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(54) **EFFICIENT AC OPERATION USING DEW-POINT TEMPERATURE**

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(65) **Prior Publication Data**

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(51) **Int. Cl.**

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F25D 21/00	(2006.01)
F24F 3/14	(2006.01)
B60H 1/00	(2006.01)

(52) **U.S. Cl.** .... **701/36**; 62/150; 62/176.2; 62/176.6; 73/29.01; 165/202; 165/222; 165/230; 236/91 C; 236/91 F; 700/278

(58) **Field of Classification Search** .... 62/80.115, 62/150, 151, 156, 176.1, 176.2, 176.6, 244, 62/498, 515; 73/29.01; 165/202, 204, 222, 165/223, 229, 230, 253, 257, 287, 288, 291, 165/41, 42; 236/91 R, 91 C, 91 D, 91 F, 236/44 R, 44 C; 374/28, 142, 109; 454/121, 454/127; 700/278; 701/36

See application file for complete search history.

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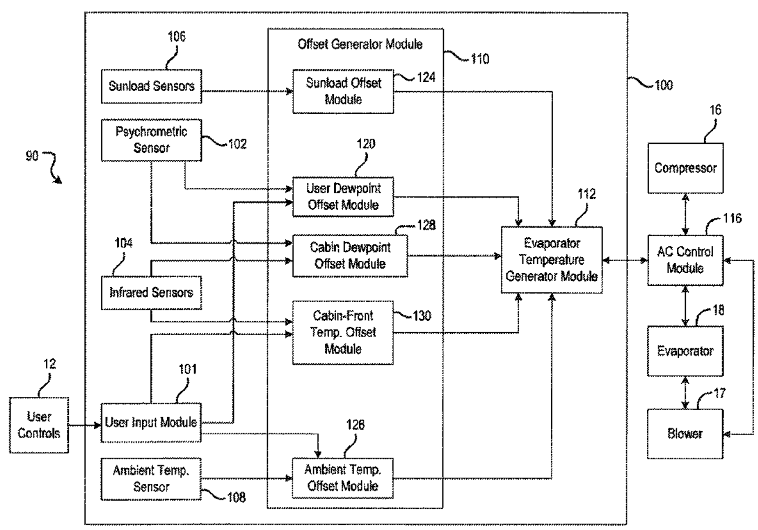
(57) **ABSTRACT**

A system for controlling air-conditioning of a vehicle includes an input, an offset generator module, and an evaporator temperature control module. The input receives an input temperature. The offset generator module receives a psychrometric parameter of air inside the vehicle and generates offsets based on the input temperature and the psychrometric parameter. The evaporator temperature control module generates a target evaporator temperature based on the offsets.

