluid Flow and Convective Heat Transfer, in: *Advances in Heat Transfer*, Vol. 49, 397-421, 2017.

37. J.M. Gorman, E.M. Sparrow, J.P. Abraham, W.J. Minkowycz, Heat Exchangers and Their Fan/Blower Partners Modeled as a Single Interacting System by Numerical Simulation, in: *Advances in Numerical Heat Transfer Vol. 5,* Taylor and Francis, New York, 2017.

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.

42. J.P. Abraham, E.M. Sparrow, W.J. Minkowycz, R. Ramazani-Rend, and J.C.K. Tong, Modeling Internal Flows by an Extended Menter Transition Model, in: *Turbulence: Theory, Types, and Simulation*, Nova Publishers, New York, 2011.

43. S. Ramadhyani, J.P. Abraham, and E.M. Sparrow, A Mathematical Model to Predict Tissue Temperatures and Necrosis During Microwave Thermal Ablation of the Prostate, in: *Advances in Numerical Heat Transfer Vol. 3: Numerical Implementation of Bioheat Models and Equations*, Taylor and Francis, New York, 2009.

44. J.P. Abraham and E.M. Sparrow, Heat-Transfer and Temperature Results for a Moving Sheet Situated in a Moving Fluid, in: *Heat-Transfer Calculations, 2nd ed.,* editor, Myer Kutz, McGraw-Hill, 2005.

Publications (author of 309 journal papers)

2025

1. B. Nourani, F. Salmasi, and J.P. Abraham, Investigating Seepage and Stability of Unsaturated Embankment Dams Under Transient Conditions, *Transportation Infrastructure Geotechnology*, Vol. 12, pp. 1-27, 2025.

2. P. Karimzadeh, F. Salmasi, B. Nourani, and J.P. Abraham, Utilizing Gene Expression Programming Strategies for Estimating Relative Uplift Pressure Head at Keypoints Beneath Straight Horizontal Aprons, *Journal of Hydraulic Engineering*, (in press), 2025.

3. F. Salmasi and J.P. Abraham, Pore-water Pressure and Seepage Through Earth Dams (Numerical Case Study: Doiraj Dam), *J. of Hydraulic Engineering* (in press), 2025.

4. L. Cheng, J.P. Abraham, K.E. Trenberth, et al., Record High Temperatures in the Ocean in 2024, *Advances in Atmospheric Physics*, (in press), 2025.

5. S. Pourhani, F. Salmasi, B. Nourani, and J.P. Abraham, Investigation of Effect Capillary Fringe in Seepage Characteristics of Only Saturated and Unsaturated-

Saturated Materials Used in Earthen Dams, *Journal of Hydraulic Engineering,* (in press).

6. P N. Karimzadeh, F. Salmasi, B. Nourani, H. Arvanaghi, and J.P. Abraham, Development of Formulas to Estimate the Uplift Force and Pressure Beneath Aprons with Single Cut-off Walls Including Relative Permeability, *International Journal of Geomechanics*, Vol. 25, article no. 06024026, 2025.

7. B. Bourani, F. Salmasi, and J.P. Abraham, Transportation Infrastructure Geotechnology, Vol. 12, article no. 17, 2025.

8. F. Salmasi and J.P. Abraham, Investigating Seepage and Stability of Embankment Dams in the Unsaturated-Transient State: A Case Study of Doiraj Embankment Dam, *Transportation Infrastructure Geotechnology*, (in press).

9. B. Nourani, F. Salmasi, A. Abbaspour, H. Arvanaghi, and J.P. Abraham, Determination of the Factor of Safety against Sliding of Finite Slopes Using Classical Regression and Soft Computing Approaches, *Iranian Journal of Science and Technology, Transactions on Civil Engineering*, (in press).

10. R. Aminvash, R. Daneshfaraz, V. Sume, S. Sadeghfam, and J.P. Abraham, On the Multiple steady Flow States in Spindle Shaped Geometry of Bridge Foundations*,* *Journal of Applied Fluid Mechanics*, Vol. 18, pp. 1-15, 2025.

11. B. Nourani, F. Salmasi, A. Abbaspour, H. Arvanaghi, and J.P. Abraham, Determination of the Factor of Safety against Sliding of Finite Slopes Using Classical Regression and Soft Computing Approaches, *Geotechnical and Geological Engineering*, (in press).

2024

12. S. Abbasi, M. Seifollahi, S. Farzaneh, R. Daneshfaraz, V. Sume, N. Sadraei, and J.P. Abraham, Design Optimization of Concrete Gravity Dams Using Grasshopper Optimization Algorithm, *Innovative Infrastructure Solutions*, Vol. 9, article 453, 2024.

13. R. Daneshfaraz, H. Sadeghi, A. Ghaderi, and J.P. Abraham, The Effect of Gabion Steps on the Hydraulic Jump Characteristics Downstream of Stepped Spillways, *Water Science*, Vol. 38, pp. 128-139, 2024.

14. D. Firoozna, M. Vauezi, R. Daneshfaraz, and J.P. Abraham, Numerical Investigation of Leakage in GRP Pipe Joints with Double-Gasketed Coupling Connections under Various Angular Deflections, *ASCE Journal of Pipeline Systems Engineering and Practice*, (accepted).

15. K. Sini, T. Clair, V Puneeth[1], and J. P Abraham The Thermal Analysis of a Nanofluid Flow Past a Stretching Sheet in the Presence of Radiation, Fluid Dynamics (accepted).

16. Y. Hassanzadeh, H. Anbbaszadeh, A. Abedi, and J.P. Abraham, Numerical Simulation of the Effect of Downstream Material on Scouring-Sediment Profile of Combined Spillway-Gate, Water, *Infrastructure, Ecosystems, and Society* (*AQUA*), Vol. 73, pp. 2322-2343, 2024

17. R. Daneshfaraz, V. Sume, E. Aminvash, M. Rezaie, and J.P. Abraham, Experimental Study of the Effect of Non-Structural Materials on Scouring of Bridge Piers with Removal of River Material: Cationic Polyacrylamide, *Innovative Infrastructure Solutions,* Vol. 9, article no. 486, 2024.

18. M.K. Behbahabi, S.M., Sajjadi, J. Ahadiyan, J.P. Abraham, and H.A. Nadian, Hydraulic Performance of Multiple LOPAC Gates, AQUA – *Water Infrastructure, Ecosystems and Society,* (accepted).

19. F.T. Akyildiz, K. Vajravelu, C. Tunc, and J.P. Abraham. Chebyshev Delta Shaped and Chebyshev Pseudo-Spectral Methods for Solutions of the Poisson and Poisson-Boltzmann Equations, *Mathematics and Computers in Simulation*, (accepted).

20. M. Haghdoost, S.M. Sajjadi, J. Ahadiyan, R. Norouzi, and J.P. Abraham, The Effect of Sheet Piles' Inclination Angle, Number, and Distance on the Seepage Through an Earthfill Dam, *Ain Shams Engineering Journal*, Vol. 15, article no. 103056, 2024.

21. L. Cheng, Y. Pan, Z. Tan, H. Zheng, Y. Zhu, W. Wei, J. Du, H. Yuan, G. Li, H. Ye, V. Gouretski, Y. Li, K.E. Trenberth, J.P. Abraham, Y. Jin, F. Reseghetti, X. Lin, J. Zhu, IAPv4 Ocean Temperature and Ocean Heat Content Gridded Dataset, *Earth System Science Data,* Vol. 16, pp. 3517-3546, 2024.

22. F. Salmasi and J.P. Abraham, Numerical Solution of Rigid Column Theory Governing Equations for Surge Tank Analysis in Hydropower Plants Using a Microsoft Excel Platform, *Journal of Hydraulic Engineering,* (accepted).

23. F. Salmasi and J.P. Abraham, Estimation of Manning's Roughness Coefficient Using Observational Data, *ISH Journal of Hydraulic Engineering*, Vol. 30, pp. 623-632, 2024.

24. F. Salmasi and J.P. Abraham, Effect of Flywheels in Pump Stations for Reducing the Volume of Air Chambers, *Journal of Hydraulic Engineering*, (accepted).

25. S. Bhattacharyya, T. Bhatt, D. K. Vishwakarma, A.C. Benim, and J.P. Abraham, Effect of Mechanical Vibration and its Influence on Thermal Performance of a Nanofluid Heat Exchanger, *Numerical Heat Transfer Part A*, (in press), doi: 10.1080/10407782.2024.2331589.

26. H. Apaydin, S.N. Mousavi, M.T. Sattari, and J.P. Abraham, Extreme Pressure Coefficients – Modeling a Hydraulic Jump Using Deep-Learning Based Methods, *Sadhana*, Vol. 49, article number 151, 2024.

27. E. Aminvash, F. Kalateh, R. Daneshfaraz, and J.P. Abraham, Investigation of the Performance of Soft-Computing Methods in the Hydraulic Evaluation of the Slot Fishway on the Inclined Drop, *Journal of Hydraulic Structures*, Vol. 10, pp. 46-65, 2024.

28. Abraham, J.P., Cheng, L., and Gorman, J.M., CFD Simulation Models and Diffusion Models for Predicting Carbon Dioxide Plumes Following Tank and Pipeline Ruptures – Laboratory Test and a Real-World Case Study, *Energies*, Vol. 17, paper no. 1079, 2024.

29. R. Daneshfaraz, V. Sume, Mamidzadeh, J.P. Abraham, Experimental Investigation and Application of Soft Computing Models for Predicting Flow Energy Loss in Arch-Shaped Constrictions, *AQUA – Water Infrastructure, Ecosystems, and Society Production System*, Vol. 73, pp. 637-661, 2024.

30. F. Kalateh, E. Aminvash, and J.P. Abraham, On the Effect of Flow Regime and Slope of the Channel Bed on the Hydraulic Performance of the Sharp-Crested Rectangular Side Weir: A Numerical Simulation, *European Journal of Environmental and Civil Engineering*, Vol. 28, pp. 2327-2344, 2025, doi: 10.1080/19648189.2024.2314112.

31. H. Abbeszadeh, R. Daneshfaraz, V. Sume, and J.P. Abraham, Experimental Investigation and Application of Soft Computing Models for Predicting Flow Energy Loss in Arc-Shaped Constrictions, *Water Infrastructure, Ecosystems, and Society*, vol. 23, pp. 637-661, 2024.

32. E. Aminvash, F. Kalateh, R. Daneshfaraz, and J.P. Abraham, The Performance of KNN and SVM Algorithms in Evaluating the Hydraulic Parameters of Inclined Drop with the Presence of Fishways, *Journal of Hydraulic Structures*, (submitted).

