

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent of: Brent W. Murray, et al.
U.S. Patent No.: 7,207,181 Attorney Docket No. 43789-0259IP1
Issue Date: April 24, 2007
Appl. Serial No.: 11/069,378
Filing Date: March 1, 2005
Title: REFRIGERATION UNIT CONDENSATION
PREVENTION

DECLARATION OF DR. GREGOR P. HENZE, PH.D., P.E.

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(iii)	Element [1.b]: a dew point sensing unit adapted for monitoring ambient air temperature and relative humidity outside of the display case and including a carrier having at least one dew point sensing component thereat;	69
(iv)	Element [1.c]: a control unit communicating with said sensing units and including processing means connected for activating the display case frame/door heater when monitored display case door or frame temperature drops below a preselected set point above a dew point value derived from monitored ambient temperature and relative humidity; and	71

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(iv)	Element [1.c]: a control unit communicating with said sensing units and including processing means connected for activating the display case frame/door heater when monitored display case door or frame temperature drops below a preselected set point above a dew point value derived from monitored ambient temperature and relative humidity; and	127

- (v) Element [1.d]: housing means for locating said sensing units including structure establishing thermal isolation of said sensing units by minimizing heat transfer contacts between said sensing units and said housing means and locating said temperature sensor and said at least one dew point sensing component amid insulated air pockets formed by said structure of said housing means. 128
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 - (i) Element [3]: The apparatus of claim 2 wherein said frame temperature sensing unit housing includes a single locating post at said cover for securing position of said temperature sensing unit relative to said cover. 136
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	(ii) Element [1.a]: a frame temperature sensing unit adapted for monitoring temperature of one of the display case door or display case frame and including a carrier having a temperature sensor thereat;	161
	(iii) Element [1.b]: a dew point sensing unit adapted for monitoring ambient air temperature and relative humidity outside of the display case and including a carrier having at least one dew point sensing component thereat;	161
	(iv) Element [1.c]: a control unit communicating with said sensing units and including processing means connected for activating the display case frame/door heater when monitored display case door or frame temperature drops below a preselected set point above a dew point value derived from monitored ambient temperature and relative humidity; and	162
	(v) Element [1.d]: housing means for locating said sensing units including structure establishing thermal isolation of said sensing units by minimizing heat transfer contacts between said sensing units and said housing means and locating said temperature sensor and said at least one dew point sensing component amid insulated air pockets formed by said structure of said housing means.	163
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(i)	Element [4]: The apparatus of claim 1 wherein said housing means includes a dew point sensing unit housing, said dew point sensing unit housing including a mounting base and cover, said cover including a cover face opening therethrough for receiving said at least one dew point sensing component therein, said cover face opening including a protective shield thereover having air gaps therearound allowing air flow between said protective shield and said cover and thus over said at least one dew point sensing component.	170
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(ii)	Element [8.a]: sensing and control apparatus configured for location at each display case in the array of display cases, ...	175
(iii)	Element [8.b]: said apparatus including a frame temperature sensing unit adapted for mounting at the display case for monitoring temperature of one of the display case door or display case frame, ...	176
(iv)	Element [8.c]: said apparatus including...a dew point sensing unit adapted for mounting at the display case for monitoring ambient air temperature and relative humidity outside of the display case, ...	176
(v)	Element [8.d]: said apparatus including...an internal case temperature sensing unit positionable inside the display case, and.....	176
(vi)	Element [8.e.i]: said apparatus including...processing means mountable at the display case and connected for activating the display case frame/door heater when monitored display case door or frame temperature drops below a first preselected set point above a dew point value derived from monitored ambient temperature and relative humidity, for deactivating the frame/door heater when monitored display case door or frame temperature rises above a second preselected set point above said dew point value, and	177
(vii)	Element [8.e.ii] processing means...connected...for storing data related to readings at said sensing units and operation of the frame/door heater; and	177
(viii)	Element [8.f]: a communication control unit associated with said processing means for coordinating programming and data download access to said processing means of said apparatus.	178
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(i)	Element [9]: The system of claim 8 further comprising a central processing unit and wherein said communication control unit includes a transmitter/receiver for wireless communication with said central processing unit.	178
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5.	Claim 12	180
(i)	Element [12]: The system of claim 8 wherein said frame temperature sensing unit and said dew point sensing unit are mounted together in a housing.....	180
6.	Claim 13	181
(i)	Element [13]: The system of claim 8 further comprising housing means for locating said temperature sensing unit and said dew point sensing unit and including structure establishing thermal isolation of said sensing units by minimizing heat transfer contacts between said temperature sensing unit and said dew point sensing unit and said housing means and locating said temperature sensing unit and said dew point sensing unit amid insulating air pockets formed by said structure of said housing means.	181
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LISTING OF CHALLENGED CLAIMS

Claim 1	
[1.pre]	Condensation control apparatus for a refrigerated display case having at least one door, a frame and at least one frame/door heater, said apparatus comprising:
[1.a]	a frame temperature sensing unit adapted for monitoring temperature of one of the display case door or display case frame and including a carrier having a temperature sensor thereat;
[1.b]	a dew point sensing unit adapted for monitoring ambient air temperature and relative humidity outside of the display case and including a carrier having at least one dew point sensing component thereat;
[1.c]	a control unit communicating with said sensing units and including processing means connected for activating the display case frame/door heater when monitored display case door or frame temperature drops below a preselected set point above a dew point value derived from monitored ambient temperature and relative humidity; and
[1.d]	housing means for locating said sensing units including structure establishing thermal isolation of said sensing units by minimizing heat transfer contacts between said sensing units and said housing means and locating said temperature sensor and said at least one dew point sensing component amid insulated air pockets formed by said structure of said housing means.

Claim 2	
[2]	The apparatus of claim 1 wherein said housing means includes a frame temperature sensing unit housing, said frame temperature sensing unit housing including a base and a cover, said cover having a depth creating a first one of said air pockets at one side of said temperature sensing unit and said base including an opening for receiving said temperature sensor therethrough, said opening having an opening area greater than surface area of said temperature sensor thus establishing a second one of said air pockets around said temperature sensor.

Claim 3	
[3]	The apparatus of claim 2 wherein said frame temperature sensing unit housing includes a single locating post at said cover for securing position of said temperature sensing unit relative to said cover.

Claim 4	
[4]	The apparatus of claim 1 wherein said housing means includes a dew point sensing unit housing, said dew point sensing unit housing including a mounting base and cover, said cover including a cover face opening therethrough for receiving said at least one dew point sensing component therein, said cover face opening including a protective shield thereover having air gaps therearound allowing air flow between said protective shield and said cover and thus over said at least one dew point sensing component.

Claim 5	
[5]	The apparatus of claim 4 wherein said cover of said dew point sensing unit housing includes opposite end openings to establish ambient air flow through said dew point sensing unit housing.

Claim 6	
[6]	The apparatus of claim 4 wherein said mounting base of said dew point sensing unit housing includes protrusions establishing retaining pockets receiving said carrier of said dew point sensing unit at outer edges of said carrier and further establishing a first one of said air pockets amid said protrusions and adjacent to said carrier.

Claim 7	
[7]	The apparatus of claim 1 wherein said housing means includes a cover and a base, said cover including a cover face opening therethrough for receiving said at least one dew point sensing component therein, said cover face opening including a protective shield thereover having air gaps therearound allowing air flow between said protective shield and said cover and thus over said at least one dew point sensing component, and said base having depth creating a first one of said air pockets at least at one side of said temperature sensing unit and a second one of said air pockets at one side of said dew point sensing unit.

Claim 8	
[8.pre]	A system for condensation control at an array of refrigerated display cases, the cases each having at least one door, a frame and at least one frame/door heater, said system comprising:
[8.a]	sensing and control apparatus configured for location at each display case in the array of display cases,
[8.b]	said apparatus including a frame temperature sensing unit adapted for mounting at the display case for monitoring temperature of one of the display case door or display case frame,

[8.c]	[said apparatus including...] a dew point sensing unit adapted for mounting at the display case for monitoring ambient air temperature and relative humidity outside of the display case,
[8.d]	[said apparatus including...] an internal case temperature sensing unit positionable inside the display case, and
[8.e.i]	[said apparatus including...] processing means mountable at the display case and connected for activating the display case frame/door heater when monitored display case door or frame temperature drops below a first preselected set point above a dew point value derived from monitored ambient temperature and relative humidity, for deactivating the frame/door heater when monitored display case door or frame temperature rises above a second preselected set point above said dew point value, and
[8.e.ii]	[processing means...connected...] for storing data related to readings at said sensing units and operation of the frame/door heater; and
[8.f]	a communication control unit associated with said processing means for coordinating programming and data download access to said processing means of said apparatus.

Claim 9	
[9]	The system of claim 8 further comprising a central processing unit and wherein said communication control unit includes a transmitter/receiver for wireless communication with said central processing unit.

Claim 10	
[10]	The system of claim 8 wherein said processing means of said apparatus is separately housed in a housing having dimensions selected so that said housing is mountable between standard door frame mullions provided at the display case.

Claim 11	
[11]	The system of claim 8 wherein said processing means of said apparatus includes a reset/programming interface.

Claim 12	
[12]	The system of claim 8 wherein said frame temperature sensing unit and said dew point sensing unit are mounted together in a housing.

Claim 13	
[13]	The system of claim 8 further comprising housing means for locating said temperature sensing unit and said dew point sensing unit and including structure establishing thermal isolation of said sensing units by minimizing heat transfer contacts between said temperature sensing unit and said dew point sensing unit and said housing means and locating said temperature sensing unit and said dew point sensing unit amid insulating air pockets formed by said structure of said housing means.

Claim 14	
[14.pre]	A system for condensation control at a refrigerated display case having at least one door, a frame and at least one frame/door heater, said system comprising:
[14.a]	a temperature sensing unit in contact with the display case frame to monitor case frame temperature;
[14.b]	a dew point sensing unit on the display case to monitor ambient air temperature and relative humidity outside the display case; and

[14.c]	control means for receiving data from said sensing units and utilizing monitored case frame temperature, ambient air temperature and relative humidity to anticipate formation of condensation at the display case and activating and deactivating the frame/door heater responsive thereto.
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Claim 15

[15]	The system of claim 14 further comprising means for thermally isolating said dew point sensing unit from variations in temperature of the display case frame or display case door.
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Claim 16

[16]	The system of claim 14 further comprising means for thermally isolating said temperature sensing unit from variations in temperature of ambient air.
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Claim 17

[17]	The system of claim 14 further comprising an internal case temperature sensing unit mounted inside the display case and communicating with said control means for monitoring internal case temperature.
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Claim 18

[18]	The system of claim 17 further comprising data storing means communicating with said control means for storing data related to readings at said sensing units and operation of the frame/door heater.
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Claim 19	
[19]	The system of claim 18 further comprising means for wirelessly accessing stored data at said data storing means.

Claim 20	
[20]	The system of claim 14 wherein said means for wirelessly accessing data is configured for remotely updating control parameters at said control means utilized for monitoring case frame temperature, ambient air temperature and relative humidity to anticipate formation of condensation at the display case and activating and deactivating the frame/door heater.

I, Gregor P. Henze, declare as follows:

I. INTRODUCTION

1. I have been retained as a technical expert on behalf of Anthony Inc. (“Anthony”/“Petitioner”). I understand that Anthony is requesting that the Patent Trial and Appeal Board institute an *inter partes* review (“IPR”) proceeding with respect to U.S. Patent No. 7,207,181 (“the ’181 patent”) (EX1001).

2. I have been asked to provide my independent analysis of the ’181 patent in light of certain prior art publications, and I have done so based on my personal knowledge and experience.

3. I am not, and never have been, an employee of Anthony. I received no compensation for this Declaration beyond my normal hourly compensation based on my time spent analyzing the ’181 patent, the prior art publications cited below, and various issues related thereto. I will not receive any added compensation based on the outcome of any IPR or other proceeding involving the ’181 patent.

II. QUALIFICATIONS

4. In formulating my opinions, I have relied on my knowledge, training, and experience in the relevant field. My education and experience are described more fully in the attached curriculum vitae (Appendix A). For ease of reference, I have highlighted certain information below.

5. I have roughly 30 years of experience and familiarity with the art of thermal sciences, building systems, and associated control systems. That experience includes both academic study and industry experience at several institutions.

6. I earned a Vor-Diplom (Bachelor of Science degree) in mechanical engineering (energy and process engineering) in 1989 from the Technical University of Berlin. I then earned a Master of Science degree in mechanical engineering with a focus in thermal sciences in 1991 from Oregon State University as a Fulbright scholar. I also earned a Diplom-Ingenieur (equivalent to a Master of Science degree) in mechanical engineering with a focus in energy and process engineering in 1992 from the Technical University of Berlin.

7. In 1995, I earned a doctoral degree in civil engineering, focusing on building systems engineering, from the University of Colorado. During my graduate study, I investigated advanced building control strategies and conducted experiments on the performance and robustness of direct digital control systems in a commercial-scale HVAC (heating, ventilation, and air conditioning) laboratory.

8. From 1996 to 1999 I worked at Johnson Controls, Inc., a manufacturer of control and automation equipment, initially as an engineer and later as an engineering manager. My work at Johnson Controls involved the development of strategies and implementation of energy efficiency retrofit projects to improve energy utilization and decrease utility costs in commercial buildings.

9. From 1999 to 2008 I was an assistant professor and then an associate professor at the University of Nebraska–Lincoln. I was a founding faculty member of the Durham School of Architectural Engineering and Construction in the College of Engineering. During that time, I also worked as a visiting scientist and visiting professor at various companies (such as the HVAC and controls research laboratories at Siemens Building Technologies in Zug, Switzerland) and research institutions (such as the Fraunhofer Institute for Solar Energy Systems in Freiburg, Germany).

10. Since 2008, I have been a full professor and since 2017 an endowed professor at the University of Colorado Boulder in the Department of Civil, Environmental, and Architectural Engineering in the College of Engineering and Applied Science. My teaching focuses in part on building mechanical and energy systems design as well as their associated control and automation systems. My current research emphasis is in part on sensor network and fusion systems for building occupancy detection, fifth-generation district energy systems, as well as model predictive and reinforcement learning based control for grid-interactive efficient residential and commercial buildings.

11. From 2017 to 2021, I served as associate director for energy systems integration and later as interim co-director of the Renewable and Sustainable Energy Institute, a joint research institute between the University of Colorado in Boulder,

Colorado and the National Renewable Energy Laboratory (“NREL”) in Golden, Colorado. In this context, I initiated new and grew existing R&D partnerships between University of Colorado faculty and collaborators at NREL in the power systems engineering and building research groups with expertise in building and urban energy systems engineering, building efficiency, grid integration, and other renewable and sustainable research topics.

12. I have authored or co-authored nearly 200 papers related to various aspects of HVAC systems and their control and operation, four of which have received best paper awards, three from the American Society of Mechanical Engineers (“ASME”) and one from the Architectural Engineering Institute (“AEI”). Since 2011, I have organized seven conferences dedicated to intelligent building operations focusing on novel sensing, control, and fault detection approaches. I am certified by the American Society of Heating, Refrigerating, and Air Conditioning Engineers as a High-Performance Building Design Professional.¹ I am also a licensed professional mechanical engineer (P.E.) in Nebraska.

¹ The American Society of Heating, Refrigerating and Air-Conditioning Engineers is a recognized organization in the HVAC industry and has published many handbooks and other documents that are used in the industry.

13. In 2022, I served as the Fulbright Distinguished Chair for Science and Technology at the Commonwealth Scientific and Industrial Research Organization (CSIRO) Energy Center in Newcastle, New South Wales, Australia.

14. I have researched and conducted projects involving a variety of different building control systems, including those employing control strategies for operating vapor compression refrigeration cycles in chillers, heat pumps, air-cooled condensers, and thermal energy storage systems. Moreover, at the National Renewable Energy Laboratory I have investigated waste heat recovery opportunities for commercial refrigeration systems. As such, I am well-versed in the system requirements, performance, and components used to design such systems.

III. LEGAL PRINCIPLES

15. In forming my analysis and conclusions expressed in this Declaration, I have applied the legal principles described in the following paragraphs, which were provided to me by counsel for the Petitioner.

A. Person of Ordinary Skill in the Art

16. I understand that the factors considered in determining the ordinary level of skill in a field of art include: the level of education and experience of persons working in the field; the types of problems encountered in the field; the teachings of the prior art regarding solutions to such problems; and the sophistication of the

technology at the time of the alleged invention. I understand that a person of ordinary skill in the art (“POSITA”) is not a specific real individual, but rather is a hypothetical individual having the qualities reflected by the factors above and knowledge of all relevant prior art references, including the references I cite below.

B. Obviousness

17. I have been informed that a patent claim is invalid as “obvious” in light of one or more prior art references if it would have been obvious to a POSITA at the time of the alleged invention, taking into account (1) the scope and content of the prior art, (2) the differences between the prior art and the claims, (3) the level of ordinary skill in the art, and (4) any so called “secondary considerations” of non-obviousness, which include: (i) “long-felt but unresolved need” for the claimed invention, (ii) commercial success attributable to the claimed invention, (iii) unexpected results of the claimed invention, and (iv) “copying” of the claimed invention by others.

18. While I do not know the exact date that the alleged invention of the ’181 patent was made, I do know that the ’181 patent’s earliest claimed priority date—its filing date—is March 1, 2005. For purposes of my obviousness analysis, I have applied a date of March 1, 2005 as the date of the alleged invention (“Critical Date”), although in many cases the same analysis would hold true even if the date of the alleged invention were earlier or later.

19. I have been informed that a claim can be obvious in light of a single prior art reference or multiple prior art references. To be obvious in light of a single prior art reference or multiple prior art references, there must be a reason that would have prompted a POSITA to modify or supplement the single prior art reference, or to combine two or more references, in a manner that provides the elements of the claimed invention. This reason may come from a teaching, suggestion, or motivation to combine, or may come from the reference(s) themselves, the knowledge or “common sense” of a POSITA, or from the nature of the problem to be solved, and this reason may be explicit or implicit from the prior art as a whole. I have been informed that, under the law, the combination of familiar elements according to known methods is likely to be obvious when it does no more than yield predictable results. I also understand it is improper to rely on hindsight in making the obviousness determination.

20. I understand that an obviousness determination also requires that a POSITA would have had a reasonable expectation of success. This concept has been explained to me as relating to the relative likelihood or predictability—from the perspective of a POSITA—of successfully modifying the prior art in a manner that would meet the claimed limitations of the patent being challenged (here the ’181 patent). I understand that the expectation of success need only be “reasonable” and,

thus, does not require the absolute certainty gleaned from physically creating the proposed prior art modification.

C. Claim Interpretation

21. I understand that, for purposes of my analysis in this *inter partes* review proceeding, the terms appearing in the patent claims should be interpreted according to their “ordinary and customary meaning.” In determining the ordinary and customary meaning, I understand that the words of a claim are first given their plain meaning that those words would have had to a person of ordinary skill in the art at the time of the alleged invention. I also understand that the structure of the claims, the specification and file history may be used to better construe a claim. Moreover, I understand that even treatises and dictionaries may be used, albeit under limited circumstances, to determine the meaning attributed by a person of ordinary skill in the art to a claim term.

IV. MATERIALS CONSIDERED

22. My analysis in this Declaration is based on my knowledge and experience. Based on my above-described qualifications in Section II, the Patent Trial and Appeal Board should consider me to be an expert in the field. Also, based on my experiences, I understand and know of the capabilities of persons of ordinary skill in this field.

23. As part of my independent analysis for this Declaration, I have considered the following: the '181 patent (EX1001) and its prosecution history (EX1002); the background knowledge/technologies that were commonly known to persons of ordinary skill; my own knowledge and experience gained from my work in the field; my experience in teaching and advising others in this field; and my experience working with others involved in this field. In addition, I have analyzed the following publications and materials:

EX1004	U.S. Patent No. 7,137,262 (Carter)
EX1005	U.S. Patent No. 6,422,062 (King)
EX1006	U.S. Patent No. 5,778,689 (Beatenbough)
EX1007	U.S. Patent No. 6,502,409 (Gatling)
EX1008	U.S. Patent No. 5,396,796 (Kotani)
EX1009	U.S. Publication No. 2005/0172649
EX1010	U.S. Prov. Appl. No. 60/569,581
EX1011	U.S. Prov. Appl. No. 60/559,113
EX1012	U.S. Patent No. 3,939,666
EX1013	U.S. Patent No. 3,696,360
EX1014	U.S. Publication No. 2005/0007136
EX1015	ACT2-CS Convenience Store Controller, Johnson Controls (1999)
EX1016	U.S. Patent No. 4,260,876
EX1017	<i>CPC Products</i> , Computer Process Controls (Sept. 1, 2004), https://web.archive.org/web/20040901092452/http://www.cpcus.com/products.htm
EX1018	Altech Controls EPRT Eagle Controls Manual (Section A-B)
EX1019	Altech Controls EPRT Eagle Controls Manual (Section C)

EX1020	Sensirion, SHT1x/SHT7x Humidity & Temperature Sensor (revised May 2005).
EX1021	Altech Controls AASC Anti-Sweat Heater Controller
EX1022	Anthony Engineering Change Notice—Engineering Drawings for Altech Controls AASC Control Assembly and Altech Controls Sensors
EX1023	Steven J. Slayzak & Joseph P. Ryan, Instrument Uncertainty Effect on Calculation of Absolute Humidity Using Dewpoint, Wet-Bulb, and Relative Humidity Sensors (National Renewable Energy Laboratory) 1998
EX1024	David H. Walker et al., Investigation of Energy-Efficient Supermarket Display Cases, Oak Ridge National Laboratory (Dec. 2004)
EX1025	P.H.J. van Eijk, Verifying Relay Circuits using State Machines (Utrecht University, Department of Philosophy) (1997)
EX1026	Robert P. Benedict, P.E., Fundamentals of Temperature, Pressure, and Flow Measurements (3d ed. 1984)
EX1027	Contemporary Control Systems Inc., <i>Introduction to Control</i> , Vol. 2. Issue 2 (2001)
EX1028	Shivakumar Raman & Paul H. Cohen, <i>Remote sensing for on-line temperature estimation in machining: A basic framework</i> , 38 J. of Materials Processing Tech. 613 (1993)
EX1029	U.S. Publication No. 2004/0050072
EX1030	Sensirion, SHTxx Humidity & Temperature Sensmitter, Application Note Dew-point Calculation (revised January 2005)
EX1031	ASHRAE Psychometric Chart No. 1 (1992)
EX1032	<i>Low Cost Humidity Sensor SHT10</i> , Sensirion (Mar. 12, 2006), https://web.archive.org/web/20060312033617/http://www.sensirion.com/en/02_sensors/00_products.htm?cat=3&category=&art=11&product=humidity%20sensor%20SHT10
EX1033	Larry D. Wittie, Microprocessors and Microcomputers (Encyclopedia of Computer Science) (2003)
EX1034	Ramin Faramarzi, P.E. et al., <i>Anti-Sweat Heaters in Refrigerated Display Cases</i> , ASHRAE J. 64 (2001)
EX1035	U.S. Publication No. 2007/0130968

EX1036	U.S. Patent No. 5,369,753
EX1039	American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., <i>2002 ASHRAE Handbook: Refrigeration</i> (excerpt)
EX1040	U.S. Patent No. 5,778,147
EX1041	U.S. Patent No. 3,859,502
EX1042	U.S. Patent No. 4,862,701

24. Note that my citations to non-patent literature throughout this Declaration reference the absolute page number added to the exhibit (as opposed to the original pagination of the document). For patent literature, I've used the column/line numbers or paragraph numbers. Note also that, unless I've indicated otherwise, all emphasis in any quoted text are ones I have added.

25. Although I cite and quote to selected portions of various references in this Declaration, the reader should understand that these citations are representative examples. A POSITA would have viewed each reference in its entirety and in combination with other references. Accordingly, I intend the references identified in this Declaration to be viewed as incorporated in their entireties.

V. THE '181 PATENT

26. The '181 patent involves systems that use “frame and/or door heating” for “remediat[ing] condensation build-up in refrigerated display cases.” EX1001 ('181 patent), 1:6–10. Accordingly, the '181 patent characterizes its disclosure as “relat[ing] to...devices and methods for activation and deactivation of such heating.” Figure 1 (below) illustrates “a common commercial freezer/cooler display unit 21 including a display container 23 having a frame [27]...and doors 25.” EX1001 ('181 patent), 5:14–20. The display unit 21 further includes “a local controller unit 31” connected to an array of sensors—e.g., “external case frame temperature sensor 35 and dew point sensor 37.” EX1001 ('181 patent), 5:14–27.

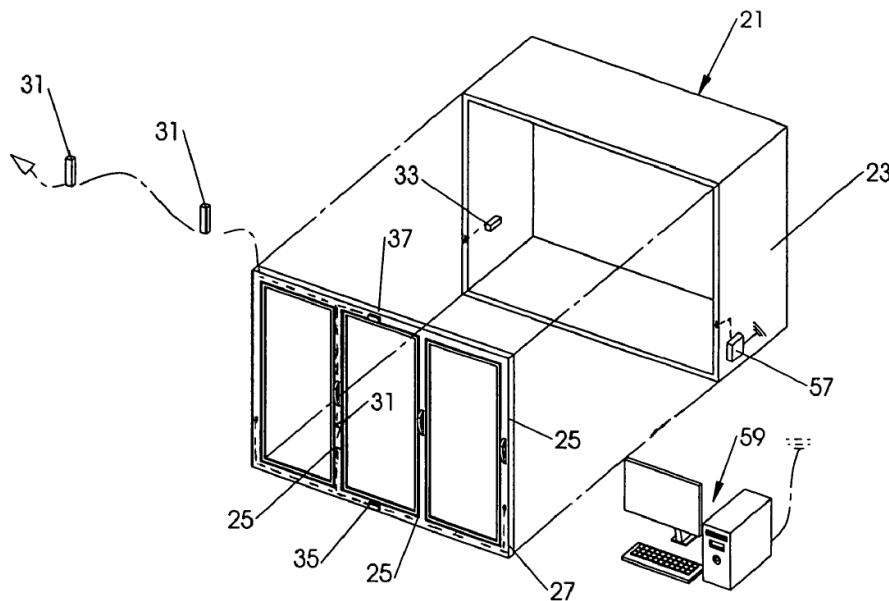
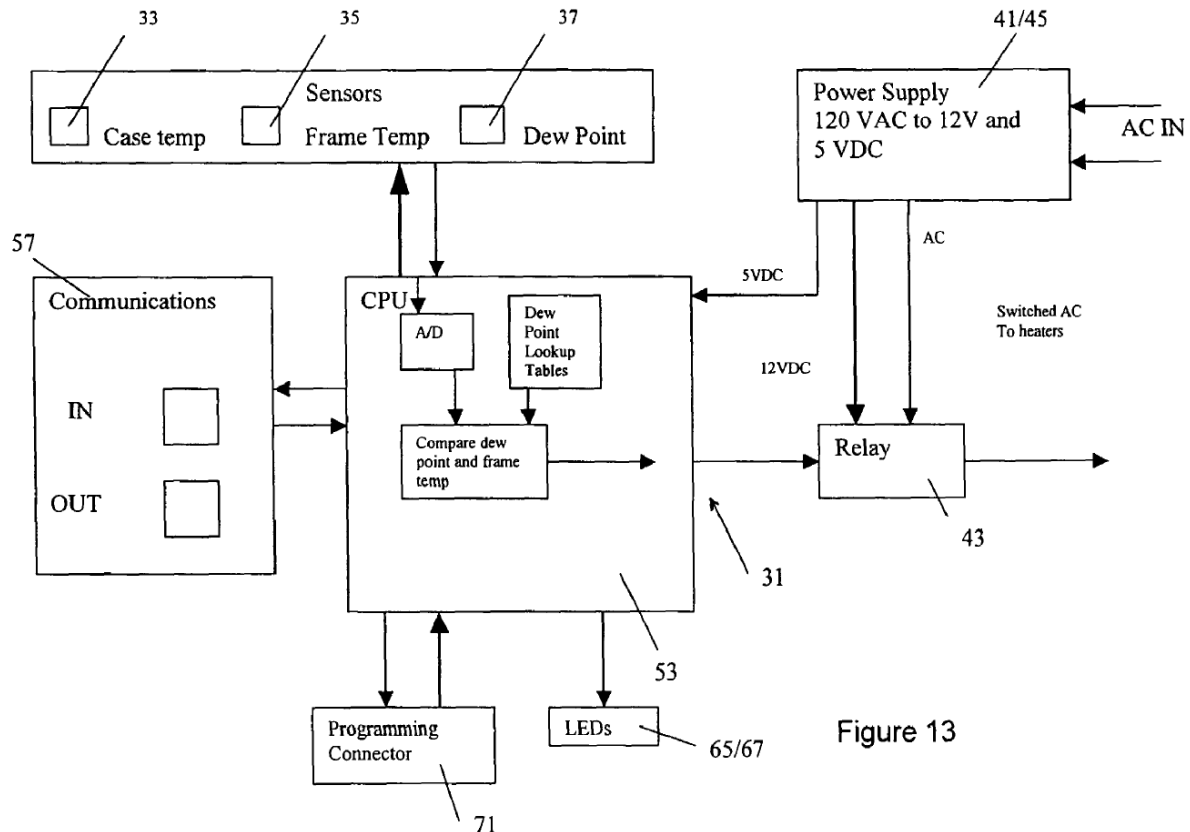


FIGURE 1

EX1001 ('181 patent), Figure 1

27. The local controller unit 31 utilizes inputs from sensors 35, 37 to derive a dew point value and activate door/frame heaters using a relay 43 when “the frame temperature approaches the dew point.” EX1001, 8:29–45, 8:53–9:3, Figure 13 (below).



EX1001 ('181 patent), Figure 13

28. Notably, as I will discuss further below at Section VI.B.1, controlling door/frame heaters based on monitored dew point values was not new at the time of the '181 patent in 2005. It was well known and widely documented in contemporaneous literature. The '181 patent concedes this point:

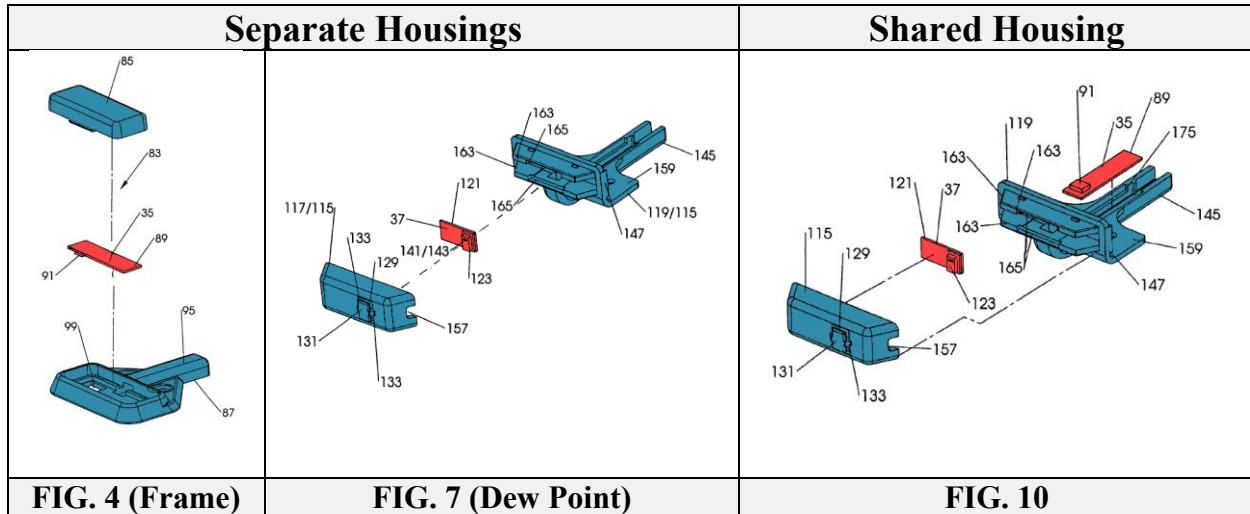
Other devices have suggested condensation control utilizing dew point calculation. Monitoring air temperature, relative humidity and surface temperatures to initiate condensation control events has been utilized in a variety of applications including refrigeration (see, for example, U.S. Patent Publication No. US 2004/0050072 A1 and U.S. Pat. Nos. 6,470,696, 5,778,689, 5,778,147, and 4,127,765). Some such devices or systems have utilized temperature sensing of both cold surfaces and the surrounding ambient air in condensation control response calculations. As is known, when a cold surface temperature is equal to or lower than the dew point of the ambient air, condensation forms on the cold surface.

EX1001 ('181 patent), 1:41–53.

29. Though the '181 patent acknowledges the extensive condensation-control prior art, it nevertheless claims that “[s]uch devices and systems have not proven altogether successful...due to inaccuracy of temperature readings,” which “has resulted in erratic condensation control.” EX1001 ('181 patent), 1:54–2:10.

30. The '181 patent suggests that its inventors solved this sensor accuracy problem with housing structures that locate the sensors amid air pockets and, thus, thermally isolated from heat sources/sinks that might otherwise bias the readings. *E.g.*, EX1001 ('181 patent), 2:21–26, 3:19–25, 6:50–8:10. In the embodiments of Figures 3–9 (below, left), the frame surface temperature sensor and dew point sensor components (red) are housed in separate structures (blue). *See* EX1001 ('181

patent), 6:32–7:62. In the embodiments of Figures 10–12 (below, right), these same sensors (red) are housed in a single, shared structure (blue). *See* EX1001 ('181 patent), 8:11–28.



VI. PERSON OF ORDINARY SKILL IN THE ART

A. A POSITA's Ordinary Level of Skill

31. Based on my knowledge and experience in the field and my review of the '181 patent and its file history, I believe that a POSITA would hold a bachelor's degree in mechanical engineering, electrical engineering, or a comparable field and at least three to five years of professional experience working with heating, ventilating, air conditioning, and refrigeration (HVAC&R) systems. Such experience could be obtained through research and study in a graduate program or through comparable exposure through industry employment, and additional years of experience could substitute for the advanced-level degree.

32. My analysis and conclusions expressed in this Declaration are based on the perspective of a POSITA having this level of knowledge and skill. My education, technical expertise and personal knowledge discussed in Section II shows that I meet the qualifications of a POSITA.

B. A POSITA's Background Knowledge and Understanding of the Pertinent Technology

33. As I will show in the immediately following sections, condensation control for use in refrigeration systems was known long before the '181 patent, and those of skill in the art had already integrated various sensors, as well as control and monitoring systems, for use in anti-condensation devices for refrigeration systems. I have cited numerous textbooks, papers, and patent documents that support my understanding, each of them either preceding the '181 patent or representing information that was known to a POSITA before the '181 patent in 2005. A POSITA would have known of these references and considered them representative examples regarding the state of the art.

1. Condensation Control in Refrigeration Systems

34. Use of condensation control in refrigeration systems began long before the '181 patent's 2005 Critical Date. The '181 patent itself acknowledges that condensation control was known before 2005 in a variety of different applications. For example, the '181 patent states that an approach was already known in the art

for sensing the presence of condensation on a freezer and activating a heater in response. EX1001 ('181 patent), 1:23–29. Further, the '181 patent mentions the prior existence of a system that performs dew point calculation using monitored values for “air temperature, relative humidity, and surface temperatures to initiate condensation control” in a “variety of applications including refrigeration.” EX1001 ('181 patent), 1:41–47.

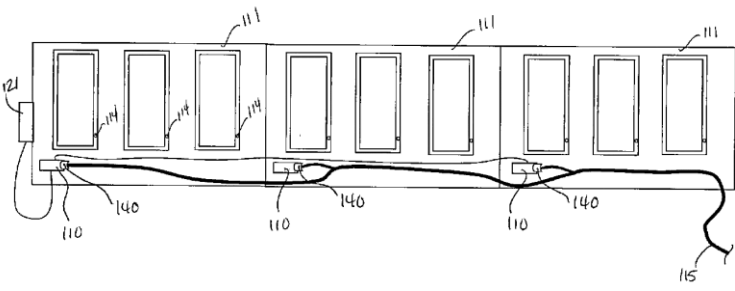
35. Contemporaneous literature confirms that, by 2005, systems designed to automatically activate a heater for condensation control in refrigeration units had been known for decades. Such condensation control systems and their constituent components were often referred to in the literature and industry using the descriptive term “anti-sweat.”² According to the 2002 ASHRAE Handbook on refrigeration by the American Society of Heating, Refrigeration and Air-Conditioning Engineers, anti-sweat systems were used in retail food stores “on most low temperature open display cases as well as reach-in cases with glass doors”; their purpose being “to prevent condensation on metal surfaces” and “reduce fogging of the glass doors of reach-in cases, a phenomenon that can hurt product merchandising.” EX1039, 35.

36. As one example of a decades-old anti-sweat system, in 1981 inventor Jerome Hochheiser was granted U.S. Patent No. 4,260,876 titled “Dew Point

² Accordingly, I use terms like “anti-sweat system” and “condensation control system” interchangeably throughout my explanations and analyses.

Differential Power Controller.” EX1016, Title. The ’876 patent disclosed “a control circuit” for controlling heaters to prevent condensation on “transparent windows and other selected surfaces of refrigerated cabinets.” EX1016, Abstract; *see also* EX1024, 34 (“Anti-sweat heaters are used in display cases to prevent condensate formation on cold surfaces...The anti-sweat heater controls consist of a device capable of cycling the door heaters based on either door-temperature or ambient-dew-point measurement.”).

37. The patent literature is rich with relevant disclosures that are similar to the Hochheiser patent. The Carter US (EX1004), Beatenbough (EX1006), Gatling (EX1007) references that I discuss below as part of my obviousness analysis are all examples of condensation control in refrigeration systems. Additional examples include:

Document	Description
EX1009 U.S. Publication No. 2005/0172649 Inventors: John Bunch et al. Filed: February 11, 2004	EX1009 describes a system “to prevent condensation on the doors and frames of a refrigerator 111 in conjunction with a heater (not shown, but usually incorporated in the door or frame) ...” [0013] 

EX1010 U.S. Prov. Appl. No. 60/569,581 (incorporated in U.S. Publication No. 2005/0268627) Inventors: Richard P. Vogh III Filed: May 10, 2004	EX1010 describes “[a] system and method for preventing condensation on refrigerated display case doors.” [0001] “The control system and method according to the invention achieves a door temperature slightly higher than dew point of the humid air adjacent the door.” [0009]
EX1011 U.S. Prov. Appl. No. 60/559,113 (incorporated in U.S. Publication No. 2005/0229614) Inventors: Roger Ansted Filed: April 2, 2004	EX1011 “relates to a system and method for heating outer surfaces of a cooled container to prevent condensation or sweat.” [0001] “More particularly, the present invention relates to a system and method for heating outer surfaces of a cooled container to prevent condensation or sweat, where the apparatus includes a container, a cooling system and a heating system, where the heating system maintains outer surfaces above a dew point temperature[.]” [0002]
EX1012 U.S. Patent No. 3,939,666 Inventors: Bashark Filed: September 30, 1974	In a preferred embodiment of EX1012, an apparatus is described comprising “a refrigeration appliance defining a side-by-side refrigerator portion 11 and a freezer portion 12.” 2:6–10. The system further comprises a “mullion heater 17” and a “stile heater 19” used “for controlling condensation on the cabinet adjacent the door seals.” 2:13–17.

38. Some earlier condensation control systems turned on heaters when condensation was detected. EX1009, [0003] (“One anti-sweat controller known in the art attaches one or more condensation sensors to the refrigerator door and turns on a door heater when condensation is sensed.”). However, those working in the art began to recognize the problems with waiting to initiate condensation control until after condensation had already occurred. EX1009, [0003] (“These devices fail, however, to prevent condensation because the heater is not activated until after condensation is sensed.”); EX1013, 1:3–7 (“the element is placed to warn of impending condensation conditions that would be injurious to the element so that steps can be taken to avoid the impending condensation conditions...”).

39. Accordingly, as the technology developed, more sophisticated systems were designed to prevent condensation before it started. For example, U.S. Publication No. 2005/0172649, filed February 11, 2005, discloses a system “to provide door heating where condensation has not yet been detected but is anticipated.” EX1009, [0006]; *see also* EX1013, 1:1–10 (describing a system that would warn of “impending condensation” before any condensation had formed at all).

40. By the time of the ’181 patent in 2005, the state of the art had matured to a stage where skilled artisans were solving secondary problems with automated condensation control systems, such as how to operate them more effectively and

efficiently. *See* EX1024, 25 (“The door anti-sweat heaters represent a major share of the refrigeration load for frozen food door reach-in cases”); *see also* EX1012, 1:5–14 (“Because of recent energy supply problems, it has been found desirable to improve the efficiency of such anti-condensation heaters.”); EX1034, 1–2 (“Using energy-efficient technologies can reduce the power consumption of [Anti-sweat heaters] and the refrigeration system.”). For example, in 2001, “industry representatives, including all major display case manufacturers, engineering personnel from 4 large food chains, and leading researchers in the field of commercial refrigeration” attended a workshop to discuss the topic of improving display case performance. EX1024, 44. Attendees to the workshop identified “[r]educ[ing] use of anti-sweat heaters through...improved heater controls” as a technology of interest for generating energy savings in refrigerated display cases. EX1024, 44–45. Similarly, the American Society of Heating, Refrigerating and Air-Conditioning Engineers explained in the 2002 refrigeration handbook that “[energy] savings can be achieved by controlling antisweat heaters,” which would otherwise “stay on round-the-clock.” EX1039, 34–35; *see also* 36 (noting the industry’s “emphasis on energy efficiency”).