20 Claims, 16 Drawing Sheets



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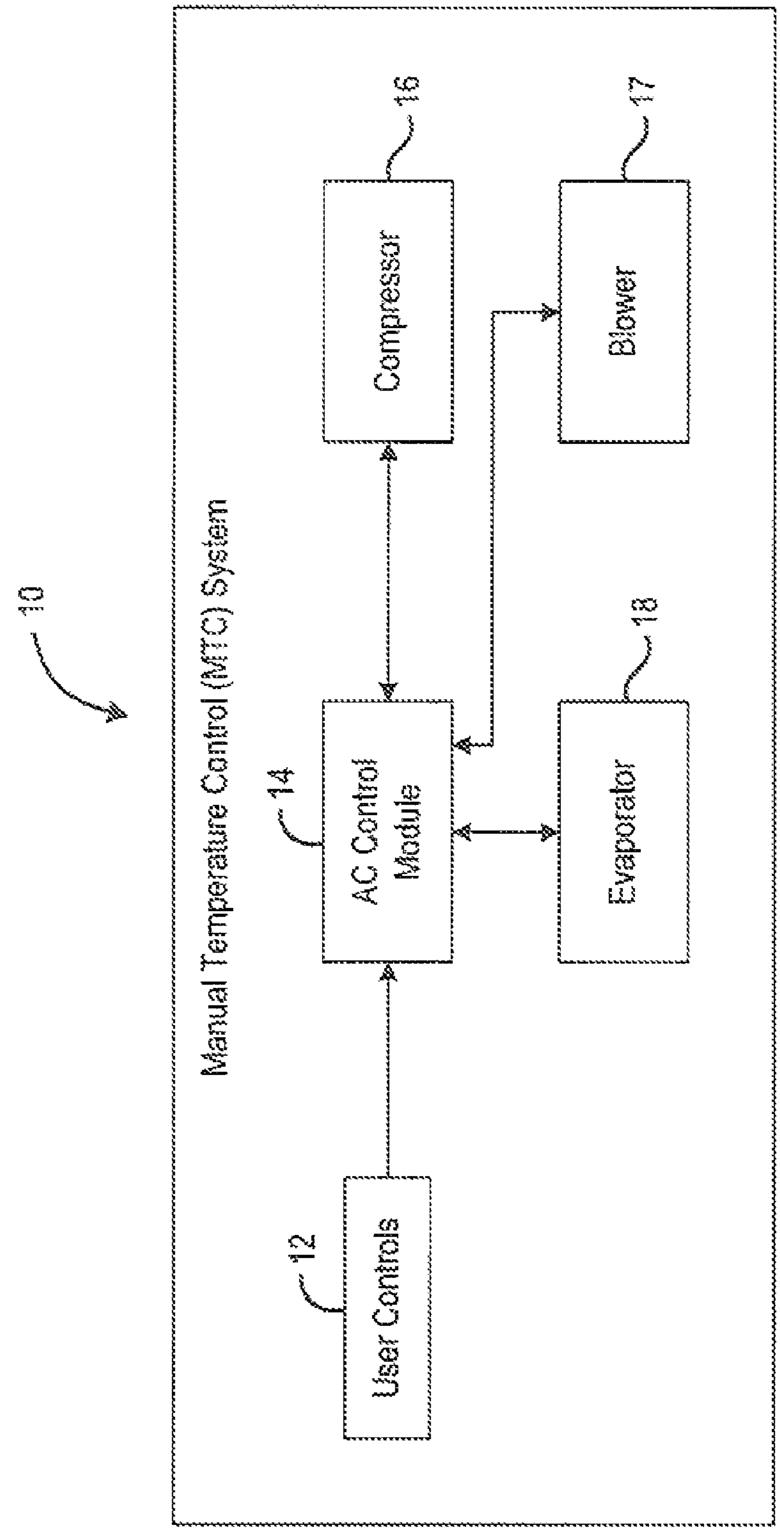