33. E. Aminvash, F. Kalateh, R. Daneshfaraz, and J.P. Abraham, The Performance of KNN and SVM Algorithms in Evaluating the Hydraulic Parameters of Inclined Drop with the Presence of Fishways, *Journal of Hydraulic Structures*, Vol. 10, pp. 46-65, 2024.

34. 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,* 2024, doi: 10.1007s00376-024-3378-5.

35. R. Salmasi, F. Salmasi, and J.P. Abraham, Flood Spreading Effects on Soil Chemical Properties: Case Study in Tasuj Station, Iran, *Water Supply*, Vol. 24, pp. 995-1004, 2024.

36. R. Daneshfaraz, H. Sadeghi, A. Ghaderi, and J.P. Abraham, Characteristics of Hydraulic Jump and Energy Dissipation in the Downstream of Stepped Spillways with Rough Steps, *Flow Measurement and Instrumentation*, Vol. 96, paper no. 102506, 2024.

2023

37. B. Nourani, H. Arvanaghi, F.A. Pourhosseini, M. Javidnia, and J.P. Abraham. Enhanced Support Vector Machine with Particle Swarm Optimization and Genetic Algorithm for Estimating Discharge Coefficients of Circular-Crested Oblique Weirs, Iranian Journal of Science and Technology, *Transactions of Civil Engineering*, Vol. 47, pp. 3185-3198, 2023.

38. V. Sume, R. Daneshfaraz, A. Kerim, H. Abbaszadeh, and J.P. Abraham, Investigation of Clean Energy Production in Drinking Water Networks, *Water Resources Management*, Vol. 38, pp. 2189-2208, 2024.

39. F. Salmasi, P. Sihag, J.P. Abraham, and M. Nouri, Experimental Investigation and Prediction of Free Fall Jet Scouring Using Machine Learning Models, *International Journal of Sediment Research*, Vol. 38, pp. 405-420, 2023.

40. F. Salmasi, J.P. Abraham, and A. Salmasi, Evaluation of Various Design Models of Irrigation Sedimentation Basins, *International Journal of Environmental Science and Technology*, Vol. 20, pp. 11301-11308.

41. H. Abbaszadeh, R. Norouzi, V. Sume, A. Kuriqi, R. Daneshfaraz, J.P. Abraham, and R. Daneshfaraz, Sill Role Effect on the Flow Characteristics (Experimental and Regression Model Analytical), *Fluids*, Vol. 8, paper 235.

42. S. Abbasi, M. Seifollahi, R. Daneshfaraz, F. Mohammadi, and J.P. Abraham, Correction to Estimation of Vertical Settlement of Earthen Dams Caused by Earthquake Using ANN Model and Wavelet-ANN Composition, Geotechnical and Geological Engineering, Vol. 41, pg. 3187, 2023.

43. F. Salmasi, S. Razi, J.P. Abraham, Hydraulics of Flow in Gabion Stepped Spillways, an Experimental Study, *Journal of Hydraulic Structures*, Vol. 9, pp. 75-100, 2023.

44. R. Daneshfaraz, R. Norouzi, J.P. Abraham, P. Ebadzadeh, B. Akhondi, and M. Akbar, Numerical Simulation Using the Finite Volume Method to Investigate the Effect on the Length of Sharp-Crested Triangular Plan Form Weirs on the Hydraulic Parameters, *Water Science Journal*, (accepted).

45. R. Daneshfaraz, R. Norouzi, J.P. Abraham, P. Ebadzadeh, B. Akhondi, and M. Abar, Determination of the Flow Characteristics Over Sharp-Crested Triangular Plan Form Weirs Using Numerical Simulation, *Water Science*, Vol. 37, pp. 211-224, 2023.

46. R Daneshfaraz, P. Rezaie, E. Aminvash, V. Sume, and J.P. Abraham, On the Effect of Green Non-Structural Materials on Scour Reduction Downstream of Grid Dissipators, *AQUA – Water Infrastructure, Ecosystems and Society*, Vol. 72, pp. 1344-1357, 2023.

47. B. Nourani, F. Salmasi, A. Abbaspour, J. Arvanghi, and J.P. Abraham, Determination of the Factor of Safety Against Slide of Finite Slopes Using Classical Regression and Soft Computing Approaches, *J. of Hydroinformatics* (submitted).

48. R. Daneshfaraz, E. Aminvash, S. Veli, M. Rezair, A. Ghaderi, and J.P. Abraham, Experimental Study of New Green and Non-Structual Materials Effects on Scour Reduction Downstream of a Screen, Water, Infrastructure, Ecosystems, and Society, (accepted).

49. S. Abbasi, M. Seifollahi, R. Daneshfaraz, F. Mohammadi, J.P. Abraham, and H. Abbaszadeh, Estimation of Vertical Settlement of Earthen Dams Caused by Earthquake Using ANN Model and Wavelet-ANN Composition, Geotechnical and Geological Engineering, Vol. 41, pp. 2169-3186, 2023.

50. S. Abbasi, S. Ravaz, M. Heidapour, R. Daneshfaraz, J.P. Abraham, Investigating and Comparing the Performance of Collar and Cable Composition on Scouring of Cylindrical Bridge Piers, *Sadhana Academy Proceedings in Engineering Sciences*, Vol. 48, pp. 149 and following.

51. A. Aghdam, F. Salmasi, A. H. Zadeh Dalia, A. Abbaspoour, and J.P. Abraham, Experimental and Numerical Investigation of the Trajectories of Free and Pressurized Jets Through Storage Dams, *Water Supply*, Vol. 23, paper no. 1297, 2023.

52. Y. Pan L. Cheng. K. von Schuckmann, K.E. Trenberth, G. Li, J.P. Abraham, Y. Liu, V. Gouretski, Y. Yu, H. Liu, C. Liu, Annual Cycle in Upper Ocean Heat Content and the Global Energy Budget, *J. Climate*, Vol. 36, pp. 5003-5026, 2023.

53. M. Haghdoost, E. Lakzian, R. Norouzi, J.P. Abraham, S. Sajjadi, and J. Ahadiyan, Numerical Simulation Using the Finite Element Method to Investigate the Effect of Internal Cutoff Walls on Seepage and Hydraulic Gradients in Homogeneous Earth Dams, Modeling Earth Systems and Environment, (in press), doi: 10.1007/s40808-023-01755-w, 2023.

54. D.K. Vishwakarma, S. Bhattacharya, M.K. Sonja, and J.P. Abraham, Thermal and Flow Analysis of Air in a Uniformly Heated Channel with an Inlet Flap Obstruction in Laminar, Transitional, and Turbulent Flow Regimes, *Heat Transfer Engineering*, in press, doi: 10.1080/01457632.2023.2275235.

55. F. Salmasi, F. Nahrain, J.P. Abraham, and A.T. Aghdam, Prediction of Discharge Coefficients for Broad-Crested Weirs Using Expert Systems, *Journal of Hydraulic Engineering*, Vol. 29, pp. 1-11, 2023.

56. J.P. Abraham, T. Wei, L. Cheng, Validation of a New Method of Providing Case-Specific Time-of-death Estimates Using Cadaver Temperatures, *Journal of Forensic Science*, Vol. 68, pp. 884-897, 2023.

57. F. Salmasi and J.P. Abraham, Hydraulic Characteristics of Flow Over Stepped and Chute Spillways (Case Study: Zirdan Dam), *Water Supply*, Vol. 23, pp. 851-866, 2023.

58. M. Naghavi, M. Mohammadi, G. Mahtabi, and J.P. Abraham, Experimental Assessment of Velocity and Bed Shear Stress in the Main Channel of a Meandering Compound Channel with One-Sided Blocks in Floodplain, *Journal of Hydrology*, Vol. 617, Part C, paper no. 129073, 2023.

59. T. Wei and J.P. Abraham, Comment on the Marshall-Hoare-Henssge Model for Estimating the Time Since Death, *Journal of Forensic Science*, Vol. 68, pp. 676-681, 2023.

60. R. Daneshfaraz, R. Norouzi, P. Ebadzadeh, S. Di Francesco, J.P. Abraham, Experimental Study of Geometric Shape and Sill of Sill Effects on the Hydraulic Performance of Sluice Gates, *Water*, Vol. 15, paper no. 314, 2023.

61. 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.

62. A.T. Aghdam, A. Hosseinzadeh, F. Salmasi, A. Abbaspour, and J.P. Abraham, Numerical and Experimental Study of Trajectory for Free Falling Jets, *Iranian Journal of Science and Technology,* Vol. 47, pp. 2423-2435, 2023.

63. T. Wei, J.P. Abraham, and Y. Wang, New Temperature and Heat Loss Charts for One-Dimensional, Transient Heat Conduction, *Journal of Heat Transfer*, Vol. 145, paper no. 014502, 2023.

2022

64. M. Seifollahi, S. Abbasi, A. Pourtaghi, R. Daneshfaraz, and J.P. Abraham, Performance Efficiency of Data-Based Hybrid Intelligent Approaches to Predict Crest Settlement in Rockfill Dams, *Arabian Journal of Geosciences*, Vol. 15, paper 1701, 2022.

65. L. Cheng, K. von Schuckmann, J.P. Abraham, K. Trenberth, M. Mann, L. Zanna, M.H. England, J. D. Zika, J. Fasullo, Y. Yu,, Y. Pan, J. Zhu, E. Newsom, B. Bronselaer, and X. Lin, Past and Future Warming, *Nature Reviews Earth and Environment*, Vol. 3, pp. 778-794, 2022 (**Altmetric – 595, May 2023, top 1% of similar papers)**.

66. F. Salmasi, P. Sihag, J.P. Abraham M. Nouri, Experimental Investigation and Prediction of Free Fall Jet Scouring Using Machine Learning Models, *International Journal of Sediment Research*, Vol. 38, pp. 1-20, 2022.

67. R. Daneshfaraz and J.P. Abraham, Laboratory Study of Energy Dissipation on Gabion Vertical Drop, *Innovative Infrastructure Solutions*, Vol. 7, article number 328, 2022.

68. J.P. Abraham and L. Cheng, Intersection of Climate Change, Energy, and Adaptation, *Energies,* Vol. 15, paper no. 5886, 2022.

69. Y. Wang, H. Wan, T. Wei, and J.P. Abraham, Enhancement of Heat and Mass Transfer By Herringbone Microstructures in a Simple Shear Flow, *Physics of Fluids*, Vol. 34, paper no. 082012, 2022.

70. M. Seifollahi, S. Abbasi J.P. Abrahan, R. Norouzim R. Daneshfaraz, M-A. Lotfollahi-Yaghin, and A. Alkan, Optimization of Gravity Concrete Dams Using the Grasshopper Algorithm (Case Study: Koyna Dam), Geotechnical and Geological Engineering, Vol. 40, pp. 5481-5496, 2022.