41. The focus by skilled workers in the industry on improving efficiency in condensation control systems led to disclosures in the patent literature such as Carter (EX1004). As I will explain in further detail below, Carter sought to provide

supplemental heat “such that it is only activated under conditions that would promote surface condensation” because continuous heating “can waste unnecessary energy and drive up operating/maintenance costs of the freezer/refrigeration system.” EX1004 (Carter), 2:4–21. Carter teaches that readings from the sensor assembly unit are used to compare a surface temperature of the refrigeration equipment to a dew point value and “determine whether it is necessary to supply supplemental heat” to prevent condensation. EX1004 (Carter), 5:15–20, 7:7–9. Like Carter, some commercial anti-sweat systems were also designed to account for dew point and frame temperature. EX1021, 3.³ One such example was the Altech Controls “AASC controller,” “a stand alone anti-sweat heater controller that determine[d] the store’s dewpoint and monitor[ed] the actual frame temperature [of a refrigerated case] to control the frame heat to maintain the frame temperature just above the dewpoint.” *Id.* The AASC also “compensate[d] for frame conditions where the frame sensor [was] not located at the coldest spot on the frame” by incorporating an “‘offset’ from the dewpoint.” *Id.*

³ I have been informed by counsel for Petitioner that the Altech AASC controller described in EX1021 was available to the refrigeration industry before or contemporaneous with the filing date of the ’181 patent in 2005. This understanding is supported by Anthony, Inc.’s internal engineering change records, which mention the Altech AASC controller and are marked with dates in the January–February 2005 range. *See, e.g.*, EX1022.

2. Temperature and Humidity Sensor Packaging

42. As should be apparent from my prior discussion, automated condensation control systems rely on sensors to monitor conditions such as temperature and humidity. EX1024, 34 (“The anti-sweat heater controls consist of a device capable of cycling the door heaters based on either door-temperature or ambient-dew-point measurement.”). It was further known to house said temperature and humidity sensors either in an integrated package or individually. *See* EX1011, [0022] (“a humidity and surrounding air temperature sensor 114 (the sensor includes a humidity sensing component and a temperature sensing component)...Moreover, the sensor 114 can be [] two sensor[s] housed separately, a humidity sensor and a surrounding air temperature sensor”). Additionally, it was known that the accuracy of the control system is affected by the accuracy of the temperature and humidity sensors. EX1027, 2 (“The point here is that you cannot control a variable more accurately than you can measure it. Therefore, measurement is fundamental to control.”).

43. The need to isolate sensors for more accurate measurements has been well known in the art long before 2005. For example, Steven J. Slayzak and Joseph P. Ryan of the National Renewable Energy Laboratory published a paper in 1998 titled “Instrument Uncertainty Effect on Calculation of Absolute Humidity Using Dewpoint, Wet-Bulb, and Relative Humidity Sensors.” EX1023, 1. The experiment

described in the paper was directed toward determining the maximum accuracy possible for several common methods for humidity ratio measurement and calculation. *Id.*, 3. To properly measure the uncertainty of said methods, the authors describe methods for reducing “typical errors” in the measurements. *Id.*, 4. Accordingly, temperature and humidity sensors are typically held in housings designed to support the sensing elements, protect the sensing elements, and isolate the sensing elements from outside factors (things not being sensed) that would otherwise bias the measurements or damage the sensors. Common sources of measurement bias for both air temperature and humidity sensors include radiation heat transfer with nearby surfaces. *See also* EX1020, 6 (“The relative humidity of a gas strongly depends on its temperature. It is therefore essential to keep humidity sensors at the same temperature as the air of which the relative humidity is to be measured.”).

44. For instance, Slayzak and Ryan’s paper describes one method for isolating humidity sensors from outside influence and interference. The sensors are placed in a housing of “stainless steel sampling tubes” that “prevent moisture exchange with the tube walls.” EX1023, 4. By preventing moisture exchange, the housing protects the humidity sensors from being affected by outside factors. Similarly, the tubes are wrapped with “heat tape and insulation” to “ensure that condensation does not occur through heat exchange with laboratory ambient

temperature.” *Id.* In this way, the physical and thermal isolation of the humidity sensors helps to achieve accurate measurement.

45. Additionally, various methods were known in the art for thermally isolating a combined temperature and humidity sensor package, as well as protecting the sensors from other elements. For example, Sensirion’s SHT1x/SHT7x Humidity & Temperature Sensor (the “Sensirion Chip”) is a combined sensor that is also capable of accurately calculating dewpoint. EX1020, 1, 5 (“Since humidity and temperature are both measured on the same monolithic chip, the [chip] allows superb dewpoint measurements.”). Similar to the ’181 patent, the Sensirion Chip may be mounted on a PCB. *Id.*, 7. However, to ensure the reliability of its measurements, Sensirion Chip is to “be mounted far away” from any “electronic components that give off heat.” *Id.*, 6. Additionally, the Sensirion Chip’s housing must remain “well ventilated.” *Id.*

46. Further, “[t]o reduce heat conduction copper layers between the [Sensirion chip] and the rest of the PCB should be minimized and a slit may be milled in between (see figure 13).” EX1020, 6, Figure 13 (below). A POSITA would understand this open-air slit to thermally isolate the sensors from the PCB.

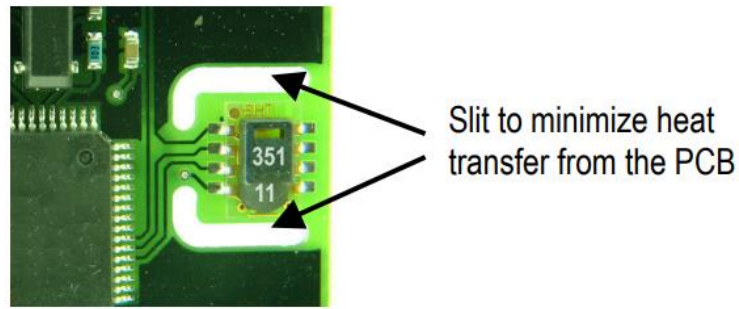


Figure 13 SHT1x PCB Mounting example

47. The Sensirion Chip further utilizes a “membrane filter cap” to “prevent dirt from entering the housing and to protect the sensor.” EX1020, 6, Figure 14 (below). The membrane is “mounted through a housing” such that “the interior can be protected from the environment while still allowing high quality measurements.” *Id.*, 7. Accordingly, the Sensirion Chip teaches protection not only from temperature, but also from various elements that might interfere with the accurate operation of the temperature and humidity sensor package.

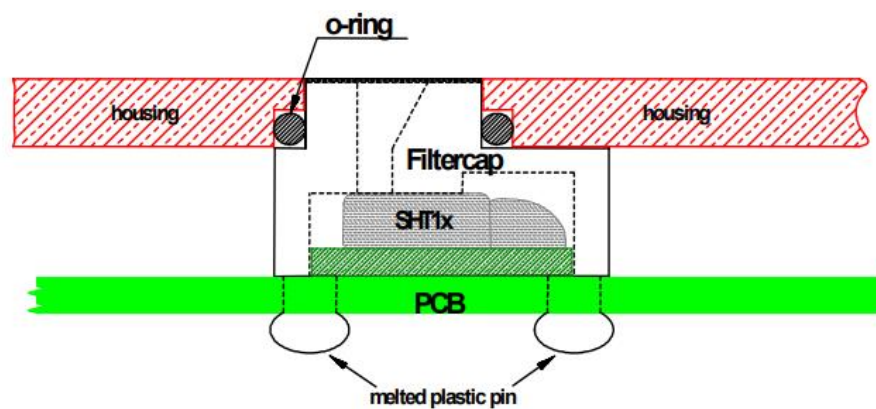


Figure 14 SF1 IP67 filter cap mounting example

48. Similar to the milled slit utilized by the Sensirion Chip, a POSITA would have been aware that air gaps or air pockets could be used to achieve thermal isolation. For further example, U.S. Publication No. 2005/0007136, filed on July 28, 2004, and published on January 13, 2005, describes one such system. EX1014 (“Feder”), Abstract. Feder describes a “thermal control wafer” comprising an optional “temperature sensor 9” and an “active control logic circuit 11” where the circuit 11 is “adapted to control a thermal output of the heater 7, preferably based on input from sensor 9.” *Id.*, [0026]. Feder further discloses “substantially thermally isolat[ing]” thermal elements 5 using “thermal isolation regions 13” which “may comprise air gap isolation trenches in the [Thermal Control Wafer] substrate 1 ...” *Id.*, [0027]; Fig. 2 (see below).

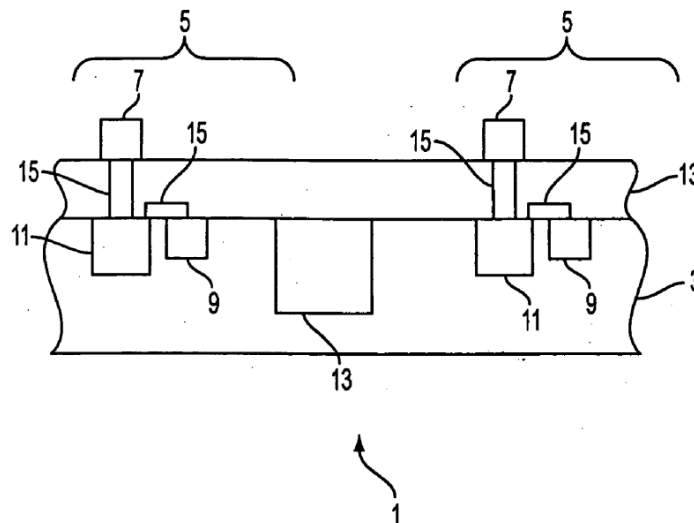


FIG. 2

49. Moreover, as early as 2004, the refrigeration industry was producing frame mounted combination dew point and frame temperature sensors. For example, Altech Controls was producing such a sensor for its AASC Anti-Sweat Heater Control system. *See* EX1021, 4–5; EX1022, 7–12 (Drawings for part numbers 57001, 57002, & 57003). Altech’s “AASC Combination Sensor” contained “all the sensing elements for operation of [its] AASC Controller.” EX1021, 5, FIG. C-1 (below).

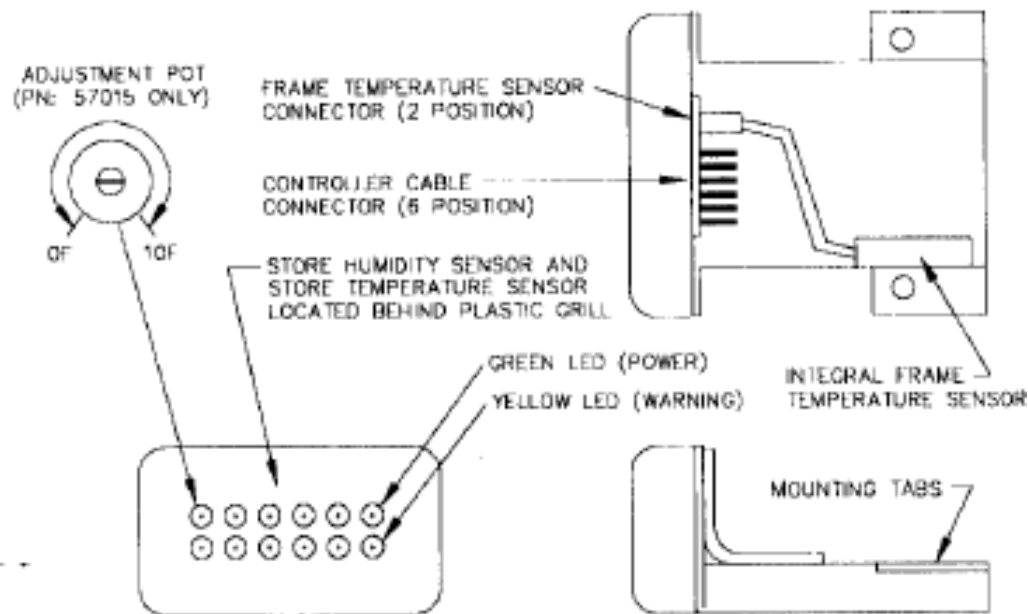


Figure C-1: AASC Combination Sensor

The AASC Combination Sensor specifically included “the store temperature and humidity sensors used to determine [a] store dewpoint” and “an integral frame temperature sensor...used as the feedback element for the AASC Controller.” EX1021, 5. The integration of these two sensors into one housing served to

“simplif[y] installation and service” of the system. *Id.*, 3. Similar to condensation control systems discussed above (including Carter (EX1004)), the Altech AASC Controller used information from the Combined Sensor to control anti-sweat heaters. *Id.*, 5 (“The AASC Controller receives the sensor information from the Combination Sensor and determines if the anti-sweat heaters are to be energized ...”).

3. Control and Monitoring in Refrigeration Systems

50. Controllers have long been known in the art for controlling and monitoring refrigeration systems. *See* EX1015, 1 (“The ACT2-CS Convenience Store controller is a fully programmable, economical controller ... [t]he end result is a stable and dependable control of refrigeration ...”); EX1039, 24 (explaining that the refrigeration industry has “migrated...toward the use of specialized microprocessors, programmable logic controllers, and computers for unit and system control”); *see also* EX1018; EX1019.

51. Refrigeration system controllers known in the art prior to the ’181 patent in 2005 had a variety of capabilities. One such exemplary controller, the ACT2-CS Convenience Store Controller (“ACT2”) sold by Johnson Controls, is described in the 1999 Johnson Controls Product Bulletin. *See* EX1015. The Product Bulletin discloses that the ACT2 is operable to monitor product temperatures and control the refrigeration unit using, for example, “defrost with time or temperature termination.” EX1015, 1.

52. The ACT2 contains “generic inputs and outputs [to] provide flexibility to control items” within predefined refrigeration or HVAC control schemes as well as “items not included” in those predefined schemes. EX1015, 2. The Product Bulletin further discloses that the inputs include low and high temperature sensors, humidity sensors, and pulse sensors (among others), while the outputs include “anti-sweat heaters on freezer doors.” *Id.* Therefore, it was known at least as of the 1999 publication date of the Johnson Controls Product Bulletin to include anti-sweat and internal temperature control with the same controller.

53. Additionally, the ACT2 is capable of logging data from each of the inputs. EX1015, 2–3. The ACT2 provides storage for 500 readings and 20 alarms, such that a “history” of ACT2 data is available to the consumer. EX1015, 3.

54. As shown below, a user can view the status and setup of refrigeration and system parameters via the “ACT2 Controller Front Panel” display. EX1015, 4.

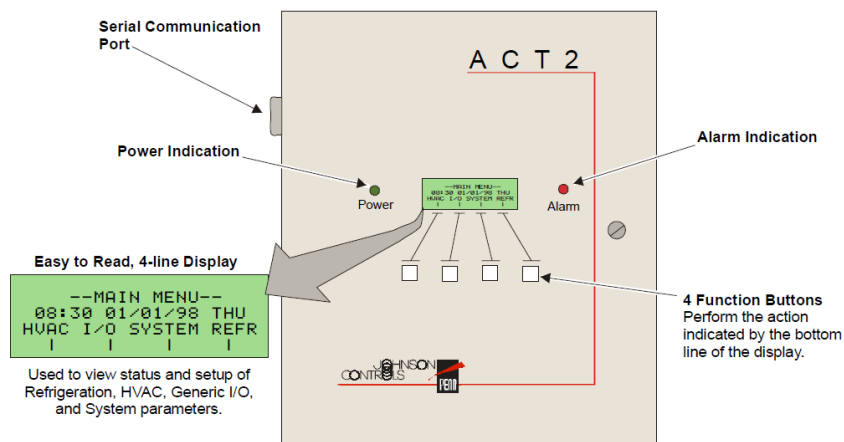


Figure 2: ACT2 Controller Front Panel

55. The controllers in the prior art as of 1999 could communicate data to remote systems. *See* EX1015, 2 (“Maestro software package provides local or remote programming[.]”), 3 (“A single ACT2 controller or a network of controllers can communicate with a remote computer via a modem connection—this allows monitoring of multiple stores from one location...”); *see also* EX1039, 43 (“Microprocessors offer the option of remote control and system operation[.]”).

VII. OVERVIEW OF CONCLUSIONS FORMED

56. This Declaration explains the conclusions that I have formed based on my independent analysis. To summarize those conclusions:

- Based upon my knowledge and experience, and my review of the materials listed above, I believe that Claims **1–2, 14–18** of the '181 patent are obvious in view of Carter (EX1004). *See* Ground 1A at Section IX.
- Based upon my knowledge and experience, and my review of the materials listed above, I believe that Claims **1–7, 14–18** of the '181 patent are obvious in view of Carter (EX1004), Beatenbough (EX1006), and King (EX1005). *See* Ground 1B at Section X.
- Based upon my knowledge and experience, and my review of the materials listed above, I believe that Claims **17–20** of the '181 patent are obvious in view of Carter (EX1004), Beatenbough (EX1006), King (EX1005), and Gatling (EX1007). *See* Ground 1C at Section XI.
- Based upon my knowledge and experience, and my review of the materials listed above, I believe that Claims **1–6** of the '181 patent are obvious in view of Carter (EX1004), Beatenbough (EX1006), and Kotani (EX1008). *See* Ground 1D at Section XII.

- Based upon my knowledge and experience, and my review of the materials listed above, I believe that Claims **8–13** of the '181 patent are obvious in view of Carter (EX1004), Beatenbough (EX1006), and Gatling (EX1007). *See* Ground 1E at Section XIII.

VIII. CLAIM CONSTRUCTION

57. I have been asked to analyze the '181 patent's claims based on interpretations of certain claim terms that use the word “means” as a generic noun followed by a verb that begins the articulation of a functional limitation (e.g., “processing means...for activating”). I have been informed that such terms require not only the recited function in the claim, but also the corresponding structure disclosed in the '181 patent's specification (or equivalents of such disclosed structure). Below, for each of these “means” claim terms, I identify the claimed function and the corresponding structure.

A. “Processing means connected for activating...” (Element [1.c])

58. **Claimed Function:** “[A]ctivating the display case frame/door heater when monitored display case door or frame temperature drops below a preselected set point above a dew point value derived from monitored ambient temperature and relative humidity.”

59. **Corresponding Structure:** A “microprocessor” executing the three-step algorithm of: [1] Discounting frame temperature by a preselected set point; [2] Determining if the discounted frame temperature is below a dew point value derived from ambient temperature and relative humidity; and [3] Turning on a heater relay if the discounted frame temperature is below the dew point value. *See* EX1001, 5:34–50 (discussing microprocessor 53), 8:29–45, 8:63–9:5 (discussing algorithm), Figure 13, Figure 14b.

B. “Housing means for locating...” (Element [1.d])

60. **Claimed Function:** “[L]ocating said sensing units.”

61. **Corresponding Structure:** Here, the corresponding structure for the claimed “means” is set forth in the surrounding claim language. For example, the surrounding claim language makes clear that the “locating” function is performed by a “housing,” which is a term commonly used in the art with an understood structural connotation. The surrounding claim language further specifies that the “housing” includes “structure establishing thermal isolation of said sensing units by minimizing heat transfer contacts between said sensing units and said housing means and locating said temperature sensor and said at least one dew point sensing component amid insulated air pockets formed by said structure of said housing means.” Notably, the surrounding language provides more details regarding the structure of the claimed “means” than about the “locating” function it performs.

62. Alternatively, if it is argued or determined that the structural details in the surrounding claim language are insufficient, the corresponding structure in the '181 patent's specification constitutes: A "base" and a "cover" that, when mated together, establish the claimed insulated air pockets. *See* EX1001, 6:32–7:10, Figures 3–6 (frame/door surface temperature sensor housing 83 including cover 85 and base 87 establishing air pockets 105 and 107), 7:11–62, Figures 7–9 (dew point sensor housing 115 including cover 117 and base 119 establishing air pocket 155), 8:11–28, Figures 10–12 (a single housing 115 "utilized to house both sensors").

C. "Processing means...connected for activating...for deactivating...and for storing" (Elements [8.e.i]–[8.e.ii])

63. Claimed Function:

- "[A]ctivating the display case frame/door heater when monitored display case door or frame temperature drops below a first preselected set point above a dew point value derived from monitored ambient temperature and relative humidity";
- "[D]eactivating the frame/door heater when monitored display case door or frame temperature rises above a second preselected set point above said dew point value"; and
- "[S]toring data related to readings at said sensing units and operation of the frame/door heater."

64. **Corresponding Structure:**

- **Activating Structure:** *See supra* at §VIII.A (discussing materially the same claim language).
- **Deactivating Structure:** A “microprocessor” executing the three-step algorithm of: [1] Discounting frame temperature by a preselected set point; [2] Determining if the discounted frame temperature is above a dew point value derived from ambient temperature and relative humidity; and [3] Turning off a heater relay if the discounted frame temperature is above the dew point value. *See* EX1001, 5:34–50 (discussing microprocessor 53), 8:29–45, 8:63–9:5 (discussing algorithm), Figure 13, Figure 14b (similar).
- **Storing Structure:** A “processor” or “microprocessor.” *See* EX1001, 2:59–63 (“The processor stores data related to readings at the sensing units and operation of the frame/door heater...”), 5:34–45 (“microprocessor 53”), 8:29–45, 8:63–9:11 (“Microprocessor 53 looks up the dew point value from a stored table...”), Figure 13, Figure 14b.

D. “Housing means for locating...” (Element [13])

65. *See supra* at §VIII.B (discussing materially the same claim language).

E. “Control means for receiving data...and [for] activating and deactivating” (Element [14.c])

66. Claimed Function:

- “[R]eceiving data from said sensing units and utilizing monitored case frame temperature, ambient air temperature and relative humidity to anticipate formation of condensation at the display case”; and
- [A]ctivating and deactivating the frame/door heater responsive thereto.”

67. Corresponding Structure:

- **Receiving Structure:** A “microprocessor.” *See* EX1001, 5:34–45 (explaining that “microprocessor 53” includes “frame temperature sensor and dew point sensor connectors”), 8:29–45 (“Sensors 33 and 35 inputs are...input to the central processing unit microprocessor 53...”), 8:63–9:11 (explaining that microprocessor 53 uses “[i]nput from monitored dew point sensor 37 and frame temperature sensor 35”), Figure 13, Figure 14b.
- **Activating Structure:** *See supra* at §VIII.A (articulating three-step heater activation algorithm).
- **Deactivating Structure:** *See supra* at §VIII.C (articulating three-step heater deactivation algorithm).

**F. “Means for thermally isolating said dew point sensing unit...”
(Element [15])**

68. **Claimed Function:** “[T]hermally isolating said dew point sensing unit from variations in temperature of the display case frame or display case door.”

69. **Corresponding Structure:** A “housing” having a base and a cover that, when mated together, establish an air pocket around the dew point sensing unit. *See* EX1001, 7:11–62, Figures 7–9 (dew point sensor housing 115 including cover 117 and base 119 establishing air pocket 155), 8:11–28, Figures 10–12 (a single housing 115 “utilized to house both sensors”); *see also supra* §VIII.B.

**G. “Means for thermally isolating said temperature sensing unit...”
(Element [16])**

70. **Claimed Function:** “[T]hermally isolating said temperature sensing unit from variations in temperature of ambient air.”

71. **Corresponding Structure:** A “housing” having a base and a cover that, when mated together, establish an air pocket around the temperature sensing unit. *See* EX1001, 6:32–7:10, Figures 3–6 (frame/door surface temperature sensor housing 83 including cover 85 and base 87 establishing air pockets 105 and 107), Figures 10–12 (a single housing 115 “utilized to house both sensors”); *see also supra* §VIII.B.

H. “Data storing means...for storing data...” (Element [18])

72. **Claimed Function:** “[S]toring data related to readings at said sensing units and operation of the frame/door heater.”

73. **Corresponding Structure:** *See supra* at §VIII.C (discussing materially the same claim language).

I. “Means for wirelessly accessing...” (Element [19])

74. **Claimed Function:** “[W]irelessly accessing stored data at said data storing means.”

75. **Corresponding Structure:** A “communication board/transmitter/receiver.” *See* EX1001, 5:33–6:8, 9:10–14.

IX. GROUND 1A: Claims 1–2, 14–18 Are Obvious Over Carter

A. Carter (EX1004)

76. Carter’s disclosure, like the ’181 patent, relates to the “control of heating functions” in refrigeration or freezer equipment for the purpose of “prevent[ing] condensation from forming.” EX1004 (Carter), 1:7–11, Abstract. As shown in Figure 1 (below), Carter’s refrigeration equipment 10 includes “a door having an installed door latch assembly 14” in addition to “a control unit 28, a switching unit 30, a sensor assembly unit 32, and a heating unit 34.” EX1004 (Carter), 3:54–67, 4:36–43.

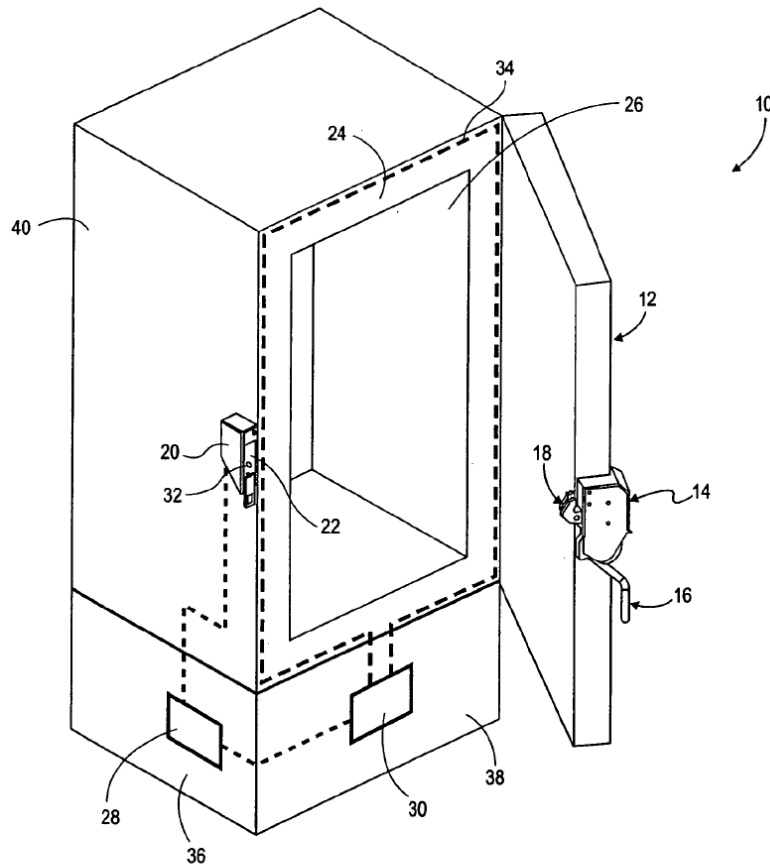


FIG. 1

EX1004 (Carter), Figure 1

77. As the '181 patent concedes was known, Carter teaches that readings from the sensor assembly unit are used to compare a surface temperature of the refrigeration equipment to a dew point value and “determine whether it is necessary to supply supplemental heat” to prevent condensation. EX1004 (Carter), 5:15–20, 7:7–9; EX1001 ('181 patent), 1:41–53. For example, the control unit 28 receives information from the sensor assembly unit 32 and determines whether “a set condition approached or reached a state which would promote surface condensation.” EX1004 (Carter), 4:44–55. If the set condition exists, the control

unit 28 activates the heating unit 34, thereby heating the area on and around the sealing surface 24. EX1004 (Carter), 4:44–61. As below in Figure 3, in one embodiment, the set condition occurs when the measured “cabinet surface temperature is less than or equal to the dew point plus 2 degrees C.” EX1004 (Carter), 5:31–54.

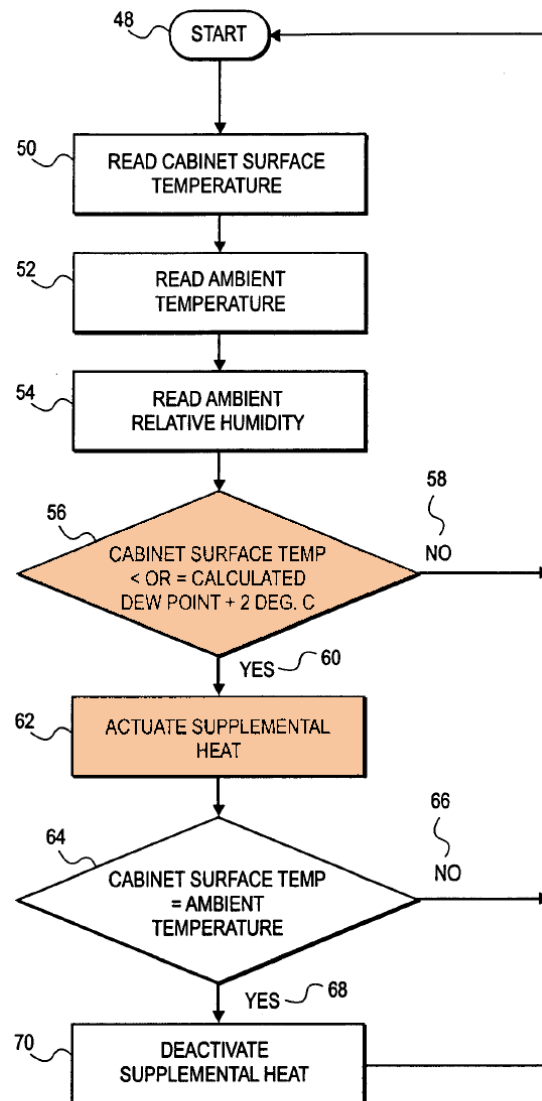


FIG. 3

EX1004 (Carter), Figure 3

78. As shown below in Figure 2, Carter's "sensor assembly unit 32 includes a surface temperature sensor, an ambient temperature sensor, and an ambient relative humidity sensor." EX1004 (Carter), 5:1–20. "[T]he sensor assembly unit 32 is integrated within the interior portion 22 of the door latch cover assembly 20," which adds "protection from outside elements" and, like the '181 patent, helps "localize the measurements of the sensor assembly unit 32 to generally produce more accurate temperature readings." EX1004 (Carter), 5:1–20.

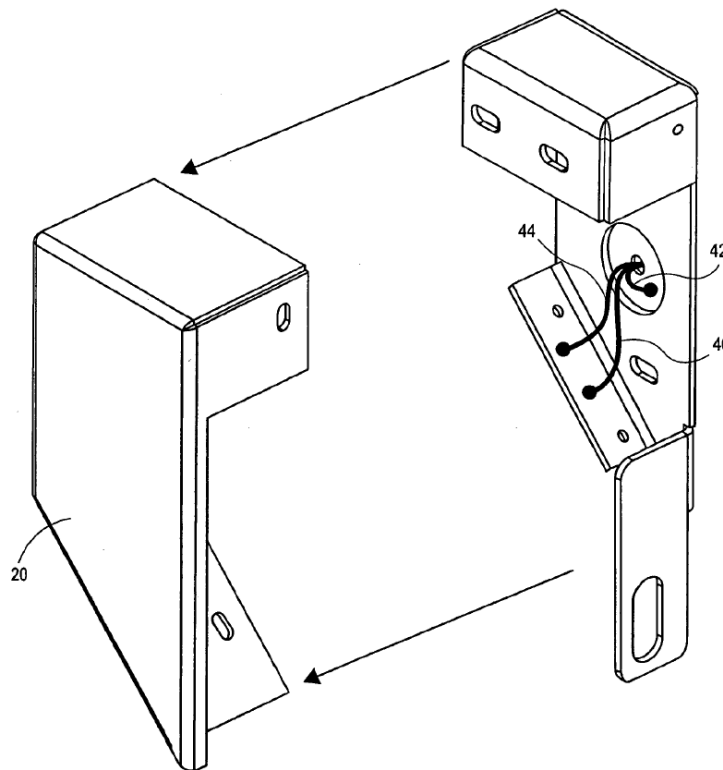


FIG. 2

EX1004 (Carter), Figure 2

B. Claim Element Analysis

1. Claim 1

- (i) ***Element [1.pre]: Condensation control apparatus for a refrigerated display case having at least one door, a frame and at least one frame/door heater, said apparatus comprising:***

79. Carter describes an “***apparatus*** that provides supplemental heat from a heat source based upon the operating environment of a ***refrigerat[or]*** or freezer,” where “[t]he supplemental heat is automatically ***controlled*** to provide heating to a sealing area to prevent ***condensation*** from forming.” EX1004 (Carter), Abstract; *see also* 1:1–11, 2:22–31, 2:35–43, 3:40–53, 4:44–55, 6:30–49.

80. Carter’s Figure 1 (below) illustrates exemplary “***refrigerator*** or freezer equipment 10” in the form of a ***case*** with “a ***door*** 12 having an installed door latch assembly 14 attached thereto” and “a sealing surface 24...[that] serve[s] to retain and maintain an operating temperature within a compartment chamber 26.” EX1004 (Carter), 3:54–4:2. The sealing surface 24 is part of a ***frame*** against which the door 12 seals when held shut by the door latch assembly 14. EX1004 (Carter), 3:54–4:2. A (***frame/door***) “***heating*** unit 34” “traverses” this portion of the frame, “providing supplement[al] heat generally to the sealing surface area” of both the frame and door, such that “the effects of condensation can be...prevented.” EX1004 (Carter), 4:36–67.

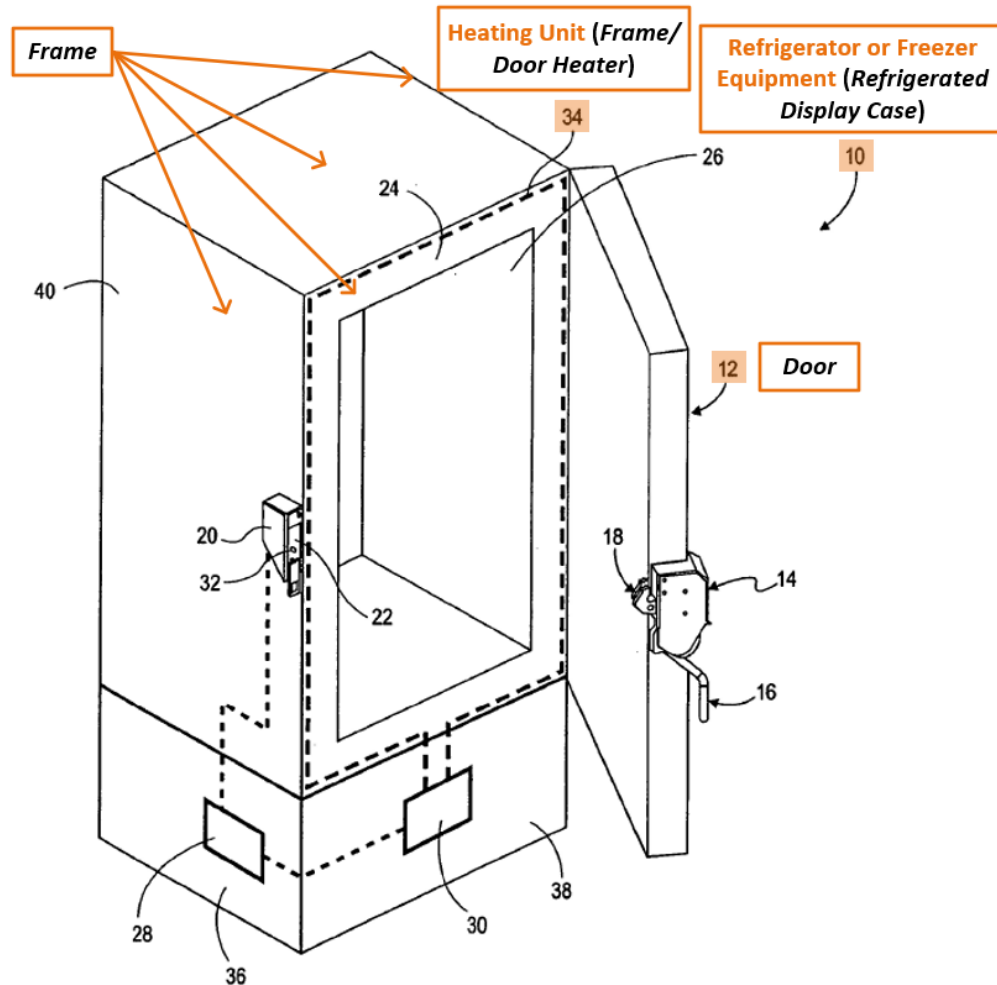


FIG. 1

EX1004 (Carter), Figure 1 (annotated)

81. Though Carter does not expressly teach putting the contents within the *refrigerated case* on *display*, a POSITA would have been motivated to apply Carter's *apparatus* to the well-known use case of *refrigerated display cases* that store retail food items in an environment where “undesirable condensation can occur.” EX1004, 1:15–2:32; *see supra* §VI.B.1 (explaining that condensation control systems were commonly employed on refrigerated display cases used in

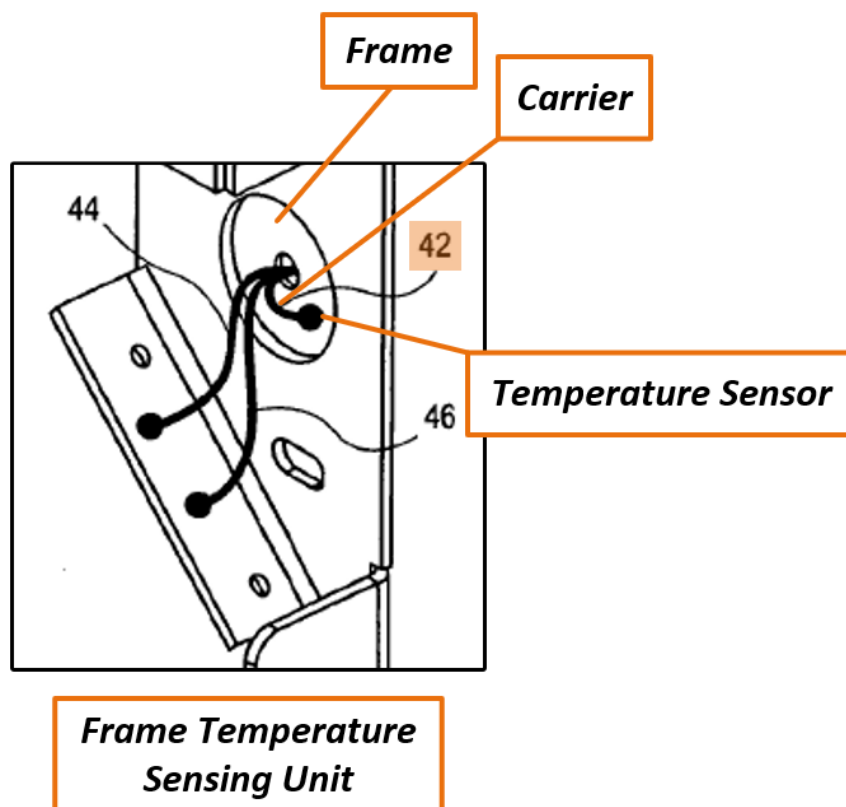
retail food stores). For one, the POSITA would have appreciated the fundamental similarities between the refrigerated case Carter describes and the kinds of refrigerated display cases commonly found in retail stores. Both are designed to maintain perishables at a prescribed low temperature to prevent spoilage. For example, Carter explains that his refrigerated case can be used for “housing specimens requiring subjection to certain operating temperatures for one of a variety of reasons,” such as “to ensure that it doesn’t spoil.” EX1004 (Carter), 4:3–12. Carter further explains that allowing “condensation [to] develop and/or freeze along any freezer/refrigeration sealing areas such as a gasket” can cause “the gasket...los[ing] its ability to remain flexible in order to seal surfaces completely,” a result that increases the risk of multiple complications—e.g., “an inability of the freezer/refrigeration equipment to maintain a prescribed operating temperature” and “a loss of energy and time...in attempting to generate and maintain an operating temperature.” EX1004, 1:45–62. Preventing sealing failures caused by condensation, and the complications they cause, is as important in the retail food industry as any other. Accordingly, the POSITA would have recognized that implementing Carter’s teachings in the context of a refrigerated display case would have provided the same predictable advantages of improved operational effectiveness and efficiency that Carter described. In short, just as *condensation control apparatus* were desirable in the context of refrigerated cases for specimens,

they were likewise sought by those of skill in the art for refrigerated cases used to display food items. *See also supra* §VI.B.1 (discussing the background of condensation control systems in refrigerated display cases).

(ii) ***Element [1.a]: a frame temperature sensing unit adapted for monitoring temperature of one of the display case door or display case frame and including a carrier having a temperature sensor thereat;***

82. Carter describes a “sensor assembly unit 32 [that] is composed of a surface ***temperature sensor*** 42, an ambient temperature sensor 44, and an ambient relative humidity sensor 46.” EX1004 (Carter), 5:1–20; *see also* 4:36–43. Using surface ***temperature sensor*** 42, sensor assembly unit 32 ***monitors*** a “surface ***temperature*** of the refrigerator or freezer equipment 10” (***display case***). EX1004 (Carter), 5:31–40, Figure 3; *see also* 3:42–46 (“mo[nitor]ing external surface temperature”), 4:17–22 (similar).

83. A POSITA would have known that a surface temperature sensor, such as Carter describes, is designed to provide analog or digital output corresponding to the temperature of the surface against which the sensor is placed. As shown below in Figure 2, Carter’s illustrated embodiment portrays surface temperature sensor 42 placed against—and, thus, ***monitoring the temperature of***—the display case ***frame***.