FIG. 1A
Prior Art

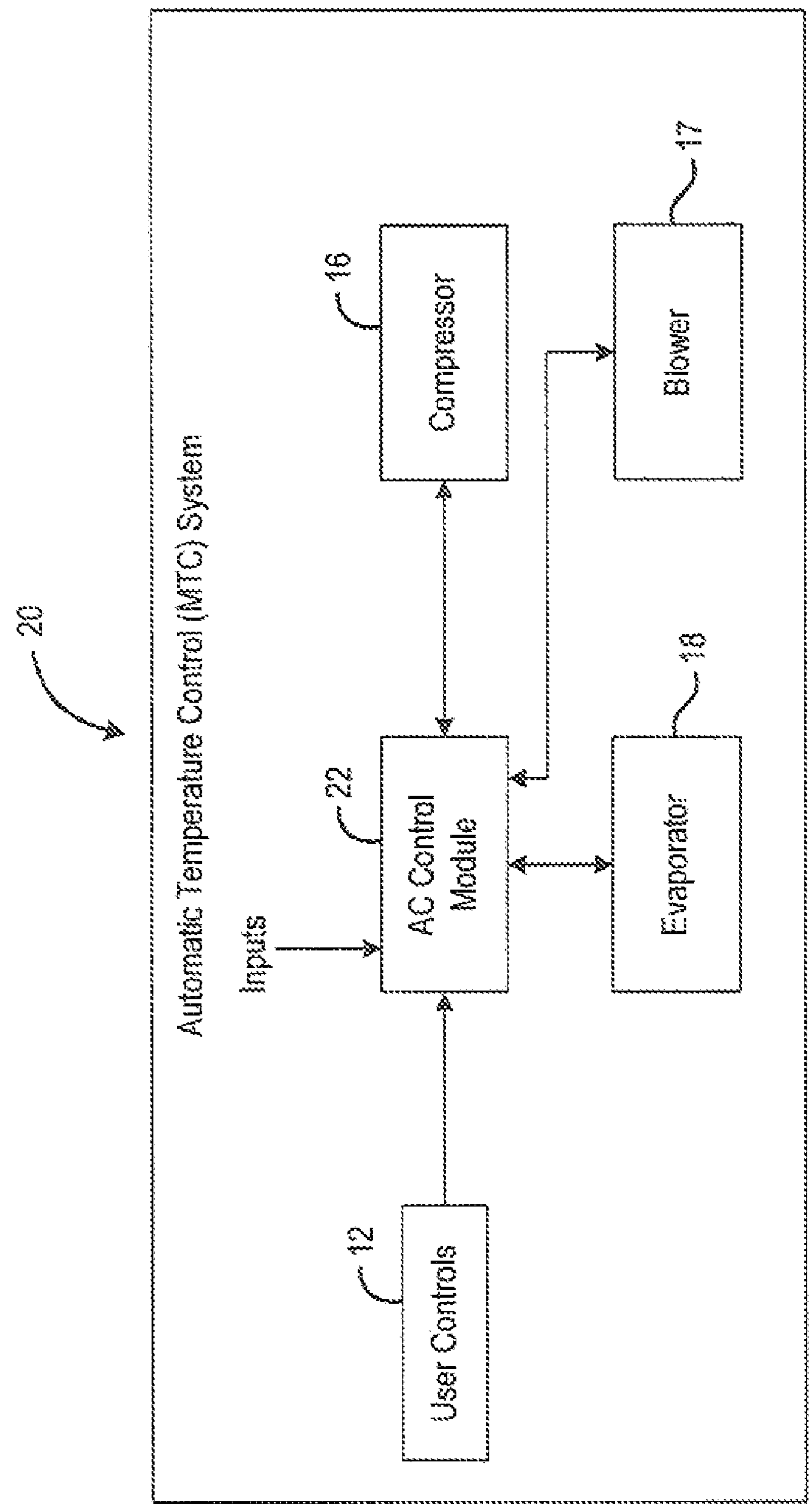


FIG. 1B
Prior Art

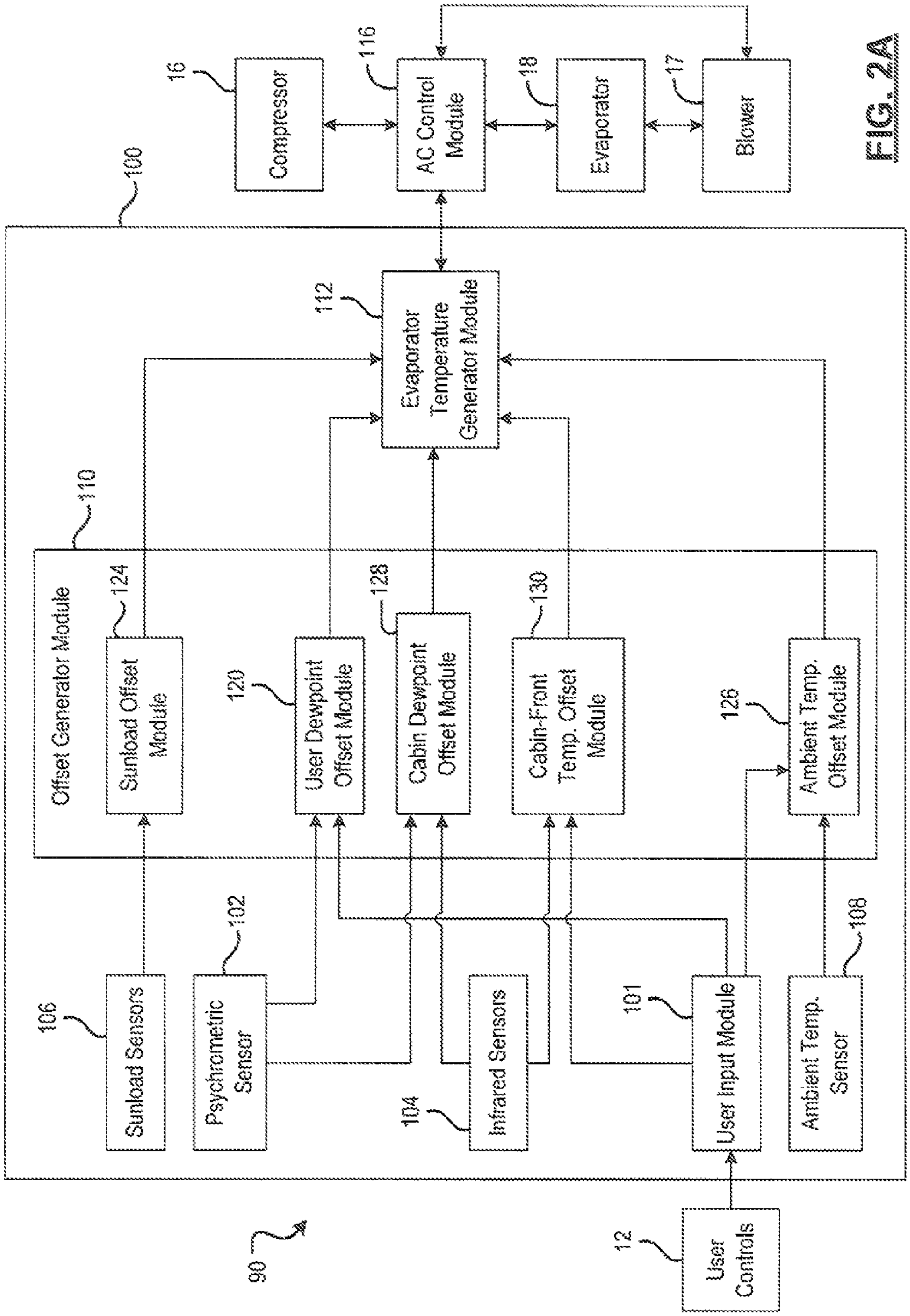

16
Compressor
116
AC Control Module
18
Evaporator
17
Blower
100
112
Evaporator Temperature Generator Module
110
Offset Generator Module
124
Sunload Offset Module
120
User Dewpoint Offset Module
128
Cabin Dewpoint Offset Module
130
Cabin-Front Temp. Offset Module
126
Ambient Temp. Offset Module
106
Sunload Sensors
102
Psychrometric Sensor
104
Infrared Sensors
101
User Input Module
108
Ambient Temp. Sensor
12
User Controls
90