71. T. Tian, L. Cheng, G. Wang, J.P. Abraham, J. Zhu, J. Song, and H. Leng, Reconstructing High-Resolution Ocean Subsurface Salinity State Using Machine Learning Approach, *Earth System Science Data* (in press).

72. J.P. Abraham, L. Cheng, M.E. Mann, K.E. Trenberth, K. von Schuckmann, The Ocean Response to Climate Change Guides Both Adaptation and Mitigation Efforts, *Atmospheric and Oceanic Science Letters*, Vol. 15, paper no. 100221, 2022.

73. R. Biabani, F. Salmasi, M. Npouri, and J.P. Abraham, Flow Over Embankment Gabion Weirs in Free Flow Conditions, *Journal of Hydro-Environmental Research,* Vol. 44, pp. 65-76, 2022.

74. B. Nourani, F. Salmasi, H. Arvanaghi, and J.P. Abraham, Development of Explicit Formulas for Estimating Seepage Characteristics Underneath Aprons with Equal and Unequal End Vertical Double-Piles, *International Journal of Geomechanics*, Vol. 22, paper no. 04022237, 2022.

75. L. Cheng, G. Foster, Z. Hausfather, K.E. Trenberth, J.P. Abraham, Improved Quantification of the Rate of Ocean Warming, *Journal of Climate*, Vol. 35, pp. 4827-4840, 2022.

76. F. Salmasi and J.P. Abraham, Effect of Slope on Energy Dissipation for Flow Over a Stepped Spillway, *Water Supply*, Vol. 22, pp. 5056-5069, 2022.

77. Y. Liu, L. Cheng, Y. Pan, Z. Tan, J.P. Abraham, B. Zhang, J. Zhu, and J. Song, How Well do CMIP6 and CMIP5 models simulate the climatological seasonal variations in ocean salinity, *Advances in Atmospheric Sciences*, doi: 10.1007/s00376-022-1381-2.

78. J.M. Gorman, W. Tan, and J.P. Abraham, Numerical Simulation of Microwave Ablation in the Human Liver, Heat Transfer in Biomedical Applications, edited by A. Andreozzi, M. Iasiello, V. Timochenko, and K. Vafai, published in *Processes*, Vol. 10, paper no. 361, 2022.

79. F. Salmasi, S. Shadkani, J.P. Abraham, F. Malekzadeh, Experimental Investigation For Determination of Discharge Coefficients for Inclined Slide Gates and Comparison with Data-Driven Models, *Iranian Journal of Science and Technology, Transactions of Civil Engineering*, Vol. 46, pp. 2495-2509, 2022.

80. F. Salmasi and J.P. Abraham, Multivariate Nonlinear Regression for Predicting Free Falling-Jet Scouring: An Experimental Study, Iranian Journal of Science and Technology, *Transactions of Civil Engineering*, (in press) doi: 10.1007/s40996-022-00817-w.

81. F. Salmasi, J.P. Abraham, A. Salmasi, Evaluation of Variable Speed Pumps in Pressurized Water Distribution Systems, *Applied Water Science*, Vol. 12, article no. 51, 2022.

82. J.P. Abraham, L. Cheng, P.L. Hudson, and A.N. Abraham, Assessing Burn Patterns and Severity Using IR Visualization – A Case Study Approach, *Journal of Forensic Science and Criminology,* Vol. 9, pp. 1-19, 2022.

83. J. P. Abraham, L. Cheng, L. Vallez, and T. Wei, Using Cadaver Temperatures to Estimate Time of Death, A Case-Specific Numerical Approach, *Journal of Forensic Sciences*, Vol. 67, pp. 1049-1059, 2022. (**Awarded JFS Noteworthy article of 2022**).

84. 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, pp. 373-385, 2022.

85. R. Daneshfaraz, S. Sadeghfam, E. Arminvash, and J.P. Abraham, Experimental Investigation of Multiple Supercritical Flow States and the Effect of Hysteresis on the Relative Residual Energy in Sudden and Gradual Contractions, *Iranian Journal of Science and Technology, Transactions of Civil Engineering*, doi: 10.1007/s40996-022-00818-9.

86. R. Daneshfaraz, E. Aminvash, R. Mirzaei, and J.P. Abraham, Predicting the Energy Dissipation of a Rough Sudden Expansion Rectangular Stilling Basin Using the SVM Algorithm, *Journal of Applied Research in Wastewater*, (in press). Doi: 10.22126/arww.2021.5886.1195.

87. A. Armanous, A. Negm, A. Javadi, J.P. Abraham, and T. Gado, Impact of Inclined Double-Cutoff Walls Under Hydraulic Structures on Uplift Forces, Seepage Discharge, and Exit Hydraulic Gradient, *Ain Shams Engineering Journal*, Vol. 13, paper no. 101531, 2022.

88. R. Daneshfaraz, S. Sadeghfam, V. Hasanniya, J.P. Abraham, and R. Norouzi, Experimental Investigation on Hydraulic Efficiency of Vertical Drop Equipped with Vertical Screens, *Teknit Dergi*, Vol. 33, no. 5, 2022. DOI: 10.18400/tekderg.755938.

89. A. Ghaderi, M. Dasineh, R. Daneshfaraz, and J.P. Abraham, Reply to the Discussion on Paper: 3-D Numerical Simulation of Water Flow over a Broad Created weir with Openings by Daneshfaraz et al 2019, *ISH Journal of Hydraulic Engineering*, Vol. 28, pp. 564-566, 2022.

90. F. Salmasi and J.P. Abraham, Discharge Coefficients for Ogee Spillways, Water Supply, Vol. 22, pp. 1255-1274, 2022.

91. R. Norouzi, P. Sihag, R. Daneshfaraz, J.P Abraham, and V. Hasanna, Predicting Relative Energy Dissipation for Vertical Drops Equipped with a Horizontal Screen Using Soft Computing Techniques, *Water Supply*, Vol. 22, pp. 1075-1093, 2022.

92. F. Malekzadeh, F. Salmasi, J.P. Abraham, and H. Arvanaghi, Numerical Investigation of the Effect of Geometric Parameters on Discharge Coefficients for Broad-Crested Weirs with Sloped Upstream and Downstream Faces, *Applied Water Science*, Vol. 12, paper no. 110, 2022.

93. F. Salmasi and J.P. Abraham, Genetic Algorithms to Optimizing Stepped Spillways to Maximize Energy Dissipation, *Water Supply*, Vol. 22, pp. 1255-1274, 2022.

94. Y. Liu, L. Cheng, Y. Pan, J.P. Abraham, B. Zhang, J. Zhu, and J. Song, Climatological seasonal variation of the upper ocean salinity, *International Journal of Climatology*, Vol. 42, pp. 3477-3498, 2022.

2021

95. M. Seifollahi, S, M. Lotfollahi-Yaghin, F. Kalateh, R. Daneshfaraz, S. Abbasi, and J.P. Abraham, Estimation of the Local Scour from a Cylindrical Bridge Pier Using a Compilation Wavelet Model and Artificial Neural Network, *Journal of Hydraulic Structures,* Vol. 7, pp. 1-22, 2021.

96. B. Ferry and J.P. Abraham, Mechanical Design of Long-Term Body-Adhered Medical Devices to Maximize On-Body Survival, *Journal of Biomedical Science and Engineering*, Vol. 19, pp. 325-337, 2021.

97. F. Salmasi, J.P. Abraham, and A. Salmasi, Effect of Stepped Spillways on Increasing Dissolved Oxygen in Water, an Experimental Study, *Journal of Environmental Management*, Vol. 299, paper 113600, 2021.

98. C. Garcia-Soto, L. Cheng, L. Caeser, E.B. Jewett, A. Cheripka, I.G. Rigor, A. Cabellero, S. Chiba, J.C. Baez, T. Zielinski, and J.P. Abraham, An Overview of Ocean Climate Change Indicators: Sea Surface Temperature, Ocean Heat Content, Ocean pH, Dissolved Oxygen Concentration, Artic Ice Extent, Thickness, and Volume, *Frontiers in Marine Science, Global Ocean and Future Ocean,* Vol. 8, paper 642372, 2022: doi: 0.3389/fmars.2021.642372, 2021.

99. J.P. Abraham, T. Wei, and Y. Wang, Layered Structure of Turbulent Natural Convection Over a Vertical Flat Plate, *International Journal of Heat and Mass Transfer*, Vol. 181, paper 121866, 2021.

100. F. Salmasi, F. Nahrain, J.P. Abraham, and A.T. Aghdam, Prediction of Discharge Coefficients for Broad-Crested Weirs Using Expert Systems, *Journal of Hydraulic Engineering*, doi: 10.1080/09715010.2021.1983477.

101. F. Salmasi and J.P. Abraham, Closure to “Expert System for Determining Discharge Coefficients for Inclined Slide Gates Using Genetic Programming”, *Journal of Irrigation and Drainage Engineering,* Vol. 147, paper no. 07021018, 2021.

102. L. Olsen, S. Bhattacharyya, L. Cheng, W. Minkowycz, and J. Abraham, Heat Transfer Enhancement for Internal Flows with a Centrally Located Circular Obstruction and the Impact of Buoyancy, *Heat Transfer Engineering* doi: 10.1080/01457632.2021.2016129.

103. F. Salmasi and J.P. Abraham, Closure to “Discharge Coefficients for Rectangular Broad-Crested Gabion Weirs: An Experimental Study”, *Journal of Irrigation and Drainage Engineering*, Volume 147, 2021.

104. R. Daneshfaraz, E. Aminvash. S. Di Francesco, A. Najibi, and J.P. Abraham, Three-Dimensional Study of the Effect of Block Roughness Geometry on Inclined Drop, *Journal of Numerical Methods in Civil Engineering*, Vol. 6, pp. 1-9, 2021.

105. J.C.K. Tong, J.M.Y. Tse, J.P. Abraham, P.J. Jones, Correlation Between Simulations and Measurements of an Eco-House Design for Mongolia, *Journal of Building Engineering*, Vol. 42, no. 10, paper no. 102774, 2021. DOI:10.1016/j.jobe.2021.102774.

106. R. Daneshfaraz, M. Abam, M. Heidarpour, S. Abbasi, M. Seifollahi, and J.P. Abraham, The Impact of Cables on Local Scouring of Bridge Piers Using

Experimental Study and ANN, ANFIS Algorithms, *Water Supply* (in press). DOI:10.2166/ws2021.215

107. R. Daneshfaraz, E. Aminvash, A. Ghaderi, A. Kuriqi, and J.P. Abraham, Three-Dimensional Investigation of Hydraulic Properties of Vertical Drop in the Presence of Step and Grid Dissipators*, Symmetry, Computer Engineering Science and Symmetry Turbulence and Multiphase Flows*, Vol. 13, paper no. 895, 2021.