EX1004 (Carter), Figure 2 (annotated)

84. Carter’s Figure 2 (above) depicts surface temperature sensor 42 as a *unit* comprised of a sensing probe at the end of a wire/cable. I have been informed that Patent Owner has taken a broad interpretation of the claim language reading: *a carrier having a temperature sensor thereat*. Specifically, though I am not involved in the co-pending district court litigation between the parties, I have been informed that Patent Owner’s position in asserting Claim 1 against Petitioner is that “[t]he carrier is the wire” and “[t]he temperature sensor is [at] the end of the wire.” If Claim 1 is interpreted as broadly as Patent Owner suggests—where the claimed *carrier* can be said to constitute a wire or cable—it clearly follows that Carter

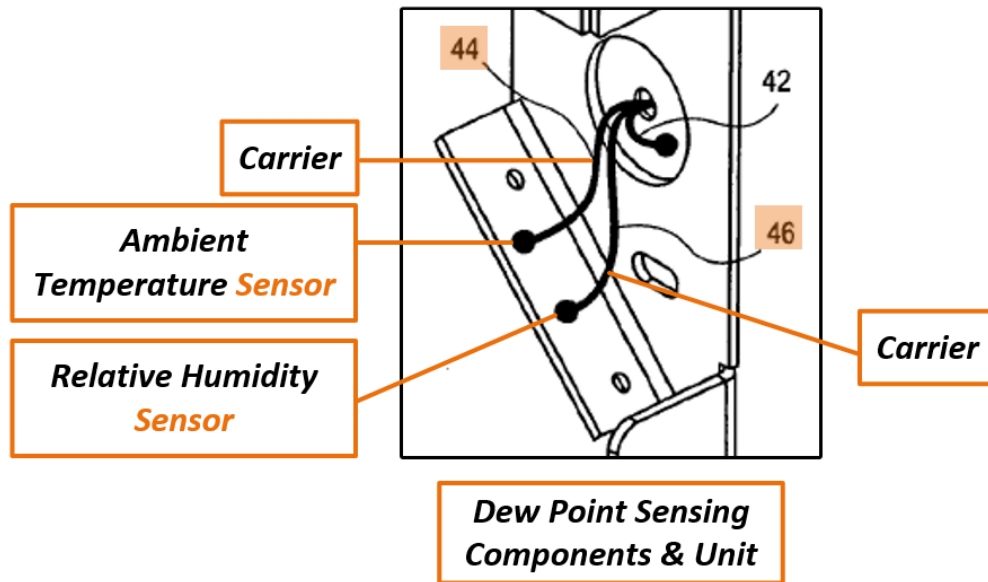
teachings regarding surface temperature sensor 42 render obvious *a carrier having a temperature sensor thereat*.

- (iii) *Element [1.b]: a dew point sensing unit adapted for monitoring ambient air temperature and relative humidity outside of the display case and including a carrier having at least one dew point sensing component thereat;*

85. Carter describes a “sensor assembly unit 32 [that] is composed of a surface temperature sensor 42, an *ambient temperature* sensor 44, and an ambient *relative humidity* sensor 46.” EX1004 (Carter), 5:1–20. Using sensors 44 and 46, sensor assembly unit 32 *monitors* “the *ambient temperature* and...the ambient *relative humidity*” *outside of the display case*. EX1004 (Carter), 5:31–40; *see also* 1:5–11 (providing supplemental heat “based upon the operating environment of refrigeration or freezer equipment”), 1:15–28, 2:22–32. These ambient temperature and relative humidity readings from sensors 44 and 46 are used to “calculate[] *dew point*.” EX1004 (Carter), 2:44–67, 5:31–40, 6:30–40, 7:1–9 (“calculating a dew point from the first ambient temperature measurement and the ambient relative humidity”), Figure 3.

86. The ’181 patent’s specification confirms my opinion that Carter’s ambient temperature sensor 44 and relative humidity sensor 46 are constituent *components* of a *dew point sensing unit*. Like Carter, the ’181 patent explains that its controller can achieve the design goal of activating the heaters “just above dew

point” using “any known sensor(s)...for monitoring ambient air temperature (for example, thermistors...) and relative humidity (capacitive polymer or thin film type, for example...)” EX1001 (’181 patent), 8:55–63. As the ’181 patent confirms, such sensors are not only “known” but also “commercially available.” *Id.*



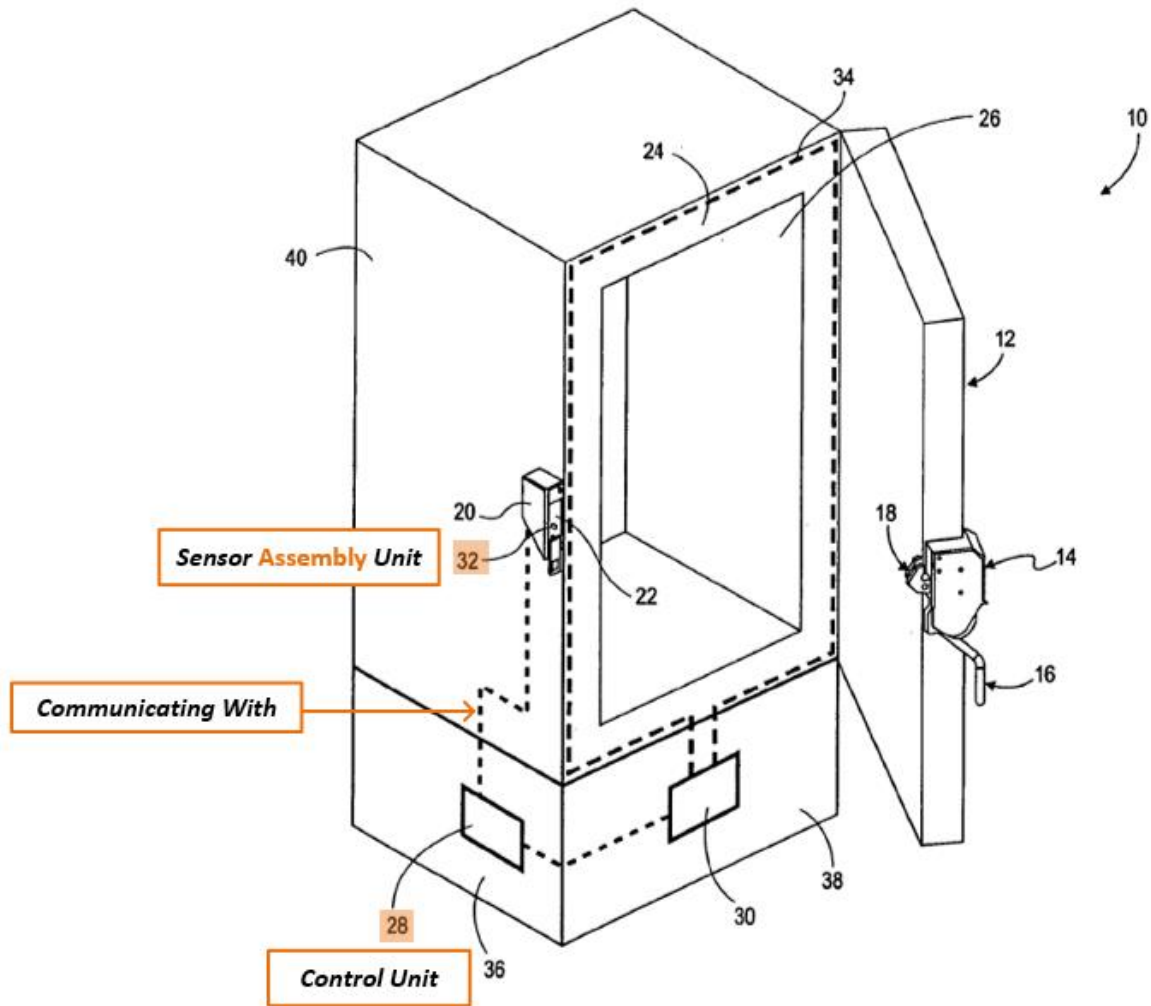
EX1004 (Carter), Figure 2 (annotated)

87. Carter’s Figure 2 depicts each of ambient temperature sensor 44 and relative humidity sensor 46 as part of a ***unit*** comprised of sensing probes at the end of flexible wires/cables. As I explained above at Element [1.b], counsel for Petitioner informed me that Patent Owner has taken a position that the claimed ***carrier*** can be said to constitute a wire or cable. Under such a broad interpretation, it clearly follows that Carter teachings regarding ambient temperature sensor 44 and relative humidity sensor 46 render obvious ***a carrier having at least one dew point sensing component thereat.***

- (iv) ***Element [1.c]: a control unit communicating with said sensing units and including processing means connected for activating the display case frame/door heater when monitored display case door or frame temperature drops below a preselected set point above a dew point value derived from monitored ambient temperature and relative humidity; and***

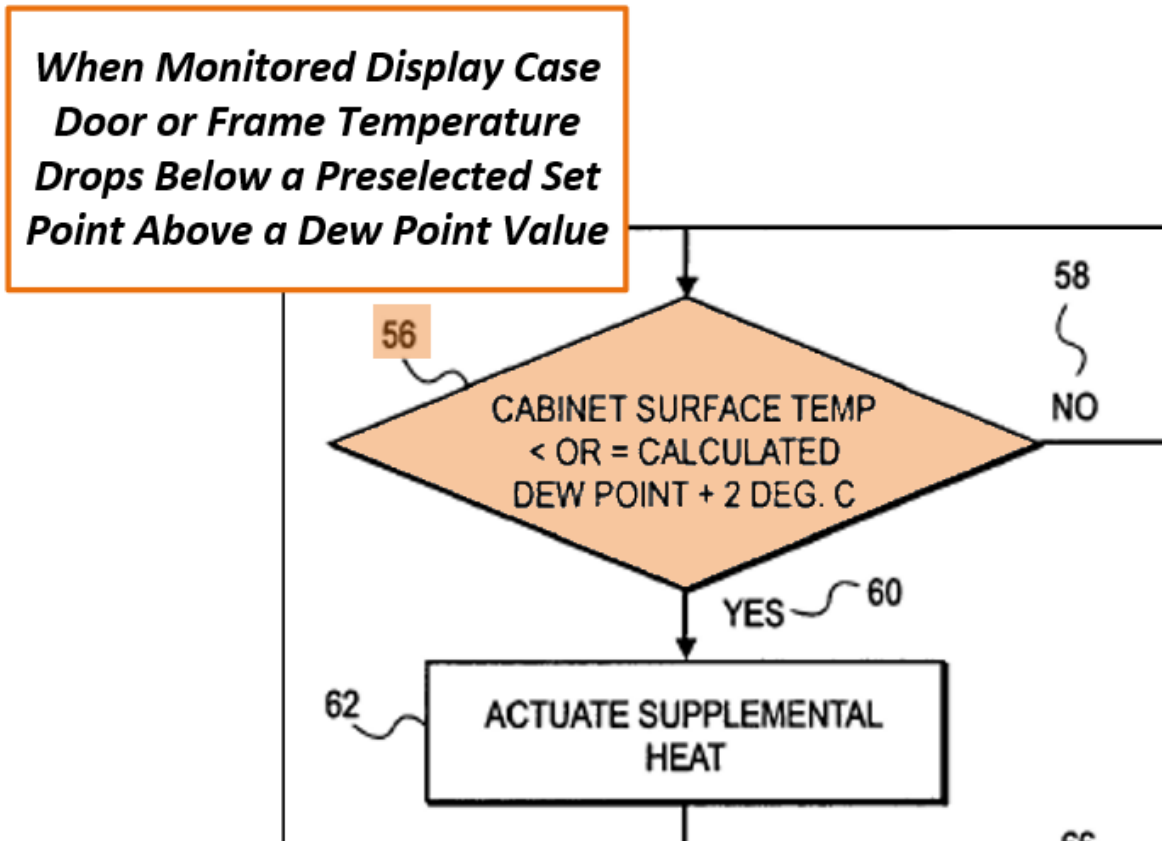
88. Referencing Figure 1 (below), Carter discloses a condensation control apparatus including “a ***control unit*** 28, a switching unit 30, [and] a ***sensor assembly unit*** 32.”⁴ EX1004 (Carter), 4:36–55, Figure 1. “The control unit 28 is generally responsible for receiving information from”—and, thus, ***communicating with***—“the sensor assembly unit 32 and for [determining] whether a set condition exists that would promote surface condensation.” *Id.* The dotted lines in Figure 1 between control unit 28 and sensor assembly unit 32 indicate that these components are in ***communication with*** one another. As a POSITA would have known, lines of this sort are a conventional illustration technique for depicting an electronic pathway in a diagram like Carter’s Figure 1. Carter’s accompanying text clarifies that the pathway is used for communicating “information” between the control unit 28 and the sensor assembly unit 32.

⁴ See Elements [1.a]–[1.b], mapping sensor assembly unit 32 to the ***sensing units***.



EX1004 (Carter), Figure 1 (annotated)

89. As shown below, Carter goes on to teach a “*process*” where this “set condition” corresponds to *when* “the cabinet surface temperature” (*monitored display case door or frame temperature*, per Element [1.a]) “is less than” (*drops below*) “the *dew point* plus 2 degrees C.” EX1004 (Carter), 5:21–54, Figure 3.

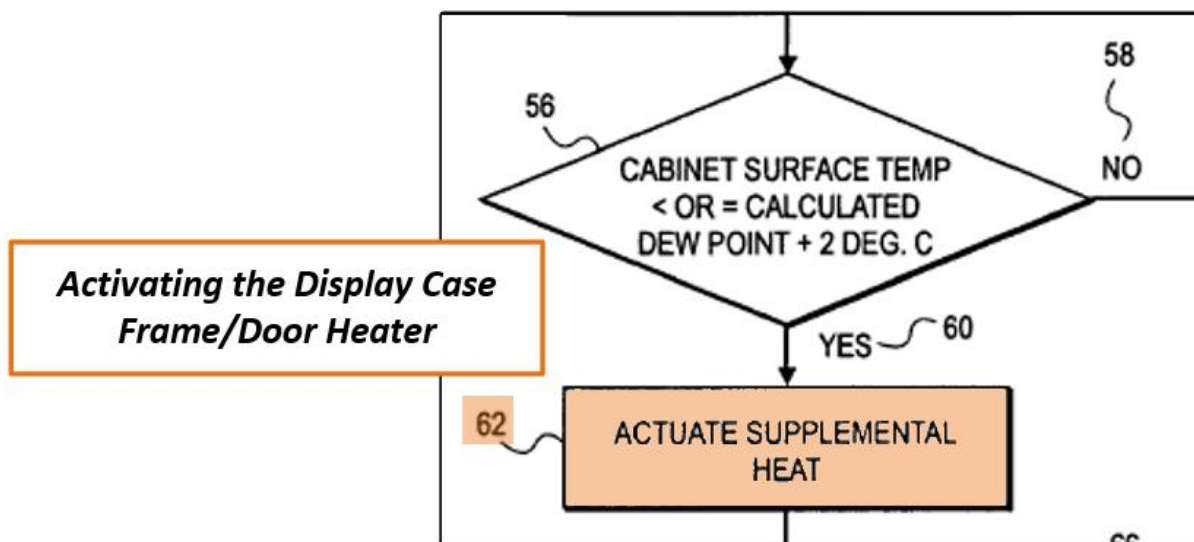


EX1004 (Carter), Figure 3 (excerpted-annotated)

90. Understanding the well-established principle that condensation begins when a cold surface reaches dew point, a POSITA would have appreciated that Carter's "2 degrees C" is a value that serves as a buffer, allowing the control unit to predict the onset of condensation shortly before it occurs by detecting a predetermined "set condition." EX1004 (Carter), 5:21–54, Figure 3. Notably, Carter describes "2 degrees C" as a "constant" point value, rather than a function or a dynamic/floating variable. As would have been clear to the POSITA, a "constant" like Carter's "2 degrees C" that plays a key role in the control algorithm would have

been selected (e.g., by a technician or manufacturer) before operating the refrigeration unit, rather than being determined on the fly. Thus, from a POSITA's perspective Carter's "2 degrees C" *point* value is a "constant" *selected* for determining whether the likely condensation "condition exists" and, thus, teaches or at least renders obvious the claimed *preselected set point*.

91. Carter further describes that when a "positive determination is made" regarding the likely condensation condition, "the control unit 28 enacts the switching unit 30 to *activate* supplemental heat 62 to the sealing surface 24 of the refrigerator or freezer equipment via the heating unit 34" (*display case frame/door heater*, per Element [1.pre]). EX1004 (Carter), 5:49–54; *see also* 2:4–32, 3:40–53.



EX1004 (Carter), Figure 3 (excerpted-annotated)

92. Based on the reasoning provided above in ¶¶89–91, my conclusion is that Carter teaches or renders obvious the recited function of *activating the display*

case frame/door heater when monitored display case door or frame temperature drops below a preselected set point above a dew point value derived from monitored ambient temperature and relative humidity.

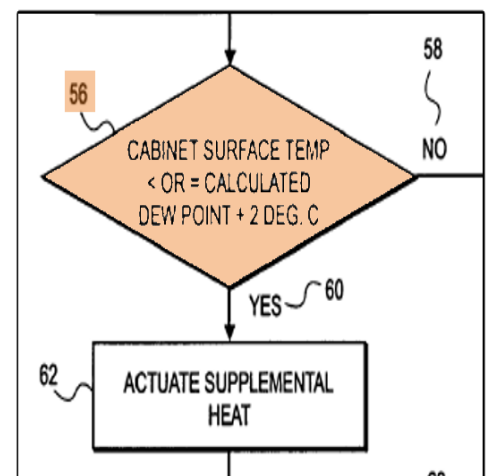
93. Next, I will address Carter’s teachings with respect to the ’181 patent’s corresponding structure for the claimed *processing means*, which, as I outlined above at §VIII.A, includes a microprocessor executing the three-step algorithm of:

Step 1. Discounting frame temperature by a preselected set point;

Step 2. Determining if the discounted frame temperature is below a dew point value derived from ambient temperature and relative humidity; and

Step 3. Turning on a heater relay if the discounted frame temperature is below the dew point value.

94. Consistent with my discussion above, Carter’s algorithm shown in the flow chart of Figure 3 (at right) compares “CABINET SURFACE TEMP” (*frame temperature*, per Element [1.a]) to a “CALCULATED *DEW POINT*” value using a less-than inequality operator and a *preselected set point* of “2 DEG. C.” EX1004 (Carter), 5:21–54.



95. Carter's inequality expression increases the calculated *dew point* value by the *preselected set point*, which is a mathematically equivalent operation to the '181 patent's approach of discounting the *frame temperature* by the *preselected set point*. The point of distinction between them boils down to which side of the less-than inequality operator the set point resides on. In Carter's algorithm, the set point is on the dew point side, resulting in an arithmetic sum operation that adds the set point to the dew point value. In the '181 patent's algorithm, the set point is on the frame temperature side, resulting in an arithmetic difference operation that subtracts the set point from the frame temperature. This distinction is not a material one. Again, the two algorithms are mathematically equivalent in this respect.

96. Moreover, this aspect of Carter's algorithm and the '181 patent's algorithm are patently obvious variants when viewed through the lens of a POSITA. While studying Carter's Figure 3, the POSITA would have immediately understood that Step 56 could be performed using the illustrated arithmetic sum or its inverse, an arithmetic difference. Understanding that these two mathematically equivalent options produce the same result in substantially the same way, the POSITA would have faced a binary design choice between them, with each being equally obvious.

97. Additionally, and like the '181 patent's algorithm, when the less-than inequality between *frame temperature* and *dew point* is true, Carter's process "ACTUATE[S] SUPPLEMENTAL HEAT"—i.e., "the control unit 28 enacts the

switching unit 30 to activate supplemental heat 62...via the heating unit 34,” such as an “electrical heater.” EX1004 (Carter), 5:48–54, Figure 3; *see also* 2:35–43 (“a switching unit that switches the heating unit on and/or off”). A POSITA would have understood Carter’s disclosure of a “switching unit” that activates an “electrical heater” to teach, suggest, or render obvious the notion of turning on a relay, as disclosed in the ’181 patent. As was well known at the time of the ’181 patent in 2005, “a relay is an electrically operated switch.” EX1025, 2. Relays were commonly used to activate (switch on) and deactivate (switch off) electrical components, such as Carter’s “electrical heaters.” EX1004 (Carter), 4:28–31, 4:56–61, 6:8–18; *see also* EX1025, 2–3 (“Relays have been in use for over a hundred years now”). Given their widespread use, relays could be easily obtained as an off-the-shelf component, were commercially available in a variety of different sizes and design specifications, and were relatively inexpensive. Accordingly, upon reading Carter’s disclosure, the POSITA exercising mere common sense and ordinary creativity would have naturally thought to implement Carter’s “switching unit” as a relay.

98. Further still, Carter teaches that the above-discussed process algorithm is orchestrated by a singular “control unit 28” that is “mounted...along the refrigerator or freezer equipment at a lower side surface.” EX1004 (Carter), 4:36–55. From a POSITA’s perspective, Carter’s disclosure of a locally mounted control

unit that performs a task-specific algorithm (*see, e.g.*, Figure 3) teaches, suggests, or at least renders obvious the ubiquitous structure of a microprocessor, as disclosed by the '181 patent. *See* EX1001 ('181 patent), 8:42–45, 8:63–9:9.

99. By the time of the '181 patent in 2005, most electronic devices and systems like Carter's with automated functionality employed microprocessors—i.e., computer processors having the arithmetic, logic, and control circuitry on a single integrated circuit (or a small number of integrated circuits). *See* EX1033, 1 (describing the components of a microprocessor), 8 (describing known microprocessor applications); EX1039, 24 (explaining that the refrigeration industry has “migrated...toward the use of specialized microprocessors...for unit and system control”), 25 (“All control systems consistent of four main building blocks,” including “Controller(s)—Microprocessor with control software...”); EX1004 (Carter) 2:25–27 (expressing an objective to “provide automatic control of the supplemental heat provided to the freezer/refrigeration equipment”), 3:42–51, 4:13–25, 4:56–61, 6:57–58 (“the control unit operates automatically”). It was discovered decades beforehand that combining the functions of a central processing unit on a single chip yields significant advantages in terms of cost, size, and reliability. EX1033, 4–5 (describing the long-known benefits of microprocessors), 8 (“unmatched performance to cost ratio”). Microprocessors therefore became the predominant type of modern computer processor, which were easy to obtain as off-

the-shelf/catalog components by 2005. EX1033, 1, 8. Accordingly, when reading Carter’s disclosure of a “control unit” that executes a multi-step algorithm, the POSITA would have naturally thought to implement such teachings using a conventional microprocessor.

100. Based on the reasoning provided above in ¶¶93–99, my conclusion is that Carter teaches, suggests, or renders obvious the ’181 patent’s microprocessor-executed, three-step algorithm that constitutes the structure corresponding to the claimed *activating* function of the *processing means*. To the extent there are any distinctions between that which a POSITA would have gleaned from Carter and the ’181 patent, such distinctions do not constitute a material difference. That is because Carter’s overall algorithm performs the ’181 patent’s claimed *activating* function in the same or substantially the same way—i.e., comparing frame temperature to dew point using a buffer value—to achieve the same or substantially the same result—i.e., heater activation responsive to sensed conditions likely to produce condensation.

101. Lastly, I have been asked to consider whether Element [1.c] (and Claim 1 as a whole) would still be obvious even under a narrower formulation of the corresponding structure that incorporates implementation details from the ’181 patent’s disclosure that are not necessary to perform the claimed *activating* function—e.g., averaging multiple sensor readings, or using a lookup table to retrieve stored dew point values. See EX1001 (’181 patent), 8:63–9:3, Figure 14b.

102. Having considered this hypothetical scenario, I have determined that my conclusions on obviousness would still hold. Maintaining a running average of sensor readings and/or dew point values is a simple statistical operation that is easily performed by a microprocessor receiving information from the requisite temperature and humidity sensors (a system configuration that a POSITA would have gleaned from Carter). Moreover, averaging was a known technique for obtaining the predictable benefit of mitigating the effect of random error and measurement uncertainty, which is inherent in all sensor measurements. EX1026, 21 (“It is a mathematical fact that the arithmetic average...is the best representation of the given set”), (“the best estimate of the true value of the population mean μ at a given input value is the average $\bar{X}$ of the available measurements”). This technique was well-documented in both historical and contemporaneous texts. *Id.* Using a lookup table, rather than an on-the-fly calculation, for converting ambient temperature and relative humidity to a dew point value was likewise known and nothing more than a simple design choice for a POSITA based on the resources available in a given implementation. *See* EX1029, [0074] (“Thereafter, the CPU computes or determines through direct calculation [], by accessing an internal look-up table or by sequentially accessing a look-up table and interpolating or extrapolating and calculation, the dew-point temperature of the ambient space steam partial pressure.”). For example, an on-the-fly calculation may require comparatively more

processing capacity, while a lookup table may require comparatively more data storage capacity. These sorts of implementation details are obvious. From a POSITA's perspective, they do not materially change the way and result of the '181 patent's algorithm (or Carter's).

- (v) ***Element [1.d]: housing means for locating said sensing units including structure establishing thermal isolation of said sensing units by minimizing heat transfer contacts between said sensing units and said housing means and locating said temperature sensor and said at least one dew point sensing component amid insulated air pockets formed by said structure of said housing means.***

103. Carter explains that “the sensor assembly unit 32”—including surface *temperature sensor* 42 (of the *frame temperature sensing unit*, per Element [1.a]), ambient temperature sensor 44, and relative humidity sensor 46 (*components* of the *dew point sensing unit*, per Element [1.b])—“is integrated within the interior portion 22 of the door latch cover assembly 20.” EX1004 (Carter), 5:1–20, Figures 1–2; *see also* 6:50–56. A *housing for locating the sensing units*, Carter's door latch cover assembly provides “added protection from outside elements” and “helps localize the measurements...to generally produce more accurate temperature readings.” *Id.*

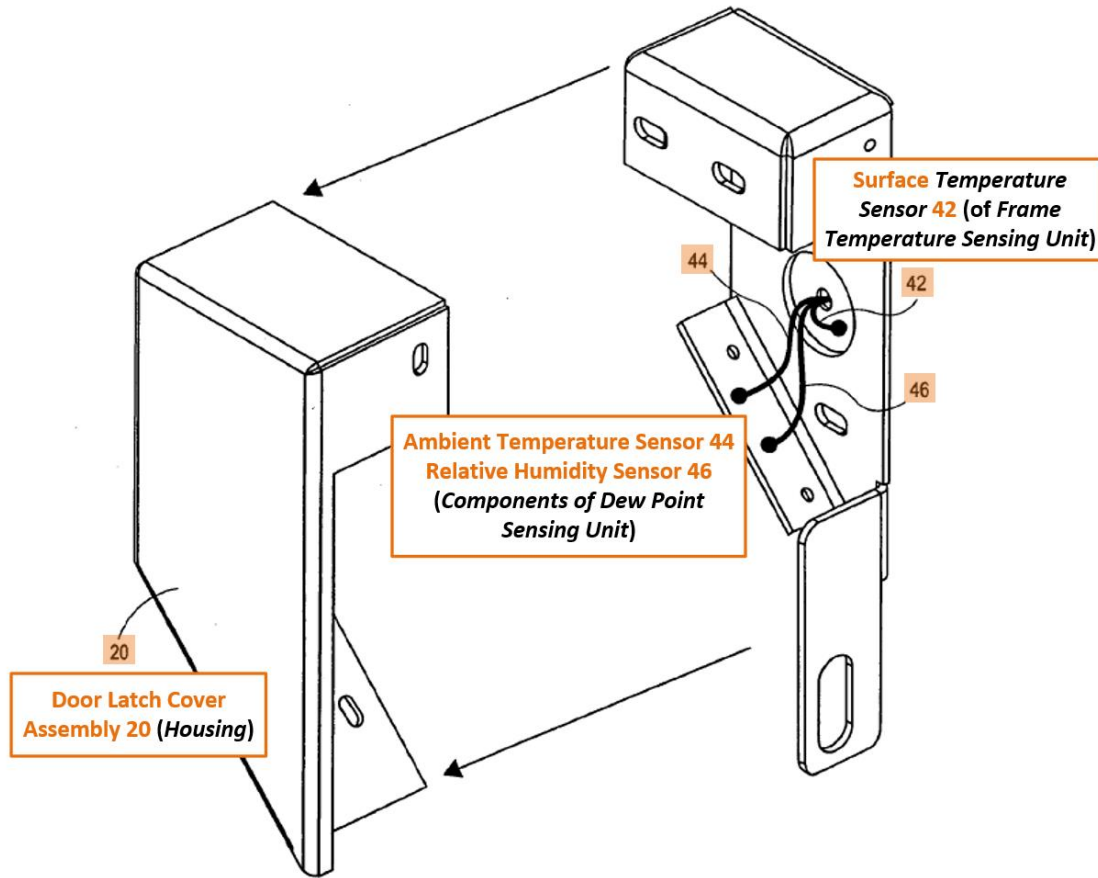


FIG. 2

EX1004 (Carter), Figure 2 (annotated)

104. In addition to *housing* these *sensing units*, it would have been apparent or obvious to a POSITA that Carter's door latch cover assembly also *includes* the claimed *structure establishing thermal isolation of the sensing units by minimizing heat transfer contacts between said sensing units and said housing means and locating said temperature sensor and said at least one dew point sensing component amid insulated air pockets formed by said structure of said housing means*. For clarity, I will use subheadings to organize the remainder of my detailed

analysis regarding a POSITA's understandings gleaned from Carter and the claim language of Element [1.d].

*minimizing heat transfer contacts between
said sensing units and said housing means*

105. For at least the following three reasons (taken individually or collectively), it would have been apparent or obvious to a POSITA reading Carter's disclosure that the *structure* of the door latch cover assembly (*housing*) has *minimized heat transfer contacts* with the *sensing units*.

106. First, Carter suggests as much by emphasizing that the design of the door latch assembly makes the sensor readings "more accurate." EX1004 (Carter), 5:12–15. As a POSITA would have known, the accuracy of humidity and temperature readings is diminished by inadvertent heat transfer—i.e., heat transfer between the sensing elements and a source other than the subject of the measurement. EX1020, 6 ("The relative humidity of a gas strongly depends on its temperature. It is therefore essential to keep humidity sensors at the same temperature as the air of which the relative humidity is to be measured."); *see also supra* §VI.B.2. Here, where the subjects of the measurement are the surface of the refrigerated case and the ambient air, achieving Carter's goal of "more accurate" sensor readings would naturally entail *minimizing heat transfer contacts between*

the sensing units and other heat sources/sinks, including the door latch cover assembly (*housing*).

107. Second, even without Carter’s teaching to promote sensor accuracy, doing so was a known design goal that a POSITA would have sought to achieve in the normal course of pursuing a control system like Carter’s that relies on sensor readings to operate heating elements in a manner that prevents condensation. As the POSITA would have known, the effectiveness of a “control unit [that] operates automatically,” (EX1004 (Carter) 6:57–58), is affected by the accuracy of the sensor measurements on which it depends. EX1027, 2 (“The point here is that you cannot control a variable more accurately than you can measure it. Therefore, measurement is fundamental to control.”). When considering Carter’s automated system—a system designed to prevent condensation effectively and efficiently by activating electrical heaters only when sensed conditions are ripe—the POSITA would have appreciated the importance of sensor accuracy. Inaccurate sensor readings would cause the control unit to activate the heaters prematurely, which would waste energy, or belatedly, which would allow condensation to form. Neither result would be satisfactory to the POSITA. As a result, motivated by the benefit of promoting sensor accuracy, the POSITA would have employed the known technique of *minimizing heat transfer contacts between the sensing units and their housing enclosure*.

108. Third, Carter's Figures 1–2 (above) illustrate an arrangement where there is *minimal* (if any) *heat transfer contact between the sensing units and* the door latch cover assembly (*housing*). As these figures show, the *sensing units* reside at the ends of wires that extend through an aperture in a wall of the *housing* in a manner that indicates a lack of *heat transfer contact* between the sensing units and the housing. Carter's corresponding description supports this understanding of Figures 1–2. Notably, Carter only states that the components of “the sensor assembly unit 32 [are] integrated within the interior portion 22 of the door latch cover assembly 20” (*housing*) and never says or implies that these components *contact* the housing. EX1004 (Carter), 5:1–20. Here, the absence of disclosure from Carter regarding contact between the sensing units and the housing would be interpreted by a POSITA as indicative of the fact that no such contact exists. The POSITA would have known that heat transfer contact between the housing and the sensing units would introduce a detrimental bias in the sensor readings. *See supra* §VI.B.2. For example, the temperature readings would partially reflect the temperature of the housing, rather than the temperature of the frame and the ambient air. Accordingly, a POSITA would have expected minimal heat transfer contact between the sensing units and the housing, and Carter's figures and written description confirm this understanding.

locating said temperature sensor and said at least one dew point sensing component amid insulated air pockets formed by said structure of said housing means

109. It would have been apparent or obvious that the ***structure*** of Carter's ***housing*** (door latch cover assembly 20) ***locates the temperature sensor*** (surface temperature sensor 42) ***and the at least one dew point sensing component*** (including ambient temperature sensor 44 and/or ambient relative humidity sensor 46) ***amid insulated air pockets formed by the structure of the housing***. As I mentioned above, Carter explains that these components of "the sensor assembly unit 32 [are] integrated within the interior portion 22 of the door latch cover assembly 20" (***housing***), and Carter's figures show that this interior portion receives the sensing components ***amid insulated air pockets formed by the structure of the housing***. EX1004, 5:1–20, 6:50–56, Figures 1–2 (annotated below).

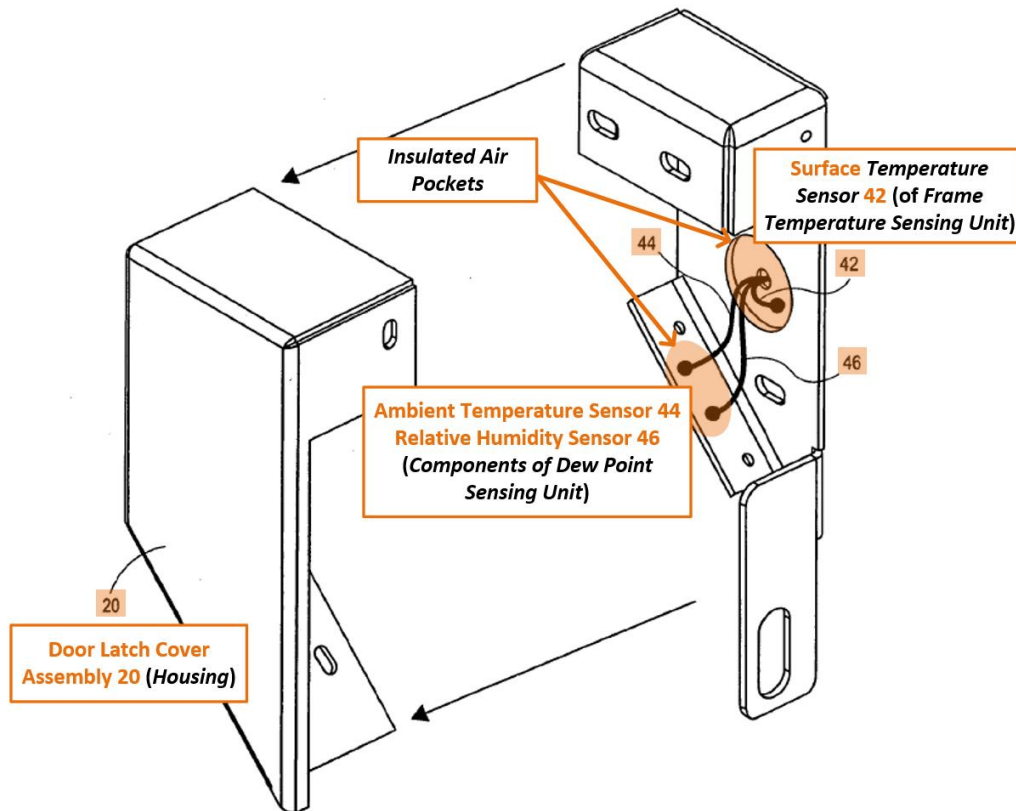
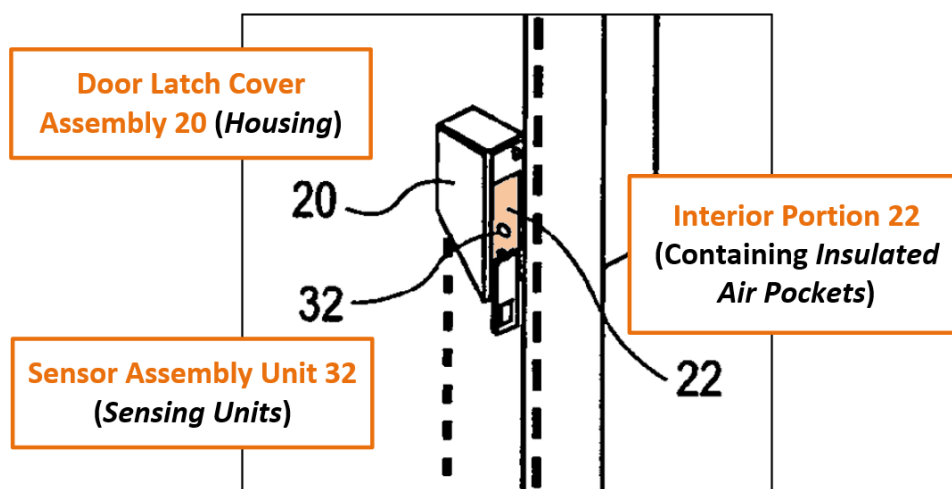


FIG. 2

EX1004 (Carter), Figure 2 (annotated)

110. As demonstrated below, it is visually apparent from Carter's figures that the "interior portion" of the *housing* is a hollow space created by the gaps between surfaces of the cover and base. As the POSITA would have understood, the areas—or *pockets*—within the *housing*'s hollow space are filled with *air*. That is, they are *air pockets*. This is so because the housing is not sealed, and the interior space is not a vacuum. For example, Carter's Figure 1 shows that the housing's front has an opening (shaded orange) for allowing ingress of ambient air and, thus, exposing the air temperature and humidity sensors to the same. Additionally, the

POSITA would have been aware of the well-known fact that still air is a thermal *insulator*. EX1028, 4 (“Air is a thermal insulator and its thermal conductivity is negligible”).



EX1004 (Carter), Figure 1 (excerpted-annotated)

Corresponding Structure

111. Based on the reasoning provided above in ¶¶103–110, my conclusion is that Carter teaches or renders obvious the recited structural and functional limitations of a *housing for locating said sensing units including structure establishing thermal isolation of said sensing units by minimizing heat transfer contacts between said sensing units and said housing means and locating said temperature sensor and said at least one dew point sensing component amid insulated air pockets formed by said structure*.

112. Next, I will address Carter’s teachings with respect to the additional structure disclosed in ’181 patent’s specification for the claimed *housing means*,

which, as I outlined above at §VIII.B, includes: A base and a cover that, when mated together, establish the claimed *insulated air pockets*. As shown below and discussed above, Carter's door latch cover assembly (*housing*) likewise includes a base and a mated cover that together form *insulated air pockets* receiving temperature and dew point sensing components. EX1004, 5:1–20, 6:50–56, Figures 1–2. Thus, in comparison to the '181 patent, Carter teaches a *housing* solution that accomplishes the claimed *locating* function in the same/substantially the same way—i.e., via a mated base and cover—to achieve the same/substantially the same result—i.e., receiving the sensing components within air pockets between the base and cover.

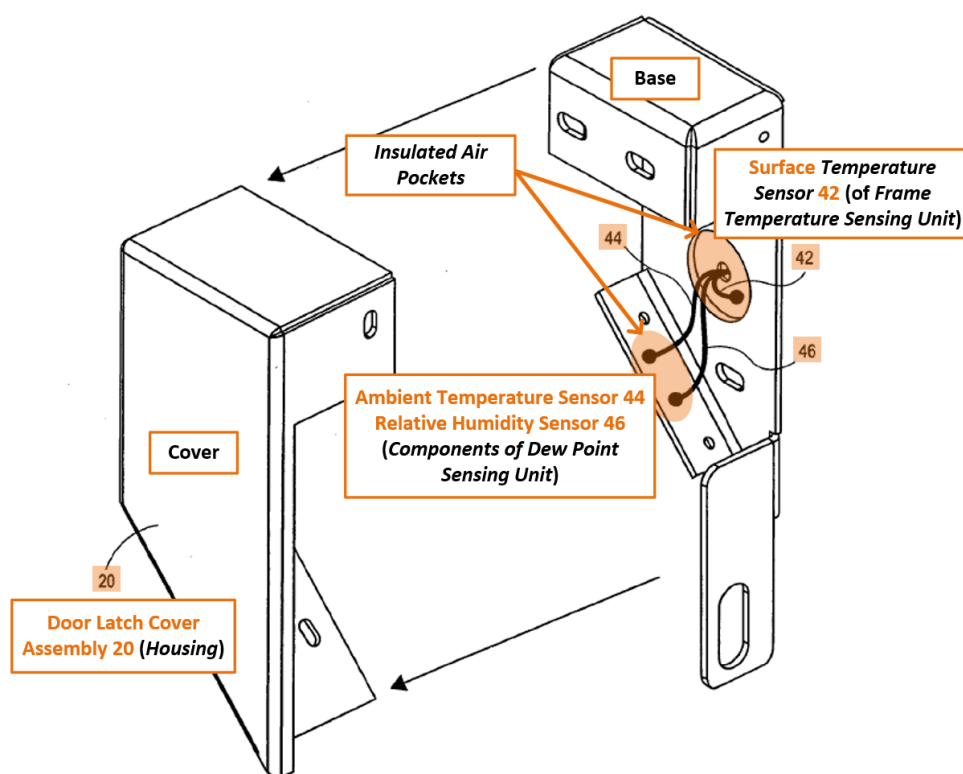


FIG. 2

EX1004 (Carter), Figure 2 (annotated)

113. To the extent the shape and size of Carter's housing differ from those of the housing shown in the '181 patent's figures, any such distinctions are not substantial or material concerning how the structure of the housing performs the claimed **locating** function. What matters is that the housing is comprised principally of two complementary components—a base and a cover—that receive and position the sensing units in air pockets for protection and thermal isolation, all for the purpose of promoting accurate sensor readings. In this regard, Carter's disclosure and the '181 patent's disclosure are not significantly different.

2. Claim 2

- (i) ***Element [2]: The apparatus of claim 1 wherein said housing means includes a frame temperature sensing unit housing, said frame temperature sensing unit housing including a base and a cover, said cover having a depth creating a first one of said air pockets at one side of said temperature sensing unit and said base including an opening for receiving said temperature sensor therethrough, said opening having an opening area greater than surface area of said temperature sensor thus establishing a second one of said air pockets around said temperature sensor.***

114. As discussed at Element [1.d], Carter teaches a **housing** (door latch cover assembly) having a **base** and a mated **cover** that together **create air pockets** around the **frame temperature sensing unit** (temperature sensor 42, per Element [1.a]). Carter's Figure 2 shows that **the cover has a depth creating a first air pocket, and the base includes an opening for receiving the temperature sensor, the**

opening having an opening area greater than surface area of said temperature sensor thus establishing a second one of the air pockets around the temperature sensor.