FIG. 2A

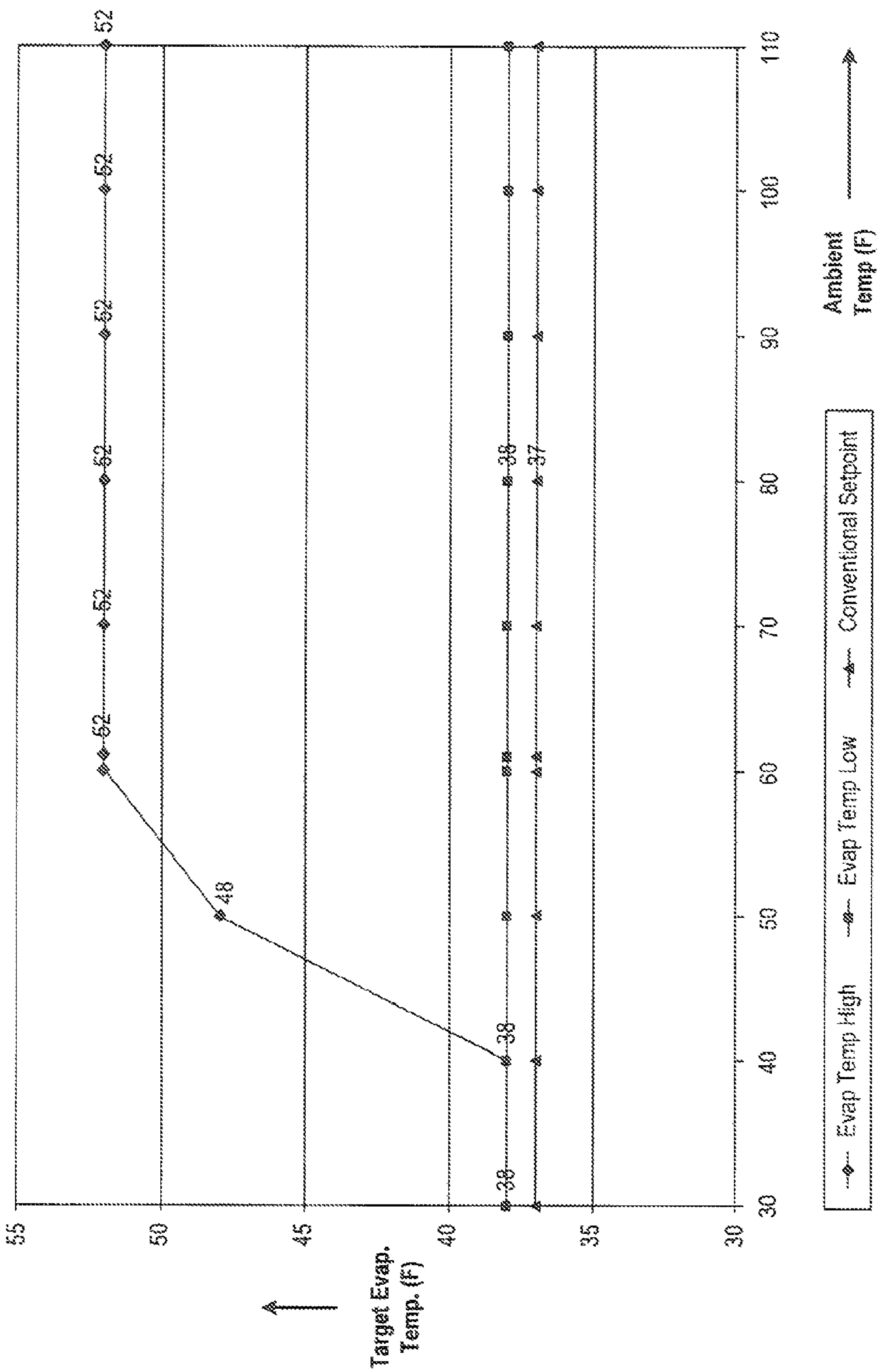

Target Evap. Temp. (F)
55
50
45
40
35
30
30
40
50
60
70
80
90
100
110
Ambient Temp (F)
52
52
52
52
52
52
48
38
38
38
37
Evap Temp High
Evap Temp Low
Conventional Setpoint

FIG. 2B

Ambient Temp (F)	Evap Temp High (F)	Evap Temp Low (F)
30	38	38
40	38	38
50	48	38
60	52	38
61	52	38
70	52	38
80	52	38
90	52	38
100	52	38
110	52	38

FIG. 2C

RH @ Nose Tip =															
Customer Set Temp		45%	45%	46%	47%	48%	49%	50%	50%	51%	52%	53%	54%	55%	55%
Temp [°F]	Temp [°C]	Dewpoint [°C]	Dewpoint [°F]	Dewpoint [°C]	Dewpoint [°C]	Dewpoint [°C]	Dewpoint [°C]	Dewpoint [°C]	Dewpoint [°F]	Dewpoint [°C]	Dewpoint [°C]	Dewpoint [°C]	Dewpoint [°C]	Dewpoint [°C]	Dewpoint [°F]
86.0	30.0	16.8	62.2	17.1	17.5	17.8	18.1	18.4	65.2	18.8	19.1	19.4	19.7	20.0	67.9
85.0	29.4	16.3	61.3	16.6	16.9	17.3	17.6	17.9	64.3	18.2	18.6	18.9	19.2	19.5	67.0
84.0	28.9	15.8	60.4	16.1	16.4	16.8	17.1	17.4	63.4	17.7	18.0	18.3	18.6	18.9	66.1
83.0	28.3	15.3	59.5	15.6	15.9	16.3	16.6	16.9	62.4	17.2	17.5	17.8	18.1	18.4	65.2
82.0	27.8	14.8	58.6	15.1	15.4	15.8	16.1	16.4	61.5	16.7	17.0	17.3	17.6	17.9	64.2
81.0	27.2	14.3	57.7	14.6	14.9	15.3	15.6	15.9	60.6	16.2	16.5	16.8	17.1	17.4	63.3
80.0	26.7	13.8	56.8	14.1	14.4	14.8	15.1	15.4	59.7	15.7	16.0	16.3	16.6	16.9	62.4
79.0	26.1	13.3	55.9	13.6	13.9	14.2	14.6	14.9	58.8	15.2	15.5	15.8	16.1	16.4	61.5
78.0	25.6	12.7	54.9	13.1	13.4	13.7	14.1	14.4	57.9	14.7	15.0	15.3	15.6	15.8	60.5