108. T. Wei, Y. Wang, and J.P. Abraham, Integral Properties of Turbulent Natural Convection over a Vertical Flat Plate, *International Communications in Heat and Mass Transfer*, Vol. 125, paper 105286, 2021.

109. R. Daneshfaraz, E. Aminvash, A. Ghaderi, M. Bagherzadeh, J.P. Abraham, SVM Performance in Predicting the Effect of Horizontal Screens on Vertical Hydraulic Performance of a Vertical Drop, *Applied Sciences*, Vol. 11, no. 9, paper no. 4238, 2021. DOI: 10.3390/app11094238.

110. F. Salmasi, M. Nouri, P. Sihag, and J.P. Abraham, Application of SVM, ANN, GRNN, RF, GP, and RT Models for Predicting Discharge Coefficients of Oblique Sluice Gates Using Experimental Data, *Water Supply*, Vol. 21, pp. 232-248, 2021.

111. A. Aghdam, F. Salmasi, J.P. Abraham, and H. Arvanaghi, Effect of Drain Pipes on Uplift Force and Exit Hydraulic Gradient and the Design of Gravity Dams Using the Finite Element Method, *Geotechnical and Geological Engineering*, Vol. 39, pp. 3383-3399, 2021.

112. Z. Tan, F. Reseghetti, J.P. Abraham R. Cowley, K. Chen, J. Zhu, B. Zhang, and L. Cheng, Examining the Influence of Recording System on the Pure Temperature Error in XBT Data, *Journal of Atmospheric and Oceanic Technology,* Vol. 38, pp. 759-776, 2021.

113. R. Daneshfaraz, V. Hasannia, R. Norouzi, P. Sihag, S. Sadeghfam, and J.P. Abraham, Investigating the Effect of Horizontal Screen on Hydraulic Parameters of a Vertical Drop, Iranian Journal of Science and Technology, *Transactions of Civil Engineering*, Vol. 45, pp. 1909-1917, 2021.

114. 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 = 1057, top 1%, January 2021.**

115. M. Nouri, P. Sihag, F. Salmasi, and J.P. Abraham, Prediction of Homogeneous Earthen Slope Safety Factors Using the Forest and Tree Based Modeling, *Geotechnical and Geological Engineering*, Vol. 39, paper no. 04020148, 2021.

116. F. Salmasi, B. Nourani, J.P. Abraham, and R. Nouzi, Numerical Investigation of Relief Well Performance for Decreasing Uplift Pressure Under Embankment Dams, *International Journal of Environmental Science and Technology*, Vol. 18, pp. 2819-2830, 2021. doi: 10.1007/s13762-020-03030-2.

117. R. Daneshfaraz, M. Bagherzadeh, R. Esmaeeli, R. Norouzi, and J.P. Abraham, Study of the Performance of Support Vector Machine for Predicting Vertical Drop Hydraulic Parameters in the Presence of Dual Horizontal Screens, *Water Supply,* Vol. 21, pp. 217-231, 2021.

118. F. Salmasi, J.P. Abraham, Prediction of Discharge Coefficients for Sluice Gates Equipped With Different Geometry Sills Under the Gate Using Multiple Non Linear Regression (MNLR), *Journal of Hydrology*, Vol. 597, paper 125728, 2021. doi:10.1016/j.jhydrol.2020.125728.

119. F. Salmasi, N. Sabahi, and J. P. Abraham, Discharge Coefficients for Rectangular Broad Crested Gabion Weirs: An Experimental Study, *Journal of Irrigation and Drainage Engineering,* Vol. 147, paper 04021001, 2021.

120. M. Asl, R. Daneshfaraz, J.P. Abraham, S. Valizadeh, Effects of Hydraulic Characteristics, Sedimentary Parameters, and Mining of Bed Material on Scour Depth of Bridge Pier Groups, *Journal of Performance of Constructed Facilities*, Vol. 35, paper no. 04020148, 2021.

121. 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 = 700, top 1%, July 2021.**

122. N. Sartipi, F. Salmasi, J. Abraham, and A.D. Dalir, Investigation of the Effect of Depth and Distance Between Cutoff Walls on Uplift Force for Gravity Dams, *International Journal of Environmental Science and Technology*, Vol. 18. pp. 1361-1378, 2021.

123. R. Daneshfaraz, R. Norouzi, M. Macedi, A. Bazyar, and J.P. Abraham, Laboratory Study of Energy dissipation in Inclined Drops with a Screen, *Journal of Applied Water Engineering and Research*, Vol. 9, pp. 184-193, 2021.

124. A. Ghaderi, R. Daneshfaraz, J.P. Abraham, and M. Torabi, Effect of Different Channels on Discharge Coefficient of Labyrinth Weirs, *Teknik Dergi*, Vol. 32 paper no. 626, pp. 11081-11096, 2021.

2020

125. A. Ghaderi, R. Daneshfaraz, S. Abbasi, and J.P. Abraham, Numerical Analysis of the Hydraulic Characteristics of Modified Labyrinth Weirs, *International Journal of Energy and Water Resources*, Vol. 4, pp. 425-436, 2020.

126. F. Salmasi and J.P. Abraham, An Expert System for Determining Discharge Coefficients for Inclined Slide Gates Using Genetic Programing, *Journal of Irrigation and Drainage Engineering*, Vol. 146, paper number 060200013, 2020.

127. A. Ghaderi, M. Shokri. J.P. Abraham, Estimation of Actual Evapotranspiration Using Remote Sensing Method and SEBAL Algorithm- A Case Study: Ein Khosh Plain, Iran, *Hydrology*, Vol. 7, doi: 10.3390/hydrology7020036, 2020.

128. F. Salmasi, M. Nouri, and J.P. Abraham, Upstream Cutoff and Downstream Filters to Control Seepage in Dams, *Water Resources Management*, Vol. 34, pp. 4271-4288, 2020.

129. L. Cheng, K.E. Trenberth, N. Gruber, M.E. Mann, J.P. Abraham, J.T Fasullo, G. Li, X. Zhao, and J. Zhu, Improved Estimates of Changes in Upper Ocean Salinity and the Hydrological Cycle, *Journal of Climate*,Vol.33, pp. 10357-10381, 2020.

130. F. Salmasi, R. Norouzi, J.P. Abraham, B. Nourani, S. Samadi, Effect of Inclined Clay Core on Embankment Dam Seepage and Stability Through LEM and FEM, *Geotechnical and Geological Engineering*, Vol. 38, pp. 6571-6586, 2020.

131. A. Ghaderi, R. Daneshfaraz, S. Abbasi, and J.P. Abraham, Numerical Analysis of the Hydraulic Characteristics of Modified Labyrinth Weirs, *International Journal of Energy and Water Resources,* Vol. 4, pp. 425-436, 2020.

132. 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 = 376, top 1%, July, 2021.**

133. A. Ghaderi, R. Daneshfaraz, M. Torabi, J.P. Abraham, and H.M. Azamathulla, Experimental Investigation on Effective Scouring Parameters Downstream from Stepped Spillways, *Water Supply*, Vol. 20, pp. 1988-1998, 2020.

134. F. Salmasi, and J.P. Abraham, Predicting Seepage from Unlined Earthen Channels Using the Finite Element Method and Multi Variable Nonlinear Regression, *Agricultural Water Management*, Volume 234, Paper no. 106148, 2020.

135. F. Salmasi, B. Naourani, and J.P. Abraham, Investigation of the Effect of Different Configurations of Double-Cutoff Walls Beneath Hydraulic Structures on Uplift Forces and Exit Hydraulic Gradients, *Journal of Hydrology*, vol. 586, dpo: 10.1016/j.hydrol.2020.123858, 2020.

136. A. Ghaderi, S. Abbasi, J.P. Abraham, H. M. Azamathulla, Efficiency of Trapezoidal Labyrinth Shaped Stepped Spillways, *Flow Measurement and Instrumentation*, paper no. 101711, 2020, doi: 10.1016/j.flowmeasinst.2020.101711.

137. 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. Recipient of the 2022 AAS Esteemed News and Views Award).**

138. F. Salmasi, and J.P. Abraham, Discussion of "Hydrodynamics of Rectangular Broad-Crested Porous Weirs" by Akbar Safarzadeh and Seyed Hossein Mohajeri, *J. Irrig. Drain. Eng*. Vol. 146, paper no. 07020004, 2020.

139. R. Daneshfaraz, M.M. Asl, S. Razmi, R. Norouzi, and J.P. Abraham, Experimental Investigation of the Effect of Dual Horizontal Screens on the Hydraulic Performance of a Vertical Drop, *International Journal of Environmental Science and Technology*, Vol. 17, pp. 2927-2937, 2020.

140. J.M. Gorman, et al., Memoriam, Ephraim Sparrow, *International Journal of Heat and Mass Transfer*, Vol. 148, article no. 18755, 2020.

141. F. Salmasi, J.P. Abraham, Discharge Coefficients for Ogee Weirs Including the Effects of a Sloping Upstream Face, *Water Science and Engineering*, doi: 10.2166/ws.2020.064, 2020.

142. F. Salmasi, and Abraham J.P., Discussion of "Hydrodynamics of Rectangular Broad-Crested Porous Weirs" by Akbar Safrazadeh and Seyed Moharjeri, *Journal of Irrigation and Drainage Engineering*, Vol. 146, doi: 10.1061/%28ASCE%29IR.1943-4774.0001450, 2020.

143. R. Daneshfaraz, E. Aminvash, R. Esmaeli, S. Sadeghfam, and J.P. Abraham Experimental and Numerical Investigation for Energy Dissipation of Supercritical Flow in Sudden Contractions, *Journal of Groundwater Science and Engineering*, Vol. 8, pp. 396-404, 2020.

144. R. Daneshfaraz, O. Minaeri, J.P. Abraham, and S. Dadashi, 3-D Numerical Simulation of Flow Over a Broad-Crested Weir with Opening, *Journal of Hydraulic Engineering*, Vol. 24, doi: 10.1080/09715010.1581098, 2020.

2019

145. A. Ghaderi, M. Dasineh, S. Abbasi, and J.P. Abraham, Investigation of Trapezoidal Sharp-Crested Weir Discharge Coefficients Under Subcritical Flow Regimes, *Applied Water Science*, Vol. 10, article no. 31, 2019.

146. G. Li, Y. Zhang, J. Xiao, J.P. Abraham, L. Cheng, and J. Zhu, Examining the Salinity change in the upper Pacific Ocean During the Argo Period, *Climate Dynamics* Vol. 53, pp. 6055-6074, 2019.

147. J.P. Abraham, K. Diller, A Review of Hot Beverages – Satisfying Consumer Preferences and Safety, *J. Food Science*, Vol. 84, pp. 2011-2014, 2019.