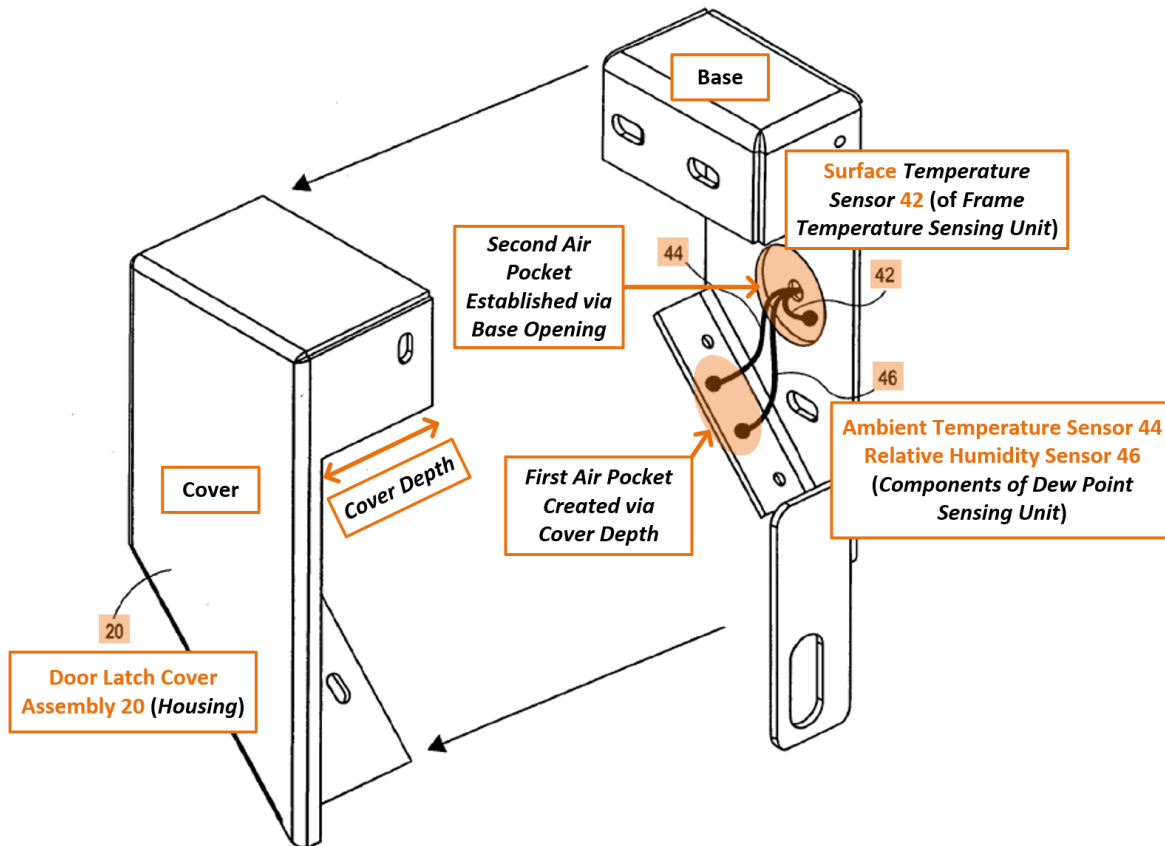


FIG. 2

EX1004 (Carter), Figure 2 (annotated)

3. Claim 14

- (i) ***Element [14.pre]: A system for condensation control at a refrigerated display case having at least one door, a frame and at least one frame/door heater, said system comprising:***

115. Based on the similar claim language, my conclusion is that Carter renders obvious Element [14.pre] for the same or substantially the same reasons discussed above at Element [1.pre].

- (ii) ***Element [14.a]: a temperature sensing unit in contact with the display case frame to monitor case frame temperature;***

116. Based on the similar claim language, my conclusion is that Carter renders obvious Element [14.a] for the same or substantially the same reasons discussed above at Element [1.a] (explaining that temperature sensor 42 is placed against a surface of the display case frame).

- (iii) ***Element [14.b]: a dew point sensing unit on the display case to monitor ambient air temperature and relative humidity outside the display case; and***

117. Based on the similar claim language, my conclusion is that Carter renders obvious Element [14.b] for the same or substantially the same reasons discussed above at Element [1.b].

- (iv) ***Element [14.c]: control means for receiving data from said sensing units and utilizing monitored case frame temperature, ambient air temperature and relative humidity to anticipate formation of condensation at the display case and activating and deactivating the frame/door heater responsive thereto.***

118. As discussed at Element [1.c], Carter teaches a “***control*** unit 28 [that] is generally responsible for ***receiving*** information [(data)] ***from the sensor*** assembly ***unit*** 32 and for [determining] whether a set condition exists that would promote surface condensation.”⁵ EX1004 (Carter), 4:36–55, Figure 1; *see also* 2:22–32, 3:42–53, 4:13–35. Thus, instead of merely reacting to the existence of condensation, Carter’s ***control*** unit seeks to proactively “prevent” this phenomenon in the first place by “switching on [(activating)] electrical ***heaters***” ***in response to anticipating the formation of condensation*** based on “thermal conditions” reflected by “sensors ***monitoring*** external surface [(frame)] ***temperature***[...] ***ambient temperature***, and the ambient ***relative humidity***.” EX1004 (Carter), 4:13–55; *see also* 5:21–54.

119. As discussed at Section VIII.E, the ’181 patent’s structure corresponding to Element [14.c]’s heater ***activating*** function of the claimed ***control means*** is the same as that of Element [1.c]’s heater ***activating*** function of the claimed ***processing means***. Accordingly, Carter renders obvious a microprocessor executing the same or an equivalent algorithm as that of the ’181 patent for all the same reasons

⁵ See Elements [1.a]–[1.b], mapping sensor assembly unit 32 to the ***sensing units***.

discussed above at Element [1.c]. EX1004 (Carter), 2:4–32, 3:40–53, 4:13–61, 5:21–54, 6:8–18, 6:57–58, Figure 3.

120. Carter also teaches or renders obvious the claimed function of *deactivating the frame/door heater responsive to anticipating the formation of condensation*. Recognizing that “providing a continuous[] supply of supplemental heat...can waste unnecessary energy and drive up the operating/maintenance costs of the freezer/refrigeration system,” Carter explains that such supplemental heat “is only activated under conditions that would promote surface condensation.” EX1004 (Carter), 2:4–32; *see also* 3:42–53. When *condensation* is no longer *anticipated*—e.g., “[i]f the cabinet surface temperature is equal to the ambient temperature”—“the control unit will *deactivate* the supplemental *heat*.” EX1004 (Carter), 5:55–63, Figure 3.

121. Next, I will address Carter’s teachings with respect to the ’181 patent’s corresponding structure for the claimed *control means* and the claimed *deactivating* function. As I outlined above at §VIII.E, the structure includes a microprocessor executing the three-step algorithm of:

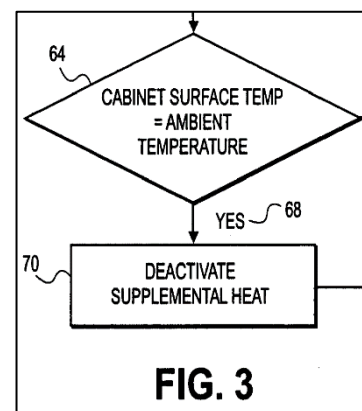
Step 1. Discounting frame temperature by a preselected set point;

Step 2. Determining if the discounted frame temperature is above a dew point value derived from ambient temperature and relative humidity; and

Step 3. Turning off a heater relay if the discounted frame temperature is above the dew point value.

122. As discussed, Carter teaches that the heater is deactivated when the frame temperature reaches the ambient temperature:

If the cabinet surface temperature is equal to the ambient temperature 38 the control unit 28 will deactivate the supplemental heat 70 by deactivating the switching unit[] 30. If the cabinet surface temperature is not equal to the ambient temperature 66, supplemental heat will continue to be supplied to the sealing surface 24 via the heating unit 34.



EX1004 (Carter), 5:58–63, Figure 3 (above, right).

123. A POSITA would have recognized that Carter’s technique employs a floating offset responsive to ambient conditions. As was well known in the art, dew point is generally defined as the temperature at which air at a prevailing pressure becomes saturated and vapor begins to condense out of the air. EX1030, 1 (providing a definition of dew point). Accordingly, the POSITA would have known

that ambient temperature is virtually always greater than dew point and that the difference between them depends on—floats according to—the relative humidity of the ambient environment. A psychrometric chart, which provides a graphical representation of the physical and thermal properties of moist air, confirms this point. EX1031. In other words, ambient temperature differs from the dew point by a floating offset. As a result, Carter’s comparison expression shown in Figure 3 (Step 64):

$$\textit{Cabinet Surface Temp} = \textit{Ambient Temp}$$

is mathematically equivalent to:

$$\textit{Cabinet Surface Temp} = \textit{Dew Point} + \textit{Floating Offset},$$

which parallels the ’181 patent’s expression from Figure 14b:

$$\textit{Frame Temp} - \textit{Set Point High} > \textit{Dew Point}$$

and its mathematical equivalent:

$$\textit{Frame Temp} > \textit{Dew Point} + \textit{Set Point High}.$$

124. From the perspective of a POSITA, the differences between Carter’s algorithm and the ’181 patent’s algorithm are insubstantial.

125. First, it has already been established above at Element [1.a]/Element [14.a] that Carter’s cabinet surface temperature provides the surface temperature of the display case frame—i.e., frame temperature.

126. Second, it would have been apparent or obvious to the POSITA that Carter's teaching to determine when the cabinet/frame temperature reaches ambient temperature is not limited to a strict equal-to (" = ") operator but would also include a greater-than (" > ") operator. This conclusion naturally flows from applying basic logic to the Carter's disclosure as a whole, which is precisely what a POSITA would have done.

127. As I have explained, Carter's design goals were to avert "wast[ing] unnecessary energy and driv[ing] up the operating costs of the freezer/refrigeration system." EX1004, 2:4–32. And Carter sought to achieve these goals by avoiding situations where the supplemental heater is running continuously, as opposed to "only...under conditions that would promote surface condensation on the sealing surface of [the] freezer/refrigeration equipment." *Id.* With this baseline understanding of Carter, it would have been clear to the POSITA that Carter did not intend to require an exact match between the measured frame temperature and the target temperature for deactivation (e.g., ambient temperature in the Figure 3 embodiment). As the POSITA would have understood, requiring an exact temperature match would promote the very operating condition that Carter sought to avoid—continuously running the heater even when there is no anticipation of condensation. Stated differently, the heater would remain running unless and until there was an exact match in temperature, which would undermine Carter's goal of

avoiding wasted energy and increased operating/maintenance costs associated with running the heater continuously.

128. Consider, for instance, a scenario where the heater is activated at time t_0 , the measured frame temperature at time t_1 is 1°C less than the target deactivation temperature, and the measured frame temperature at time t_2 is 1°C greater than the target deactivation temperature. If Carter's control algorithm required an exact match between the measured frame temperature and the target deactivation temperature, the heater would remain active at time t_2 , even though there is no imminent risk of condensation. Given that Carter's stated design goals are contrary to this result, a POSITA would have interpreted (or been motivated to implement) Step 64 of Carter's Figure 3 so that heater deactivation occurs when the frame temperature reaches or exceeds the target deactivation temperature. Applying this common-sense approach to the hypothetical scenario I outlined above results in the heater being deactivated at time t_2 , just as Carter intended.

129. Third, that the '181 patent uses a preselected set point and Carter uses a floating offset is an insubstantial and obvious distinction to a POSITA. In each case, the set point/offset serves as a buffer value to ensure that the frame temperature of the display case is far enough away from the dew point value to prevent anticipated condensation and without excessive on-off cycling of the heater. Absent an appropriate buffer value, the activating and deactivating target temperatures could

be close enough to one another that minor variations or errors/uncertainty in temperature readings would cause the control unit to repeatedly oscillate between switching the heater on/off. Doing so would undermine the effectiveness of the control system and unnecessarily risk damage/wear to electromechanical components, such as the relay. The '181 patent's preselected set point and Carter's floating offset are both buffer values that aim to prevent this sort of unwanted, erratic control behavior.

130. Nevertheless, a POSITA looking to improve Carter would have been motivated to augment or replace Carter's teaching of a floating offset with the notion of a preselected set point for the purpose of achieving a more flexible control system, e.g., one more adaptable to different climates and conditions. As the POSITA would have appreciated, Carter's floating offset varies with the relative humidity of ambient conditions: The lower the ambient air's relative humidity for the same ambient dry-bulb air temperature, the greater the temperature difference and thus the floating offset between the dew point temperature and the ambient air temperature. For example, at sea level for an ambient air temperature of 75°F and 40% relative humidity there is a temperature difference of 26°F, while at 70% relative humidity the temperature difference is only 10°F. EX1031. Moist air relationships are nonlinear because the amount of water vapor air can hold is directly tied to its temperature, meaning as temperature increases, the capacity for moisture

exponentially rises, creating a saturation curve rather than a straight line when plotting the relationship between temperature and maximum humidity; essentially, warm air can hold significantly more moisture than cold air, making the change in moisture content disproportionate to a change in temperature.

131. Accordingly, in humid indoor conditions, Carter's floating offset is smaller; and in dry conditions, the floating offset is larger. When conditions are very dry, the larger offset value would risk running the heaters longer than necessary, undermining efficiency. When indoor environmental conditions are very humid, the smaller offset would risk running the heater for too short an amount of time, potentially rendering the system less effective at preventing condensation or promoting repeated on/off switching of the heaters.

132. As the POSITA would have understood, because the offset is a function of ambient conditions, it cannot be selected, adjusted, or modified. Thus, the POSITA would have appreciated the efficiency and operational advantages of providing a control system that allows a manufacturer, technician, or operator to select the buffer value as a set point based on existing or expected conditions. One obvious and predictable approach for the POSITA would be to replace Carter's ambient temperature target for heater deactivation with a target temperature equal to dew point plus a preselected set point. Another obvious and predictable approach

for the POSITA would be to introduce the set point feature as a user-selectable alternative mode of operation for the control system.

133. For all these reasons, Carter teaches, suggests, or renders obvious the '181 patent's three-step algorithm that constitutes the structure corresponding to the claimed **deactivating** function of the **control means**. Stated differently, Carter's overall algorithm (and/or a predictable and obvious variation of Carter's algorithm) performs the '181 patent's claimed **deactivating** function in the same or substantially the same way—i.e., comparing frame temperature to dew point using a buffer value—to achieve the same or substantially the same result—i.e., heater deactivation responsive to conditions unlikely to produce condensation.

4. Claim 15

- (i) ***Element [15]: The system of claim 14 further comprising means for thermally isolating said dew point sensing unit from variations in temperature of the display case frame or display case door.***

134. Based on the similar claim language, my conclusion is that Carter renders obvious Element [15] for the same or substantially the same reasons discussed above at Element [1.d] (discussing Carter's teachings regarding housing means for thermally isolating components the dew point sensing unit amid insulated air pockets).

5. Claim 16

- (i) ***Element [16]: The system of claim 14 further comprising means for thermally isolating said temperature sensing unit from variations in temperature of ambient air.***

135. Based on the similar claim language, my conclusion is that Carter renders obvious Element [16] for the same or substantially the same reasons discussed above at Element [1.d] (discussing Carter’s teachings regarding housing means for thermally isolating components the frame temperature sensing unit amid insulated air pockets).

6. Claim 17

- (i) ***Element [17]: The system of claim 14 further comprising an internal case temperature sensing unit mounted inside the display case and communicating with said control means for monitoring internal case temperature.***

136. Carter repeatedly emphasizes the importance of “maintain[ing] a prescribed operating temperature” within the freezer/refrigeration equipment (***refrigerated display case***, per Element [1.pre]) to ensure its contents do not “spoil.” EX1004 (Carter), 1:45–62, 1:34–44. As a POSITA would have well known, temperature-controlled refrigeration systems were ubiquitous in the art at the time of the ’181 patent, and they were known to include ***an internal case temperature sensing unit mounted inside the display case*** for the purpose of facilitating closed

control loops and product quality monitoring. EX1035, [0097] (“Special attention is paid to the refrigerators (freezers) for commercial use so that variation in internal temperature distribution are controlled in order that food materials may be stored with a predetermined quality level.”)⁶; EX1039, 41 (“Electronic sensor control is the most accurate” kind of “[t]emperature control” system.). The POSITA would have expected a feature-rich system like Carter’s—one featuring a supplemental closed control loop for preventing condensation—to include basic closed-loop refrigeration control for maintaining a prescribed internal operating temperature.

137. Additionally, it would have been obvious to place such an *internal case temperature sensing unit in communication with the* above-described *control means*. Using Carter’s control unit (*control means*, per Element [14.c]) as a local nerve center for coordinating the various functions of the freezer/refrigeration equipment would have been nothing more than a rudimentary design choice that a POSITA would have been motivated to pursue based on the known benefits of consolidated centralized control systems (e.g., simplified system architecture and lower capital costs from fewer controllers). *See supra*, ¶52.

⁶ Note that EX1035 is a published patent application with a claimed priority date of October 18, 2004.

7. Claim 18

- (i) ***Element [18]: The system of claim 17 further comprising data storing means communicating with said control means for storing data related to readings at said sensing units and operation of the frame/door heater.***

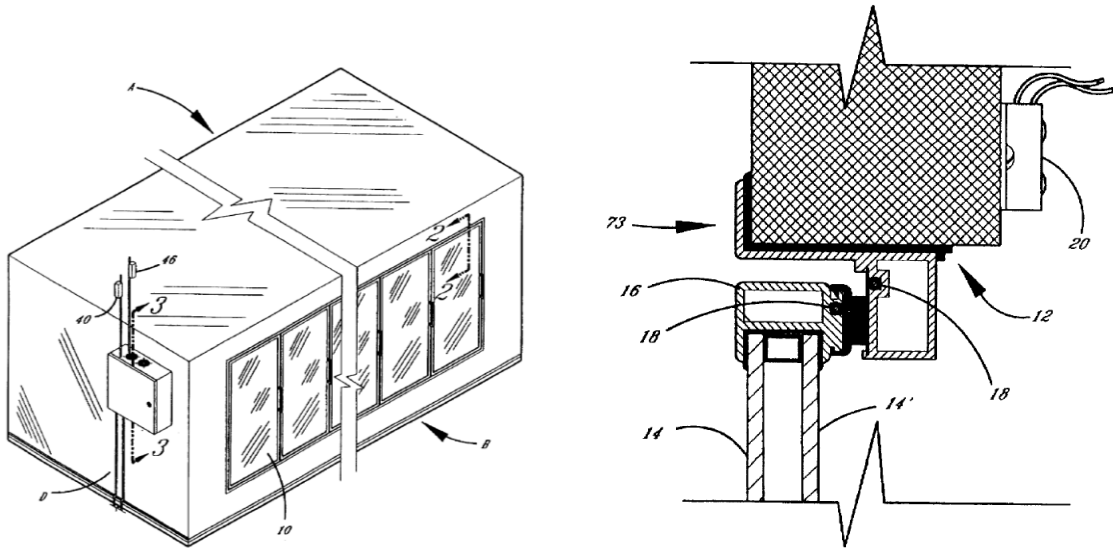
138. As discussed at Elements [1.a]–[1.c] and Elements [14.a]–[14.c], Carter renders obvious the notion of a control unit implemented via a microprocessor (*control means*) that utilizes *data related to readings at the sensing units and operation of the frame/door heater* (e.g., temperature readings, operational parameters such as set points, and algorithmic program instructions). It would have been further apparent or obvious to a POSITA that provisioning a microprocessor to access and utilize such *data* would naturally involve *storing* the *data*—for at least a short period of time—using well-known computer memory structures (*means*), such as a cache, register, or active memory module associated with the microprocessor. *See, e.g.*, EX1036, 1:35–45, 4:41–47; *see also* §VIII.H (identifying a microprocessor as the corresponding structure of *data storing means for storing data*).

X. GROUND 1B: Claims 1–7, 14–18 Are Obvious Over Carter, Beatenbough, and King

A. Beatenbough (EX1006)

139. Like the '181 patent, Beatenbough describes “a system for maintaining glass doors of refrigeration/freezer units free of condensation.” EX1006

(Beatenbough), Abstract, 1:6–9. As shown below in Figures 1–2, the “glass display doors” are mounted in a “metal frame 16,” which contains “a plurality of resistance wires 18” used “for heating the surface of the glass” to prevent “the formation of condensation.” EX1006 (Beatenbough), 1:46–52, 2:59–3:6.



EX1006 (Beatenbough), Figure 1 (left), Figure 2 (right)

140. According to Beatenbough, a “processor” causes the wires 18 to heat the door by delivering “an electrical pulse having a determined width” based on the current dew point. EX1006 (Beatenbough), Abstract, 1:45–2:3, 3:27–4:6.

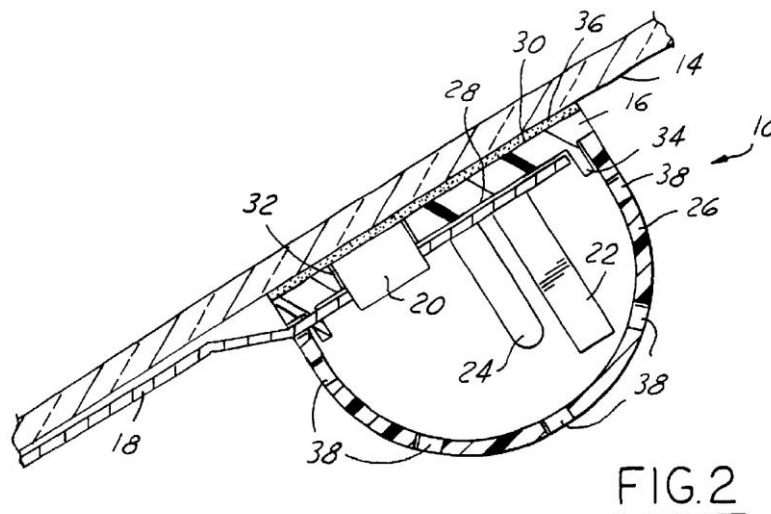
B. King (EX1005)

1. Brief Summary of King’s Disclosure

141. King describes “an automotive windshield fog sensor” that provides the necessary data to “predict glass fog formation.” EX1005 (King), Abstract, 1:4–6.

Similar to the '181 patent, King's sensor package includes "an ambient air temperature sensor [22], an ambient humidity sensor [24] and a glass temperature sensor [20]" that is "in thermal contact with the glass surface 14 in order to measure [its] temperature." EX1005 (King), 1:54–60, 2:48–50.

142. As shown below, these sensors are connected by a "flex circuit" and located in a shared housing formed by a "thermal barrier tray 16" and "a protective dome 26." EX1005 (King), 1:61–2:7, 2:40–50. The flex circuit and tray each act as a "thermal barrier" for the sensors. EX1005 (King), 2:4–7. For example, both the "ambient air temperature sensor 22" and "relative humidity sensor 24" are separated from the glass surface 14 by the tray 16, such that "surface 14 temperature does not alter the ambient air temperature or relative humidity levels at the sensor 22 and sensor 24 locations." EX1005 (King), 2:40–60.



EX1005 (King), Figure 2

143. Similar to Carter and the '181 patent, King teaches that glass fog can be predicted by comparing the “glass surface temperature 56” with the “ambient dew point 54.” EX1005 (King), 3:20–30 (“If the ambient dew point 54 is greater than the glass surface temperature 56, the glass surface 14 is either fogged or will eventually fog.”). The ambient dew point 54 can be calculated using the “humidity and ambient temperature values” provided by the sensors. EX1005 (King), 3:22–25. According to King, the ambient air temperature sensor 22 and relative humidity sensor 24 are adjacent or “integrated therewith” to provide “substantially similar” response times and therefore “accurate dew point calculations.” EX1005 (King), 3:31–35.

2. A POSITA Would Have Recognized King as Analogous Prior Art to the '181 Patent

144. King is analogous art to the '181 patent. I understand that a prior art reference is analogous to the patent in question if the reference is [1] within the same field of endeavor as the patent and/or [2] has reasonable pertinence to one or more of the problems purportedly solved by the patent's inventors. Here, King is both within the same field of endeavor as the '181 patent and is also pertinent to one or more problems addressed by the '181 patent.

145. First, King is within the same field of endeavor as the '181 patent. The '181 patent pertains to the field of “remediat[ing] condensation build up” in Heating,

Ventilating, Air Conditioning, and Refrigerating (HVAC&R) systems. EX1001 ('181 patent), 1:5–10. Although its preferred embodiments and claims involve refrigeration systems, a POSITA would have understood that the '181 patent's focus on condensation control invokes the broader context of HVAC&R.

146. Tellingly, the '181 patent expressly confirms that the kind of “condensation control” techniques it describes are not limited to refrigeration and are instead “utilized in a variety of applications.” EX1001 ('181 patent) 1:41–47. For example, at Column 1, Line 46, the '181 patent cites US2004/0050072, a published patent application from 2004 directed to “sensing or predicting when condensation having a given physical state is present or imminent and for suppressing such condensation from a surface, such as a vehicle windscreen, eyewear, goggles, helmet visor, computer monitor screen, window, electronic equipment, etc.,” (EX1029 at Abstract). Then again, at Column 1, Line 47, the '181 patent cites US5,778,147, an issued patent from 1998 describing “[a] dew preventing mechanism [that] prevents the formation of dew on the grilles of an air discharge port of a room air conditioner,” (EX1040 at Abstract). Clearly, the inventors of the '181 patent appreciated that condensation control is a broad technical field, one not limited to refrigeration.

147. Accordingly, a POSITA would have understood that King's disclosure of an integrated sensor package for use in a system that prevents “fog”—a

manifestation of the condensation phenomenon—falls within the '181 patent's broad technical field.

148. Second, King is reasonably pertinent to the problem(s) addressed by the '181 patent. King and the '181 patent similarly address the design problem of provisioning a housing for a sensor package including a surface temperature sensor, an ambient air temperature sensor, and a relative humidity temperature sensor. *Compare* §V (summarizing the '181 patent), *with* §X.B.1 (summarizing King). In both King and the '181 patent, the design problem involves mechanically supporting, electrically connecting, and thermally isolating the sensors. King is therefore reasonably pertinent to at least one of the problems that the '181 patent's inventors were trying to solve.

149. Indeed, someone faced with the kind of sensor packaging problem addressed by the '181 patent would have thought to pursue references like King that propose viable solutions, regardless of their technical field. Because automated control systems are used in so many kinds of electrical devices/systems, sensors are likewise deployed in a wide variety of different fields. Accordingly, a person looking to design, improve, and/or procure a sensor package would not have confined themselves to prior art references from any particular field.

C. Motivation to Combine and Reasonable Expectation of Success

150. The Carter-Beatenbough-King Combination represents the predictable and expected result of applying in the context of Beatenbough's refrigerated display case with condensation control capabilities: **(a)** Carter's complementary teachings on triggering heater activation/deactivation based on door/frame surface temperature; and **(b)** King's complementary teachings on an integrated sensor package suitable for implementing the Carter-Beatenbough condensation control scheme. From a POSITA's perspective in 2005, integrating the complementary teachings of Carter, Beatenbough, and King would have involved nothing more than applying known solutions to known problems and achieving predictable outcomes. The fundamental aspects of Beatenbough's disclosure would remain intact, bolstered by the beneficial teachings of Carter and King in a way that the POSITA would reasonably expect to succeed.

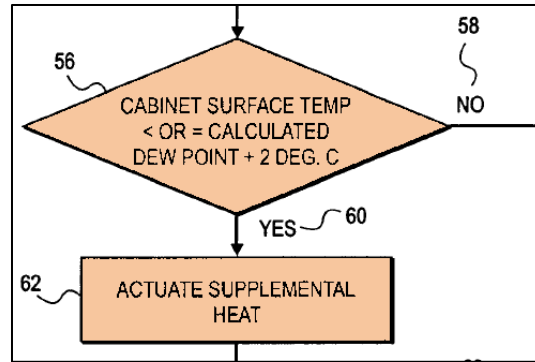
1. Applying Carter's complementary teachings on triggering heater activation/deactivation based on door/frame surface temperature

151. A POSITA would have been motivated to incorporate Carter's teachings on selectively triggering heater activation/deactivation based on the monitored door/frame surface temperature of a refrigerated case with Beatenbough's teachings of a variable pulse width technique for operating the heater(s) on a refrigerated display case more efficiently. Each of these references is primarily

concerned with using supplemental heat to prevent condensation from forming on the refrigerated case. *See supra* §IX.A (summarizing Carter); §X.A (summarizing Beatenbough). Thus, the predictable result of this Carter-Beatenbough Combination includes a refrigerated display case with a comprehensive condensation control scheme that operates the heater(s) on the case in an energy-efficient manner to prevent condensation.

152. The following reasons, taken separately or collectively, support the Carter-Beatenbough Combination.

153. First, the teachings and suggestions gleaned from Beatenbough would have prompted a POSITA to pursue this Combination. For example, Beatenbough discloses that the doors of the display case should “be kept at no less than 2° above the dew point.” EX1006 (Beatenbough), 4:7–8. This teaching would have suggested to the POSITA that heater activation should occur when the sensed temperature at the door drops to a point at or below the dew point temperature plus a buffer value of two degrees. Motivated by this understanding, the POSITA would have pursued supplemental references like Carter that disclose specific algorithmic steps to implement such a control scheme—namely, actuating supplemental heat when the measured surface temperature of the refrigerated case is less than or equal to dew point plus 2° C (EX1004 (Carter), Figure 3 at Steps 62 and 64).



EX1004 (Carter), Figure 1

154. Second, even if one were to assume that Beatenbough does not specifically suggest Carter's approach to heater activation (which it does), there would still be ample motivation for a POSITA to combine these references. For example, assuming Beatenbough's disclosure gives no hint as to the appropriate control scheme, a POSITA looking to implement a refrigerated display case in accordance with Beatenbough's teachings would have sought one out. In other words, the POSITA would have been prompted to make the Carter-Beatenbough Combination by the evident design need to seek an appropriate control algorithm for achieving Beatenbough's goal of maintaining the door of the refrigerated case "at no less than 2° above the dew point." EX1006 (Beatenbough), 4:7–8.

155. As I explained above at Section VI.B.1, the POSITA would have understood that condensation control systems existed long before the '181 patent in 2005. Like Beatenbough and Carter, these pre-existing systems used heaters to prevent or resolve condensation, and determining when to turn the heater on was a necessary design task. While Beatenbough's disclosure focuses on an improved

variable pulse width technique for actuating the heater (e.g., EX1006, 3:51–4:35), it leaves other implementation details—such as determining when to actuate the heater—for the POSITA to fill in with common knowledge and/or supplemental disclosures. Examining Beatenbough’s BACKGROUND OF THE INVENTION makes this point clear. *See* EX1006 (Beatenbough), 1:9–22. There, for example, Beatenbough points to a sampling of patents that describe older techniques for switching on the heater of a condensation control system—e.g., US3,859,502, “in which electrical heating means...[are] turned off or on, depending upon whether the relative humidity is below or above a selected level,” (EX1041, Abstract), and US4,862,701, which describes the technique of switching on/off heaters when “condensation [] form[s] directly on the sensor under those conditions that will lead to...condensation on the parts of the [refrigeration] device,” (EX1042, 1:44–2:18). These older prior art references underscore the distinction between controlling operation of an activated heater, the focus of Beatenbough’s proposed pulse width technique, and triggering activation of the heater in the first place. Recognizing that Beatenbough invites supplementation on the latter, the POSITA would have appreciated that Carter’s common-sense proposal to trigger heater activation based on surface temperature and dew point provides a known, suitable, and simple solution for achieving Beatenbough’s design goal of maintaining the door of the

refrigerated case “at no less than 2° above the dew point.” EX1006 (Beatenbough), 4:7–8.

156. Third, a POSITA would have pursued the Carter-Beatenbough Combination based on the understanding that Carter’s heater activation technique and Beatenbough’s variable pulse width technique for heater operation rely on a shared operating variable—a dew point value derived from ambient temperature and relative humidity sensor readings. *See* EX1004 (Carter), 5:31–54; EX1006 (Beatenbough), 3:51–4:34. Given that Beatenbough’s condensation control system is already monitoring the dew point value on which Carter’s control scheme depends, the POSITA would have appreciated that integrating the teachings of these two references would have been particularly straightforward and predictable. More, the POSITA would have recognized that utilizing a single dew point value for driving multiple aspects of the automated functionality—i.e., both determining when to activate the heater and dictating how to operate the activated heater—promotes computational simplicity and efficiency in the control algorithm.

157. Fourth, a POSITA would have been motivated to pursue the Carter-Beatenbough Combination because Carter’s heater activation technique further promotes Beatenbough’s desire to increase energy efficiency. Where Beatenbough fulfills a need in the art for accurately “determining the percent of [heater] run time required” and avoiding wasted energy, (EX1006 (Beatenbough), 1:5–43), Carter

similarly seeks to improve energy efficiency by remedying the fact that prior solutions were “typically configured to provide continuous heating,” an approach that “can waste unnecessary energy and drive up the operating/maintenance costs,” (EX1004 (Carter), 1:15–2:32). Given their shared focus on energy efficiency and concomitant cost savings, a POSITA would have naturally sought to combine the teachings of Beatenbough and Carter to maximize these benefits while providing a comprehensive condensation control system. *See supra* §VI.B.1 (explaining that skilled workers in the field were pursuing solutions for improving the efficiency of anti-sweat systems).

158. Note that this “Fourth” reason for combining Beatenbough and Carter applies under any foreseeable interpretation of Beatenbough regarding heater activation. Whether one interprets Beatenbough as suggesting the same scheme as Carter (as I conclude above at ¶153), some different scheme (e.g., continuous heater activation), or no scheme at all (as I assume as a hypothetical above at ¶¶154–155), the POSITA would have appreciated that employing Carter’s teachings to selectively activate the heater based on dew point would produce the beneficial result of furthering Beatenbough’s goal to increase energy efficiency and cost savings.

2. Applying King's integrated sensor package teachings for implementing the Carter-Beatenbough condensation control scheme

159. A POSITA would have been motivated to incorporate King's teachings of an integrated sensor package for implementing the Carter-Beatenbough condensation control scheme. The following reasons, taken separately or collectively, support the Carter-Beatenbough-King Combination.

160. First, a POSITA would have been prompted to integrate King's teachings with Carter and Beatenbough based on the following understandings:

- that the Carter-Beatenbough condensation control scheme relies on surface temperature, ambient air temperature, and relative humidity sensors;
- that the housing and mounting accommodations for these sensors significantly impacts the accuracy of their sensor readings, and
- that the accuracy of the sensor readings significantly impacts whether the heater on the refrigeration case is operated effectively and efficiently, as envisioned by Carter and Beatenbough.

Thus, when tasked with implementing the Carter-Beatenbough condensation control scheme, the POSITA would have faced a routine sensor packaging problem.

161. This problem would have prompted the POSITA to pursue supplemental teachings from references like King that provide solutions in the shared technical field of condensation control. Like Carter, King recognizes that

condensation can be “predicted” based on “surface temperature” and “dew point,” which “is calculated from the ambient air temperature and ambient humidity.” EX1005 (King), 1:9–35. Instead of mounting the requisite sensors separately, King proposed an “integrated” approach that packages the sensors together in a single housing. EX1005 (King), 2:4–7, 2:34–3:2. King’s idea of using a single sensor housing in a condensation control system based on dew point and surface temperature would have been familiar to a POSITA because similar proposals had already been applied to refrigerated display cases in older prior art references. *See* EX1016 (US 4,260,876), Abstract, 2:15–52 (a “dew point sensing device” that is both “thermally coupled to the mullion surface [of a refrigerated display case]” and “exposed to adjacent ambient air outside”), 4:13–40, Figures 2–3.

162. Recognizing that King’s disclosure represents a known and suitable solution to the sensor packaging design problem raised by Carter-Beatenbough—a solution that specifically addresses the three types of sensors at issue—the POSITA would have been motivated to make the Carter-Beatenbough-King Combination.

163. Second, a POSITA would have been motivated to make the Carter-Beatenbough-King Combination because King’s teachings provide the advantage of a compact solution that mounts and houses all three of the requisite sensors in a single package. As the POSITA would have understood, King’s integrated sensor package would facilitate a more streamlined installation process compared to other

designs that mount the sensors separately. The nature of this advantage is simple and straightforward: A POSITA would expect mounting one sensor housing to be faster and more efficient than mounting two or three separate sensor housings. Even on a single refrigerated display case, the reduced time and effort could be significant depending on where and how the sensors are mounted, the distance between the mounting location(s) and the case controller, and/or the way the wires are routed between the sensors and the controller. And the effect would be multiplied when propagated across many display cases, such as field installation at large grocery stores or in a high-volume manufacturing setting.

164. Third, a POSITA would have appreciated that King's integrated sensor package provides the further advantage of lowering manufacturing, assembly, and installation costs by reducing the number of components compared to other designs that mount the sensors separately. *E.g.*, EX1039, 25 ("wiring installation costs can be reduced") (noting "component costs" and "installation costs" as design considerations) ("Evaluate the proposed [control system] architecture for cost, including field wiring, components..."). As a POSITA would have appreciated, reducing the number of sensor packages would likewise reduce the number of constituent housing, circuit board, and wiring harness components, each of which represents a capital cost for procurement, assembly, and/or testing and configuration. Accordingly, King expressly confirms what the POSITA would have already known

as a matter of common sense and ordinary practice: Reducing the number of components is a known and obvious way to reduce manufacturing costs and, thus, increase profit margins. *See, e.g.*, EX1005 (King), 1:36–45 (explaining that other designs may “require[] separate wire harnesses” to mount the ambient temperature and relative humidity sensors away from the surface temperature sensor), 2:8–16 (“reducing manufacturing costs” by “simplification of [the] wiring by use of a common ground”) (“providing a simple, inexpensive” solution).