77.0	25.0	12.2	54.0	12.6	12.9	13.2	13.5	13.9	56.9	14.2	14.5	14.8	15.0	15.3	59.6
76.0	24.4	11.7	53.1	12.1	12.4	12.7	13.0	13.3	56.0	13.7	14.0	14.2	14.5	14.8	58.7
75.0	23.9	11.2	52.2	11.6	11.9	12.2	12.5	12.8	55.1	13.1	13.4	13.7	14.0	14.3	57.7
74.0	23.3	10.7	51.3	11.1	11.4	11.7	12.0	12.3	54.2	12.6	12.9	13.2	13.5	13.8	56.8
73.0	22.8	10.2	50.4	10.6	10.9	11.2	11.5	11.8	53.3	12.1	12.4	12.7	13.0	13.3	55.9
72.0	22.2	9.7	49.5	10.1	10.4	10.7	11.0	11.3	52.4	11.6	11.9	12.2	12.5	12.8	55.0
71.0	21.7	9.2	48.6	9.6	9.9	10.2	10.5	10.8	51.4	11.1	11.4	11.7	12.0	12.2	54.0
70.0	21.1	8.7	47.7	9.0	9.4	9.7	10.0	10.3	50.5	10.6	10.9	11.2	11.4	11.7	53.1
69.0	20.6	8.2	46.8	8.5	8.9	9.2	9.5	9.8	49.6	10.1	10.4	10.7	10.9	11.2	52.2
68.0	20.0	7.7	45.9	8.0	8.4	8.7	9.0	9.3	48.7	9.6	9.9	10.1	10.4	10.7	51.2
67.0	19.4	7.2	45.0	7.5	7.8	8.2	8.5	8.8	47.8	9.1	9.3	9.6	9.9	10.2	50.3
66.0	18.9	6.7	44.1	7.0	7.3	7.6	8.0	8.2	46.8	8.5	8.8	9.1	9.4	9.7	49.4
65.0	18.3	6.2	43.2	6.5	6.8	7.1	7.4	7.7	45.9	8.0	8.3	8.6	8.9	9.1	48.5
64.0	17.8	5.7	42.3	6.0	6.3	6.6	6.9	7.2	45.0	7.5	7.8	8.1	8.4	8.6	47.5
63.0	17.2	5.2	41.4	5.5	5.8	6.1	6.4	6.7	44.1	7.0	7.3	7.6	7.8	8.1	46.6
62.0	16.7	4.7	40.4	5.0	5.3	5.6	5.9	6.2	43.2	6.5	6.8	7.1	7.3	7.6	45.7
61.0	16.1	4.2	39.5	4.5	4.8	5.1	5.4	5.7	42.3	6.0	6.3	6.5	6.8	7.1	44.7
60.0	15.6	3.7	38.6	4.0	4.3	4.6	4.9	5.2	41.3	5.5	5.7	6.0	6.3	6.6	43.8
59.0	15.0	3.2	37.7	3.5	3.8	4.1	4.4	4.7	40.4	5.0	5.2	5.5	5.8	6.0	42.9