148. J.M. Gorman, et al., In Memoriam, Ephraim M. Sparrow (May 27, 1928 – August 1, 2019), *Numerical Heat Transfer Part A*, Vol. 76, pp. 181-184, 2019.

149. F. Jafari, F. Salmasi, and J.P. Abaham, Numerical Investigation of Granular Filer Under the Bed of a Canal, *Applied Water Science*, Vol. 9, Article no. 137, 2019

150. J. P. Abraham, Heat risks associated with synthetic fields, *International Journal of Hyperthermia*, Vol. 24, pp. 516-517, 2019.

151. T. Wei and J.P. Abraham, Heat Transfer Regimes in Fully Developed Circular tube flows, a map of flow regimes, *International Communications in Heat and Mass Transfer*, Vol. 104, 147-152, 2019.

152. B.D. Plourde, A. Gikling, T. Marsh, M.A. Riemenschneider, J.L. Fitzgerald, W.J. Minkowycz, J. Kiplagat, J.P. Abraham, Design and Evaluation of a Concentrated Solar-Powered Thermal-Pasteurization System, *Journal of Solar Energy Research*, Vol. 6, pp. 34-42, 2019.

153. E. Dodangeh, K. Shahedi, K. Solalani, J.T., Shiu, J.P. Abraham, Data-Based Bivariate Uncertainty Assessment of Extreme Rainfall-Runoff Using Copulas: Comparison Between Annual Maximum Series (AMS) and Peaks Over Threshold (POT), *Environmental Monitoring and Assessment*, Vol. 191:67, 2019.

154. F. Salmasi, M. Nouri, and J.P. Abraham, Laboratory Study of the Effect of Sills on Radial Gate Discharge Coefficient, *KSCE Journal of Civil Engineering*, Vol. 23, pp. 2117-2125, 2019.

155. Benoit et al., Measuring Global Ocean Heat Content to Estimate the Earth Energy Imbalance, *Frontiers in Marine Science*, *OceanObs'19: An Ocean of Opportunity*, Vol. 6, pp. 198-228, doi: 10.3389/fmars.2019.00432, 2019.

156. 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.**

157. L. Cheng, G. Wang, J.P. Abraham, G. Huang, Decadal Ocean Heat Redistribution Since the Late 1990s and its Association with Key Climate Modes, *Climate*, Vol. 6, 91, 2019 (editor's choice award winner).

158. 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, ranked 18 out of the top 30 papers in the field of Global Sustainability.**

159. J.P. Abraham, E.M. Sparrow, J.M. Gorman, Y. Zhao, and W.J. Minkowycz, Application of an Intermittency Model for Laminar, Transitional, and Turbulent Internal Flows, *Journal of Fluids Engineering*, Vol. 141, paper no. 071204, 2019.

160. J.P. Abraham, J. R. Stark, J.M. Gorman, E. M. Sparrow, W.J. Minkowycz, Tissue Burns Due to Contact Between a Skin Surface and Highly Conducting Metallic Media in the Presence of Inter-Tissue Boiling, *Burns*, Vol. 45, pp. 369-378, 2019.

161. J.M. Gorman, E. M. Sparrow, C.J. Smith, A. Ghoash, J.P. Abraham, R. Daneshfaraz, A. Rezazedeh Joudi, In-Bend Pressure Drop and Post-Bend Heat Transfer for a Bend with a Partial Blockage at its inlet, *Numerical Heat Transfer A*, Vol. 73, pp. 743-767, 2018.

162. A. Bahro, Z. Igyarto, C. Williams, J.P. Abraham, and B.J. Martinsen, Treatment of Critical Hand Schemia via Orbital Atherectomy and Focal Force Balloon Angioplasty: A Mini-Review, *Cardiovascular Revascularization Medicine*, Vol. 20, pp. 248-253, 2019.

2018

163. J.P. Abraham, R. Maki, Hydrodynamics of Laminar Flow Through Dimpled Pipes, *MOJ Civil Engineering*, Vol. 4, pp. 150-154, 2018.

164. L. Cheng, H. Luo, T. Boyer, R. Cowley, J. Abraham, V. Gouretski, F. Reseghetti, and J. Zhu, How Well Can We Correct Systematic Errors in Historical XBT Data? *Journal of Atmospheric and Oceanic Technology*, Vol. 35, pp. 1103-1125, 2018.

165. G. Wang, L. Cheng, J.P. Abraham, C. Li, Consensuses and Discrepancies of Basin-Scale Ocean Heat Content Changes in Different Ocean Analyses, *Climate Dynamics*, Vol. 50, pp. 2471-2487, 2018

166. R. Daneshfaraz, A.R. Joudi, J.P. Abraham, Numerical Investigation on the Effect of Sudden Contraction on Flow Behavior in a 90-Degree Bend, *Korean Journal of Civil Engineering*, Vol. 22, pp 603-612, 2018.

167. M. T. Sattari, A. Farkhondeh, and J.P. Abraham, Estimation of Sodium Adsorption Ratio Indicator Using Data Mining Methods: A Case Study in Urmia Lake Basin, Iran, *Environmental Science and Pollution Research*, Vol. 25, pp. 4776-4786, 2018.

168. M.T. Sattari, R. Misabbasi, R. S. Sushab, and J.P. Abraham, Prediction of Groundwater Level in the Ardebil Plain Using Support Vector Regression and the M5 Tree Model, *Groundwater Journal,* Vol. 56, pp. 636-646, 2018.

169. L. Cheng, K.E. Trenberth, J. T. Fasullo, J.P. Abraham, T.L. Boyer, K. von Schuckmann, and J. Zhu, Taking the Pulse of the Planet, *EOS,* Vol. 98, pp 14-15, 2018.

170. J.P. Abraham, B.D Plourde, L. J. Vallez, Comprehensive Review and Study of Buoyant Air Flow Within Positive-Pressure Hospital Operating Rooms, *Numerical Heat Transfer A*, Vol. 72, pp. 1-20, 2018.

171. M.R. Sattari, M. Pal, R. Mirabbasi, and J.P. Abraham, Ensemble of M5 Model Tree Based Modelling of Sodium Adsorption Ratio, *Journal of Artificial Intelligence and Data Mining*, Vol. 6, pp. 69-78, 2018.

2017

172. J.P. Abraham, A Global Warming Primer: Answering Your Questions about the Science, the Consequences, and the Solutions, *Physics Today*, Vol. 70, no. 3, 2017.

173. M.R. Sattari, Dodangeh, and J.P. Abraham, Estimation of Daily Soil Temperature Via Data Mining Techniques in Semi-Arid Climate Conditions, *Earth Sciences Research Journal*, Vol. 21, pp. 85-93, 2017.

174. J.P. Abraham, L. Cheng, M.E. Mann, Future Climate Projections Allow Engineering Planning, *Forensic Engineering*, Vol. 170, pp. 54-57, 2017.

175. B.D. Plourde, L.J. Vallez, B. B. Nelson-Cheeseman, J.P. Abraham, Transcutaneous Recharge: A Comparison of Numerical Simulation to In Vivo Experiments *Neuromodulation*, Vol. 20, pp. 613-621, 2017.

176. E.M. Sparrow, B.B Nelson-Cheeseman, W.J. Minkowycz, J.M. Gorman, and J.P. Abraham, Use of Multi-Lumen Catheters to Preserve Injected Stem Cell Viability and Injection Dispersion*, Cardiovascular Revascularization Medicine*, Vol. 18, pp. S49-S57, 2017.

177. L.J. Vallez, B.D. Plourde, J.E. Wentz, B. B. Nelson-Cheeseman, J.P. Abraham, A Review of Scald Burn Injuries, *Internal Medicine Review*, Vol. 3, pp. 1-18, 2017.

178. R. Daneshfaraz, H. Sadeghi, A. R. Joudi, J.P. Abraham, Experimental Investigation of Hydraulic Jump Characteristics in Contractions and Expansions, *Sigma Journal of Engineering and Natural Sciences*, Vol. 35, pp. 87-98, 2017.

179. 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.**

180. 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.

181. R.T. Bourdon, B.B. Nelson-Cheeseman, and J.P. Abraham, Review on the Treatment and Avoidance of Scald Injuries, *World Journal of Dermatology*, Vol. 6, pp. 17-26, 2017.

2016

182. B.D. Plourde, J.R. Stark, J. P. Abraham, A New Catheter Technology to Deliver Vascular Stem-Cells, *Global Journal of Stem Cell Biology and Transplantation*, Vol. 2, pp. 7-16, 2016.

183. J.R. Stark, S.R. Romero, J.M. Gorman, J.P. Abraham, E.M. Sparrow, Modulated-Power Implantable Neuromodulation Devices and Their Impact on Surrounding Tissue Temperatures, *Journal of Biomedical Science and Engineering*, Vol. 9, pp. 545-562, 2016.

184. L. Cheng, K.E. Trenberth, M.D. Palmer, J. Zhu, and J.P. Abraham Observed and Simulated Full-Depth Ocean Heat Content Changes for 1970-2005, *Ocean Sciences*, Vol. 12, pp. 925-935, 2016.

185. J.M. Gorman, E.M. Sparrow, J.P. Abraham, W. J. Minkowycz, Evaluation of the Efficacy of Turbulence Models for Swirling Flows and Effect of Turbulence Intensity on Heat Transfer, *Numerical Heat Transfer B*, Vol. 70, pp. 485-502, 2016.

186. J.P. Abraham, B.B. Nelson Cheeseman, E. M. Sparrow, J.E. Wentz, J.M. Gorman, S. E. Wolf, Comprehensive Method to Predict and Quantify Scald Burns from Beverage Spills, *Int. J. Hyperthermia*, Vol. 32, pp. 900-910, 2016.

187. B.D. Plourde, L.J. Vallez, B. Sun, B.B. Nelson-Cheeseman, J.P. Abraham, Alterations of Blood Flow Through Arteries Following Atherectomy and the Impact on Pressure Variation and Velocity, *Cardiovascular Engineering and Technology*, Vol. 7, pp. 280-289, 2016.

188. N.K. Langat, T. Thorusa, J.P. Abraham, J. Wanyoko, Performance of an Improved Fluidized System for Processing Green Tea, *World Academy of Science Engineering and Technology*, Vol. 10, 1045-1050, 2016.

189. L. Cheng, J. Abraham, G. Goni, T. Boyer, S. Wijffels, R. Cowley, V. Gouretski, F. Reseghetti, S. Kizu, S. Dong, F. Bringas, M. Goes, L. Houpert, J. Sprintall, and J. Zhu, XBT Science: Assessment of XBT Biases and Errors, *Bulletin of the American Meteorological Society*, Vol. 97, pp. 924-933, 2016.

190. J.P. Abraham, R. Cowley, L. Cheng, Quantification of the Effect of Water Temperature on the Fall Rate of eXpendable BathyThermographs, *Journal of Atmospheric and Oceanic Technology*, Vol. 6, pp. 1271-1284, 2016.