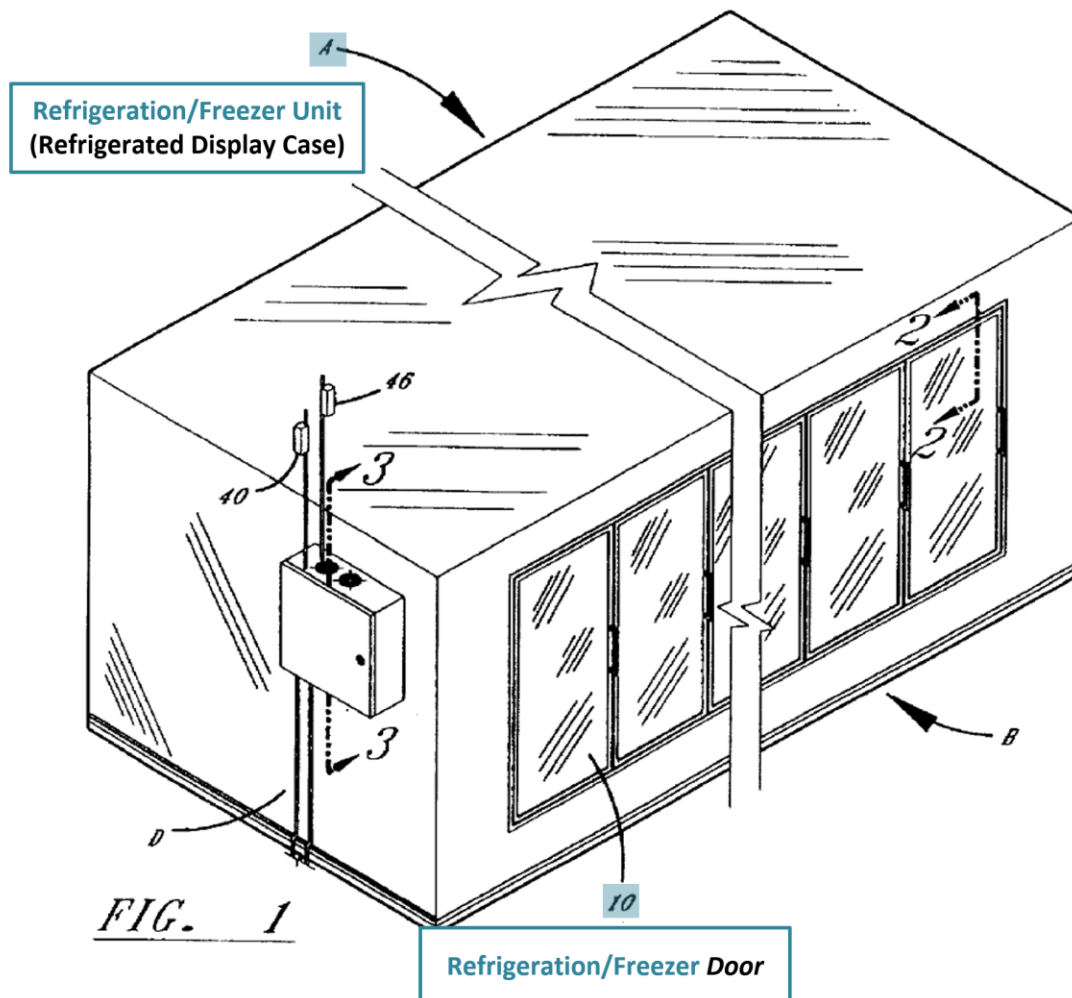
D. Claim Element Analysis

1. Claim 1

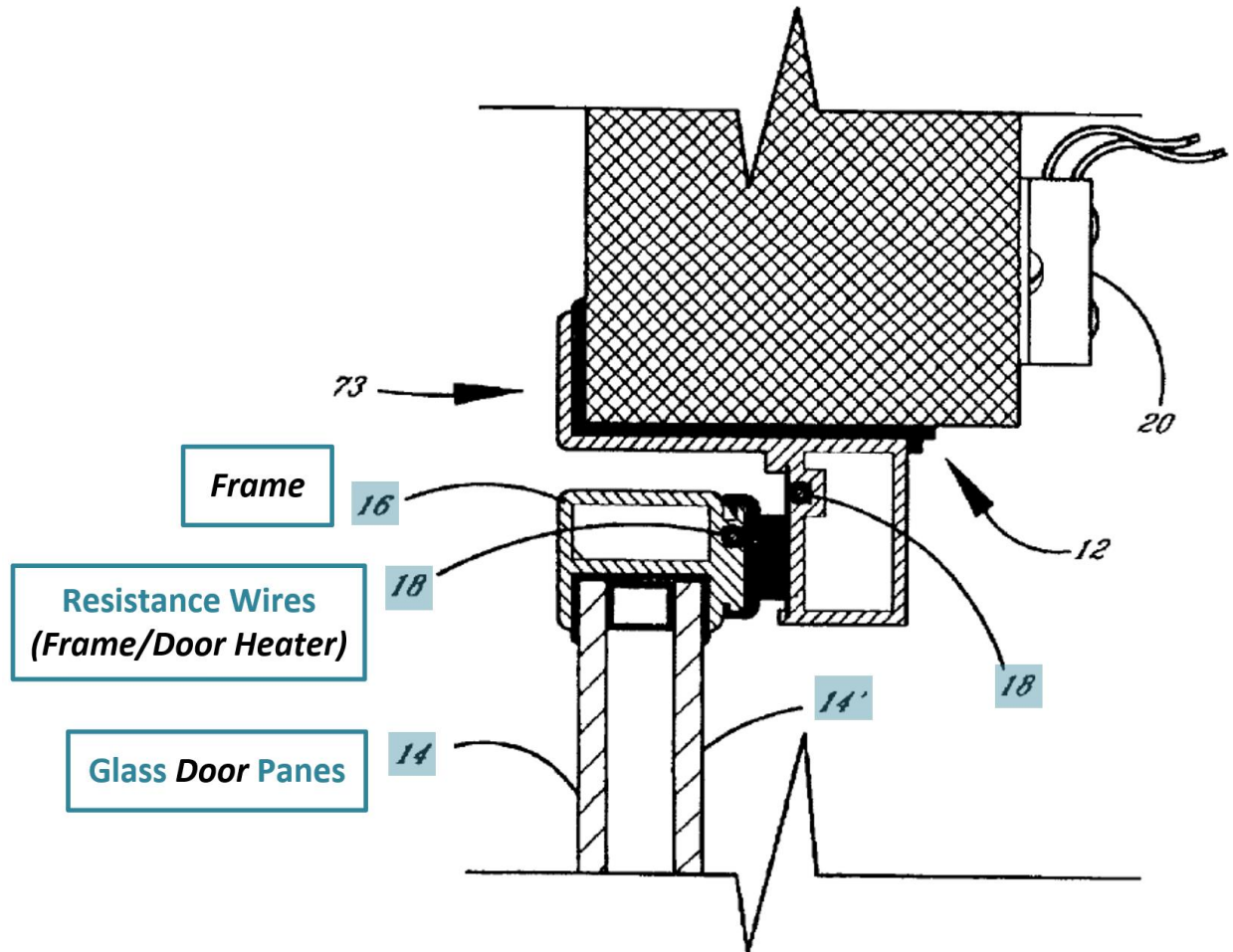
- (i) ***Element [1.pre]: Condensation control apparatus for a refrigerated display case having at least one door, a frame and at least one frame/door heater, said apparatus comprising:***

165. The Carter-Beatenbough-King Combination includes Beatenbough’s teachings to deploy a ***condensation control apparatus*** “for use with ***display*** type ***refrigeration*** and freezer units [(***cases***)] having glass ***display doors*** for preventing the formation of ***condensation*** and frost on the glass of the doors.” EX1006 (Beatenbough), Abstract, 1:1–2:33, 3:2–4:42; *see also* EX1004, Abstract 1:1–11, 2:22–31, 2:35–43, 3:40–53, 4:44–55, 6:30–49 (Carter disclosing a ***condensation control apparatus***), *supra* Element [1.pre] of Ground 1A. Per Beatenbough, “[a] single refrigeration/freezer unit (A)” (***refrigerated display case***) has “a bank of

individual *doors* (B),” where each “*door* 10 is supported in [a] metal door jam[b] 12 and includes a glass area usually consisting of two glass panes 14, 14’ mounted in [a] metal *frame* 16.” EX1006 (Beatenbough), 2:59–65. “Door jam[b] 12 and *door frame* 16 are provided with a plurality of resistance wires 18,” serving as a *frame/door heater*, “for heating the surface of the glass” via a “very thin transparent electrically conductive layer” coated on one of the glass panes. EX1006 (Beatenbough), 2:65–3:2.



EX1006 (Beatenbough), Figure 1 (annotated)

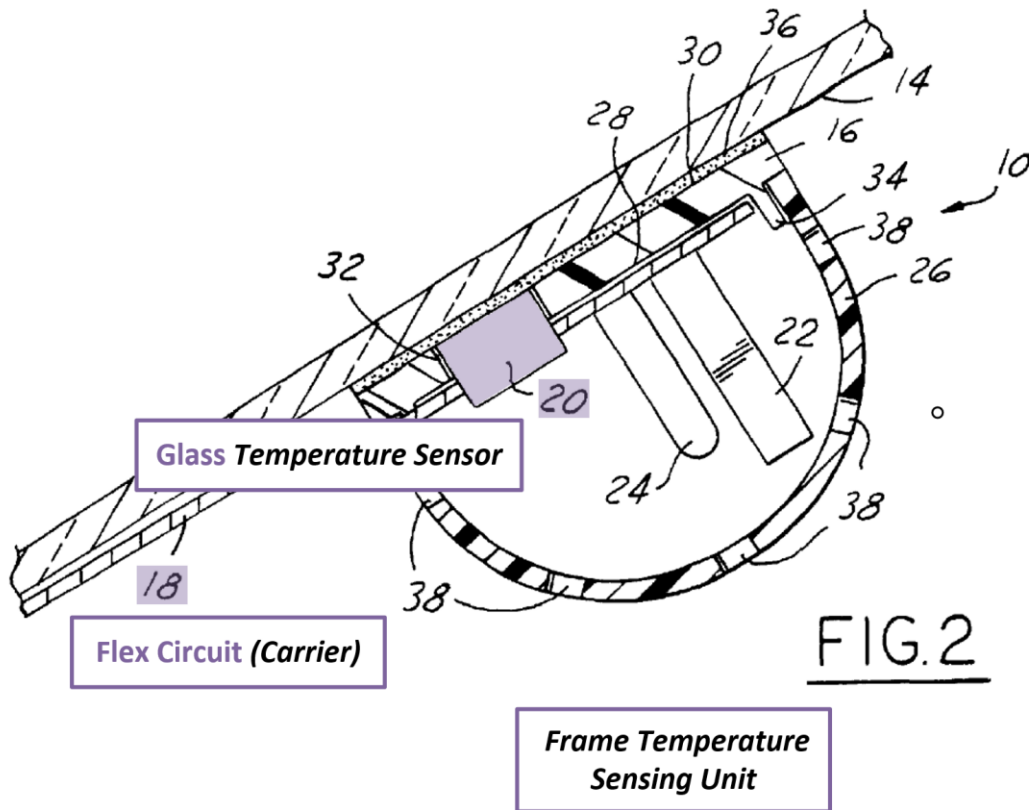


EX1006 (Beatenbough), Figure 2 (annotated)

- (ii) *Element [1.a]: a frame temperature sensing unit adapted for monitoring temperature of one of the display case door or display case frame and including a carrier having a temperature sensor thereat;*

166. The Carter-Beatenbough-King Combination features King's teachings regarding a "*sensor unit*" in conjunction with teachings from Beatenbough and Carter regarding a *refrigerated display case* with a condensation control apparatus. King's *sensor unit* includes "an ambient air temperature sensor, an ambient humidity sensor and a glass *temperature sensor*," where "[t]he electrical

connections are made by using a flex circuit.” EX1005 (King), 1:54–60. The flex circuit (*carrier*) serves to physically locate and secure the sensors and functions as a “thermal barrier.” *See, e.g.*, EX1005 (King), 1:66–2:7, 3:3–19 (“Sensors 20, 22, and 24 are typically soldered to flex circuit end 42.”).

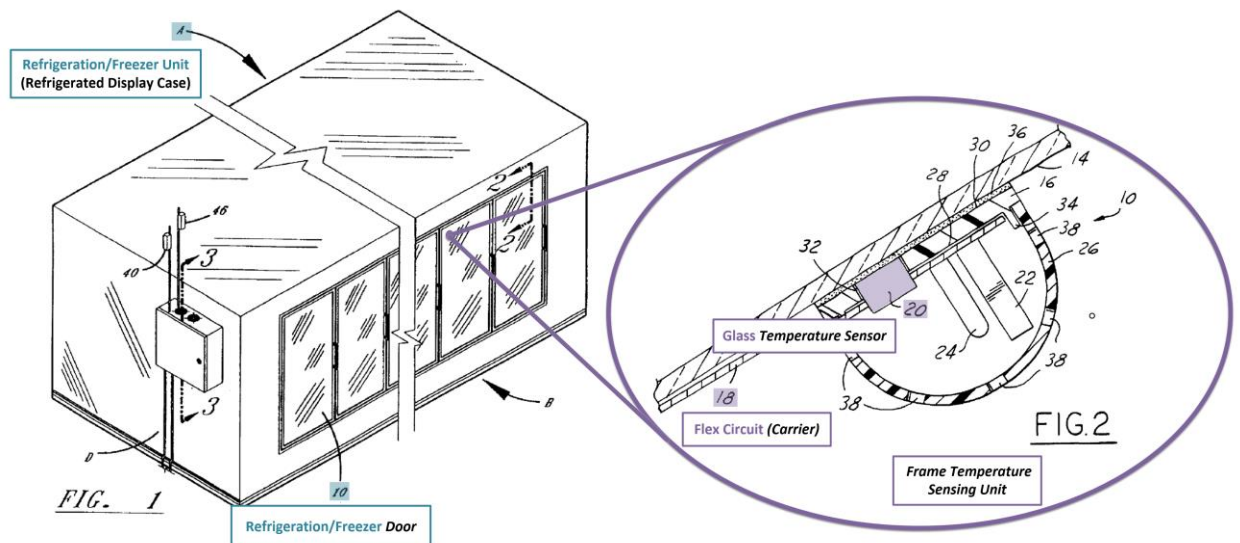


EX1005 (King), Figure 2 (annotated)

167. In pursuing the Carter-Beatenbough-King Combination, a POSITA would have contemplated locating a “*sensor unit*” according to King’s teachings such that the above-discussed glass *temperature sensor* is placed against—and, thus, *monitors the temperature of*—the outer glass pane supported by the *frame* of Beatenbough’s display case *door*. Given that King discloses this sensor in the

context of monitoring the temperature of a glass surface, the POSITA would have naturally thought to employ the device similarly in the Combination with Beatenbough and Carter. Additionally, the POSITA would have considered implementing King's surface temperature sensor in this way based on an understanding that the glass pane of a refrigerated display case is a location where condensation is likely to occur.

168. The visual aid below conceptually demonstrates this aspect of the Combination involving Beatenbough (blue) and King (purple).



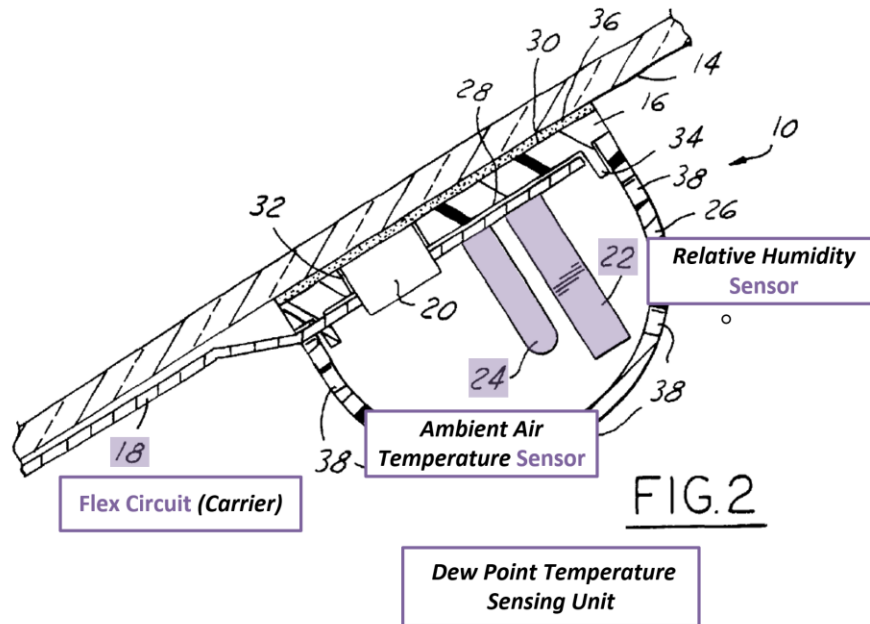
169. It would have been an obvious alternative solution to locate a “*sensor unit*” like the one King teaches against the *display case frame* to monitor frame temperature, as was well known in the art and even taught by Carter (*see* Element [1.a], Ground 1A). As a POSITA would have appreciated, a frame-mounted deployment would position the sensor unit more discreetly without sacrificing its

functional capabilities. Stated differently, the sensor unit could still perform its intended function even if it were placed at a location along the frame of the refrigerated display case, as in Carter, instead of the glass plane, as in King. Particularly in a retail setting, customers would be less likely to see or potentially touch/damage the sensor unit in such a location.

(iii) ***Element [1.b]: a dew point sensing unit adapted for monitoring ambient air temperature and relative humidity outside of the display case and including a carrier having at least one dew point sensing component thereat;***

170. The Carter-Beatenbough-King Combination features King's teachings regarding a "***sensor unit***" in conjunction with teachings from Beatenbough and Carter regarding a ***refrigerated display case*** with a condensation control apparatus. King's ***sensor unit*** includes "an ***ambient air temperature*** sensor, an ambient ***humidity*** sensor and a glass temperature sensor," where "[t]he electrical connections are made by using a flex circuit." EX1005 (King), 1:54–60. The flex circuit (***carrier***) serves to physically locate and secure the sensors and functions as a "thermal barrier." See, e.g., EX1005 (King), 1:66–2:7, 3:3–19 ("Sensors 20, 22, and 24 are typically soldered to flex circuit end 42."). As in Beatenbough and Carter, King teaches that "humidity and ambient temperature values" produced by sensors 22 and 24 (***dew point sensing components***) are used "for the calculation of the

ambient dew point.” EX1005 (King), 3:21–4:10, Figure 4; *see also* 1:9–14, 2:52–60.



EX1005, Figure 2 (annotated)

171. I have been asked to analyze Claim 1 under a narrow interpretation requiring two separate *carriers*, one for the *frame temperature sensing unit* of Element [1.a] and another for the *dew point sensing unit* of Element [1.b]. Though I see no reason to narrowly interpret Claim 1 this way, I have nevertheless considered the interpretation as a hypothetical and determined that my conclusions on obviousness would still hold.

172. The notion of implementing King’s flex circuit (*carrier*) as a two-piece structure—one piece for the surface temperature sensor (of the *frame temperature sensing unit*) and another piece for the ambient temperature and relative humidity

sensors (of the *dew point sensing unit*)—would have been an obvious design choice for a POSITA. For example, the POSITA would have realized that using a larger, shared flex circuit (*carrier*) to support all three of the sensors provides a potential path for heat transfer between them and, therefore, risks biasing the sensor readings. One apparent solution to this potential heat-transfer problem that a POSITA would have considered is to use separate flex circuits for sensors exposed to different temperatures—i.e., a first flex circuit for the surface temperature sensor exposed to the cold glass/frame of the refrigerated display case and a second flex circuit for the relative humidity and ambient temperature sensors exposed to the warmer air around the case. Doing so would decrease the risk of unintentional heat transfer between the sensors (e.g., the cold surface temperature drawing heat away from the warmer air temperature and humidity sensors), promoting improved thermal isolation and increased sensor accuracy. This notion of separating temperature and humidity sensors from other aspects of a supporting circuit was known in the art and employed in commercial products. *E.g.*, EX1020, 6–7 (describing a “milled” “slit” between the air temperature and humidity sensors and “the rest of the PCB” for thermal isolation purposes).

- (iv) ***Element [1.c]: a control unit communicating with said sensing units and including processing means connected for activating the display case frame/door heater when monitored display case door or frame temperature drops below a preselected set point above a dew point value derived from monitored ambient temperature and relative humidity; and***

173. As discussed at Section X.C.1, the Carter-Beatenbough-King Combination employs Carter's condensation control scheme in the context of Beatenbough's refrigerated display case. The Combination thus renders obvious Element [1.c] for at least the same reasons presented in Ground 1A regarding Carter.

174. I also note that Beatenbough's teachings further support my Ground 1A analysis. For example, Beatenbough expressly discloses the notion of implementing a condensation control scheme using a control unit with a "processor" that activates heating elements via "relays." EX1006 (Beatenbough), Abstract, 1:46–2:3, 2:7–9, 2:59–3:9, 3:10–27. As I explained in Ground 1A, these aspects of the '181 patent's corresponding structure for the claimed ***activating*** function are no doubt provided or rendered obvious by Carter. Beatenbough confirms the point with respect to the Carter-Beatenbough-King Combination of Ground 1B.

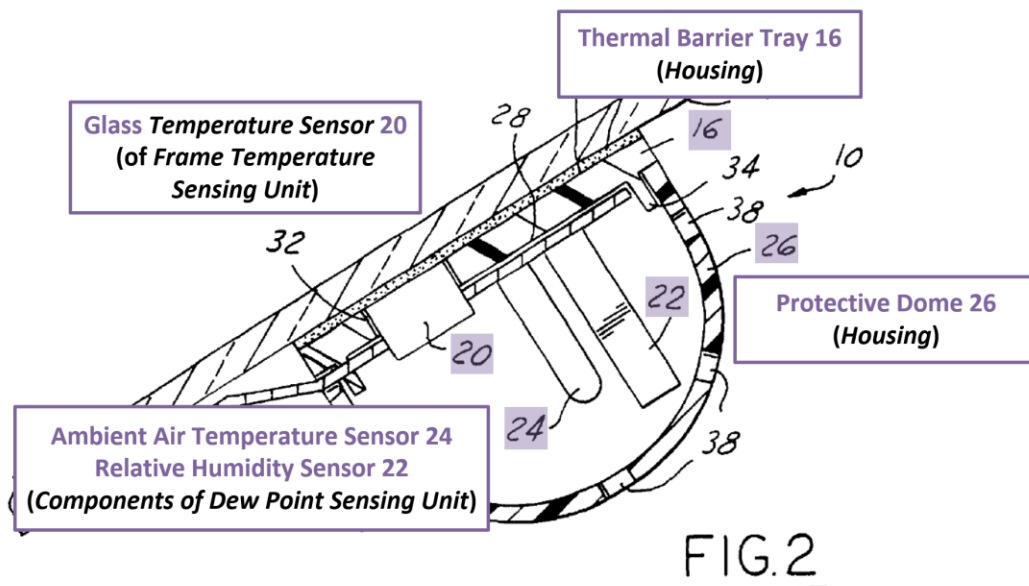
175. I have been asked to analyze Claim 1 under a narrow interpretation of Element [1.c] requiring the ***preselected set point*** to be user-adjustable in the field during operation of the refrigerated display case. Though I see no reason to narrowly interpret Element [1.c] this way, I have nevertheless considered the interpretation as

a hypothetical and determined that my conclusions on obviousness regarding the Carter-Beatenbough-King Combination would still hold. For example, Beatenbough teaches the notion of providing user-adjustable “rotary dials” to “*set*” operational parameters for a condensation control scheme. EX1006 (Beatenbough), 3:45–4:6. Appreciating the benefits of increased flexibility and adaptability to different locations, climates, and conditions, a POSITA would have been motivated to apply Beatenbough’s teachings regarding operational setpoints that are selected by a user in the field as a predictable improvement on Carter’s teaching to provide a “constant” buffer value of “2 degrees C.” EX1004, 5:21–54, Figure 3.

- (v) ***Element [1.d]: housing means for locating said sensing units including structure establishing thermal isolation of said sensing units by minimizing heat transfer contacts between said sensing units and said housing means and locating said temperature sensor and said at least one dew point sensing component amid insulated air pockets formed by said structure of said housing means.***

176. As discussed above, the Carter-Beatenbough-King Combination features King’s teachings regarding a “sensor unit” including a glass ***temperature sensor*** 20 (of the ***frame temperature sensing unit***, per Element [1.a]), an ambient air temperature sensor 22, and relative humidity sensor 24 (***components*** of the ***dew point sensing unit***, per Element [1.b]). According to King, “[a]ll three sensors are located beneath a protective dome which is secured to a perimeter wall of [a thermal

barrier] tray.” EX1005 (King), 1:48–65, Figure 2. The tray “assures that surface temperature does not alter the ambient air temperature or relative humidity levels,” and “the protective dome surrounds, and serves to protect, the sensors from any impacts.” EX1005 (King), 2:55–63; *see also* 1:48–65 (“The tray and the flex circuit also serve as a thermal barrier isolating the ambient air sensor and humidity sensor from the potentially cold glass surface.”). In this way, the protective dome and the thermal barrier tray together form a *housing for locating the sensing units*.



EX1005 (King), Figure 2 (annotated)

177. In addition to *housing* these *sensing units*, it would have been apparent or obvious to a POSITA that King’s dome-and-tray assembly also *includes* the claimed *structure establishing thermal isolation of the sensing units by minimizing heat transfer contacts between said sensing units and said housing means and locating said temperature sensor and said at least one dew point sensing*

component amid insulated air pockets formed by said structure of said housing means. For clarity, I will use subheadings to organize the remainder of my detailed analysis regarding a POSITA's understandings gleaned from King and the claim language of Element [1.d].

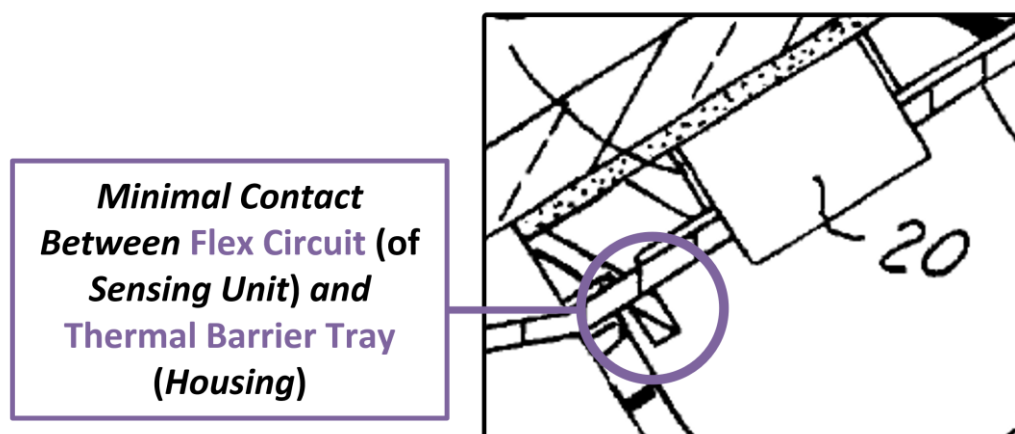
*minimizing heat transfer contacts between
said sensing units and said housing means*

178. For at least the following three reasons (taken individually or collectively), it would have been apparent or obvious to a POSITA from King's disclosure that the *structure* of the dome-and-tray assembly (*housing*) has *minimized heat transfer contacts* with the *sensing units*.

179. First, King teaches that the *sensing units* are secured to the dome-and-tray assembly (*housing*) by an interface between the flex circuit and the tray's perimeter wall. EX1005 (King), 3:11–16 (“The conductor sensor end 42 [of the flex circuit 18] generally conforms to the perimeter wall 34, thereby securing the end 42 and soldered sensors 20, 22, and 24 to 15 the tray 16.”). King makes no mention of any further contact between the housing in the sensing units, and a POSITA would have appreciated that contact limited to the outer periphery of the flex circuit and the tray's perimeter wall is *minimal*.

180. Second, King's figures illustrate the *minimal heat transfer contact* between the *sensing units* and the dome-and-tray assembly (*housing*). EX1005

(King), Figures 1–2. Consistent with King’s description, the only contact interface King illustrates is at the periphery of the flex circuit and the perimeter wall of the tray, which a POSITA would have deemed *minimal*.



EX1005 (King), Figure 2 (excerpted-annotated)

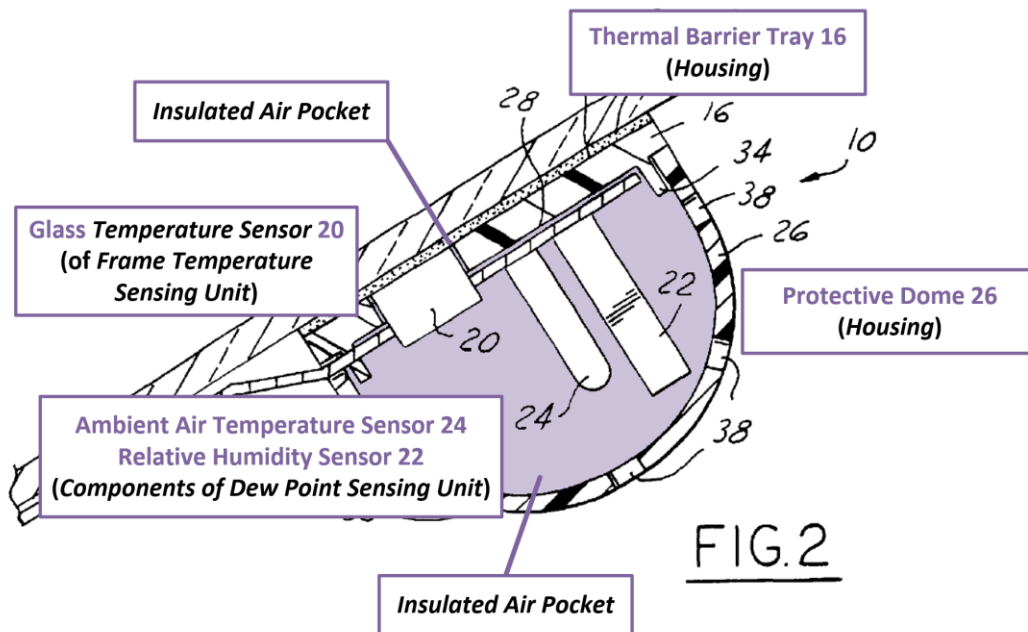
181. Third, as discussed above in Ground 1A, a POSITA would have been motivated to pursue the commonplace design goal of promoting sensor accuracy, particularly in the context of a condensation control system reliant on sensor readings like that of the Carter-Beatenbough-King Combination. As the POSITA would have known, the effectiveness of such an automated control system is affected by the accuracy of the sensor measurements on which it depends. EX1027, 2 (“The point here is that you cannot control a variable more accurately than you can measure it. Therefore, measurement is fundamental to control.”). When considering the Combination’s automated system—a system designed to prevent condensation effectively and efficiently by activating electrical heaters only when sensed conditions are ripe and controlling the activated heaters according to defined pulse

widths based on dew point (*see* above at Section X.C)—the POSITA would have appreciated the importance of control system effectiveness and, thus, sensor accuracy. As one example, inaccurate sensor readings would cause the control unit to activate the heaters prematurely, which would waste energy, or belatedly, which would allow condensation to form. As another example, inaccurate sensor readings would cause the control unit to use the pulse widths that are too wide or too narrow, likewise wasting energy or allowing condensation to form. These results would not be satisfactory to the POSITA. As a result, motivated by the benefit of promoting sensor accuracy, the POSITA would have employed the known technique of *minimizing heat transfer contacts between the sensing units and* any potential heat sources/sinks—like the protective *housing*—that are not the subject of the respective sensor measurements to avoid measurement bias errors.

locating said temperature sensor and said at least one dew point sensing component amid insulated air pockets formed by said structure of said housing means

182. It would have been apparent or obvious that the *structure* of King's dome *housing* (dome 26 and tray 16) *locates the temperature sensor* (glass temperature sensor 20) *and the at least one dew point sensing component* (ambient air temperature sensor 22 and/or relative humidity sensor 24) *amid air pockets formed by the structure of the housing*. For example, King's figures show that these sensing components are received *amid air pockets formed by the structure of*

the housing. EX1005 (King), 1:48–65 (“The glass temperature sensor sits within a hole, penetrating the tray and the flex circuit...[and a]ll three sensors are located beneath a protective dome which is secured to a perimeter wall of the tray.”), 2:40–3:2, Figures 1–2. Additionally, the POSITA would have been aware of the well-known fact that air is a thermal *insulator*. EX1028, 4 (“Air is a thermal insulator and its thermal conductivity is negligible”).



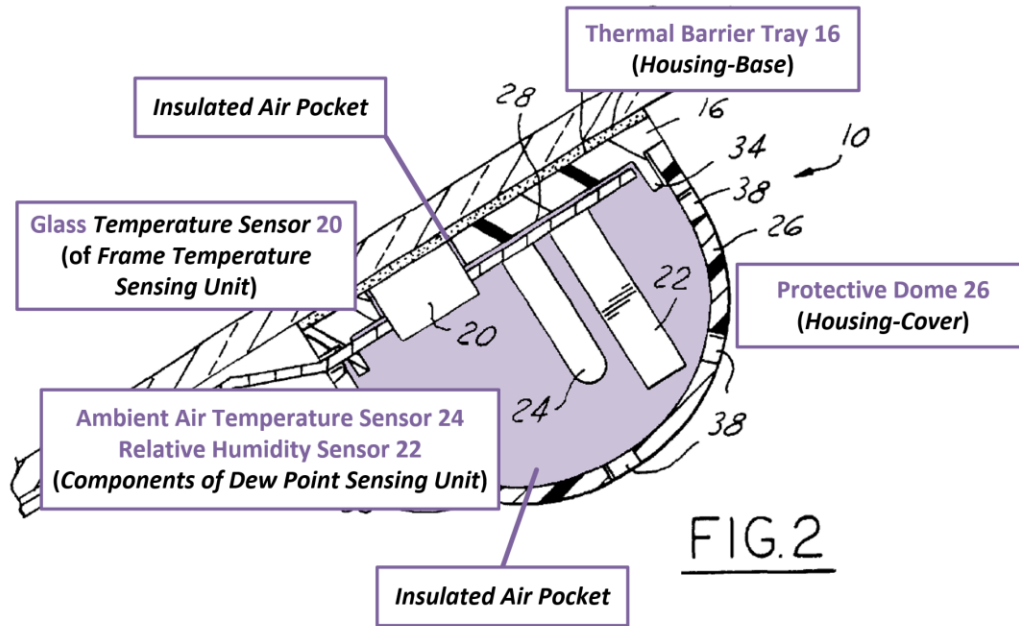
EX1005 (King), Figure 2 (annotated)

Corresponding Structure

183. Based on the reasoning provided above in ¶¶176–182, my conclusion is that King teaches or renders obvious the recited structural and functional limitations of a *housing for locating said sensing units including structure establishing thermal isolation of said sensing units by minimizing heat transfer*

contacts between said sensing units and said housing means and locating said temperature sensor and said at least one dew point sensing component amid insulated air pockets formed by said structure.

184. Next, I will address the Carter-Beatenbough-King Combination with respect to the additional structure disclosed in '181 patent's specification for the claimed *housing means*, which, as I outlined above at §VIII.B, includes: A base and a cover that, when mated together, establish the claimed *insulated air pockets*. As shown below and discussed above, the Combination's *housing* likewise includes a base (thermal barrier tray, per King) and a mated cover (protective dome, per King) that together form *insulated air pockets* receiving temperature and dew point sensing components. EX1005 (King), 1:48–65, 2:40–3:2, Figures 1–2. Thus, in comparison to the '181 patent, the Carter-Beatenbough-King Combination includes a *housing* solution that accomplishes the claimed *locating* function in the same/substantially the same way—i.e., via a mated base and cover—to achieve the same/substantially the same result—i.e., receiving the sensing components within air pockets.



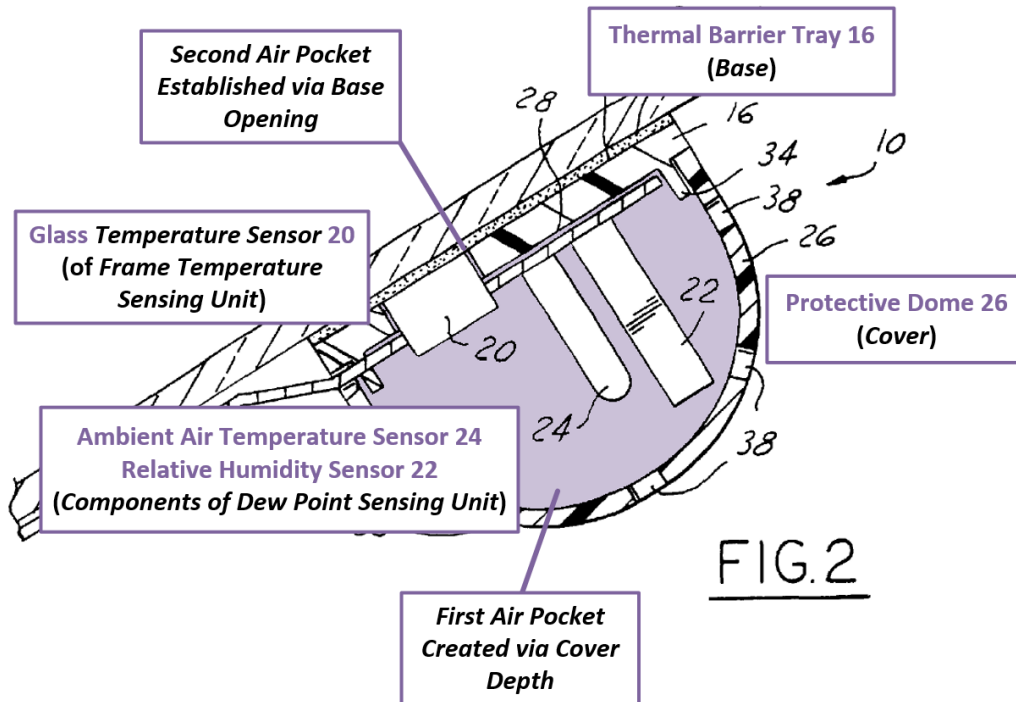
EX1005 (King), Figure 2 (annotated)

2. Claim 2

- (i) *Element [2]: The apparatus of claim 1 wherein said housing means includes a frame temperature sensing unit housing, said frame temperature sensing unit housing including a base and a cover, said cover having a depth creating a first one of said air pockets at one side of said temperature sensing unit and said base including an opening for receiving said temperature sensor therethrough, said opening having an opening area greater than surface area of said temperature sensor thus establishing a second one of said air pockets around said temperature sensor.*

185. As discussed at Element [1.d], King teaches a *housing* having a *base* (thermal barrier tray) and a mated *cover* (protective dome) that together *create air pockets* around the *frame temperature sensing unit* (glass temperature sensor, per Element [1.a]). King's Figure 2 shows that *the cover has a depth creating a first*

air pocket, and the base includes an opening for receiving the temperature sensor, the opening having an opening area greater than surface area of the temperature sensor thus establishing a second one of said air pockets around the temperature sensor.



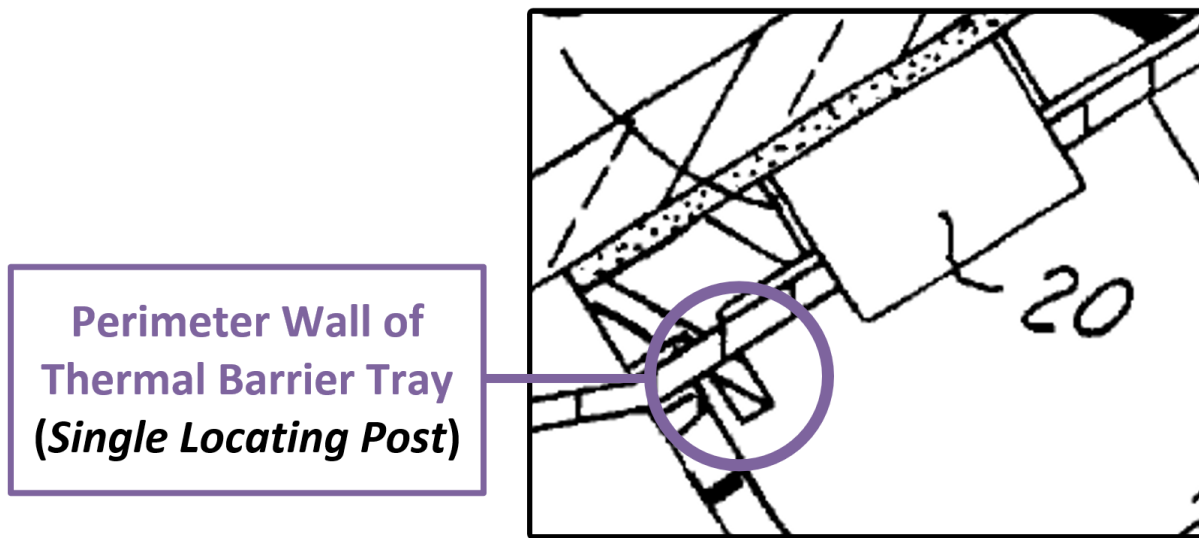
EX1005 (King), Figure 2 (annotated)

3. Claim 3

- (i) ***Element [3]: The apparatus of claim 2 wherein said frame temperature sensing unit housing includes a single locating post at said cover for securing position of said temperature sensing unit relative to said cover.***

186. As discussed above at Element [1.d], King's ***housing*** provides a single contact interface between the flex circuit 18 and the perimeter wall 34 of the tray 16, which serves as ***a single locating post for securing the position of the temperature***

sensing unit relative to the protective dome 26 (*cover*). See EX1005 (King), 3:11–16 (“The conductor sensor end 42 [of the flex circuit 18] generally conforms to the perimeter wall 34, thereby securing the end 42 and soldered sensors 20, 22, and 24 to 15 the tray 16.”). As shown below, the perimeter wall 34 (*locating post*) is proximate and adjacent to (*at*) the protective dome 26 (*cover*).



EX1005 (King), Figure 2 (excerpted-annotated)

187. Additionally, I have been asked to analyze Element [3] under a narrow interpretation where the *locating post* must be an integral part of the *cover*. Though I see no reason to narrowly interpret Element [3] this way, I have nevertheless considered the interpretation as a hypothetical and determined that my conclusions on obviousness would still hold because it would have been a binary design choice—and thus obvious—to incorporate the *locating post* taught by King as part of the protective dome 26 (*cover*) rather than the thermal barrier tray 16. As a POSITA

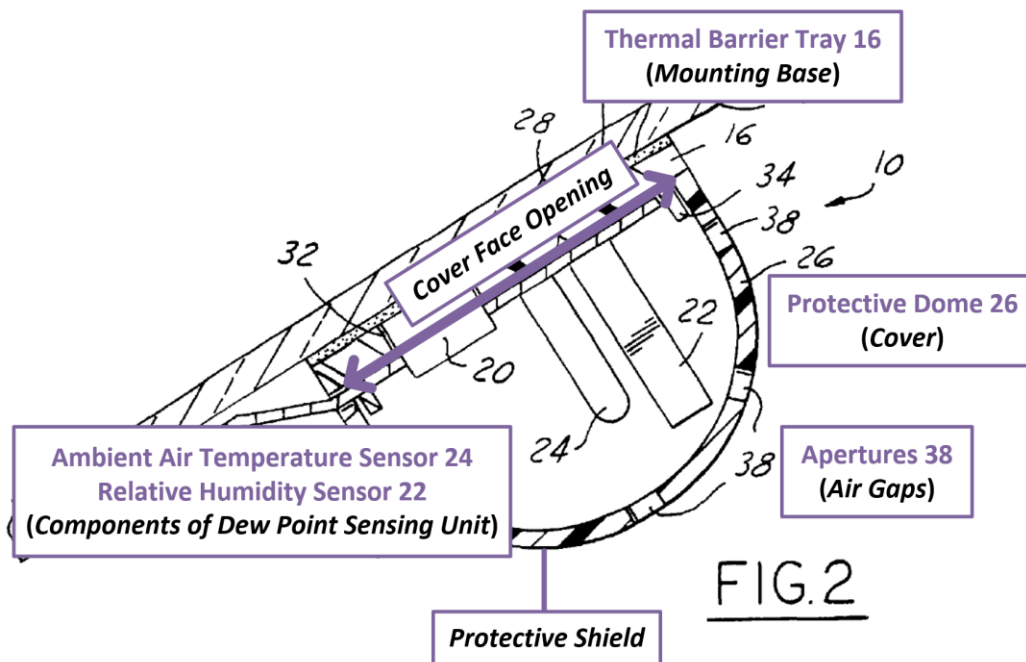
would have recognized, there are only two components to the **housing**—the tray (**base**) and dome (**cover**)—and the **locating post** used to secure the flex circuit (and thus the **sensors**) can be part of either housing component without changing its function of effectiveness.

4. Claim 4

- (i) ***Element [4]: The apparatus of claim 1 wherein said housing means includes a dew point sensing unit housing, said dew point sensing unit housing including a mounting base and cover, said cover including a cover face opening therethrough for receiving said at least one dew point sensing component therein, said cover face opening including a protective shield thereover having air gaps therearound allowing air flow between said protective shield and said cover and thus over said at least one dew point sensing component.***

188. As discussed at Element [1.d], King teaches a **housing** having a **mounting base** (thermal barrier tray) and a mated **cover** (protective dome) that together **create air pockets** within which **components** of the **dew point sensing unit** (ambient air temperature sensor 22 and relative humidity sensor 24, per Element [1.b]) reside. King's Figure 2 shows that the **cover includes a cover face opening therethrough for receiving the dew point sensing components therein, the cover face opening including a protective shield thereover having air gaps therearound allowing air flow between the protective shield and the cover and thus over the at least one dew point sensing component.** See EX1005 (King), 2:61–3:2 (“The

protective dome 26 surrounds, and serves to protect, the sensors 20, 22 and 24 from any impacts...Dome 26 has a plurality of apertures 38 of sufficient size and number so that the ambient air temperature sensor 22 and the relative humidity sensor 24 located within dome 26 are exposed to true ambient air temperature and humidity values within the immediate vicinity.”); Figure 2 (below).