FIG. 3A

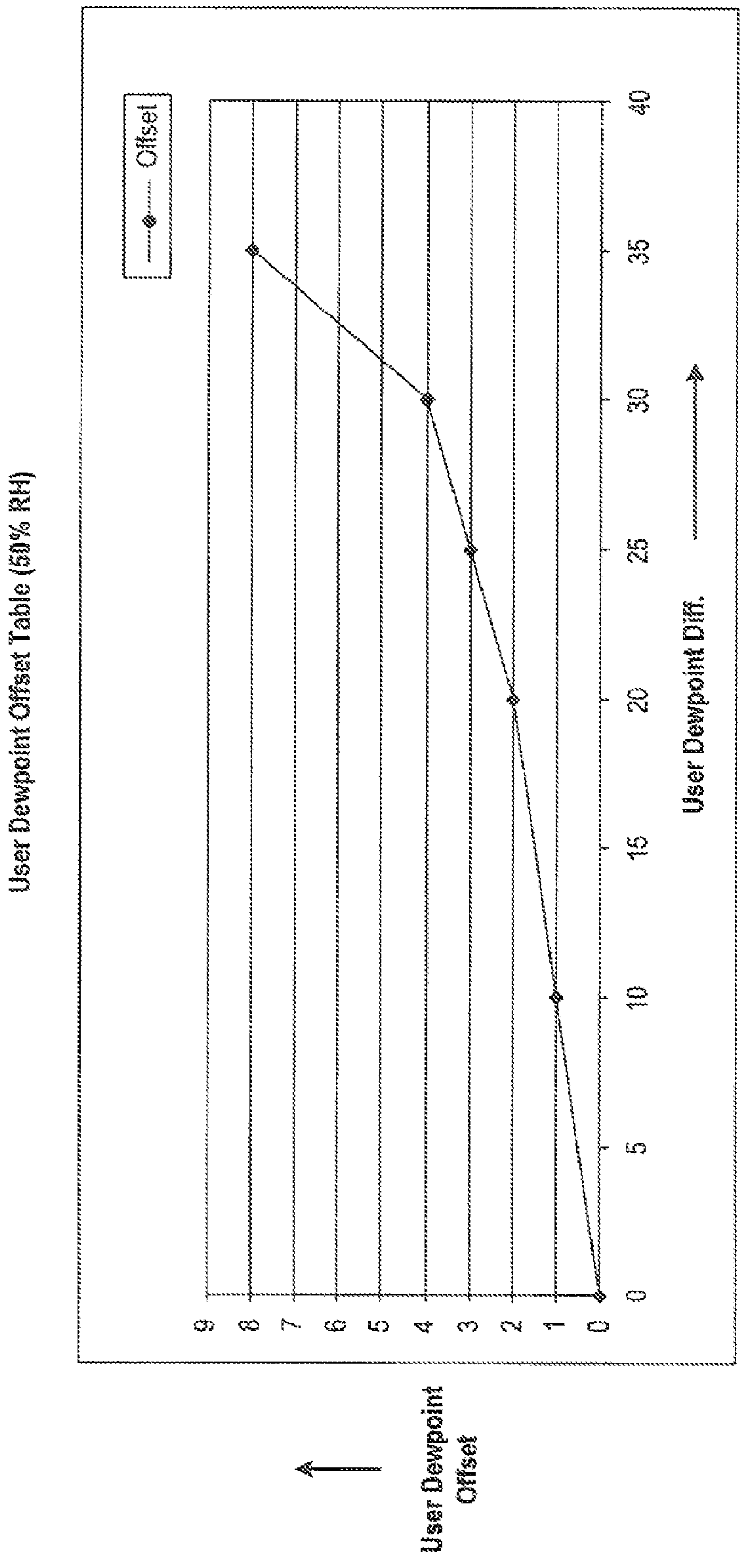

User Dewpoint Offset Table (50% RH)
Offset
0
1
2
3
4
5
6
7
8
9
0
5
10
15
20
25
30
35
40
User Dewpoint Diff.
User Dewpoint Offset

FIG. 3B

User Dewpoint Offset Table
(50% RH)