191. R.T. Bourdon, B.B. Nelson-Cheeseman, and J.P. Abraham, Prediction, Identification, and Initial Treatment Guidelines for Scald Injuries, *Austin Journal of Emergency and Critical Care Medicine, Special Issue on Burns*, Vol. 3, pp. 1043-1049, 2016.

192. J.C.K. Tong, J.P. Abraham, J.M.Y. Tse, W.J. Minkowycz, and E.M. Sparrow, New Archive of Heat Transfer Coefficients from Square and Chamfered Cylinders in Crossflow, *International Journal of Thermal Sciences*, Vol. 105, pp. 218-223, 2016.

193. L. Cheng, K.E. Trenberth, M.D. Palmer, J. Zhu, and J.P. Abraham, Observed and Modeled Ocean Heat Content Changes Since 1970, *Ocean Sciences,* Vol 12, pp. 925-936, 2016.

194. R. Daneshfaraz, A. Ghahramanzadeh, A. Ghaderi, A. Rezazadeh Joudi, and J.P. Abraham, Investigation of the Effect of Edge Shape on Characteristics of Flow Under Vertical Gates, *Journal AWWA*, Vol. 8, pp. E425-432, 2016.

195. J.P. Abraham, B.D. Plourde, L.J. Vallez, and B.B. Nelson-Cheeseman, Correcting a Prevalent Misunderstanding of Burns, *Burns*, Vol. 42, pp. 715-716, 2016.

196. J. P. Abraham and B.D. Plourde, Validation of Numerically Simulated Tissue Temperatures During Transcutaneous Recharge of Neurostimulation Systems, *Journal of Neuromodulation*, Vol. 19, pp. 161-170. 2016.

197. L.J. Vallez, B.D. Plourde, and J.P. Abraham, A New Computational Thermal Model for the Whole Human Body: Applications to Patient Warming Blankets, *Numerical Heat Transfer A*, Vol. 69, pp. 227-241, 2016.

2015

198. J.P. Abraham, B.D. Plourde, B. Sun, L.J. Vallez, and C.S. Staniloae, The Effect of Plaque Removal on Pressure Drop and Flowrate Through a Stenotic Lesion*, Biology and Medicine,* Vol. 8, article no. 1000261, 2015.

199. L.J. Vallez, B. Sun, B.D. Plourde, J.P. Abraham, and C.S. Staniloae, Numerical Analysis of Arterial Plaque Thickness and its Impact on Artery Wall Compliance, *J. Cardiovascular Medicine and Cardiology*, Vol. 2, pp. 26-34, 2015.

200. 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.

201. B. Sun, L.J. Vallez, D.B. Plourde, J. R. Stark, and J.P. Abraham, Influence of Supporting Tissue on the Deformation and Compliance of Healthy and Diseased Arteries, *Journal of Biomedical Science and Engineering*, Vol. 8, pp. 490-499, 2015.

202. J.P. Abraham, B.D Plourde, L.J. Vallez, J.R. Stark, and K. R. Diller, Estimating the Time and Temperature Relationship for Causation of Deep-partial Thickness Skin Burns, *Burns*, Vol. 41, pp. 1741-1747, 2015.

203. G. Foster and J.P. Abraham, Lack of Evidence for a Slowdown in Global Temperature, US Climate Variability and Predictability Program (CLIVAR) Summer 2015, Vol. 13, pp. 6-9, 2015.

204. L. Cheng, J. Zhu, and J.P. Abraham, Global Upper Ocean Heat Content Estimation: Recent Progresses and the Remaining Challenges, *Atmospheric and Oceanic Science Letters*, Vol. 8, pp. 333-338, 2015.

205. M. Richardson, Z. Hausfather, D.A. Nuccitelli, K. Rice, and J.P. Abraham, Misdiagnosis of Earth Climate Sensitivity Based on Energy Balance Model Results, *Science Bulletin*, Vol. 60, pp. 1360-1377, 2015.

206. B.D. Plourde and J.P. Abraham, Design and Development of a New Cell Infusion Catheter, *World Biomedical Frontiers*, ISSN:2328-0166, 2015.

207. B.D. Plourde, J.P. Abraham, and W.J. Minkowycz, Continuous Flow Solar Thermal Pasteurization of Drinking Water: Methods, Devices, Microbiology, and Analysis, *Renewable Energy,* Vol. 81, pp. 795-803, 2015.

208. 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.

209. J.C.K. Tong, J.P. Abraham, J.M.Y. Tse, and E.M. Sparrow, Impact of Chamfer Contours to Reduce Column Drag, *Engineering and Computational Mechanics*, Vol. 168, pp. 79-88, 2015.

210. D. Egbe, T. Mayah, E. Ebota, P. Egbe, J. Abraham, Performance Evaluation and Improvement on a Melon Seed Shelling Machine, *World Journal of Agricultural Sciences and Engineering*, Vol. 1, pp. 157-10, 2015.

211. A. Lundardelli, J.E. Wentz, J.P. Abraham, and B.D. Plourde, Shielding Nozzle Design and Analysis for Atomization-Based Cutting Fluid Systems in Micromachining, *ASME Journal of Micro- and Nano-Manufacturing*, Vol. 3, paper no. 024501, 2015.

212. N. Langat, T. Thoruwa, J. Wanyoko, J. Kiplagat, B.D Plourde, and J.P. Abraham, Models and Experiments for Energy Consumption and Quality of Green Tea Drying, *Energy Science and Engineering*, Vol. 3, 43-50, 2015.

213. T. Scambos and J.P. Abraham, Antarctic Ice Sheet Mass Loss and Future Sea Level Rise, *Forensic Engineering, Proceedings of the Institute of Civil Engineers*, Vol. 168, pp. 81-84, 2015.

214. J.P. Abraham, J.R. Stark, W.J. Minkowycz, Extreme weather: Observations of Precipitation Changes in the USA, *Forensic Engineering, Proceedings of the Institution of Civil Engineers*, Vol. 168, pp. 68-70, 2015.

2014

---

215. N. Dib, D.B. Schwalbach, B.D. Plourde, R.E. Kohler, D. Dana, and J.P. Abraham, Impact of Balloon Inflation Pressure on Cell Viability with Single and Multi Lumen Catheters, *Cardiovascular Translation Research*, Vol. 7, pp. 781-787, 2014.

216. J.P. Abraham, J.T. Fasullo, and G. Laden, Continued Global Warming in the Midst of Natural Climate Fluctuations, *Reports of the National Center for Science Communication*, 34(6), 2014.

217. N. Dib, J.P. Abraham, B.D. Plourde, D.B. Schwalbach, D. Dana, L. Myers, K. Hunkler, S.R. D'Silva, T.R. Flower, and R.E. Kohler, TCT-155 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, *Journal American College of Cardiology*, Vol. 64, 11, 2014.

218. J.P. Abraham, B.D. Plourde, and J.R. Stark, Cryosurgical Treatment of Cancer: The Importance of Modeling, *Journal of Cancer Science and Therapy,* Vol. 6, 2014 (abstract).

219. J.P. Abraham, S. Kumar, B.R. Bickmore, and J.T. Fasullo, Issues Related to the Use of One-Dimensional Ocean Diffusion Models for Determining Climate Sensitivity, *Journal of Earth Science and Climate Change*, Vol. 5, paper 1000220, 2014.

220. T. Shepard, J.P. Abraham, D.S. Schwalbach, S. Kane, D. Sigling, and T. Harrington, Velocity and Density Effect on Impact Force During Water Entry of Spheres, *Journal of Geophysics and Remote Sensing*, Vol. 3, paper no. 1000129, 2014.

221. D.S. Schwalbach, T. Shepard, S. Kane, D. Siglin, T. Harrington, and J.P. Abraham, Effect of Impact Velocity and Mass Ratio During Vertical Sphere Water Entry, *Developments and Applications of Oceanic Engineering*, Vol. 3, 55-62, 2014.

222. J.P. Abraham, B.D. Plourde, J.R. Stark, and W.J. Minkowycz, Improvements to the Quality and Quantity of Ocean Heat Content Measurements, *Journal of Earth Science and Climate Change,* Vol. 5, pp. 100, 2014 (abstract).

223. J.P. Abraham, B.D. Plourde, and K.E. Trenberth, Closing Earth's Energy Balance, *Journal of Earth Science and Climate Change*, Vol. 5, pp. 69, 2014 (abstract).

224. J.M. Gorman, E.M. Sparrow, and J.P. Abraham, Temperature Determination by Means of Optoacoustic Measurements, *Studies in Engineering and Technology*, Vol. 1, 15-20, 2014.

225. J.M. Gorman, E.M. Sparrow, and J.P. Abraham, Slot Jet Impingement Heat Transfer in the Presence of Jet Axis Switching, *International Journal of Heat and Mass Transfer,* Vol. 78, 50-57, 2014.

226. J.P. Abraham, A review of the HANDY Study, *Cosmopolis*, Vol. 2014-1, pp. 8-87, 2014.

227. J.P. Abraham, Climate Change in the Midwest: Impacts, Risks, Vulnerabilities, and Adaptation. A Review of New Biological Books, *The Quarterly Review of Biology*, Vol. 89, pp. 171-172, 2014.

228. B.D. Plourde, D.B. Schwalbach, J.P. Abraham, and R.E. Kohler, Intracoronary Injection of Medication from Multi-lumen Injection Catheters, *Journal of Medical Devices,* Vol. 8, paper number 020901, 2014.

229. J.P. Abraham, J. Cook, J. T. Fasullo, P. H. Jacobs, S. A. Mandia, and D. A Nuccitelli, Review of the Consensus and Asymmetric Quality of Research on Human-Induced Climate Change, *Cosmopolis*, Vol. 2014-1, pp. 3-18, 2014.

230. B.L. Viglianti, M.W. Dewhirst, J.M. Gorman, and J.P. Abraham, E.M. Sparrow, Rationalization of Thermal Injury Quantification Methods: Application to Skin Burns, *Burns*, Vol. 40, pp. 896-902, 2014.

231. N.M. Naughton, B.D. Plourde, J.R. Stark, S. Hodis, and J. P. Abraham, Impacts of Waveforms on the Fluid Flow, Wall Shear Stress, and Flow Distribution in Cerebral Aneurysms and the Development of a Universal Reduced Pressure, *J. Biomedical Science and Engineering*, Vol. 7, 7-14, 2014.

232. J.M. Gorman, J.P. Abraham, D. B. Schwalbach, T. S. Shepard, J.R. Stark, and F. Reseghetti, Experimental Verification of Drag Forces on Spherical Objects Entering Water, *Journal of Marine Biology and Oceanography*, Vol. 3, paper no. 1000126, 2014.