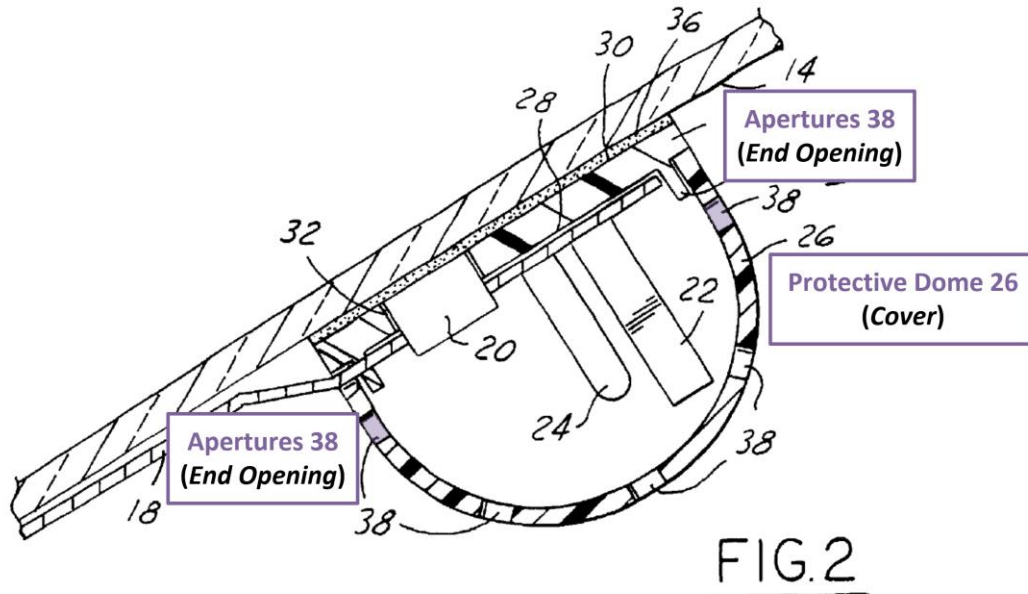


EX1005 (King), Figure 2 (annotated)

5. Claim 5

- (i) ***Element [5]: The apparatus of claim 4 wherein said cover of said dew point sensing unit housing includes opposite end openings to establish ambient air flow through said dew point sensing unit housing.***

189. King's Figure 2 shows that the *cover includes opposite end openings to establish ambient air flow through the dew point sensing unit housing*. See *supra*, Elements [1.d], [4].

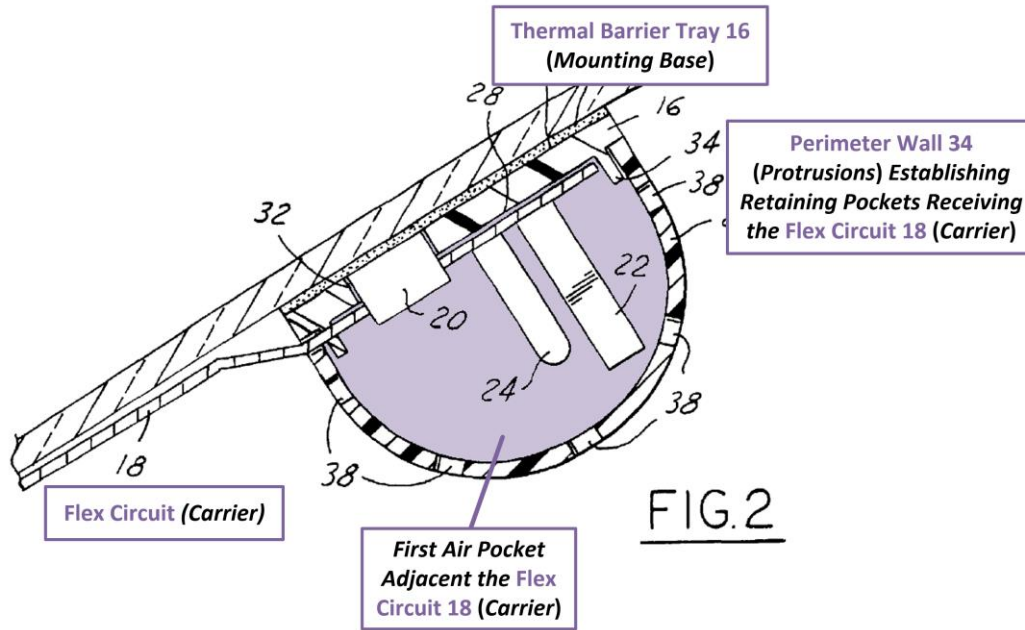


EX1005 (King), Figure 2 (annotated)

6. Claim 6

- (i) ***Element [6]: The apparatus of claim 4 wherein said mounting base of said dew point sensing unit housing includes protrusions establishing retaining pockets receiving said carrier of said dew point sensing unit at outer edges of said carrier and further establishing a first one of said air pockets amid said protrusions and adjacent to said carrier.***

190. As discussed above at Elements [1.d], [4], King's ***dew point sensing unit housing*** provides a contact interface between the flex circuit 18 (***carrier***, per Element [1.b]) and the perimeter wall 34 of the tray 16 (***mounting base***). See EX1005 (King), 3:11–16 (“The conductor sensor end 42 [of the flex circuit 18] generally conforms to the perimeter wall 34, thereby securing the end 42 and soldered sensors 20, 22, and 24 to 15 the tray 16.”). King's Figure 2 shows that the tray's perimeter wall 34 provides ***protrusions establishing retaining pockets receiving the carrier*** (flex circuit) ***of the dew point sensing unit*** (including sensors 22, 24) ***at outer edges of the carrier*** (flex circuit) ***and further establishing a first one of the air pockets.***



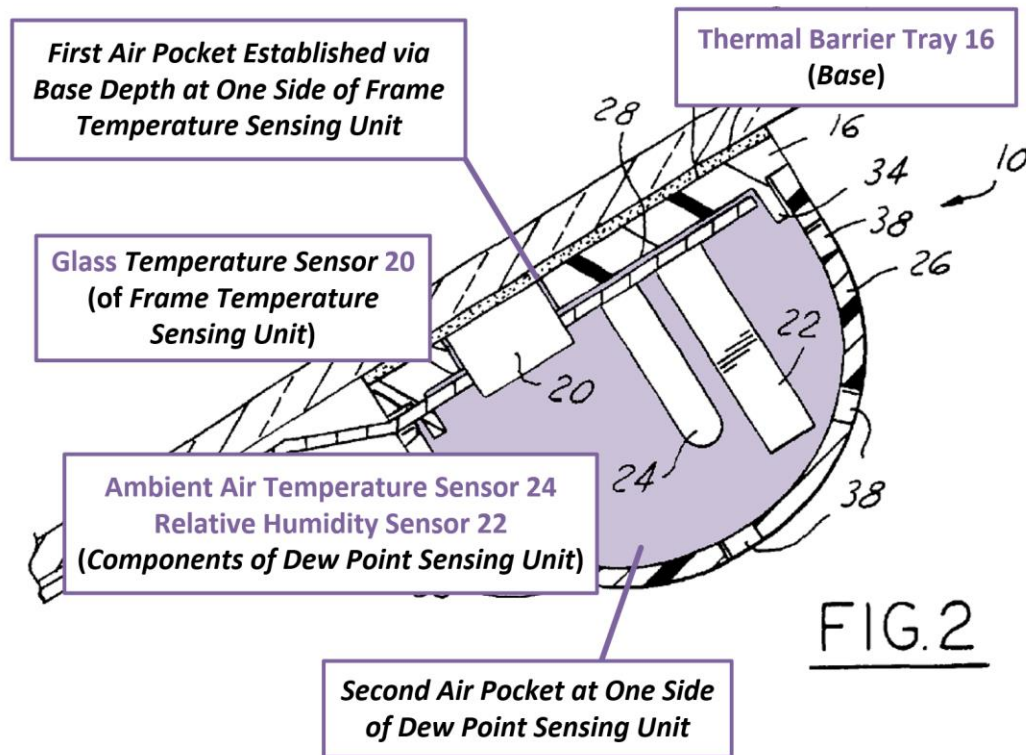
EX1005 (King), Figure 2 (annotated)

191. Notably, though I am not involved in the co-pending district court litigation between the parties, I have been informed that Patent Owner's infringement allegations against Petitioner identify a similar perimeter wall around a printed circuit board as the claimed *protrusions* of Element [6].

7. Claim 7

- (i) ***Element [7]: The apparatus of claim 1 wherein said housing means includes a cover and a base, said cover including a cover face opening therethrough for receiving said at least one dew point sensing component therein, said cover face opening including a protective shield thereover having air gaps therearound allowing air flow between said protective shield and said cover and thus over said at least one dew point sensing component, and said base having depth creating a first one of said air pockets at least at one side of said temperature sensing unit and a second one of said air pockets at one side of said dew point sensing unit.***

192. As discussed at Element [1.d], King teaches a ***housing*** having a ***base*** (thermal barrier tray) and a mated ***cover*** (protective dome) that together ***create air pockets*** around the ***frame temperature sensing unit*** (including glass temperature sensor, per Element [1.a]) and ***components*** of the ***dew point sensing unit*** (including ambient air temperature sensor 22 and relative humidity sensor 24, per Element [1.b]). As discussed at Element [4], which includes verbatim language, King further teaches the claimed limitations regarding ***a cover face opening***. Further still, and consistent with the analysis at Elements [1.d] and [2], King's Figure 2 shows that ***the base has depth creating a first one of said air pockets at least at one side of said temperature sensing unit and a second one of said air pockets at one side of said dew point sensing unit.***



EX1005 (King), Figure 2 (annotated)

8. Claim 14

- (i) ***Element [14.pre]: A system for condensation control at a refrigerated display case having at least one door, a frame and at least one frame/door heater, said system comprising:***

193. Based on the similar claim language, my conclusion is that the Carter-Beatenbough-King Combination renders obvious Element [14.pre] for the same or substantially the same reasons discussed above at Element [1.pre].

- (ii) ***Element [14.a]: a temperature sensing unit in contact with the display case frame to monitor case frame temperature;***

194. Based on the similar claim language, my conclusion is that the Carter-Beatenbough-King Combination renders obvious Element [14.a] for the same or substantially the same reasons discussed above at Element [1.a] (discussing a frame-mounted sensor deployment).

- (iii) ***Element [14.b]: a dew point sensing unit on the display case to monitor ambient air temperature and relative humidity outside the display case; and***

195. Based on the similar claim language, my conclusion is that the Carter-Beatenbough-King Combination renders obvious Element [14.b] for the same or substantially the same reasons discussed above at Element [1.b].

- (iv) ***Element [14.c]: control means for receiving data from said sensing units and utilizing monitored case frame temperature, ambient air temperature and relative humidity to anticipate formation of condensation at the display case and activating and deactivating the frame/door heater responsive thereto.***

196. Based on the similar claim language, my conclusion is that the Carter-Beatenbough-King Combination renders obvious Element [14.c] for the same or substantially the same reasons discussed above at Element [1.c] of Ground 1B (explaining that the Combination includes Carter's teachings regarding a condensation control scheme) and Elements [1.c] and [14.c] of Ground 1A

(explaining how Carter's teachings render obvious the activating/deactivating functions and at least equivalent structure to that of the '181 patent).

9. Claim 15

- (i) ***Element [15]: The system of claim 14 further comprising means for thermally isolating said dew point sensing unit from variations in temperature of the display case frame or display case door.***

197. Based on the similar claim language, my conclusion is that the Carter-Beatenbough-King Combination renders obvious Element [15] for the same or substantially the same reasons discussed above at Element [1.d] (discussing King's teachings regarding housing means for thermally isolating components the dew point sensing unit amid insulated air pockets).

10. Claim 16

- (i) ***Element [16]: The system of claim 14 further comprising means for thermally isolating said temperature sensing unit from variations in temperature of ambient air.***

198. Based on the similar claim language, my conclusion is that the Carter-Beatenbough-King Combination renders obvious Element [16] for the same or substantially the same reasons discussed above at Element [1.d] (discussing King's teachings regarding housing means for thermally isolating components the frame temperature sensing unit amid insulated air pockets).

11. Claim 17

- (i) *Element [17]: The system of claim 14 further comprising an internal case temperature sensing unit mounted inside the display case and communicating with said control means for monitoring internal case temperature.*

199. My conclusion is that the Carter-Beatenbough-King Combination renders obvious Element [17] for the same or substantially the same reasons discussed above at Element [17] of Ground 1A.

12. Claim 18

- (i) *Element [18]: The system of claim 17 further comprising data storing means communicating with said control means for storing data related to readings at said sensing units and operation of the frame/door heater.*

200. My conclusion is that the Carter-Beatenbough-King Combination renders obvious Element [18] for the same or substantially the same reasons discussed above at Element [18] of Ground 1A.

XI. GROUND 1C: Claims 17–20 Are Obvious Over Carter, Beatenbough, King, and Gatling

A. Gatling (EX1007)

201. Gatling describes a system for “monitoring and controlling temperature” in an array of refrigerated display cases. EX1007 (Gatling), 1:7–10, Abstract; Among other things, Gatling discloses placing a “product-simulating

probe 50” in each refrigerated case to measure the temperature within. EX1007 (Gatling), 4:66–5:15. The probe wirelessly transmits temperature data to a receiver, which, in turn, transmits the data to a controller that “logs and analyzes the temperature data and controls the temperature of the display case[.]” EX1007 (Gatling), 6:15–24.

B. Obviousness Analysis

1. Claim 17

- (i) ***Element [17]: The system of claim 14 further comprising an internal case temperature sensing unit mounted inside the display case and communicating with said control means for monitoring internal case temperature.***

202. The Carter-Beatenbough-King-Gatling Combination includes Gatling’s teachings to control the refrigeration of a ***display case*** based on “multiple temperature readings including air-discharge temperature sensed by a discharge temperature sensor and/or food product temperatures approximated by a product simulating probe.” EX1007 (Gatling), 4:58–65 (reference numbers omitted); *see also* 1:40–54, 3:16–4:5, 6:15–24, 6:41–61, 7:20–8:12, Figures 1, 5–8. Per Gatling, the discharge temperature sensor and product simulating probe (individually or collectively, ***internal case temperature sensing unit***) ***are mounted inside the display case for monitoring internal case temperatures. See id.***

203. A POSITA would have been motivated to incorporate Gatling's above-discussed teachings with Carter-Beatenbough-King and would have had a reasonable expectation of success in doing so. First, using temperature sensors within a refrigerated display case for monitoring temperatures within the case, as Gatling teaches, was well known at the time of the '181 patent for the beneficial purpose of facilitating closed-loop refrigeration/temperature control and ensuring product quality. EX1035, [0097] ("Special attention is paid to the refrigerators (freezers) for commercial use so that variation in internal temperature distribution are controlled in order that food materials may be stored with a predetermined quality level.")⁷; EX1039, 41 ("Electronic sensor control is the most accurate" kind of "[t]emperature control" system.). Indeed, Gatling makes clear that this approach was "conventional." EX1007 (Gatling), 1:40–45. Second, even if internal case temperature sensors were not so ubiquitous (which they were), a POSITA would have (i) appreciated that one basic design goal of a refrigerated display case is to achieve a target operating temperature and (ii) recognized that a common-sense approach to achieving that goal includes monitoring the existing temperature within the case. These understandings would have prompted a POSITA to integrate Gatling's teachings with Carter-Beatenbough-King.

⁷ Note that EX1035 is a published patent application with a claimed priority date of October 18, 2004.

204. More, as discussed at Element [17] of Ground 1A, it would have been an obvious design choice to use a common ***control means*** for controlling all the various functions of the refrigerated display case and, thus, ***communicating with*** all the various sensors—including the ***internal case temperature sensing unit***, the frame temperature sensing unit, and the dew point sensing unit.

2. Claim 18

- (i) ***Element [18]: The system of claim 17 further comprising data storing means communicating with said control means for storing data related to readings at said sensing units and operation of the frame/door heater.***

205. The Carter-Beatenbough-King-Gatling Combination renders obvious Element [18] for at least the same reasons discussed above at Element [18] of Grounds 1A–1B.

206. In addition to the above-discussed understanding of a POSITA in view of Carter’s teachings, Gatling reinforces that the Combination includes ***storing means for storing data related to readings at said sensing units and operation of the frame/door heater***. Gatling, for example, teaches a controller for a refrigerated display case with data “logging capabilities.” EX1007, 3:40–43, 6:15–24, 6:62–7:3, 1:40–41. Beyond employing short-term ***storage means*** (e.g., a cache, register, or active memory) for the purpose of allowing the ***control means***

(controller/microprocessor) to access and utilize sensor data, operational parameters, and program instructions, a POSITA would have been motivated to include a long-term *storage means* (e.g., non-volatile memory) logging *sensor readings* and *heater operation* data for the purpose of facilitating system performance analyses (e.g., monitoring system health, assessing and optimizing operational efficiency, etc.). *Supra*, ¶53 (citing EX1015, 2–3); EX1039, 25 (“historical data, reports”). Appreciating Beatenbough’s stated goals of minimizing energy consumption and obtaining cost savings (EX1006, 1:9–44), the POSITA would have been motivated to log sufficient historical data—e.g., *sensor readings* and *heater operation data*—to evaluate the effectiveness of a given system configuration. As just one example, data regarding the heater activation/deactivation times could be readily used to determine energy consumption and costs and monitor these over longer time frames. For instance, given the relationship of ambient humidity levels and the need for anti-sweat heating, an analysis could be performed to weigh the cost of maintaining the indoor environment (e.g., a grocery store) at low humidity levels against the reduced cost of anti-sweat heating.

3. Claim 19

- (i) ***Element [19]: The system of claim 18 further comprising means for wirelessly accessing stored data at said data storing means.***

207. Gatling teaches the notion of ***wirelessly accessing stored data*** from a refrigerated display case for the beneficial purpose of avoiding “expensive and extremely cumbersome” wired communications. EX1007, 1:1–3, 1:40–54, 1:55–2:6 (“A sensor...measures a parameter, and a transceiver...wirelessly transmits the measured parameter...”), 5:12–30, 6:25–61 (“The display module 46 will measure the case discharge air temperature, via the discharge temperature sensor 48 and the product simulated temperature, via the product probe temperature sensor 50 and then wirelessly transmit this data...”), Figures 6–7. More, Gatling teaches a “wireless transceiver” for carrying out this function, which mirrors (or is at least equivalent to) the ’181 patent’s corresponding structure of a “communications board/transmitter/receiver,” as I explained above at Section VIII.I.

208. A POSITA would have been motivated to employ Gatling’s teachings regarding a ***means for wirelessly accessing stored data*** for the purpose of communicating data from the above-discussed data ***storing means*** (*supra*, Element [18]) to a remote computing device. For one, the POSITA would have appreciated that the data storage, processing, and human interface capabilities on a refrigerated display case are limited compared to that of a personal computer, server, or

workstation. Accordingly, the POSITA would have been motivated to convey data collected and stored on the case to a more capable central computing device. And the POSITA would have been motivated to do so using a wireless transceiver to obtain the predictable cost, flexibility, and scalability benefits over wired transmission lines.

4. Claim 20

- (i) ***Element [20]: The system of claim 14 wherein said means for wirelessly accessing data is configured for remotely updating control parameters at said control means utilized for monitoring case frame temperature, ambient air temperature and relative humidity to anticipate formation of condensation at the display case and activating and deactivating the frame/door heater.***

209. As discussed at Element [1.c] of Ground 1B, the Carter-Beatenbough-King-Gatling Combination includes Beatenbough's teachings on providing ***updatable control parameters***—set points—for a condensation control scheme implemented by the ***control means to activate/deactivate a frame/door heater based on monitored frame temperature, ambient air temperature, and relative humidity.***

EX1006 (Beatenbough), 3:45–4:6; *see also supra*, Element [14.c] of Grounds 1A and 1B.

210. Additionally, as discussed at Element [19] of Ground 1C, Gatling teaches a wireless transceiver (***means for wirelessly accessing data***) for

communicating *remotely*. EX1007 (Gatling), 1:1–3, 1:40–54, 1:55–2:6, 5:12–30, 6:25–61, Figures 6–7. A POSITA would have been motivated to employ Gatling’s teachings on wireless communications/transceivers to predictably enhance Beatenbough’s teachings on updatable control parameters, allowing updates to be made more easily—i.e., via a remote computer rather than manual dials. Gatling reinforces this aspect of the Combination by teaching that local case controllers can be programmed/configured by a remote device. EX1007 (Gatling), 4:2–5; EX1039, 43 (“Microprocessors offer the option of remote control and system operation[.]”).

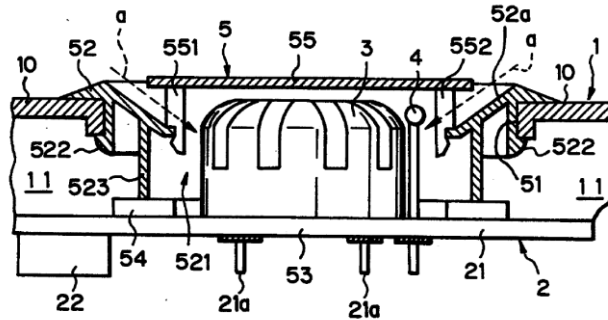
XII. GROUND 1D: Claims 1–6 Are Obvious Over Carter, Beatenbough, and Kotani

A. Kotani (EX1008)

1. Brief Summary of Kotani’s Disclosure

211. Kotani describes a “humidity meter” mounted on a printed circuit board. EX1008 (Kotani), Abstract, 1:8–12. Kotani’s humidity meter includes a humidity sensor assembly 3 and a temperature sensor 4 mounted in a shared sensor room 5. EX1008 (Kotani), 2:35–40, 2:63–3:1, 5:30–38. Like the ’181 patent, Kotani’s “sensor room 5 is completely separated from the inner space 11 of the housing 1 so that the humidity sensor assembly 3 is disposed in open air.” EX1008 (Kotani), 2:63–66, 3:32–36. With this configuration, the sensor room is “thermally

separated,” such that the sensor elements are “not influenced by heat dispersed by other circuits and provides accurate measure[ments].” EX1008 (Kotani), 5:39–44.



EX1008 (Kotani), Figure 2A

2. A POSITA Would Have Recognized Kotani as Analogous Prior Art to the '181 Patent

212. Kotani is analogous art to the '181 patent. I understand that a prior art reference is analogous to the patent in question if the reference is [1] within the same field of endeavor as the patent and/or [2] has reasonable pertinence to one or more of the problems purportedly solved by the patent's inventors. Here, Kotani is at least reasonably pertinent to one or more problems addressed by the '181 patent. For example, Kotani and the '181 patent similarly address the design problem of provisioning a housing for a sensor package including an ambient air temperature sensor and a relative humidity temperature sensor. *Compare* §V (summarizing the '181 patent), *with* §XII.B.1 (summarizing Kotani). In both Kotani and the '181 patent, the design problem involves mechanically supporting, electrically connecting, and thermally isolating the sensors. Kotani is therefore reasonably

pertinent to at least one of the problems that the '181 patent's inventors were trying to solve.

213. Indeed, someone faced with the kind of sensor packaging problem addressed by the '181 patent would have thought to pursue references like Kotani that propose viable solutions, regardless of their technical field. Because automated control systems are used in so many kinds of electrical devices/systems, sensors are likewise deployed in a wide variety of different fields. EX1039, 24 (“[C]ontrols are required in every industry[.]”). Accordingly, a person looking to design, improve, and/or procure a sensor package would not have confined themselves to prior art references from any particular field.

B. Motivation to Combine and Reasonable Expectation of Success

214. The Carter-Beatenbough-Kotani Combination represents the predictable and expected result of applying in the context of Beatenbough's refrigerated display case with condensation control capabilities: **(a)** Carter's complementary teachings on triggering heater activation/deactivation based on door/frame surface temperature sensed by a surface temperature sensor; and **(b)** Kotani's complementary teachings on a “humidity meter” for implementing the Carter-Beatenbough condensation control scheme. From a POSITA's perspective in 2005, integrating the complementary teachings of Carter, Beatenbough, and Kotani would have involved nothing more than applying known solutions to known

problems and achieving predictable outcomes. The fundamental aspects of Beatenbough's disclosure would remain intact, bolstered by the beneficial teachings of Carter and Kotani in a way that the POSITA would reasonably expect to succeed.

215. My prior discussion above in Ground 1B at ¶¶151–158 sets forth a POSITA's motivation to combine the teachings of Beatenbough and Carter to provide a refrigerated display case with a comprehensive condensation control system. Ground 1D combines Beatenbough and Carter in substantially the same way as Ground 1B, differing only in that Ground 1D further incorporates Carter's teachings directed to a surface temperature sensor mounted to and monitoring the frame of the case (as set forth in Ground 1A). The Ground 1B motivation-to-combine discussion is fully incorporated here in Ground 1D. These motivation rationales support the Carter-Beatenbough Combination as to both Carter's condensation control scheme and the concomitant surface temperature sensor, the latter providing sensor readings on which the former relies.

216. A POSITA would have been further motivated to incorporate Kotani's teachings of a "humidity meter" with a relative humidity sensor and an ambient air temperature sensor for implementing the Carter-Beatenbough condensation control scheme. The following reasons, taken separately or collectively, support the Carter-Beatenbough-Kotani Combination.

217. First, a POSITA would have been prompted to integrate Kotani's teachings with Carter and Beatenbough based on the following understandings:

- that the Carter-Beatenbough condensation control scheme relies on ambient air temperature and relative humidity sensor readings;
- that the housing and mounting accommodations for these sensors significantly impacts the accuracy of their sensor readings, and
- that the accuracy of the sensor readings significantly impacts whether the heater on the refrigeration case is operated effectively and efficiently, as envisioned by Carter and Beatenbough.

Thus, when tasked with implementing the Carter-Beatenbough condensation control scheme, the POSITA would have faced a routine sensor packaging problem. Recognizing that Kotani's disclosure represents a known, suitable, and "simple" solution to this problem—one that specifically addresses the ambient temperature and relative humidity sensors at issue—the POSITA would have been motivated to make the Carter-Beatenbough-Kotani Combination. EX1008 (Kotani), 1:34–62.

218. Second, a POSITA would have been motivated to make the Carter-Beatenbough-Kotani Combination because Kotani's teachings have the advantage of providing a modular unit including, (i) the relative humidity and ambient temperature sensors; (ii) a supporting substrate for the sensors; (iii) electronic circuits for processing the sensor output; and (iv) a single housing for all of these

components. The POSITA would have appreciated the known benefits of a modular sensor design like Kotani's that includes both the sensors and associated processing circuits—e.g., simplified installation because establishing electrical connections and performing configuration and testing work is performed during the manufacturing process. *See* EX1020, 1 (“Fully calibrated, digital output”) (“No external components required”); EX1032, 1 (“Two sensors (rh/temp.) on one single chip, fully calibrated and ready to use”).

219. Additionally, the POSITA would have recognized that sensors with digital output like Kotani's have an advantage over analog sensors in terms of flexibility, adaptability, and compatibility. Unlike a sensor with analog output, a sensor with digital output like Kotani's can interface directly with the control unit/microprocessor that receives and utilizes the sensor readings. This is so because the digital output can be directly interpreted by the control unit/microprocessor without intermediate analog-to-digital converters. Further still, because Kotani's modular sensor design that incorporates integrated processing circuitry provides the advantage of enhanced functionality. For example, in addition to analog-to-digital circuits, Kotani notes that other types of auxiliary circuits can be included to facilitate additional functions, such as “an indication circuit for visual indication of measured humidity and/or temperature on an indication screen.” EX1008 (Kotani), 2:44–52. As the POSITA would have recognized, such auxiliary circuitry could also

be used for data processing and/or statistical computations, reducing the computational load on the microprocessor of the main control unit.

220. Third, the POSITA would have appreciated that Kotani's modular sensor package is further beneficial in that the housing is specifically designed to support and protect the sensors, while at the same time promoting sensor accuracy by providing sufficient thermal isolation and exposure to ambient airflow. EX1008 (Kotani), 1:50–62 (identifying the “objects” of the design as providing sensor elements and electronic circuits “in a single housing with no undesirable affection by heat generated in the electric circuits” and “to provide a humidity meter which indicates measured humidity accurately”). Given the known benefits thermal isolation and sensor accuracy—which I discuss at length in this declaration at ¶¶42–49, ¶¶106–107, ¶172, ¶181—the POSITA would have viewed Kotani's design as particularly effective and advantageous.

C. Claim Element Analysis

1. Claim 1

- (i) ***Element [1.pre]: Condensation control apparatus for a refrigerated display case having at least one door, a frame and at least one frame/door heater, said apparatus comprising:***

221. My conclusion is that the Carter-Beatenbough-Kotani Combination renders obvious Element [1.pre] for the same or substantially the same reasons

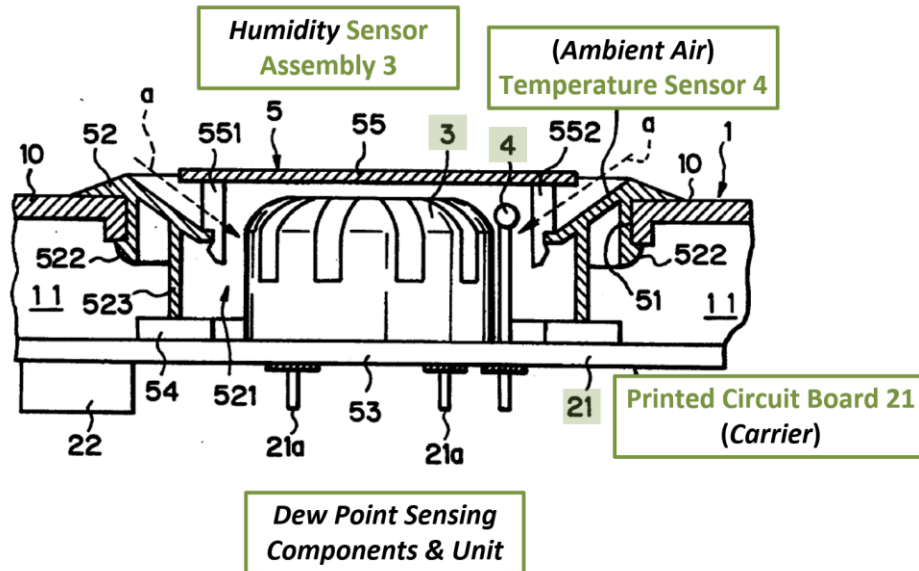
discussed above at Element [1.pre] of Ground 1B (discussing the combination of teachings from Carter and Beatenbough).

- (ii) ***Element [1.a]: a frame temperature sensing unit adapted for monitoring temperature of one of the display case door or display case frame and including a carrier having a temperature sensor thereat;***

222. My conclusion is that the Carter-Beatenbough-Kotani Combination renders obvious Element [1.a] for the same or substantially the same reasons discussed above at Element [1.a] of Ground 1A (discussing Carter’s teachings).

- (iii) ***Element [1.b]: a dew point sensing unit adapted for monitoring ambient air temperature and relative humidity outside of the display case and including a carrier having at least one dew point sensing component thereat;***

223. As discussed at Section XII.B, the Carter-Beatenbough-Kotani Combination includes the application of Kotani’s “humidity meter” (***dew point sensing unit***) ***for monitoring ambient air and relative humidity outside of the display case***. EX1008 (Kotani), 2:29–62, 2:63–3:13 (the sensors are “disposed in open air”), 3:51–4:18 (the output “is linearly proportional to measured relative humidity”), 5:30–44 (“the present device may indicate both humidity and temperature”), Figures 1–3. To this end, Kotani’s humidity meter includes a humidity sensor assembly 3 and a temperature sensor 4 (***dew point sensing components***) mounted on (***at***) a printed circuit board 21 (***carrier***). *Id.*



EX1008 (Kotani), Figure 2A (annotated)

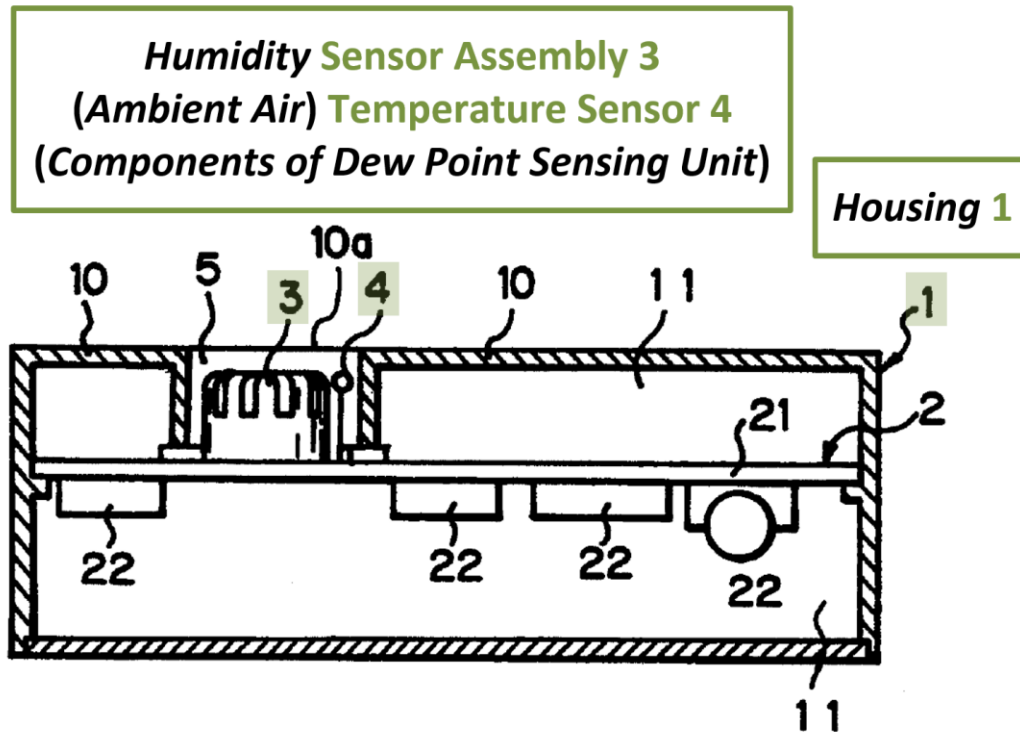
- (iv) ***Element [1.c]: a control unit communicating with said sensing units and including processing means connected for activating the display case frame/door heater when monitored display case door or frame temperature drops below a preselected set point above a dew point value derived from monitored ambient temperature and relative humidity; and***

224. My conclusion is that the Carter-Beatenbough-Kotani Combination renders obvious Element [1.c] for the same or substantially the same reasons discussed above at Element [1.c] of Ground 1B (discussing the combination of teachings from Carter and Beatenbough).

- (v) ***Element [1.d]: housing means for locating said sensing units including structure establishing thermal isolation of said sensing units by minimizing heat transfer contacts between said sensing units and said housing means and locating said temperature sensor and said at least one dew point sensing component amid insulated air pockets formed by said structure of said housing means.***

225. The analysis above at Element [1.d] of Ground 1A, incorporated fully here, addresses the functional and structural aspects of the claimed ***housing means*** concerning the ***frame temperature sensing unit*** and its ***temperature sensor*** based on Carter's teachings.

226. As for the aspects of the claimed ***housing means*** pertaining to the ***dew point sensing unit***, the Carter-Beatenbough-Kotani Combination incorporates Kotani's teachings regarding a ***housing*** 1 for ***locating*** the humidity sensor assembly 3 and the temperature sensor 4 (independently or collectively, ***dew point sensing components***, per Element [1.b]) within a sensor room 5. EX1008 (Kotani), 2:29–3:50, Figures 1–2B; *see supra*, §XII.B (motivation-to-combine).



EX1008 (Kotani), Figure 2B (annotated)

227. Additionally, it would have been apparent or obvious to a POSITA that Kotani's *housing* also *includes* the claimed *structure establishing thermal isolation of the sensing units by minimizing heat transfer contacts between said sensing units and said housing means and locating said at least one dew point sensing component amid insulated air pockets formed by said structure of said housing means*. For clarity, I will use subheadings to organize the remainder of my detailed analysis regarding a POSITA's understandings gleaned from Kotani and the claim language of Element [1.d].

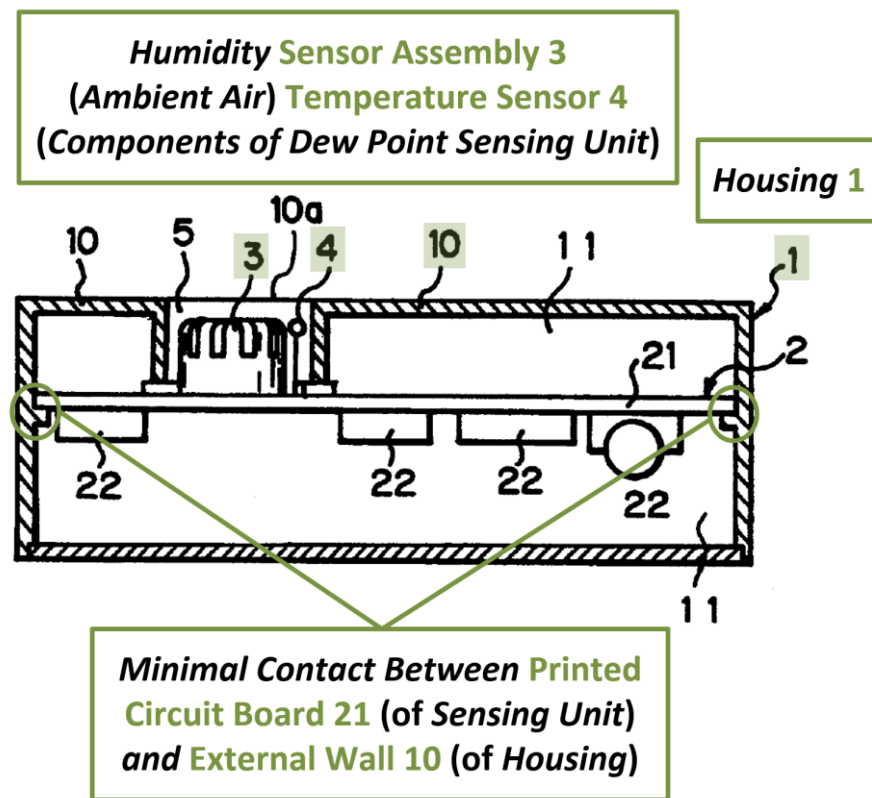
*minimizing heat transfer contacts between
said sensing units and said housing means*

228. For at least the following three reasons (taken individually or collectively), it would have been apparent or obvious to a POSITA from Kotani's disclosure that the *structure* of the *housing* has *minimized heat transfer contacts* with the *dew point sensing unit*.

229. First, Kotani suggests as much by emphasizing that the “sensor room” within which the humidity sensor assembly and temperature sensor are situated is “thermally separated” or “isolated” from the remainder of the housing to promote “accurate[]” measurements. EX1008 (Kotani), 1:34–62, 5:39–44, 5:53–6:18; *see also* 2:35–54, 3:14–50. As a POSITA would have known, the accuracy of humidity and temperature readings is diminished by inadvertent heat transfer—i.e., heat transfer between the sensing elements and a source other than the subject of the measurement. EX1020, 6 (“The relative humidity of a gas strongly depends on its temperature. It is therefore essential to keep humidity sensors at the same temperature as the air of which the relative humidity is to be measured.”); *see also supra* §VI.B.2. Here, where the subject of the measurement is ambient air, achieving the benefit of “accurate[]” sensor readings, as Kotani expressly promotes, would naturally entail *minimizing heat transfer contacts between the dew point sensing unit and* other heat sources/sinks, including the *housing*.

230. Second, even without Kotani's teaching to promote sensor accuracy, doing so was a known design goal that a POSITA would have sought to achieve in the normal course of considering a control system like that of the Carter-Beatenbough-Kotani Combination, which relies on sensor readings to efficiently operate heating elements in a manner that prevents condensation. When considering the Combination's automated system—a system designed to prevent condensation effectively and efficiently by activating electrical heaters only when sensed conditions are ripe and controlling the activated heaters according to precise pulse widths based on dew point (*see* above at Section XII.B, which cross-references Section X.C)—the POSITA would have appreciated the importance of control system accuracy and, thus, sensor accuracy. As one example, inaccurate sensor readings would cause the control unit to activate the heaters prematurely, which would waste energy, or belatedly, which would allow condensation to form. As another example, inaccurate sensor readings would cause the control unit to use the pulse widths that are too wide or too narrow, likewise wasting energy or allowing condensation to form. These results would be satisfactory to the POSITA. As a result, motivated by the benefit of promoting sensor accuracy, the POSITA would have employed the known technique of ***minimizing heat transfer contacts between the sensing units and*** any potential heat sources/sinks—like the protective ***housing***—that are not the subject of the respective sensor measurements.

231. Third, Kotani's Figures 1–2B (below) illustrate an arrangement where there is *minimal heat transfer contact between the dew point sensing unit and the housing*. Specifically, these figures show that the only contact between the housing's outer wall and the dew point sensing unit is a *minimal* engagement along the periphery of the PCB.