233. S. Beacher, E.M. Sparrow, J.M. Gorman, and J.P. Abraham, Theory and Numerical Simulation in Thermochemical Ablation, *Numerical Heat Transfer Part A*, Vol. 66, pp. 131-143, 2014.

234. J.P. Abraham, J.M. Gorman, F. Reseghetti, E.M. Sparrow, J.R. Stark, and T.G. Shepard, Modeling and Numerical Simulation of the Forces Action on a Sphere During Early-Water Entry, *Ocean Engineering,* Vol. 76, 1-9, 2014.

235. J.M. Gorman, J.P. Abraham, and E.M. Sparrow, A Novel, Comprehensive Numerical Simulation for Predicting Temperatures Within Boreholes and the Adjoining Rock Bed, *Geothermics*, Vol. 50, pp. 213-219, 2014.

2013

236. J.P. Abraham, B.D. Plourde, G.S. Mowry, and E.M. Sparrow, Experimental Test of Multi-Stage Vertical Axis Turbines for Cellular Communication Applications, *ASME Proceedings,* Paper Number ES2012-91025, pp. 1333-1339, 2013.

237. D.B. Schwalbach, B.D. Plourde, J.P. Abraham, and R.E. Kohler, Drug Dispersion for Single- and Multi-Lumen Catheters, *Journal of Biomedical Science and Engineering*, Vol. 6, pp. 1021-1028, 2013.

238. N. Dib, R.E. Kohler, J.P. Abraham, B.D. Plourde, D.B. Schwalbach, D. Dana, B.J. Baird, T.R. Flower, L. Myers, and K. Hunkler, TCT-811 Stem Cell Viability Significantly Reduced After Passing Through a Standard Single Lumen Over-the-Wire 0.014 Balloon Angioplasty Cather, *Journal of the American College of Cardiology*, Vol. 62, B246, 2013.

239. D.A. Nuccitelli, J.P. Abraham, R.E. Benestad, and S.A. Mandia, Comment on: Akasofu, S.-I. On The Present Halting of Global Warming, *Climate*, Vol. 1, pp. 76-83, 2013.

240. J.M. Gorman, E. M. Sparrow, and J.P. Abraham, Differences Between Measured Pipe Wall Surface Temperatures and Internal Fluid Temperatures, *Case Studies in Thermal Engineering,* Vol. 1, 13-16, 2013.

241. J.R. Stark, J.M. Gorman, E.M. Sparrow, J.P. Abraham, and R.E. Kohler, Controlling the Rate of Penetration of a Therapeutic Drug Into the Wall of an Artery by Means of a Pressurized Balloon, *Journal of Biomedical Science and Engineering*, Vol. 6, pp. 527-532, 2013.

242. 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.**

243. J.P. Abraham, J.R. Stark, J.M. Gorman, E.M. Sparrow, and R.E. Kohler, A Model of Drug Deposition Within Artery Walls, *J. Medical Devices*, Vol. 7, paper no. 020902, 2013.

244. E.M. Sparrow, N.T. Littlejohn, J.M. Gorman, and J.P. Abraham, Mass Transfer and Particle Separation by Swirl-Chamber and Swirl-Tube Devices, *Numerical Heat Transfer A,* Vol. 64, 611-620, 2013.

245. 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.

246. J.P. Abraham, E.M. Sparrow, J.M. Gorman, J.R. Stark, and R. E. Kohler, A Mass Transfer Model of Temporal Drug Deposition in Artery Walls, *International Journal of Heat and Mass Transfer*, Vol. 58, pp. 632-638, 2013.

247. R.R. Rend, E. M. Sparrow, D. W. Bettenhausen, and J. P. Abraham, Parasitic Pressure Losses in Diffusers and in Their Downstream Piping Systems for Fluid Flow and Heat Transfer, *International Journal of Heat and Mass Transfer*, Vol. 61, pp. 56-61, 2013.

2012

248. 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.

249. B.D. Plourde, J.P. Abraham, G.S. Mowry, and W.J. Minkowycz, Simulations of Three-Dimensional Vertical-Axis Turbines for Communications Applications, *Wind Engineering*, Vol. 36, pp. 443-454, 2012.

250. J.P. Abraham, B.D. Plourde, G.S. Mowry, and W.J. Minkowycz, Summary of Savonius Wind Turbine Development and Future Applications for Small-Scale Power Generation, *Journal of Renewable and Sustainable Energy*, Vol. 4, paper no. 042703, 2012.

251. 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.

252. E.M. Sparrow, J.M. Gorman, A. Trawick, and J.P. Abraham, Novel Techniques for Measurements of Thermal Conductivity of Both Highly and Lowly Conducting Media, *International Journal of Heat and Mass Transfer*, Vol. 55, pp. 4037-4042, 2012.

253. J.P. Abraham, J.M. Gorman, F. Reseghetti, E.M. Sparrow, and W.J. Minkowycz, Drag Coefficients for Rotating Expendable Bathythermographs and the Impact of Launch Parameters on Depth Predictions, *Numerical Heat Transfer A*, Vol. 62, pp. 25-43, 2012.

254. M. Nelson and J.P. Abraham, Hemodynamics of AV Grafts for Hemodialysis Access, *Journal of Medical Devices,* Vol. 6, article no. 017553, 2012.

255. J.P. Abraham and J. Jeske, Cryosurgical Simulations for Ablation of Kidney Tumors, *Journal of Medical Devices,* Vol. 6, article no 017504, 2012.

256. J.P. Abraham, J.M. Gorman, F. Reseghetti, W.J. Minkowycz, and E. M. Sparrow, Turbulent and Transitional Modeling of Drag on Oceanographic Measurement Devices, *Computational Fluid Dynamics and its Applications* 2012, article ID 567864, doi:10.1155/2012/567864.

2011

257. J.P. Abraham, J.M. Gorman, F. Reseghetti, K.E. Trenberth, and W.J. Minkowycz, A New Method of Calculating Ocean Temperatures Using Expendable Bathythermographs*, Energy and Environment Research*, Vol. 1, pp. 2-11, 2011.

258. J.R. Stark, J.M. Gorman, M.P. Hennessey, F. Reseghetti, J. Willis, J. Lyman, J.P. Abraham, and M. Borghini, A Computational Method for Determining XBT Depths, *Ocean Sciences*, Vol. 7, pp. 733-743, 2011.

259. B.D. Plourde, J. P. Abraham, G.S. Mowry, and W.J. Minkowycz, Use of Small-Scale Wind Energy to Power Cellular Communication Equipment, *Sensors and Transducers*, Vol. 13, pp. 53-61, 2011.

260. J.P. Gorman, E.M. Sparrow, G.S. Mowry, and J.P. Abraham, Simulation of Helically Wrapped, Compact Heat Exchangers, *Journal of Renewable and Sustainable Energy*, Vol. 3, article no. 043120, 2011.

261. R.D. Lovik, J.P. Abraham, and E.M. Sparrow, Surrogate Human Tissue Temperatures Resulting from Misalignment of Antenna and Implant During Recharging of a Neuromodulation Device, *Journal of Neuromodulation*, Vol. 14, pp. 501-511, 2011.

262. K.E. Trenberth, J.T Fasullo, and J.P. Abraham, Issues in Establishing Climate Sensitivity in Recent Studies, *Remote Sensing,* Vol. 3, pp. 2051-2055, 2011.

263. R.D. Lovik, E. M. Sparrow, J. P. Abraham, C. Zelmer, S. Oh, K. Friend, and D. K. Smith, Effect of Component Misalignment on Human Tissue Temperatures Associated with Recharged Neuromodulation Devices, *Journal of Medical Devices*, Vol. 5, 0207516, 2011.

264. T. Gebreegziabher, E.M. Sparrow, J.P. Abraham, E. Ayorinde, and T. Singh, High-Frequency Pulsatile Pipe Flows Encompassing All Flow Regimes, *Numerical Heat Transfer A*, Vol. 60, pp. 811-826, 2011.

265. J.P. Abraham, M.P. Hennessey, and W.J. Minkowycz A Simple Algebraic Model to Predict Burn Depth and Injury, *International Communications in Heat and Mass Transfer*, Vol. 38, pp. 1169-1171, 2011.

266. J.P. Abraham, B.D. Plourde, G.S. Mowry, E. M. Sparrow, and W.J. Minkowycz, Numerical Simulation of Fluid Flow Around a Vertical-Axis Turbine, *Journal of Renewable and Sustainable Energy*, Vol. 3, article no. 033109, 2011 (doi:10.1063/1.3588037).

267. B.M. Osende, J.P. Abraham, and G.S. Mowry, Small-Scale Use of Solar Power in Remote, Developing Regions: A Case Study, *Journal of Sustainable Development,* Vol. 4, pp. 3-9, 2011.

268. B.D. Plourde, J. P. Abraham, G. S. Mowry, and W. J. Minkowycz, An Experimental Investigation of a Large, Vertical-Axis Wind Turbine: Effects of Venting and Capping, *Wind Engineering,* Vol. 35, pp. 213-220, 2011.

269. N.N. Johnson, J.P. Abraham, Z.I. Helgeson, W.J. Minkowycz, and E. M. Sparrow, An Archive of Skin-Layer Thicknesses and Properties and Calculations of Scald Burns with Comparisons to Experimental Observations, *Journal of Thermal Science and Engineering Applications*, Vol. 3, paper no. 011003, 2011.

270. Z. Helgeson, J. Jenkins, J. Abraham, and E. Sparrow, Particle Trajectories and Agglomeration/Accumulation in Branching Arteries Subjected to Orbital Atherectomy, *Open Biomedical Engineering Journal*, Vol. 5, pp. 25-38, 2011.

271. L. Steck, E.M. Sparrow, and J.P. Abraham, Non-Invasive Measurement of the Human Core Temperature, *International Journal of Heat and Mass Transfer*, Vol. 54, pp. 949-982, 2011.

272. N. N. Johnson, J. P. Abraham, Z, I. Helgeson and M.P. Hennessey, Simulation of Embolization Particle Trajectories, *Frontiers in Heat Transfer*, Vol. 2, paper no. 023006, 2011.

273. G. Adams, P. Khanna, C. Staniloae, J.P. Abraham, and E.M. Sparrow, Optimal Techniques with the Diamondback 360 System Achieve Effective Results for the Treatment of Peripheral Arterial Disease, *Journal of Cardiovascular Translation Research*, Vol. 4, 220-229, 2011.

274. J.P. Abraham, E. M. Sparrow, and W. J. Minkowycz, Internal-Flow Nusselt Numbers for the Low-Reynolds-Number End of the Laminar-to-Turbulent Transition Regime, *International Journal of Heat and Mass Transfer*, Vol. 54, 584-588, 2011.

275. S. Chelikani, E.M. Sparrow, J.P. Abraham, and W.M. Minkowycz, Mass Transfer in Vascular Access Ports*, International Journal of Heat and Mass Transfer*, Vol. 54, pp. 949-958, 2011.

2010

276. R. Ramazani-Red, S. Chelikani, E. M. Sparrow, and J. P. Abraham, Experimental and Numerical Investigation of Orbital Atherectomy: Absence of Cavitation, *Journal of Biomedical Science and Engineering*, Vol. 3, pp. 1108-1116, 2010.

277. A.P. Thomas and J.P. Abraham, Sawtooth Vortex Generators for Underwater Propulsion, *Open Mechanical Engineering*, Vol. 4, pp. 1-7, 2010.

278. D. K. Smith, R.D. Lovik E. M. Sparrow, and J. P. Abraham, Human Tissue Temperatures Achieved During Recharging of New-Generation Neuromodulation Devices, *International Journal of Heat and Mass Transfer,* Vol. 53, 3292-3299, 2010.

279. J. P. Abraham, E. M. Sparrow, J. C. K. Tong, and D. W. Bettenhausen, Internal Flows which Transist from Turbulent Through Intermittent to Laminar, *International Journal of Thermal Sciences*, Vol. 49, 256-263, 2010.

280. E.M. Sparrow, J.P. Abraham, Y. Bayazit, R.D. Lovik, and D.K. Smith, Numerical and Experimental Simulations as Symbiotic Tools for Solving Complex Biothermal Problems, *Journal of Medical Devices*, Vol. 4, 027536, 2010.

2009

281. R.D. Lovik, J.P. Abraham, W.J. Minkowycz, and E.M. Sparrow, Laminarization and Turbulentization in a Pulsatile Pipe Flow, *Numerical Heat Transfer Part A*, Vol. 56, 861-879, 2009.

282. R.D. Lovik, J.P. Abraham, and E.M. Sparrow, Tissue-Damage Potential from Transcutaneous Recharge of Neuromodulation Implants, *International Journal of Heat and Mass Transfer*, Vol. 52, pp. 3518-3524, 2009.

283. E.M. Sparrow, J.P. Abraham, and W.J. Minkowycz, Flow Separation in a Diverging Conical Duct: Effect of Reynolds Number and Divergence Angle, *International Journal of Heat and Mass Transfer,* Vol. 52, pp. 3079-3083, 2009.

284. F.A. Hoover and J.P. Abraham, A Comparison of Corn-Based Ethanol with Cellulosic Ethanol as Replacements for Petroleum-Based Fuels, A Review, *International Journal of Sustainable Energy*, Vol. 28, pp. 171-182, 2009.

285. G.S. Mowry, R. Erickson, and J.P. Abraham, Computational Model of a Novel, Two-Cup Horizontal Wind-Turbine System, *Open Mechanical Engineering Journal*, Vol. 3, pp. 26-34, 2009.

286. 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.

287. W.J. Minkowycz, J.P. Abraham, and E.M. Sparrow, Numerical Simulation of Laminar Breakdown and Subsequent Intermittent and Turbulent Flow in Parallel Plate Channels: Effects of Inlet Velocity Profile and Turbulence Intensity, *International Journal of Heat and Mass Transfer*, 52, pp. 4040-4046, 2009.

288. J.P. Abraham, G.S. Mowry, R. Erickson, Analysis of Urban Wind Turbines, Clean Technology, pp. 13-16, 2009.

289. J.P. Abraham and A.P. Thomas, Induced Co-Flow and Laminar-to-Turbulent Transition with Synthetic Jets, *Computers and Fluids*, Vol. 38, pp. 1011-1017, 2009.

290. J.P. Abraham, E.M. Sparrow, and J.C.K. Tong, Heat Transfer in All Pipe Flow Regimes - Laminar, Transitional/Intermittent, and Turbulent, *International Journal of Heat and Mass Transfer,* Vol. 52, pp. 557-563, 2009.

2008

291. J.C. Tong, E.M. Sparrow, and J.P. Abraham, Unified Treatment of Natural Convection in Tall, Narrow, and Flat, Wide Rectangular Channels, *Numerical Heat Transfer A*, Vol. 54, pp. 763-776, 2008.

292. J.P. Abraham, J.C.K. Tong, and E.M. Sparrow, Breakdown of Laminar Pipe Flow into Transitional Intermittency and Subsequent Attainment of Fully Developed Intermittent or Turbulent Flow, *Numerical Heat Transfer B*, Vol. 54, pp. 103-115, 2008.

293. J.P. Abraham, E.M. Sparrow, and R.D. Lovik, Unsteady, Three-Dimensional Fluid Mechanic Analysis of Blood Flow in Plaque-Narrowed and Plaque-Free Arteries, *International Journal of Heat and Mass Transfer*, Vol. 51, 5633-5641, 2008.

294. E.M. Sparrow, J.C.K. Tong, and J.P. Abraham, Fluid Flow in a System with Separate Laminar and Turbulent Zones, *Numerical Heat Transfer A*, Vol. 53 (4), pp. 341-353, 2008.

2007

295. J.P. Abraham and C.M. George, Full-Building Radiation Shielding for Climate Control in Desert Regions, *International Journal of Sustainable Energy*, Vol. 26 (3) pp. 167-177, 2007.

296. J.P. Abraham and E.M. Sparrow, A Thermal Ablation Model Including Liquid-to-Vapor Phase Change, Necrosis-Dependent Perfusion, and Moisture-Dependent Properties, *International Journal Heat and Mass Transfer*, Vol. 50, pp. 2537-2544, 2007.

297. 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.

298. E.M. Sparrow and J.P. Abraham, A Simulation of Gas-Based, Endometrial-Ablation Therapy for the Treatment of Menorrhagia, *Annals of Biomedical Engineering,* Vol. 36 (1), pp. 171-183, 2008

2007

299. J.P. Abraham, E.M. Sparrow, and S. Ramadhyani, Numerical Simulation of a BPH Thermal Therapy – A Case Study Involving TUMT, *Journal of Biomechanical Engineering*, Vol. 129, pp. 548-557, 2007.

300. 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.

301. J.C.K. Tong, E.M. Sparrow, and J.P. Abraham, Numerical Simulation of the Urine Flow in a Stented Ureter, *Journal of Biomechanical Engineering*, Vol. 129, pp. 187-192, 2007.

2006

302. J.P. Abraham, A Guide to Curing Processes, *Journal of Precision Manufacturing*, 6, pp. 16-17, 2006.

303. J.P. Abraham and C.M. George, Micro-Geothermal Devices for Low-Energy Air-Conditioning in Desert Climates, *GHC Bull.*, Vol. 27, (4), pp. 13-16, 2006.

304. 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.

2005

305. E. M. Sparrow and J. P. Abraham, Universal Solutions for the Streamwise Variation of the Temperature of a Moving Sheet in the Presence of a Moving Fluid, *International Journal of Heat and Mass Transfer*, Vol. 48, pp. 3047-3056, 2005.

306. 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.

307. J. P. Abraham and E. M. Sparrow, Friction Drag Resulting From the Simultaneous Imposed Motion of a Freestream and its Bounding Surface, *International Journal of Heat and Fluid Flow*, Vol. 26, pp. 289-295, 2005.

308. S.K. S. Boetcher, E.M. Sparrow, and J.P. Abraham, Numerical Simulation of the Radiative Heating of a Moving Sheet, *Numerical Heat Transfer*, Vol. 47, pp. 1-25, 2005.

2004

309. E.M. Sparrow, J.P. Abraham, and J.C. K. Tong, Archival Correlations for Average Heat Transfer Coefficients for Non-Circular and Circular Cylinders and for Spheres in Crossflow, *International Journal of Heat and Mass Transfer*, Vol. 47 (24), pp. 5285-5296, 2004.

310. J.P. Abraham and E.M. Sparrow, A Simple Model and Validating Experiments for Predicting the Heat Transfer to a Load Situated in an Electrically Heated Oven, *Journal of Food Engineering*, Vol. 62 (4) pp. 409-415, 2004.

311. J.P. Abraham, Teaching Case Studies to a Multi-Disciplinary Class - Bridging the Gap Between Engineering and the Biological Sciences, *Journal of College Science Teaching*, Vol. 33 (5), March/April 2004.

2003

312. E.M. Sparrow and J.P. Abraham, A Computational Analysis of the Radiative and Convective Processes Which Take Place in Preheated and Non-Preheated Ovens, *Journal of Heat Transfer Engineering*, Vol. 24, No. 5, pp. 25-37, 2003.

313. J.P. Abraham and E.M. Sparrow, Three Dimensional Laminar and Turbulent Natural Convection in a Continuously/Discretely Wall-Heated Enclosure Containing a Thermal Load, *Numerical Heat Transfer, A,* Vol. 44, pp. 105-125, 2003.

314. E. M. Sparrow and J. P. Abraham, A New Buoyancy Model Replacing the Standard Pseudo-Density Difference for Internal Natural Convection in Gases, *International Journal of Heat and Mass Transfer*, Vol. 46, pp. 3583-3591, 2003.

2002

315. J.P. Abraham and E.M. Sparrow, Experiments on discretely heated, vented/unvented enclosures for various radiation surface characteristics of the thermal load, enclosure temperature sensor, and enclosure walls*, International Journal of Heat and Mass Transfer*, Vol. 45, pp. 2255-2263, 2002.

316. J.P. Abraham and E.M. Sparrow, Fluid Flow and Heat Transfer in Multiply-Folded, Continuous Flow Passages Including Conjugate Thermal Interaction Between the Fluid and Bounding Walls, *Numerical Heat Transfer, A*, Vol. 42, pp. 327-344, 2002.

317. E.M. Sparrow, J.P. Abraham, and Molly K. Rolfsmeier, Fabric Ducts for Air Distribution and for Décor, *Fabric Architecture*, March/April 2002.

318. E.M. Sparrow and J.P. Abraham, Heat Transfer Coefficients and Other Performance Parameters for Variously Positioned and Supported Thermal Loads in Ovens With/Without Water-Filled or Empty Blockages, *International Journal of Heat and Mass Transfer*, Vol. 45, pp. 3597-3607, 2002.

2001

319. 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.

320. 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.

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 19602015, *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 Engineerin*g, 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 Technolog*y, 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.

51. J.P. Abraham, B.D. Plourde, J.R. Stark, and W.J. Minkowycz, Improvements to the Quality and Quantity of Ocean Heat Content Measurements, *3rd International Conference on Earth Science and Climate Change,* San Francisco, CA, July 28-30, 2014.

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.

54. 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, *Complex Cardiovascular Therapeutics*, Orlando, FL, June 23-27, 2014.

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, *Flucome 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)

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

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 $12kfor 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

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