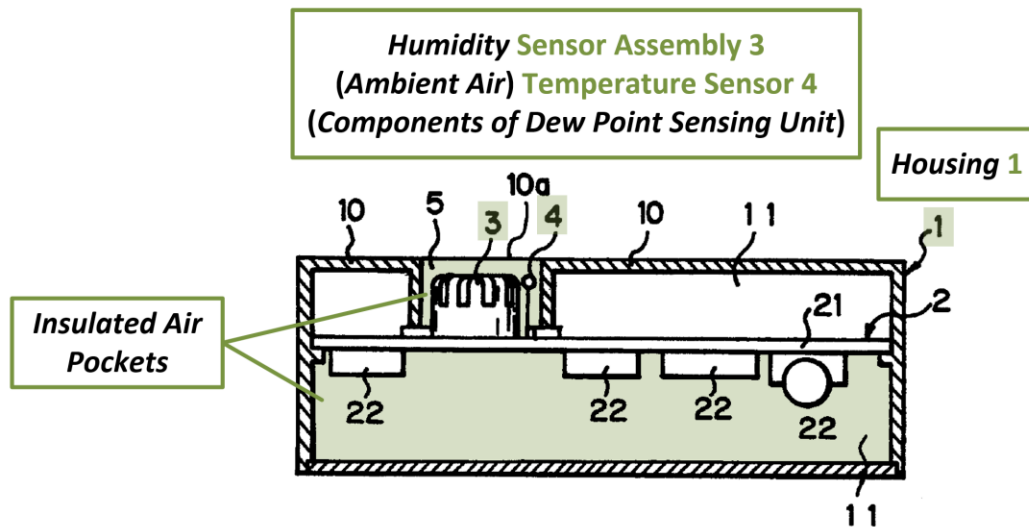


EX1008 (Kotani), Figure 1 (annotated); see also Figures 2A–2B

locating said temperature sensor and said at least one dew point sensing component amid insulated air pockets formed by said structure of said housing means

232. It would have been apparent or obvious that the *structure* of Kotani's *housing locates the at least one dew point sensing component* (including humidity

sensor assembly 3 and/or temperature sensor 4 and the supporting PCB carrier) *amid insulated air pockets formed by the structure of the housing*. Kotani explains that these components are mounted *amid insulated air pockets formed by the structure of the housing*—namely, the “sensor room 5” and the “inner space 11 of the housing 1,” which are sealed from one another. EX1008 (Kotani), 2:35–3:50, Figures 1–2B; EX1001 (’181 patent), 7:25–28 (discussing “an insulating air gap”).



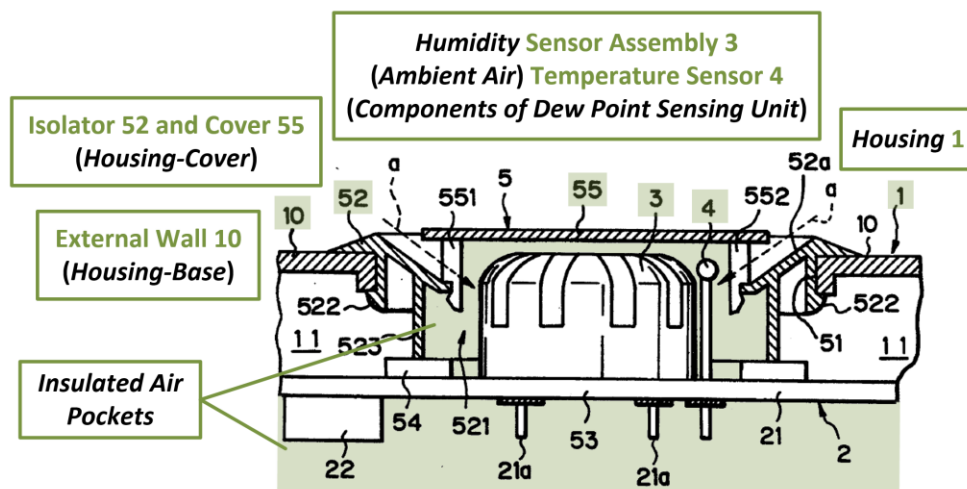
EX1008 (Kotani), Figure 1 (annotated); see also Figures 2A–2B

Corresponding Structure

233. Based on the reasoning provided above in ¶¶225–232, my conclusion is that Kotani teaches or renders obvious the recited structural and functional limitations of a *housing for locating said sensing units including structure establishing thermal isolation of said sensing units by minimizing heat transfer contacts between said sensing units and said housing means and locating said at*

least one dew point sensing component amid insulated air pockets formed by said structure.

234. Next, I will address Kotani's teachings with respect to the additional structure disclosed in '181 patent's specification for the claimed **housing means**, which, as I outlined above at §VIII.B, includes: A base and a cover that, when mated together, establish the claimed **insulated air pockets**. As shown below and discussed above, Kotani's **housing** likewise includes a base (external housing wall 10) and a mated cover (isolator 52 and cover 55) that together form **insulated air pockets** receiving temperature and dew point sensing components. EX1008, 2:35–3:50, Figures 1–2B. Thus, in comparison to the '181 patent, Kotani teaches a **housing** solution that accomplishes the claimed **locating** function in the same/substantially the same way—i.e., via a mated base and cover—to achieve the same/substantially the same result—i.e., receiving the sensing components within air pockets.



EX1008 (Kotani), Figure 2A (annotated)

2. Claims 2–3

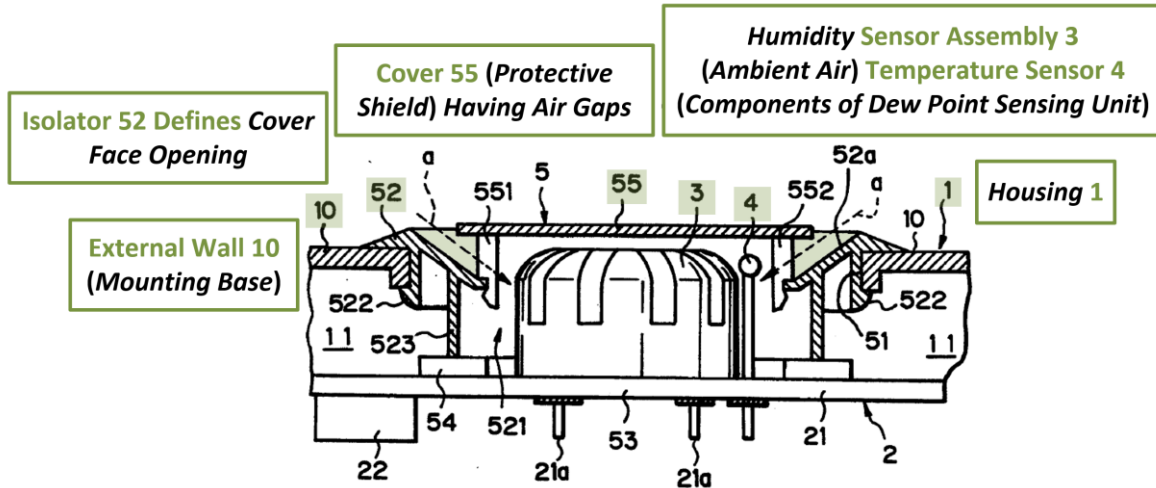
235. My conclusion is that the Carter-Beatenbough-Kotani Combination renders obvious Claims 2–3 for the same reasons discussed above in Ground 1A regarding Carter’s teachings.

3. Claim 4

- (i) *Element [4]: The apparatus of claim 1 wherein said housing means includes a dew point sensing unit housing, said dew point sensing unit housing including a mounting base and cover, said cover including a cover face opening therethrough for receiving said at least one dew point sensing component therein, said cover face opening including a protective shield thereover having air gaps therearound allowing air flow between said protective shield and said cover and thus over said at least one dew point sensing component.*

236. As discussed at Element [1.d], Kotani teaches a *housing* having a *mounting base* (external housing wall 10) and a mated *cover* (isolator 52 and cover 55) that together *create air pockets* within which *components* of the *dew point sensing unit* (including humidity sensor assembly 3 and/or temperature sensor 4 and the supporting PCB carrier, per Element [1.b]) reside. Kotani’s Figure 2A shows that the *cover includes a cover face opening* (defined by isolator 52) *therethrough for receiving the dew point sensing components therein, the cover face opening including a protective shield* (cover 55) *thereover having air gaps therearound*

allowing air flow between the protective shield and the cover and thus over the at least one dew point sensing component.



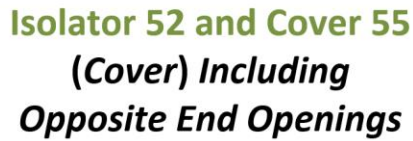
EX1008 (Kotani), Figure 2A (annotated); see also 2:35–3:50, Figures 1–2B

4. Claim 5

- (i) *Element [5]: The apparatus of claim 4 wherein said cover of said dew point sensing unit housing includes opposite end openings to establish ambient air flow through said dew point sensing unit housing.*

237. Kotani's Figure 2A shows that the *cover includes opposite end openings to establish ambient air flow through the dew point sensing unit housing.*

EX1008 (Kotani), Figure 2A (annotated below); see also 2:35–3:50, Figures 1–2B; see also *supra*, Elements [1.d], [4].

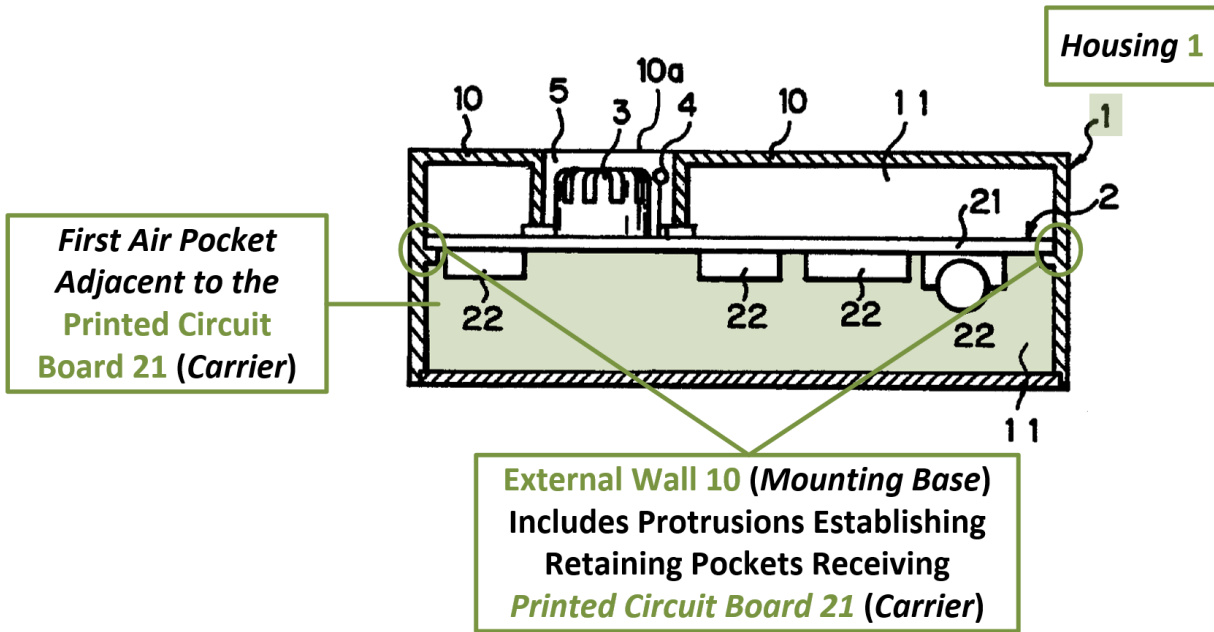


Housing 1

5. Claim 6

- (i) ***Element [6]: The apparatus of claim 4 wherein said mounting base of said dew point sensing unit housing includes protrusions establishing retaining pockets receiving said carrier of said dew point sensing unit at outer edges of said carrier and further establishing a first one of said air pockets amid said protrusions and adjacent to said carrier.***

238. As discussed above at Elements [1.d], [4], Kotani's *dew point sensing unit housing* provides a contact interface between the PCB (*carrier*, per Element [1.b]) and the housing's outer wall (*mounting base*). Kotani's Figure 1 shows this *mounting base* provides *protrusions establishing retaining pockets receiving the carrier (PCB) of the dew point sensing unit* (including sensors 3, 4) *at outer edges of the carrier (PCB) and further establishing a first one of the air pockets.*



EX1008 (Kotani), Figure 1 (annotated)

239. Notably, though I am not involved in the co-pending district court litigation between the parties, I have been informed that Patent Owner's infringement allegations against Petitioner identify a similar perimeter wall around a printed circuit board as the claimed *protrusions* of Element [6].

XIII. GROUND 1E: Claims 8–13 Are Obvious Over Carter, Beatenbough, and Gatling

A. Obviousness Analysis

1. Claim 8

- (i) ***Element [8.pre]: A system for condensation control at an array of refrigerated display cases, the cases each having at least one door, a frame and at least one frame/door heater, said system comprising:***

240. As discussed above at Element [1.pre] of Ground 1B, the combined teachings of Beatenbough and Carter provide a system for condensation control at a refrigerated display case having at least one door, a frame and at least one frame/door heater. Beatenbough further suggests the notion of expanding the condensation control system to more than one display case unit. *See* EX1006 (Beatenbough), 2:49–58 (display case units include a bank of multiple doors and a control device), 3:15–26 (discussing relay connections to “individual units”).

241. Gatling further complements Beatenbough and Carter in this respect by expressly teaching the notion of controlling “a plurality of refrigeration cases 22 in a grocery store floor space,” where “[e]ach refrigeration case 22 is arranged in separate circuits consisting of a plurality of refrigeration cases 22 that operate within a similar temperature range.” EX1007 (Gatling), 2:59–3:15, Figures 1, 5–7. A POSITA would have been motivated to expand the *condensation control system* of Carter-Beatenbough across *an array of refrigerated display cases*, as taught by

Gatling, for the beneficial purpose of accommodating mid-sized and large commercial applications, such as grocery stores and supermarkets, which typically employ more than one refrigerated display case for presenting low-temperature perishable food products to consumers. EX1007 (Gatling), 2:59–3:15 (“For example, circuit A may be for frozen food, circuit B may be for dairy, circuit C may be for meat, etc.”).

(ii) ***Element [8.a]: sensing and control apparatus configured for location at each display case in the array of display cases,***

242. As discussed above at Elements [1.a]–[1.c] of Ground 1B, the combined teachings of Carter and Beatenbough provide ***sensing and control apparatus configured for location a display case***. More, consistent with Gatling’s incorporated teachings for controlling an ***array of display cases***, it would have been apparent or obvious to a POSITA for ***each display case in the array*** to have its own local ***sensing and control apparatus***. EX1007 (Gatling), 3:40–4:5 (“separate case controllers”), 4:66–5:15 (explaining that “each refrigeration case” has its own temperature sensing probe), 6:15–24 (similar), 6:41–61 (explaining that “each refrigeration case” has its own display module), 8:1–7 (similar). Indeed, a POSITA would have been motivated to use independent local ***sensing and control apparatus*** to accommodate the unique aspects of the frame/door temperatures and surrounding environment at ***each display case***. EX1007 (Gatling), 2:59–3:15 (“For example,

circuit A may be for frozen food, circuit B may be for dairy, circuit C may be for meat, etc.”).

- (iii) ***Element [8.b]: said apparatus including a frame temperature sensing unit adapted for mounting at the display case for monitoring temperature of one of the display case door or display case frame,***

243. Based on the similar claim language, my conclusion is that the Carter-Beatenbough-Gatling Combination renders obvious Element [8.b] for the same or substantially the same reasons discussed above at Element [1.a] of Ground 1A (discussing Carter’s teachings).

- (iv) ***Element [8.c]: said apparatus including...a dew point sensing unit adapted for mounting at the display case for monitoring ambient air temperature and relative humidity outside of the display case,***

244. Based on the similar claim language, my conclusion is that the Carter-Beatenbough-Gatling Combination renders obvious Element [8.c] for the same or substantially the same reasons discussed above at Element [1.b] of Ground 1A (discussing Carter’s teachings).

- (v) ***Element [8.d]: said apparatus including...an internal case temperature sensing unit positionable inside the display case, and***

245. Based on the similar claim language, my conclusion is that the Carter-Beatenbough-Gatling Combination renders obvious Element [8.d] for the same or

substantially the same reasons discussed above at Element [17] of Ground 1C (discussing Gatling's teachings).

- (vi) ***Element [8.e.i]: said apparatus including...processing means mountable at the display case and connected for activating the display case frame/door heater when monitored display case door or frame temperature drops below a first preselected set point above a dew point value derived from monitored ambient temperature and relative humidity, for deactivating the frame/door heater when monitored display case door or frame temperature rises above a second preselected set point above said dew point value, and***

246. Based on the similar claim language, my conclusion is that the Carter-Beatenbough-Gatling Combination renders obvious Element [8.e.i] for the same or substantially the same reasons discussed above at Elements [1.c] and [14.c] of Ground 1A (discussing Carter's teachings) and/or Elements [1.c] and [14.c] of Ground 1B (discussing Carter's teachings as supplemented by Beatenbough).

- (vii) ***Element [8.e.ii] processing means...connected...for storing data related to readings at said sensing units and operation of the frame/door heater; and***

247. Based on the similar claim language, my conclusion is that the Carter-Beatenbough-Gatling Combination renders obvious Element [8.e.ii] for the same or substantially the same reasons discussed above at Element [18] of Ground 1A (discussing Carter's teachings) and/or Element [18] of Ground 1C (discussing Gatling's teachings).

- (viii) ***Element [8.f]: a communication control unit associated with said processing means for coordinating programming and data download access to said processing means of said apparatus.***

248. Based on the similar claim language, my conclusion is that the Carter-Beatenbough-Gatling Combination renders obvious Element [8.f] for the same or substantially the same reasons discussed above at Elements [19]–[20] of Ground 1C (discussing prior art teachings regarding ***a communication control unit*** in the form of a wireless transceiver for transmitting data from the refrigerated case and facilitating remote updating/configuring/programming).

2. Claim 9

- (i) ***Element [9]: The system of claim 8 further comprising a central processing unit and wherein said communication control unit includes a transmitter/receiver for wireless communication with said central processing unit.***

249. Based on the similar claim language, my conclusion is that the Carter-Beatenbough-Gatling Combination renders obvious Element [9] for the same or substantially the same reasons discussed above at Element [19] of Ground 1C (discussing Gatling’s teachings).

3. Claim 10

- (i) ***Element [10]: The system of claim 8 wherein said processing means of said apparatus is separately housed in a housing having dimensions selected so that said housing is mountable between standard door frame mullions provided at the display case.***

250. Carter and Beatenbough each disclose that the controller/processor (***processing means***) is ***separately housed*** from the sensors. See EX1004 (Carter), 4:36–43, Figure 1; EX1006 (Beatenbough), 2:49–53, Figure 1. More, as discussed at Element [1.c] of Ground 1A, it would have been apparent or obvious to implement the claimed ***processing means*** as a “microprocessor,” which suggests a small form factor. See EX1033, 1 (explaining that “[b]y 1999, the circuitry for a personal computer had shrunk to a module the size of a deck of playing cards”), 4 (“Microprocessors and microcomputers are products of a microelectronic revolution characterized by ever shrinking costs and sizes[.]”), 7 (“shrinking IC device sizes”), 9 (“As microprocessors grow in importance, they are shrinking in size and becoming nearly invisible parts[.]”). Further still, the notion of making a local processor/controller small enough to be ***mountable between standard door frame mullions*** is obvious at least because it follows a longstanding trend toward smaller and more compact integrated circuits. *Id.* Accordingly, by the time of the ’181 patent in 2005, mullion mounted case controllers would have been an obvious design option.

4. Claim 11

- (i) ***Element [11]: The system of claim 8 wherein said processing means of said apparatus includes a reset/programming interface.***

251. The Carter-Beatenbough-Gatling Combination renders obvious Element [11] for reasons similar to those discussed above at Element [20] of Ground 1C. There, I explained that a POSITA would have been motivated to combine the teachings of Gatling with Carter-Beatenbough to provide an automated condensation control system with operational parameters that are updatable from a remote computer. It would have been obvious for a POSITA to employ a ***programming interface*** to facilitate these remote updates based on the common understanding that an ***interface*** is a fundamental element of computing that allows two devices—here, a local case controller and a remote computer—to communicate with each other.

5. Claim 12

- (i) ***Element [12]: The system of claim 8 wherein said frame temperature sensing unit and said dew point sensing unit are mounted together in a housing.***

252. Based on the similar claim language, my conclusion is that the Carter-Beatenbough-Gatling Combination renders obvious Element [12] for the same or substantially the same reasons discussed above at Element [1.d] of Ground 1A (discussing Carter's teachings).

6. Claim 13

- (i) ***Element [13]: The system of claim 8 further comprising housing means for locating said temperature sensing unit and said dew point sensing unit and including structure establishing thermal isolation of said sensing units by minimizing heat transfer contacts between said temperature sensing unit and said dew point sensing unit and said housing means and locating said temperature sensing unit and said dew point sensing unit amid insulating air pockets formed by said structure of said housing means.***

253. Based on the similar claim language, my conclusion is that the Carter-Beatenbough-Gatling Combination renders obvious Element [13] for the same or substantially the same reasons discussed above at Element [1.d] of Ground 1A (discussing Carter's teachings).

XIV. CONCLUSION

254. I declare that all statements made in this Declaration of my own knowledge are true and that all statements made on information and belief are believed to be true. I further declare that these statements are 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 this 30th day of January, 2025.

A handwritten signature in black ink, appearing to read "Gregor Hunt", is written over a horizontal line.

Appendix A

Prof Gregor P Henze, PhD, PE



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ResearcherID: <https://publons.com/researcher/AFU-6920-2022/>

Experience

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CSIRO ENERGY CENTRE NEWCASTLE, AUSTRALIA JANUARY 2022 – JULY 2022

Visiting scientist in research group on energy systems, addressing challenge of transitioning Australia's current centralised electricity grid system to a low-emissions, more distributed future state, while maintaining energy affordability and reliability.

SENIOR RESEARCHER

EURAC INSTITUTE FOR RENEWABLE ENERGY BOLZANO, ITALY JULY 2021 – DECEMBER 2021

Visiting scientist in research group focusing on hybrid and efficient heating and cooling systems for buildings, sustainable districts, and their integration in industrial processes utilizing electrically and thermally driven heat pumps.

INTERIM CO-DIRECTOR

RENEWABLE AND SUSTAINABLE ENERGY INSTITUTE BOULDER, COLORADO JULY 2020 – JUNE 2021

ASSOCIATE DIRECTOR

RENEWABLE AND SUSTAINABLE ENERGY INSTITUTE BOULDER, COLORADO JULY 2017 – JUNE 2020

Providing leadership in the development and execution of sponsored research programs; mentor junior faculty and facilitate R&D partnerships between all UC Boulder faculty and potential collaborators at NREL with expertise in building systems, building efficiencies and other renewable and sustainable research topics.

VISITING SCIENTIST

INSTITUTE FOR PROSPECTIVE TECHNOLOGICAL STUDIES SEVILLA, SPAIN OCTOBER 2014 – JUNE 2015

Visiting scientist in research group providing global long-term (100 year) energy forecasting and analysis as part of the European Commission's Joint Research Center.

VISITING PROFESSOR

UNIVERSIDAD DE SEVILLA SEVILLA, SPAIN SEPTEMBER 2014 – JUNE 2015

Visiting professor in Department of Electrical Engineering with focus on building-to-grid integration and electric grid innovation.

JOINT PROFESSOR

NATIONAL RENEWABLE ENERGY LABORATORY GOLDEN, COLORADO OCTOBER 2013 – PRESENT

Joint appointment in the Commercial Buildings Research Group

AREN FACULTY DIRECTOR

UNIVERSITY OF COLORADO BOULDER, COLORADO JULY 2012 – JUNE 2014

AREN Faculty Director for Department of Civil, Environmental and Architectural Engineering

ASSOCIATE CHAIR

UNIVERSITY OF COLORADO BOULDER, COLORADO JULY 2010 – JUNE 2012

Associate Chair for Department of Civil, Environmental and Architectural Engineering

FOUNDER & CHIEF SCIENCE OFFICER

QCOEFFICIENT, INC.

CHICAGO, ILLINOIS

JULY 2008 – PRESENT

Founder and chief science officer for Chicago-based company developing model predictive control solutions to integrate commercial building HVAC operation with electric grid operations.

PROFESSOR

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AUGUST 2008 – PRESENT

Faculty member in the Building Systems Engineering Program of the Department of Civil, Environmental and Architectural Engineering in the College of Engineering and Applied Science at the University of Colorado. Teaching focus on thermal environmental engineering, mechanical systems design, building control and automation systems, advanced solar systems, applied data analysis for energy scientists and engineers, as well as sustainable building design. His research includes model predictive optimal control of building energy systems and building thermal mass, control strategies for mixed-mode buildings that incorporate both natural and mechanical ventilation, uncertainty quantification of occupant behavior and its impact, occupancy detection using distributed sensor networks as well as the integration of building energy system operations with the electric grid system.

VISITING SCIENTIST

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SEPTEMBER 2005 – JULY 2006

a) Solar Buildings Group: 1) Impact of adaptive comfort criteria and heat waves on optimal building thermal mass control. 2) Primary energy and comfort performance of ventilation assisted thermo-active building systems in continental climates.

b) Fuel Cell Group: Heat transfer analysis of a micro-reformer fuel cell system (μ -RFCS).

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SEPTEMBER 2005 – JULY 2006

Teaching responsibility for courses in heat and mass transfer, control theory, as well as building energy system modeling and simulation. Developed two new courses in computational intelligence in control engineering as well as modeling and system theory.

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SIEMENS BUILDING TECHNOLOGIES

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MAY 2005 – AUGUST 2005

a) HVAC Laboratory: Measured and recommended modifications for the radiative/convective split of sensible heat gains from cooling load simulators and human subjects for spaces employing thermo-active building structures (concrete core conditioning) using scanning net radiometry. Investigated air velocity dependence of relative humidity sensors. b) Energy Controlling and Monitoring: Analysis and recommendation for enhancements.

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FALL 2004 – JULY 2008

VISITING PROFESSOR

TECHNICAL UNIVERSITY OF DRESDEN

DRESDEN, GERMANY

AUGUST – SEPTEMBER 2002

Research exchange at the Institute of Thermodynamics and Building Systems Engineering to collaboratively develop an approach for the real-time predictive optimal control of combined active and passive building thermal storage inventory.

ASSISTANT PROFESSOR

UNIVERSITY OF NEBRASKA – LINCOLN

OMAHA, NEBRASKA

OCTOBER 1999 – SUMMER 2004

Founding faculty member of the Architectural Engineering Program in the College of Engineering at the University of Nebraska – Lincoln. Responsibilities include assisting in the development of the Architectural Engineering curriculum for the B.S., M.Eng., M.A.E., and Ph.D. degrees, developing and teaching undergraduate and graduate courses, recruiting and advising students, and establishing a research and an international exchange program.

ENERGY ENGINEERING MANAGER

JOHNSON CONTROLS, INC.

ESSEN, GERMANY

OCTOBER 1998 – SEPTEMBER 1999

Manager of engineering department responsible for energy engineering activities in Germany. Duties included project coordination, customer relations, quality assurance, standardization of business processes, and strategic planning.

PROJECT MANAGER

JOHNSON CONTROLS, INC.

FRANKFURT, GERMANY

OCTOBER 1997 – SEPTEMBER 1998

Development of a building energy performance monitoring database management system suitable for continuously monitoring and analyzing large groups of remote building sites over multiyear periods.

ENERGY ENGINEER

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JANUARY 1996 – SEPTEMBER 1997

Responsible for energy engineering in start-up energy savings performance contracting (ESPC) group. Tasks included energy analysis of more than 40 commercial buildings throughout Europe, development of strategies to improve energy utilization and decrease utility costs including financing procedures.

POST-DOCTORAL ASSISTANT

UNIVERSITY OF COLORADO

BOULDER, COLORADO

JULY 1995 – DECEMBER 1995

Development of a predictive optimal controller for thermal energy storage systems subject to uncertainty in thermal loads, ambient conditions, and underlying system models.

RESEARCH ASSISTANT

UNIVERSITY OF COLORADO

BOULDER, COLORADO

JANUARY 1993 – JUNE 1995

(1) Development of optimal control strategies for ice storage systems in commercial building cooling plants and comparison of their performance with conventional controls. (2) Experiments on the performance and robustness of direct digital control systems in a large-scale HVAC laboratory.

TEACHING ASSISTANT

TECHNICAL UNIVERSITY OF BERLIN

BERLIN, GERMANY

MAY 1990 – MARCH 1992

Assisted in courses in thermodynamics and renewable energy sources. Generation of a simulation model and setup of a digital data acquisition system for a solar domestic hot water system.

RESEARCH ENGINEER

EMS CHEMIE AG

DOMAT/EMS, SWITZERLAND

FEBRUARY 1990 – APRIL 1990

Development of improved waste heat removal concepts for polymer and synthetic fiber production at a Swiss chemical engineering company.

Consulting

- Joulea, Atlanta, GA: Consultant for building energy startup company, since 2023.
- Cala Systems, Boston, MA: Consultant for heat pump hot water heater startup company, since 2023.
- *Google, Inc. v. EcoFactor*: Representing Google as defendant in patent infringement case in the International Trade Commission regarding smart thermostats as technical expert, 2019-2022.
- *TAS Energy Inc. v. Stellar Energies Americas, Inc.*: Representing TAS Energy Inc. as plaintiff in patent infringement action regarding gas turbine inlet cooling technology as technical expert; case settled Nov 2016 (May 2015 - Nov 2016).
- *Carrier Corp. v. Goodman Global, Inc., et al* (D. Del): Representing Carrier as plaintiff in patent infringement action regarding HVAC technology as technical expert; jury trial won September 2014 (2012-2014).
- Robert Bosch GmbH: Investigation of short-term forecasting models and advanced algorithms for energy efficiency in commercial buildings (2007-2013).

- Belimo Automation AG: Evaluation of novel control valve designs (2007-today).
- Boehringer Ingelheim Pharmaceuticals: Optimal design and control of a chilled-water thermal energy storage system (2006-2007).
- Fraunhofer Institute for Solar Energy Systems: Simplified hybrid modeling of buildings and associated parameter estimation, automated fault detection and diagnostics (2006-today).
- IMR Consulting: Modeling and simulation of coupled hydraulic and thermal networks (2005 – 2007).
- MCE Stangl GmbH: Consultant for energy services (2005 – 2007).
- Johnson Controls, Inc.: Consultant assisting in the preparation of proposals for federal energy savings performance contracts, in particular for the U.S. Air Force and U.S. Army. Contributions include energy engineering, development of measurement and verification methods according to FEMP guidelines, and proposal writing (2000 – 2005).

Education

University of Colorado	Doctor of Philosophy – Ph.D. Civil Engineering – Building Systems Engineering, 1995 Dissertation: <i>“Evaluation of Optimal Control for Ice Storage Systems”</i> Advisor: Moncef Krarti
Technical University of Berlin	Diplom-Ingenieur – Dipl.-Ing. Mechanical Engineering (Energy and Processes), 1992 Thesis: <i>“Performance Characterization and Optimization of a Ceramic Vehicular Gas Turbine on the Basis of Turbo-Charger Units”</i> Advisor: Helmut Pucher
Oregon State University	Master of Science – M.S. Mechanical Engineering (Thermal Sciences), 1991 Project: <i>“Order-of-Magnitude Analysis: An Approximate Approach to the Solution of Selected Engineering Problems”</i> Advisor: Murty Kanury
Technical University of Berlin	Vor-Diplom – B.S. Mechanical Engineering (Energy and Processes), 1989

Professional Registration

ASHRAE-certified High-Performance Building Design Professional (HBDP).

Licensed professional mechanical engineer in Nebraska (license no. E-10692).

Honors and Awards

- University of Colorado College of Engineering and Applied Science **Dean’s Faculty Fellowship** 2024
- **Fulbright Distinguished Chair in Science, Technology, and Innovation** at CSIRO in Newcastle, New South Wales, Australia 2022
- Interim Co-**Director** Renewable and Sustainable Energy Institute 2020-2021
- Renewable and Sustainable Energy Institute **Associate Director** for Energy Systems for the Built Environment 2017-2020
- Charles Victor Schelke **Endowed Chair** 2017

- University of Colorado Architectural Engineering **Appreciation Award** 2015
- University of Colorado CEAE Department **Service Award** 2014
- Endowed **Lewis-Worcester Faculty Fellowship** 2014-2018
- Architectural Engineering Institute (AEI) 2013 Conference **Best Paper Award**
- University of Colorado CEAE Department **Distinguished Achievement Award** 2012
- Colorado Cleantech Industry Association **Research and Commercialization Award** 2011
- University of Colorado CEAE Department **Research Development Award** 2011
- Renewable and Sustainable Energy Institute **Founding Fellow and Executive Committee Member** 2010
- University of Nebraska-Lincoln College of Engineering **Holling Family Distinguished Teaching Award for Innovative Use of Instructional Technology** 2006
- University of Nebraska-Lincoln College of Engineering **Holling Family Teaching Award** 2006
- University of Nebraska at Omaha **Alumni Outstanding Teaching Award** 2006
- American Society of Mechanical Engineers (ASME): **Best Paper Award**, International Solar Energy Conference 2004, Portland, Oregon
- UNL College of Engineering **Faculty Fellowship** for 2003 and 2004
- American Society of Mechanical Engineers (ASME): **Best Paper Award**, National Solar Energy Conference 2002, Reno, Nevada.
- American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE): **New Investigator Award** for the year 2001 (one per year).
- American Society of Mechanical Engineers (ASME): **Best Paper Award**, International Solar Energy Conference 1996, San Antonio, Texas.
- Texas A&M University, College Station, Texas: **Winner of Energy Predictor Shootout II** in team effort with Robert H. Dodier, 1995.
- **Fulbright Scholarship** for graduate study at Oregon State University 1990 – 1991.

Grants

- Lab Venture Challenge Winner for Whisper Energy, \$125,000, 2025-2026.
- National Renewable Energy Laboratory: Joint Appointment, \$294,492, 2024-2026.
- NSF Industry University Collaborative Research Center (IUCRC): “Performance Evaluation and Grid Impacts of Intelligent Field Devices and Next-Generation Heat Pumps with an Application to Adaptive Reuse of Commercial Buildings” \$55,000, 2024-2025, G. Henze (PI).
- DOE Renew America Nonprofits: \$8,000,000, 2024-2028, M. Krarti (PI), G. Henze and J. Zhai (Co-PIs).
- NSF Industry University Collaborative Research Center (IUCRC): “Building Energy Smart Technologies (BEST)” \$375,000, 2021-2026, M. Krarti (PI), K. Baker, G. Henze, and J. Zhai (Co-PIs).
- DOE STTR Phase II: “P2P Transactions with Demand Flexibility for Increasing Solar Utilization.” \$994,698 (UCB share: \$325k), 2020-2022, V. Cushing (PI), G. Henze & G. Pavlak (Co-PIs).
- UCB CEAS Seed Grant: “Building Energy and Water Conservation Benefits from Peroxide Enhanced Germicidal Irradiation (PEGI).” \$92,449, 2019-2020, M. Hernandez (PI), G. Henze & K. Linden (Co-PIs).
- National Renewable Energy Laboratory: “The Relationship between Energy Efficiency and Demand Response.” \$256,919, 2019-2020.

- DOE EERE BTO BENEFIT: “Multiobjective Deep Reinforcement Learning for Grid-Interactive Energy-Efficient Buildings.” \$1,579,684, 2019-2023, A. Bernstein (PI), G. Henze (Co-PI).
- DOE ARPA-E: “Battery-Free RFID Sensor Network with Spatiotemporal Pattern Network Based Data Fusion System for Human Presence Sensing.” \$2,000,000, 2018-2021.
- WSP USA: “Evaluating the Value of Intelligent Building Systems.” \$72,981, 2017-2018.
- National Renewable Energy Laboratory: “Reduced Order Models for Fuel Cell Integrated Commercial Buildings.” \$11,659, 2017.
- Construction Industry Institute: “Modeling and Optimizing the Lifecycle Business Return of Building Investments.” \$128,330, 2017-2018.
- National Renewable Energy Laboratory: “Building-to-Grid Model Development for Advanced Sensing in the Distribution Grid.” \$195,000, 2016-2019.
- National Renewable Energy Laboratory: “Load Disaggregation for Distributed Energy Resource Siting and Optimization” \$39,176, 2016.
- National Renewable Energy Laboratory: “Hybrid Model-Based and Data-Driven Fault Detection and Diagnostics for Buildings.” \$49,149, 2014-2015.
- Belimo, Switzerland: “Investigation Central Plant Benefits of Energy Valves.” \$37,630, 2014.
- National Renewable Energy Laboratory: “Energy Signal Tool.” \$82,762, 2013-2014.
- Belimo, Switzerland: “Investigation Central Plant Benefits of Energy Valves.” \$36,000, 2013.
- National Renewable Energy Laboratory: “Energy Systems Integration (ESI) Visualization Framework.” \$78,180, 2013.
- The Energy Research Corporation: “Monitoring Based Commissioning Using Calibrated Building Models.” \$93,291, 2012-2013.
- Belimo, Switzerland: “Investigation Central Plant Benefits of Energy Valves.” \$34,000, 2012.
- NSF EAGER: “Centralized Control of Large-Scale Distributed Sensor/Actuator Networks: Self-organizing Amorphous Facades.” \$120,000, 2012-2013, G.P. Henze (Co-PI) with Nikolaus Correll (PI).
- Clean Urban Energy, Inc.: “Buildings2Grid: Integration of Commercial Buildings Operation with the Electric Grid System.” \$376,465, 2011-2013.
- Belimo, Switzerland: “Experimental Investigation of Pressure-Independent Control Valves.” \$32,000, 2011.
- Clean Urban Energy, Inc.: “Reduced Order Modeling for Dynamic Building Control in Response to Real-Time Utility Signals.” \$80,519, 2011.
- American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE): “Stochastic Control Optimization of Mixed-Mode Buildings for U.S. Climates,” \$297,866, 2010-2012, G.P. Henze (PI), G.S. Brager (co-PI, University of California), C. Felsmann (Co-PI, Technical University of Dresden).
- ITG Dresden, Ltd.: “Control of Thermally Activated Building Structures,” \$47,540, 2010.
- Tendril Networks, Inc.: “Evaluation and Validation of Smart Grid Automated Control Strategies for Residential Buildings,” \$37,484, 2009-2010.
- Clean Urban Energy: “Dynamic Building Control in Response to Real-Time Utility Signals.” \$77,556, 2009.
- U.S. Green Building Council: “HVAC Control Strategies for Mixed Mode Buildings,” \$249,915, 2009-2011, G.P. Henze (PI), C. Felsmann (Co-PI, Technical University of Dresden), J. Pfafferott (co-PI, Fraunhofer Institute for Solar Energy Systems).
- German Ministry for Commerce and Technology (Bundesministerium für Wirtschaft und Technologie): “Low-Exergy System Integration,” 2008-2011, level of funding: €1,170,000 (\$1,837,000), Co-PI. (PI: J. Pfafferott, Fraunhofer Institute for Solar Energy Systems with German industrial partners Johnson Controls, DS-Plan, ITG Dresden, and others.).
- U.S. Department of Education: “Nebraska Graduate Assistance in Areas of National Need (GAANN) in Engineering and Assistive Technology,” 2007-2010, level of funding \$383,643, Co-PI.

- German Ministry for Commerce and Technology (Bundesministerium für Wirtschaft und Technologie): “ModBen – Development of a Procedure for Model-Based Building Performance Analysis,” 2006-2010, level of funding: €1,200,000 (\$1,680,000), Co-PI. (PI: C. Neumann, Fraunhofer Institute for Solar Energy Systems with German industrial partners M+W Zander and Ennovatis).
- U.S. Department of Energy – National Energy Technology Laboratory: “Development of an Accurate Feed-Forward Temperature Control Tankless Water Heater,” 2005 – 2008, funding level: \$456,395, Consultant.
- Johnson Controls, Inc.: “Evaluation of Modelica for Building Control Systems Analysis,” 2005-2007, level of funding: \$90,000.
- American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE): “Evaluation of Building Thermal Mass Savings (1313-TRP),” 2004 – 2006, level of funding: \$89,101.
- University of Nebraska – Lincoln Strategic Cluster Research Grant: “Integrated Wireless Systems for Assistive Technology,” 2004 – 2006, funding level: \$80,000.
- State Technologies Advancement Collaborative Solicitation 03-STAC-1: “Real-Time Predictive Optimal Control of Active and Passive Building Thermal Storage Systems” STAC. 2004 – 2005, level of funding: \$151,656, Co-PI.
- U.S. Department of Energy – National Energy Technology Laboratory: “Converging Redundant Sensor Network Information for Improved Building Control”, 2004 – 2006, funding level: \$354,440, Co-PI.
- University of Nebraska – Lincoln: Layman Award, 2003, level of funding: \$10,000.
- Nebraska Research Initiative – “Development of the University of Nebraska Center for Building Integration”, 2002 - 2004 level of funding: \$130,732, Co-PI.
- U.S. Department of Energy – National Energy Technology Laboratory: “Analysis, Laboratory Testing, and Field Implementation of Predictive Optimal Control of Active and Passive Building Thermal Storage Inventory”, 2001 – 2004, level of funding: \$401,179.
- American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE): “Evaluation of Predictive Optimal Control of Active and Passive Building Thermal Storage Inventory” (New Investigator Award for 2001), 2001 – 2002, level of funding: \$61,185.
- University of Nebraska – Lincoln: Layman Award, 2001, level of funding: \$7,000.
- American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE): “Metering Residential Hot Water by End Use (Development of Standard Protocol),” ASHRAE 1172-TRP, 2000 – 2003, level of funding: \$70,354, Co-PI.

Professional Memberships and Service

- Co-Chair for Workshop on Intelligent Building Operations, Purdue University, July 2024
- Co-Chair for Workshop on Intelligent Building Operations, University of Colorado, August 2019 and 2023
- Co-Chair for Workshop on Intelligent Building Operations, Purdue University, June 2018
- Associate Editor for IEEE Control Systems Letters 2017 – 2020
- Co-Chair for Workshop on Intelligent Building Operations, Purdue University, June 2016
- Editorial Board Member for Journal Building Performance Simulation since 2015
- Associate Editor for ASCE Journal of Architectural Engineering 2015 – 2019
- Associate Editor of Elsevier Journal *Renewable Energy* in the topical area of “Low Energy Architecture and Buildings” for 2014 – 2015.
- Renewable and Sustainable Energy Institute (RASEI) Executive Committee Member
- Chair for Workshop on Intelligent Building Operations, Boulder, June 2013
- Taskforce on Applications of Approximate Dynamic Programming and Reinforcement Learning for the IEEE Computational Intelligence Society - ADPRL Technical Committee

- Chair for Workshop on Model Predictive Control in Buildings, Montreal, June 2011.
- American Society of Mechanical Engineers Solar Energy Division Technical Committee Chair for Conservation and Solar Buildings for 2008-2014.
- Associate Editor of the *Journal of Solar Energy Engineering* in the topical area of “Conservation and Solar Buildings” for 2008-2014.
- Member of ASHRAE committee charged with developing a certification program on Sustainable Building Design and Operation
- American Society of Heating, Refrigerating, and Air Conditioning Engineers
 - ✓ Technical Committee 7.5 Smart Building Systems: member
 - ✓ Technical Committee 1.4 Control Theory: member

Patents

Records of Invention

R. Cruickshank, G.P. Henze, A.R. Florita, C.D. Corbin, ROI-19-68 Joint optimization of electricity generation and use, April 1, 2019

Provisional Patent Application

G.P. Henze et al., Wireless Home Identification and Sensing Platform for Energy Reduction, Application No. 18/557,369 submitted Dec 31, 2023, US PTO.

Awarded

G.S. Pavlak, G.P. Henze, V.J. Cushing, Systems and Methods using Decision Analysis for Controlling Energy Consumption and Facilitating Building Participation in Ancillary Energy Markets, patent no. US11101651, awarded Aug 24, 2021, US PTO.

G.P. Henze, V.J. Cushing, C.D. Corbin, and S. Plamp, Integration of Commercial Building Operations with Electric System Operations and Markets, patent no. US10373082B2, awarded Aug 6, 2019, US PTO.

V.J. Cushing and G.P. Henze, Optimization of Attributes in a Portfolio of Commercial and Industrial Facilities, application no. 13/405,153, pending

C.J. Sloup, D. Karnes, and G.P. Henze (2011) Real-Time Global Optimization of Building Setpoints and Sequence of Operation, patent no. US7894943B2, awarded Feb 22, 2011, US PTO.

Publications

Google Scholar *h*-index = 55 with over 9300 citations (accessed Jan 30, 2025)

Books

T. Agami Reddy and Gregor P. Henze (2023) “Applied Data Analysis and Modeling for Energy Engineers and Scientists.” <https://link.springer.com/book/10.1007/978-3-031-34869-3>, Springer Science & Business Media.

Book Chapters

Henze, G.P. (2019) “Modelling and Simulation in Building Automation Systems.” Chapter 14 in *Building Performance Simulation for Design and Operation 2/e* (eds. J.L.M. Hensen and R. Lamberts), Taylor and Francis.

Henze, G.P. and C. Neumann (2012) “Modelling and Simulation in Building Automation Systems.” Chapter 14 in *Building Performance Simulation for Design and Operation* (eds. J.L.M. Hensen and R. Lamberts), Taylor and Francis.

Journal Publications – Published, In Print, or Accepted for Publication

Henze, G. P., Kircher, K. J., & Braun, J. E. (2024). Why has advanced commercial HVAC control not yet achieved its promise? *Journal of Building Performance Simulation*, 1–12.

<https://doi.org/10.1080/19401493.2024.2429728>

Nicholas Long; Katherine Fleming; Alex Swindler; Andrew Held; Robin Mitchell; Gregor P Henze: Advances in Building Data Management for Building Performance Standards using the SEED Platform, *Developments in the Built Environment*, Volume 20, 2024, <https://doi.org/10.1016/j.dibe.2024.100530>.

Zakia Afroz, Hao Wu, Subbu Sethuvenkatraman, Gregor Henze, Rune Grønborg Junker, Matt Shepit, (2024) “A study on price responsive energy flexibility of an office building under cooling dominated climatic conditions.” *Energy and Buildings*, Volume 316, 2024, 114359, ISSN 0378-7788, <https://doi.org/10.1016/j.enbuild.2024.114359>.

Klavekoske, A. B., Cushing, V. J., and Henze, G. P. (June 28, 2024). "Evaluation of the Demand Flexibility Potential Through Joint Optimization of Building Thermal Response and Indoor Air Quality in Commercial Buildings." *ASME. J. Eng. Sustain. Bldgs. Cities*. May 2024; 5(2): 021003. <https://doi.org/10.1115/1.4065704>

Linsey C. Marr, Christopher D. Cappa, William P. Bahnfleth, Timothy H. Bertram, Richard L. Corsi, Matthew J. Ellis, Gregor P. Henze, Gabriel Isaacman-VanWertz, Shelly L. Miller, Theresa Pistochini, William D. Ristenpart, Marina E. Vance, and Peter J. Vikesland (2024): Toward Clean and Green Buildings, *Journal of Environmental Engineering*, Volume 150, Issue 9, <https://doi.org/10.1061/JOEEDU.EEENG-7727>

Michael D. Murphy, Amy Allen, Gregor P. Henze, Nicholas L. Long, “Optimal environmental and economic performance trade-offs for fifth generation district heating and cooling network topologies with waste heat recovery”, *Energy Conversion and Management*, Volume 309, 2024, 118322, ISSN 0196-8904, <https://doi.org/10.1016/j.enconman.2024.118322>.

Dey, Sourav, and Henze, Gregor P. "Reinforcement Learning Building Control: An Online Approach with Guided Exploration Using Surrogate Models." *ASME. J. Eng. Sustain. Bldgs. Cities*. February 2024; 5(1): 011005. <https://doi.org/10.1115/1.4064842>

Tim Diller, Anton Soppelsa, Roberto Fedrizzi, Nagpal Himanshu, Gregor Henze (2023) “A Dynamic Programming Based Method for Optimal Control of a Cascaded Heat Pump System with Thermal Energy Storage.” *Optimization and Engineering*, Springer, <https://doi.org/10.1007/s11081-023-09853-5>.

Nagy, Zoltan, Gregor Henze, Sourav Dey, Javier Arroyo, Lieve Helsen, Xiangyu Zhang, Bingqing Chen et al. (2023) "Ten questions concerning reinforcement learning for building energy management." *Building and Environment*, 110435.

Sourav Dey, Thibault Marzullo, Xiangyu Zhang, Gregor Henze (2023). Reinforcement Learning Building Control Approach Harnessing Imitation Learning, *Energy and AI*. <https://doi.org/10.1016/j.egyai.2023.100255>.

Sourav Dey, Thibault Marzullo, Gregor Henze (2023). Inverse Reinforcement Learning Control for Building Energy Management; *Energy and Buildings*. <https://doi.org/10.1016/j.enbuild.2023.112941>

Li R, Satchwell AJ, Finn D, Christensen TH, Kummert Michaël, Le Dréau Jérôme, Lopes RA, Madsen H, Salom J, Henze G, Wittchen K, Ten questions concerning energy flexibility in buildings, *Building and Environment* (2022), doi: <https://doi.org/10.1016/j.buildenv.2022.109461>.

Allen, A., Henze, G., Baker, K., Pavlak, G., & Murphy, M. (2022). An optimization framework for the network design of advanced district thermal energy systems. *Energy Conversion and Management*, 266, 115839.

Thibault Marzullo, Sourav Dey, Nicholas Long, José Leiva Vilaplana & Gregor Henze (2022) A high-fidelity building performance simulation test bed for the development and evaluation of advanced controls, *Journal of Building Performance Simulation*, 15:3, 379-397, DOI: 10.1080/19401493.2022.2058091

Sin Yong Tan, Margarite Jacoby, Homagni Saha, Anthony Florita, Gregor Henze, Soumik Sarkar (2022) Multi-modal Sensor Fusion Framework for Residential Building Occupancy Detection, *Energy and Buildings*, 111828.

Jacoby, Margarite, Sin Yong Tan, Mohamad Katanbaf, Ali Saffari, Homagni Saha, Zerina Kapetanovic, Jasmine Garland, Anthony Florita, Gregor Henze, Soumik Sarkar, and Joshua Smith. 2021. "WHISPER: Wireless Home Identification and Sensing Platform for Energy Reduction" *Journal of Sensor and Actuator Networks* 10, No. 4: 71. <https://doi.org/10.3390/jsan10040071>

Robert Cruickshank, Gregor Henze, Anthony Florita, Charles Corbin & Killian Stone (2021): Estimating the value of jointly optimized electric power generation and end use: A study of ISO-scale load shaping applied to the residential building stock, *Journal of Building Performance Simulation*, DOI:10.1080/19401493.2021.1998222

Maggie Jacoby, Sin Yong Tan, Gregor Henze, and Soumik Sarkar (2021). A high-fidelity residential building occupancy detection dataset. *Nature Scientific Data*, 8(1), 1-14.

Cory Mosiman, Gregor Henze, and Herbert Els (2021) "Development and Application of Schema Based Occupant-Centric Building Performance Metrics." *Energies*, 14(12), 3513; <https://www.mdpi.com/1996-1073/14/12/3513>, <https://doi.org/10.3390/en14123513>.

Yang, Shiyu, Man Pun Wan, Bing Feng Ng, Swapnil Dubey, Gregor P. Henze, Wanyu Chen, and Krishnamoorthy Baskaran. "Model predictive control for integrated control of air-conditioning and mechanical ventilation, lighting and shading systems." *Applied Energy* 297 (2021): 117112.

Fleschutz, Markus, Markus Bohlayer, Marco Braun, Gregor Henze, and Michael D. Murphy. "The effect of price-based demand response on carbon emissions in European electricity markets: The importance of adequate carbon prices." *Applied Energy* 295 (2021): 117040.

Nicholas Long, Fatema Almajed, Justus von Rhein & Gregor Henze (2021) Development of a metamodeling framework for building energy models with application to fifth-generation district heating and cooling networks, *Journal of Building Performance Simulation*, 14:2, 203-225, DOI: 10.1080/19401493.2021.1884291

Nicholas Smith and Gregor Henze (2021). Modeling Wastewater Heat Recovery Heat Pump Systems. *Journal of Sustainable Development of Energy, Water and Environment Systems*, 9(1).

Nelson, John, and Gregor Henze (2021). "Evaluation of the Passive Cooling Potential of Thermal Mass Inherent in Medium to Large Commercial Buildings." *Journal of Architectural Engineering* 27(2): 04021007.

McKittrick, Adam R., and Gregor P. Henze (2021). "Cost Analysis of Annual and Monthly Net Zero Energy Performance for Multifamily Buildings in the United States." *Journal of Architectural Engineering* 27(2): 04021003.

Vazquez-Canteli, Jose R., Sourav Dey, Gregor Henze, and Zoltan Nagy. "CityLearn: Standardizing Research in Multi-Agent Reinforcement Learning for Demand Response and Urban Energy Management. *arXiv 2020. "arXiv preprint arXiv:2012.10504 (2012).*

Christina Turley, Maggie Jacoby, Gregor Henze and Gregory Pavlak (2020) "Development and evaluation of occupancy-aware HVAC control for residential building energy efficiency and occupant comfort." *Energies* 2020, 13, 5396. <https://www.mdpi.com/1996-1073/13/20/5396>.

Buffa, S.; Soppelsa, A.; Pipiciello, M.; Henze, G.; Fedrizzi, R. Fifth-Generation District Heating and Cooling Substations: Demand Response with Artificial Neural Network-Based Model Predictive Control. *Energies* 2020, 13, 4339.

Amy Allen, Gregor Henze, Kyri Baker, and Gregory Pavlak (2020) "Evaluation of Low-Exergy HVAC Systems and Topology Optimization for Deep Energy Savings at the Urban District Level." *Energy Conversion and Management*, Volume 222, 15 October 2020, 113106.

Karpilow, Alexandra; Henze, Gregor; Beamer, Walter (2020). Assessment of Commercial Building Lighting as a Frequency Regulation Resource. *Energies*, 13, 613.

Vazquez-Canteli, Jose Ramon; Deetjen, Thomas; Henze, Gregor; Kämpf, Jérôme; Nagy, Zoltan (2019). Multi-Agent Reinforcement Learning for Adaptive Demand Response in Smart Cities, *Journal of Physics: Conference Series* 1343 (012058).

Yang, S., Wan, M. P., Ng, B. F., Dubey, S., Henze, G. P., Rai, S. K., & Baskaran, K. (2019). Experimental study of a model predictive control system for active chilled beam (ACB) air-conditioning system. *Energy and Buildings*, 203, 109451.

Cruickshank, R., Henze, G., Balaji, R., Hodge, B. M., & Florita, A. (2019). Quantifying the Opportunity Limits of Automatic Residential Electric Load Shaping. *Energies*, 12(17), 3204.

Fallahi, Z., & Henze, G. P. (2019). Interactive Buildings: A Review. *Sustainability*, 11(14), 3988.

von Rhein, J., Henze, G. P., Long, N., & Fu, Y. (2019). Development of a topology analysis tool for fifth-generation district heating and cooling networks. *Energy Conversion and Management*, 196, 705-716.

Homagni Saha, Anthony Florita, Gregor Henze, Soumik Sarkar (2019). Occupancy Sensing in Buildings: A Review of Data Analytics Approaches. *Energy and Buildings*; 188–189, 278-285.

Doubleday, Kate; Hafiz, Faeza; Parker, Andrew; Elgindy, Tarek; Florita, Anthony; Henze, Gregor; Salvalai, Graziano; Pless, Shanti; Hodge, Bri-Mathias (2019). Integrated Distribution System and Urban District Planning With High Renewable Penetrations; WIREs Energy and Environment; 8(5), e339.

Patteeuw, D., Henze, G. P., Arteconi, A., Corbin, C. D., & Helsen, L. (2019). Clustering a building stock towards representative buildings in the context of air-conditioning electricity demand flexibility. *Journal of Building Performance Simulation*, 12(1), 56-67.

Elci, M., Delgado, B. M., Henning, H. M., Henze, G. P., & Herkel, S. (2018). Aggregation of residential buildings for thermal building simulations on an urban district scale. *Sustainable Cities and Society*, 39, 537-547.

Liu, C., Akintayo, A., Jiang, Z., Henze, G. P., & Sarkar, S. (2018). Multivariate exploration of non-intrusive load monitoring via spatiotemporal pattern network. *Applied Energy*, 211, 1106-1122.

Bruggmann, P., G.P. Henze (2017). Towards Grid Friendly Zero Energy Buildings. *Journal of Architectural Engineering*, 24(2).

Jiang, Z., Liu, C., Akintayo, A., Henze, G.P., & Sarkar, S. (2017). Energy prediction using spatiotemporal pattern networks. *Applied Energy*, 206, 1022-1039.

Pfafferott, J., Henze, G. P., Lang, T. (2017). Bauteilaktivierung: Welche Betriebsführungsstrategie passt zu welchem Gebäude? (In German) *Bauphysik*; October 2017.

Wang, N., Phelan, P. E., Gonzalez, J., Harris, C., Henze, G. P., Hutchinson, R., ... & Roth, K. (2017). Ten questions concerning future buildings beyond zero energy and carbon neutrality. *Building and Environment*, 119, 169-182.

Ryan, M. H., & Henze, G. P. (2017). Airside System-Type Prediction Enabled by Intelligent Pressure Independent Control Valves. *Journal of Architectural Engineering*, 23(3), 04017017.

Boxer, E., Henze, G. P., & Hirsch, A. I. (2017). A model-based decision support tool for building portfolios under uncertainty. *Automation in Construction*, 78, 34-50.

Corbin, C. D., & Henze, G. P. (2017). Predictive control of residential HVAC and its impact on the grid. Part I: Simulation framework and models. *Journal of Building Performance Simulation*, 10(3), 294-312.

Corbin, C. D., & Henze, G. P. (2017). Predictive control of residential HVAC and its impact on the grid. Part II: Simulation studies of residential HVAC as a supply following resource. *Journal of Building Performance Simulation*, 10(4), 365-377.

Lawrence, T. M., Boudreau, M. C., Helsen, L., Henze, G. P., Mohammadpour, J., Noonan, D., Patteeuw, D., Pless, S., & Watson, R. T. (2016). Ten questions concerning integrating smart buildings into the smart grid. *Building and Environment*, 108, 273-283.

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Henze, G.P., M. Laguna, and M. Krarti (1995) "Heuristics for the Optimal Control of Thermal Energy Storage." Proceedings of the Metaheuristics International Conference, Norwell, Massachusetts: Kluwer Academic Publishers.

Proceedings – Abstract Refereed as Basis for Acceptance

Henze, G.P. (2006) "Sustainable Building Design in the U.S.A." Seventh Biberach Forum Building Systems Engineering, Biberach, Germany, March 22, 2006.

Henze, G.P. (2002) "Order-of-Magnitude Analysis for the Approximate Solution of Engineering Problems." International Conference on Engineering Education, Manchester 2002.

Trade Magazines

Henze, G.P. (1996) "Performance Contracting in the Context of Political Agendas" (in German) Facility Management, Issue 5/96, pp. 66-68, Gütersloh: Bertelsmann Fachzeitschriften GmbH.

Moehl, U. and G.P. Henze (1996) "Investing Without Financing, Performance Contracting Increases the Value of Buildings" (in German) Contracting Wärmedienst, Issue 5/96, pp. 37-44, Düsseldorf: Krammer Verlag.

Contract Reports

Henze, G.P., G.S. Pavlak, A.R. Florita, R.H. Dodier, A.I. Hirsch (2015) "An Energy Signal Tool for Decision Support in Building Energy Systems." National Renewable Energy Laboratory Technical Report Number: NREL/TP-5500-63130. <http://www.nrel.gov/docs/fy15osti/63130.pdf>

Tanner, R.A, G.P. Henze, M. Pigman, K. Ackerley, G. Brager (2014) "Stochastic Control Optimization of Mixed-Mode Buildings." Final Report for ASHRAE Research Project 1597-RP, June 2014.

Henze, G.P., S. Pless, A. Petersen, N. Long, A.T. Scambos (2014) "Control Limits for Building Energy End Use Based on Engineering Judgment, Frequency Analysis, and Quantile Regression." National Renewable Energy Laboratory Technical Report Number: NREL/TP-5500-60020, February 2014.
<http://www.nrel.gov/docs/fy14osti/60020.pdf>

ModQS-Heizsysteme in Bürogebäuden optimal betreiben - Automatisierte Fehlererkennung und -analyse verbessert den laufenden Gebäudebetrieb, Bundesministerium für Wirtschaft und Technologie (BMWi) Berlin, ISSN 0937 – 8367, May 2013.

Henze, G.P. and P.T. May-Ostendorp (2012) "United States Green Building Council Green Building Research Fund Final Report - HVAC Control Algorithms for Mixed Mode Buildings." United States Green Building Council.

Neumann, C. et al. (2011) "Modellbasierte Methoden für die Fehlererkennung und Optimierung im Gebäudebetrieb (English Translation: 'Model-Based Methods for Fault Detection and Optimization in Building Operations')." Fraunhofer ISE, Technical Report 0327410A-C.

Tiller, D.K., G.P. Henze and X. Guo (2008) "U.S. Department of Energy Cooperative Agreement DE-FC26-04NT41971 –Converging redundant sensor network information for improved building control – Final Report." U.S. Department of Energy – National Energy Technology Laboratory.

Henze, G.P., M.J. Brandemuehl, C. Felsmann, A. Florita, and H. Cheng (2007) "Final Project Report for ASHRAE Research Project 1313-RP: Evaluation of Building Thermal Mass Savings." American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Atlanta, Georgia.

Henze, G.P. and S. Liu (2005) "U.S. Department of Energy Cooperative Agreement DE-FC-36-03G013026 - Real-Time Predictive Optimal Control of Active and Passive Building Thermal Storage Inventory - Final Report for Phase II: Laboratory Testing." U.S. Department of Energy – National Energy Technology Laboratory.

Henze, G.P. and M. Krarti (2005) "U.S. Department of Energy Cooperative Agreement DE-FC-26-01NT41255 – Predictive Optimal Control of Active and Passive Building Thermal Storage Inventory – Final Report." U.S. Department of Energy Information Bridge: www.osti.gov/servlets/purl/894509-GH9Mqf/.

Tiller, D.K. and G.P. Henze (2003). "Final Report on ASHRAE Project 1172-TRP: Metering Residential Hot Water by End Use (Development of Standard Protocol)." American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Atlanta, Georgia.

Henze, G.P. (2003) "ASHRAE New Investigator Award – Final Report." American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Atlanta, Georgia.

Krarti, M., M.J. Brandemuehl, and G.P. Henze (1995) "Final Project Report for ASHRAE 809-TRP: Evaluation of Optimal Control for Ice Storage Systems." American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Atlanta, Georgia.

Krarti, M., G.P. Henze, D. Bell, J.F. Kreider, M.J. Brandemuehl, and L.K. Norford (1997) "Model Based Optimizer Systems With TES: Final Report." JCEM Technical Report TR/97/15, University of Colorado at Boulder.

Selected Presentations

- Università di Napoli Federico II, Naples, Italy, June 6, 2024: Enriching Public Disclosure Data to Evaluate Advanced District Energy Systems with Thermal Storage for Grid-Interactive Efficient Districts.
- RLEM (Reinforcement Learning for Energy Management): Keynote Seminar – Opportunities and Challenges in Applying Advanced Building Controls. Nov 11, 2022, https://www.youtube.com/watch?v=u3g1HxZwh_s.
- EPRI.AI: Webinar – Opportunities and Challenges in Applying Advanced Building Controls. Sep 29, 2022.
- Organized panel discussion at CSIRO Energy Centre, Newcastle, Australia, June 2022: Creating a Zero Emission Community Pilot for the Hunter Region, <https://webcast.csiro.au/#/videos/a1fe316e-fb67-4019-8f70-a45f37042190>
- Università di Napoli Federico II, Naples, Italy, December 2021: Advanced Controls Test Bed – Or: How to Make Smart Buildings Come True
- La Sapienza Università di Roma, Rome, Italy, December 2021: Advanced Controls Test Bed – Or: How to Make Smart Buildings Come True
- Purdue University Mechanical Engineering Distinguished Lecture, April 2021: Seminar on Grid-Interactive Efficient Building Research at RASEI.
- Concordia University, Distinguished Lecture, January 2021: Seminar on Grid-Interactive Efficient Building Research at RASEI.
- IEEE Blockchain Transactive Energy Summit at the University of Colorado, February 2020: Seminar on Estimating the Value of Jointly Optimized Electric Power Generation and Residential Electrical Use as an Opportunity for Blockchain Enabled Transactions with Robert Cruickshank.
- Università di Napoli Federico II, Naples, Italy, October 2018: Overview seminar on research
- SDEWES 2018, Palermo, Sicily, October 2018: Research seminar on Modeling, Simulation, and Life Cycle Cost Analysis of Fifth-Generation District Heating and Cooling Networks.
- Libera Università di Bolzano, June 2018: Research seminar on End-to-End Modeling for Integration of Residential Building Portfolios with Electric Grid Operations.
- ETH Zurich, Department of Architecture, Chair of Information Architecture, July 2017: Research seminar on Building Response for Demand Flexibility - From Building Control to Electric Grid Integration.
- IBPSA Education Webinar: Building Automation in Building Simulation, June 2017: http://www.ibpsa.org/?page_id=695 or <https://www.youtube.com/watch?v=eg-Y30xsR-A&feature=youtu.be>
- IBPSA Building Simulation Applications Conference Bolzano, Italy, February 2017: Keynote seminar on Exploration of Building Model Complexity for Residential and Commercial MPC.
- IBPSA Building Simulation Applications Conference Bolzano, Italy, February 2017: Research seminar on Weather Scenario Generation for Stochastic Model Predictive Control using Vector Autoregressive Prediction.

- NREL Power Systems Engineering Center, September 2015: Research seminar on End-to-End Impact of Building Systems Response and Load Flexibility.
- International Institute for Energy Systems Integration (iiESI), August 2015: Research seminar on End-to-End Impact of Building Systems Response and Load Flexibility.
- Joint Research Center – Institute for Prospective Technological Studies, June 2015: Research seminar on Opportunities for Building Systems Response and Load Flexibility.
- Universidad de Sevilla, Spain, May 2015: Presentation of research seminar on the integrating of building energy consumption in smart grids focusing on residential building portfolios.
- Universidad de Sevilla, Spain, April 2015: Presentation of research seminar on the integrating of building energy consumption in smart grids focusing on commercial building portfolios.
- Universidad de Sevilla, Spain, November 2014: Presentation of research seminar on a probabilistic decision support system for building energy management.
- Joint Research Center – Institute for Prospective Technological Studies, September 2014: Research seminar on Impact of Large-Scale Distributed Residential HVAC Control Optimization on Electricity Grid Operation and Renewable Energy Integration.
- Portland State University, May 2014: Research seminar on Impact of Large-Scale Distributed Residential HVAC Control Optimization on Electricity Grid Operation and Renewable Energy Integration, available at <https://youtu.be/Ai6vxETH7ZM>
- Universidad de Sevilla, Spain, January 2014: Presentation of research seminar on Optimizing Building Operations in the Presence of Grid Feedback.
- University of California Davis, November 2013: Keynote speaker at “Green City. Smart City” German Innovation Seminars on Green Buildings: “Low-Energy Building Design and Optimal Operation”
- Santa Clara University, San Jose, California, November 2013: Keynote speaker at “Green City. Smart City” German Innovation Seminars on Green Buildings: “Net Zero Energy Buildings: State of the Industry”
- IEEE Power and Energy Society General Meeting in Vancouver, BC, July 2013: Presentation of one research seminar.
- ASHRAE Annual Meeting, Denver, Colorado, June 2013: Presentation of one research seminar.
- Intelligent Building Operations Workshop, Boulder, Colorado, June 2013: Presentation of four research seminars.
- RASEI 2013 Summer School on Energy Efficiency, Boulder, CO, May 2013: Presentation of one research seminar.
- University of Minnesota, Institute for Mathematics and Its Applications: Mathematical and Computational Challenges in the Control, Optimization, and Design of Energy-Efficient Buildings, Minneapolis, Minnesota, June 2013: Presentation of research seminar on Optimizing Building Operations in the Presence of Occupant-Driven Uncertainty and Grid Feedback
- Architectural Engineering Institute Conference, State College, PA, April 2013: Presentation of five technical papers.
- Institute for Energy Efficiency at the University of California at Santa Barbara, Oct 2012: Invited research seminar speaker on opportunities and challenges of advanced building controls.
- Joint Research Center of European Community, Ispra, Italy, June 2012: Invited research seminar speaker on opportunities and challenges of advanced building controls.
- Bosch Research and Technology Center, Pittsburgh, PA, April 2012: Invited research seminar speaker on advanced algorithms for energy efficiency in buildings.

- Society of Industrial and Applied Mathematics (SIAM) Conference on Uncertainty Quantification, Raleigh, NC, April 2012: Research seminar speaker on “Uncertainty Quantification for Better Commercial Buildings: From Design to Operation.”
- University of Colorado - Deming Center for Entrepreneurship, March 2012: Keynote speaker at “Entrepreneurship under the Microscope” annual celebration event.
- Nanyang Technological University, February 2012: Invited research seminar speaker on opportunities and challenges of advanced building controls.
- United States Green Building Council, December 2011: Invited research seminar speaker on mixed mode building design and associated advanced control.
- Lawrence Berkeley National Laboratory, Berkeley, CA, November 2011: Invited research seminar speaker on thermal mass and demand response.
- General Electric Co. (GE) Controls Symposium, Schenectady, NY, September 2011: Invited research seminar speaker on opportunities and challenges of advanced building controls.
- United Technologies Research Center, Hartford, CT, August 2011: Invited research seminar speaker on advanced building controls, past and current projects.
- Natural Resources Canada, Montreal, Canada, June 2011: Invited research seminar speaker on NZEB control.
- ASHRAE Annual Meeting, Montreal, Canada, June 2011: Presentation of research seminar.
- TetraTech, Inc. Annual Meeting, Denver, CO, May 2010: Invited dinner speaker on sustainable building design
- Lawrence Berkeley National Laboratory, Berkeley, CA, March 2010: Invited research seminar speaker
- 2009 Energy Symposium: Business and Regulatory Climate Check and Industry Forecast, Kansas City, Missouri, October 2009: Invited speaker on alternative energy technologies.
- ASME Energy Sustainability Conference, San Francisco, CA, July 2009: Presentation of three technical papers.
- Henze, G.P. 2009, “Advanced Building Control Strategies.” NSF CMMI Workshop on Multifunctional Materials and Distributed Renewable Energy for Sustainable Infrastructure, Honolulu, Hawaii, June 22, 2009.
- Henze, G.P. 2007, “European Perspectives and Experiences with High-Efficiency Commercial Buildings.” SolWest, John Day, Oregon, July 31, 2007.
- Henze, G.P. 2007, “Optimal Building Operation.” Eighth Biberach Forum Building Systems Engineering, Biberach, Germany, March 15, 2007.
- Henze, G.P. 2006, “Passive and Low-Energy Cooling Systems for Continental Climates.” Research seminar at the University of Applied Sciences Biberach, Germany, Nov. 10, 2006.
- Henze, G.P. 2006, “Optimal Building Operation.” Seminar at the federally funded workshop *Konzepte Konzepte zur optimierten Betriebsführung von Gebäuden* held in Frankfurt, Germany, July 7, 2006.
- Henze, G.P. 2006, “Impact of Adaptive Comfort Criteria and Heat Waves on Optimal Building Thermal Mass Control” Research seminar at the University of Applied Sciences Biberach, Germany, June 22, 2006.
- Henze, G.P. 2006, “Sustainable Building Design in the U.S.A.” Seventh Biberach Forum Building Systems Engineering, Biberach, Germany, March 22, 2006.
- Waters, C.E., K.W. Houser, D.K. Tiller, G.P. Henze, A.R. Florita, S. Plamp, 2005, “Center for Building Integration Research,” American Council of Engineering Companies/Nebraska - Annual Conference, Omaha, Nebraska, June 9, 2005.
- Waters, C.E., K.W. Houser, D.K. Tiller, G.P. Henze, E. Bowden, M. Eble-Hankins., 2005, “Center for Building Integration Research,” The Built Environment Conference, Omaha, Nebraska, March 3, 2005.

- Channel 7 KETV: Discussion of Ground-Source Heat Pump Heating of Residences in Nebraska, <http://www.theomahachannel.com/news/4161240/detail.html>; aired February 3, 2005.
- Swiss Federal Institute of Technology (ETH), Zurich, Switzerland, November 2004: Invited speaker at the Research Symposium “Architectural Engineering”.
- ASME Solar Energy Engineering Conference, Portland, OR, July 2004: Presentation of three technical papers.
- ASHRAE Annual Meeting, Nashville, TN, June 2004: Presentation of one technical paper and two seminars.
- ASHRAE Winter Meeting, Anaheim, CA, January 2004: Presentation of one technical paper.
- Eighth International IPBSA Conference Building Simulation 2003 in Eindhoven, Netherlands, August 2003: Presentation of two technical papers.
- American Institute of Architects, Omaha Chapter, November 2002: Invited panelist in discussion on the role of architecture in the community.
- Technical University of Dresden, Sep. 2002: Institute of Thermodynamics seminar series.
- ASHRAE Annual Meeting, Honolulu, HI, June 2002: Presentation of two technical papers.
- ASME Solar Energy Engineering Conference, Reno, NV, June 2002: Presentation of two technical papers.
- Pacific Energy Center, San Francisco, CA, December 2001: Invited speaker at day-long “Cool Thermal Storage” Seminar.
- Lawrence Berkeley National Laboratory, Berkeley, CA, December 2001: Invited speaker at Environmental Energy Technologies Division Seminar.
- ASHRAE Annual Meeting, Seattle, WA, June 1999: Presentation of one technical paper.
- ASHRAE Winter Meeting, San Francisco, CA, January 1998: Presentation of two technical papers.
- Umwelt-Campus Birkenfeld, Germany, October 1998: Invited speaker at day-long energy management workshop.
- Metaheuristics International Conference, Breckenridge, CO, July 1995: Presentation of one paper.

Graduate Student Advising

- Doctor of Philosophy (Ph.D.):
 - ✓ Nicholas Long (April 2024): Enriching Public Disclosure Data to Evaluate Advanced District Energy Systems with Thermal Storage for Grid-Interactive Efficient Districts
 - ✓ Sourav Dey (December 2023): Making Reinforcement Learning for Building Energy Management Practical
 - ✓ Amy Allen (August 2021): Development of a Topology Optimization Framework for District Thermal Energy Systems
 - ✓ Margarite Jacoby (August 2021): Battery-Free RFID Sensor Network with Spatiotemporal Pattern Network Based Data Fusion System for Human Presence Sensing
 - ✓ José Ramón Vázquez-Canteli (August 2020): Multi-Agent Reinforcement Learning for Demand Response and Load Shaping of Grid-Interactive Connected Buildings
 - ✓ Danielle Griego (April 2020): Implementing Community-Scale PV Systems as a Sustainable and Governable Urban Common

- ✓ Simone Buffa (January 2020): Advanced Control Strategies for District Heating and Cooling Systems
- ✓ Robert Cruickshank (August 2019): Estimating the Value of Jointly Optimized Electric Power Generation and Residential Electrical Use
- ✓ Anthony Florita (May 2019): A Data-Driven Toolchain for the Operational Performance Analysis and Optimization of Buildings
- ✓ Mehmet Elci (July 2018): Smart Decentralized Solar District Heating
- ✓ Peng Zhao (May 2014): Dynamic Building-to-Grid Integration Through Combined Building System Resources for Frequency Regulation Service
- ✓ Marco Giuliani (April 2014): Development of An Energy Modeling Approach to Analyse Historical Building Performance
- ✓ Gregory Pavlak (April 2014): Building-to-Grid Integration through Commercial Building Portfolios Participating in Energy and Frequency Regulation Markets
- ✓ Charles Corbin (April 2014): Assessing Impact of Large-Scale Distributed Residential HVAC Control Optimization on Electricity Grid Operation and Renewable Energy Integration
- ✓ Ryan Tanner (Jan 2014): Stochastic Optimization of Building Control Systems for Mixed-Mode Buildings
- ✓ Sebastian Burhenne (Nov 2013): Monte Carlo Based Uncertainty and Sensitivity Analysis for Building Performance Simulation
- ✓ Darcie Chinnis (Dec 2012): Exploration of a Dynamic Lighting Energy Modeling Algorithm for Data Collection Support
- ✓ Peter May-Ostendorp (May 2012): Offline Model Predictive Control of Mixed Mode Buildings for Near-Optimal Supervisory Control Strategy Development
- ✓ Dirk Jacob (Jan 2012): Optimization of Commercial Building Operations
- ✓ Abigail Watrous (Nov 2011): Environmental Impacts of the Socioeconomic Factors Affecting Energy Use for Rural Families and Migrant Workers in China
- ✓ Simeng Liu (May 2005): Analytical and Experimental Comparison of Model-Based, Model-Free, and Hybrid Learning Control of Active and Passive Building Thermal Storage Inventory
- Master of Science (M.S.):
 - ✓ Andrew Klavekoske (August 2022): Evaluating Synergistic Effects of Optimally Controlling Temperature and Ventilation in Grid-interactive Efficient Commercial Buildings
 - ✓ Logan Cole (August 2022): Recommendations for Measurement and Verification of Energy Savings from Advanced HVAC Control in Grid-Interactive Commercial Buildings Using Detailed Building Energy Models
 - ✓ Sourav Dey (August 2021): Comparison of Reinforcement Learning Algorithms Applied to High-Fidelity Building Models
 - ✓ Noah Klammer (August 2021): Model-Cluster-Reduce for Modular Multifamily Construction
 - ✓ José Ángel Leiva Vilaplana (August 2021): Evaluation of Model Order Reduction Complexity for Advanced Control of Commercial Buildings
 - ✓ Christina Turley (May 2020): Development and Evaluation of Occupancy-Aware HVAC Control for Residential Building Energy Efficiency and Occupant Comfort
 - ✓ Sade Odumuye (May 2019): Performance Evaluation of a Hybrid AFDD Tool for Small Commercial Buildings under Physical and Operational Model Parameter Mismatch
 - ✓ Adam McKittrick (May 2019): Cost Comparison between Annual and Monthly Net Zero Construction for Multifamily Buildings

- ✓ Fatema Almajed (May 2019): Increased Diversity of Reduced Order Models for Rapid Analysis of 5GDHC Networks for Commercial Buildings
- ✓ Nicholas Smith (May 2019): Modeling of a Wastewater Heat Recovery System
- ✓ John Nelson (Dec 2018): Evaluation of the passive cooling potential of mass inherent in medium to large commercial buildings
- ✓ Cory Mosiman (Aug 2018): Occupant-Centric Metrics for Occupant-Aware Buildings: An Evaluation Using Current Technologies
- ✓ Nicholas Long (Aug 2018): Reduced Order Models for Rapid Analysis of Ambient Loops for Commercial Buildings
- ✓ Catherine Dressler (Aug 2017): Data Science Modules for Energy and Buildings
- ✓ Philipp Bruggmann (April 2016): Grid-Friendly Zero Energy Building Design and Operation
- ✓ Eric Boxer (April 2015): Empirical Testing of an Energy Signal Tool: An Application of Building Energy Performance Monitoring
- ✓ Miles Ryan (Dec 2014): Optimal Control Strategy Selection for Intelligent Pressure Independent Control Valves
- ✓ Benjamin Brannon (Dec 2013): Modeling and Control Strategy Development of a Thermally Activated Residence
- ✓ Lincoln Harmer (May 2013): Monitoring Based Commissioning Using Calibrated Energy Models
- ✓ Bryce Buchanan (Nov 2012): Chilled Water Plant Taxonomy and Energy Valve Modeling
- ✓ Forest Reider (Apr 2012): Adaptive Real-Time Cooling Coil Curve Fitting Using a Computationally Simple Approach
- ✓ Jeanne Stratton (Apr 2012): Dominant Wavelengths Comprising 3- and 4-Color Combinations of LED and Laser White Light with Optimal CQS and LER
- ✓ Justin Bellucci (Apr 2012): Model Development and Experimental Validation of Pressure Independent Hydronic Circuits
- ✓ Jordan Mann (Oct 2011): Fault Detection and Diagnosis using a Probabilistic Modeling Approach
- ✓ Emily Rader (Aug 2011): Populating a Building Component Library with Retail Plug Load Model Snippets Derived from Measured Data
- ✓ James Hauswirth (Aug 2011): Design and Control of a Mixed-Mode University Building in a Continental Climate
- ✓ William Surles (May 2011): Development of a Control Analytic Tool for Evaluating Automated Residential Smart Grid Controls Strategies
- ✓ Simon Olivieri (Dec 2010): Evaluation of Commercial Building Demand Response Potential Using Optimal Short-Term Curtailment of HVAC Loads
- ✓ Rois Langner (Dec 2010): Managing the complexity of energy modeling with time efficiency: An investigation of driving factors that affect commercial high-rise office building energy consumption and demand
- ✓ Erik Greensfelder (August 2009): An Investigation of the Cost Savings Potentials Found Using Optimal Control of Passive Thermal Storage with Real Time Pricing and an Exploration of Temporal Carbon Emissions Signals
- ✓ Anthony Florita (August 2007): Development of a Simulation and Optimization Environment for the Analysis of Building Thermal Mass Control.
- ✓ Sandro Plamp (May 2006): Development of Learning Modules for Building Control and Automation Systems.

- ✓ Doreen E. Kalz (May 2004): Experimental Analysis of Model-Based Predictive Optimal Control for Active and Passive Building Thermal Storage Inventory.
- Master of Architectural Engineering (M.A.E.):
 - ✓ Matthew Pfannenstiel (2008): An Essential Utility System for a Healthcare Building in St. Luce, Madagascar.
 - ✓ Shaun Nienhueser (2008): Investigation of a Carbon-Neutral Medical Building through the Use of Cogeneration and Photovoltaics.
 - ✓ Jennifer Machacek (2008): Improving Abilities of Building Automation and Control Systems to Better Meet Client Needs.
 - ✓ Clayton Miller (2007): Technical and Economic Feasibility Study of the Peter Kiewit Institute in Attaining LEED-EB Certification.
 - ✓ Andrew Yosten (2007): Building Load Management by Means of Optimal Operation of Distributed Generation Equipment.
 - ✓ Daniel Karnes (2005): Investigation of Global Setpoint Optimization of HVAC Systems in an Office Building.
 - ✓ Chad Liechti (2005): Verification of Evaporative Cooling and Cooling Coil Model.
 - ✓ Stephanie Wright (2005): Life Cycle Cost Analysis of Cold Air Distribution Systems.
 - ✓ Daniel Barnes (2004): Modeling of Indirect/Direct Evaporative Cooling.
 - ✓ Kimberly Bunz (2004): A Comparative Study of Sustainable Building Design Practices in North America, Europe, and Asia.
 - ✓ Nick Rosenberry (2004): Guidelines for Selection of Chiller Technologies to Minimize Life Cycle Cost.
 - ✓ Nathan Sheets (2004): Comparison of Neural Network Based Controllers for Building Control.
- Diplom-Ingenieur (Dipl.-Ing.): Sebastian Kurz, Sandro Plamp, Jens Klostermann, Gregor Strassberger, Jobst Schoenmann, Ronny Goepfert, Magnus Fischer, Mathias Rieger, Mathias Roemhild.
- Post-Doctoral and Research Scholars: Thibault Marzullo (2020-today), Zahra Fallahi (2019-today), Matteo Saviozzi (2015), Ahmed Rizk (2007-2008), Robert Dodier (2004-2005), and Thoi Le (2004-2005).

Foreign Languages

German: native

Italian: intermediate (speaking, reading, writing)

Spanish: intermediate (speaking, reading, writing)