User Dewpoint Diff.	User Dewpoint Offset
0	0
10	1
20	2
25	3
30	4
35	8

FIG. 3C

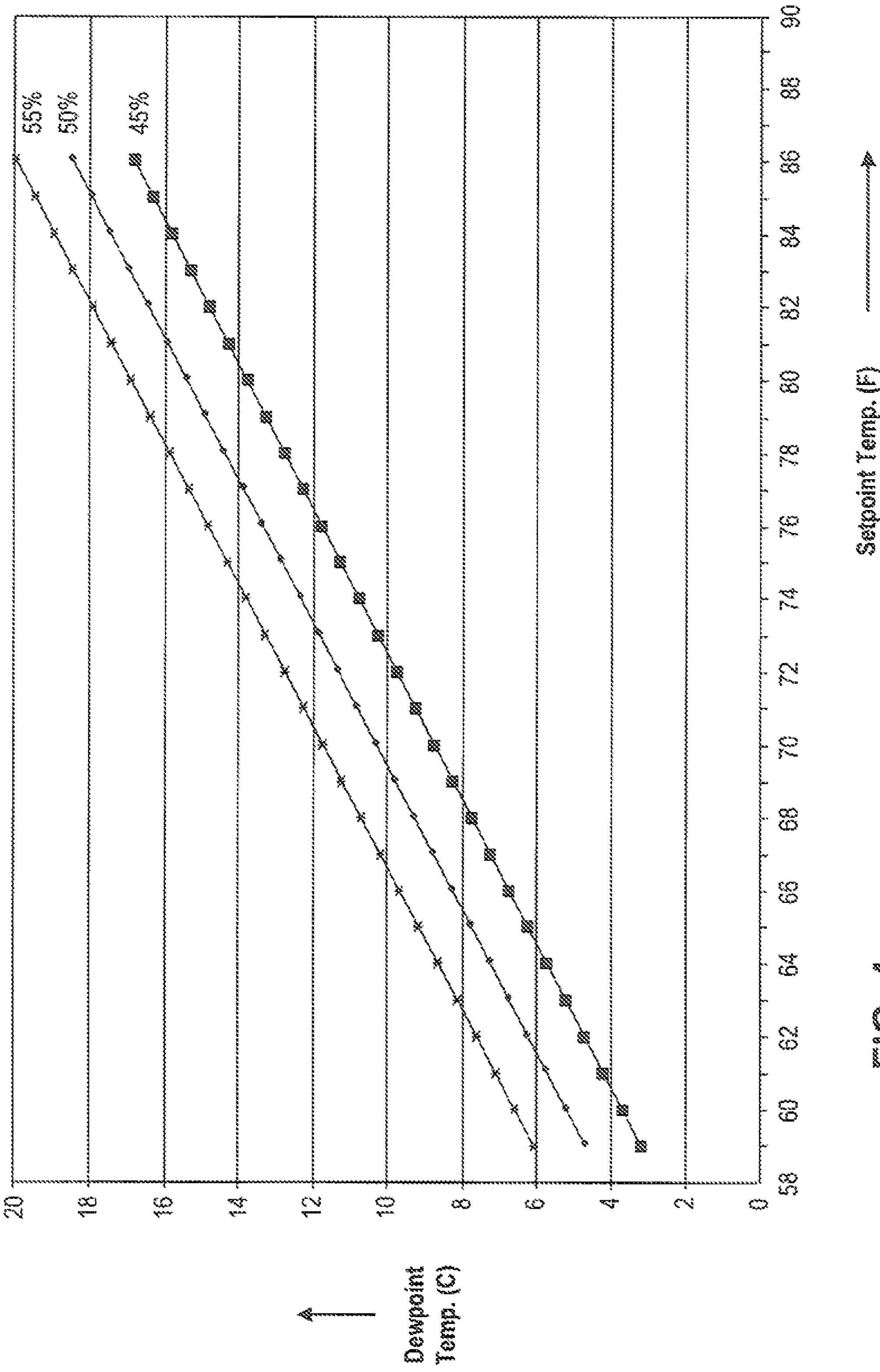

55%
50%
45%
Setpoint Temp. (F)
Dewpoint Temp. (C)
58 60 62 64 66 68 70 72 74 76 78 80 82 84 86 88 90
0 2 4 6 8 10 12 14 16 18 20

FIG. 4

Sunload Offset Table
(50% RH)

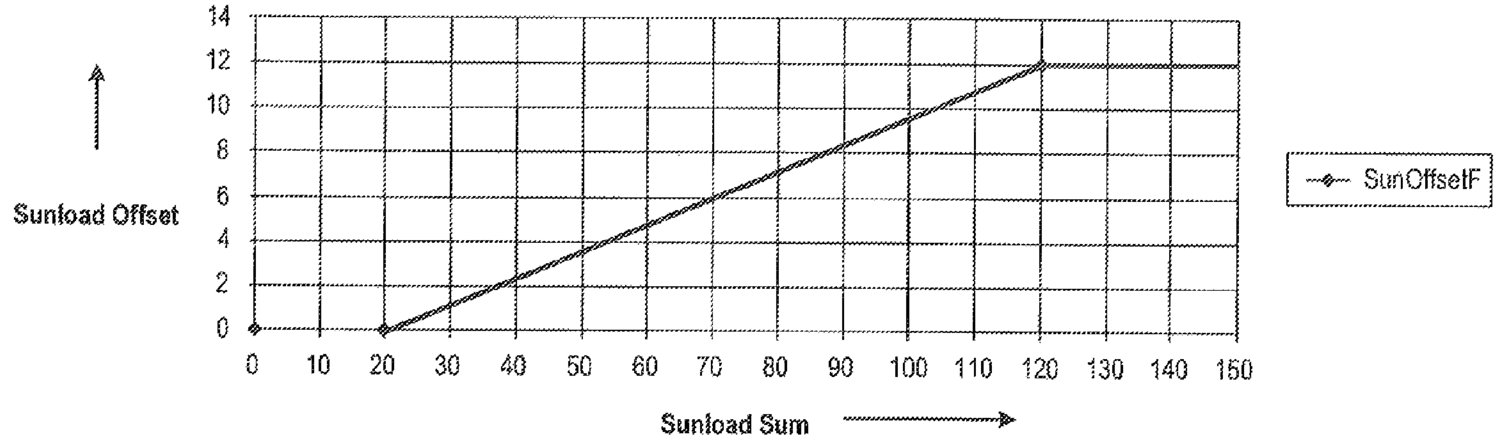


FIG. 5A

Sunload Offset Table
(50% RH)

Sunload Sum	Sunload Offset
0	0
20	0
120	12
255	12

FIG. 5B

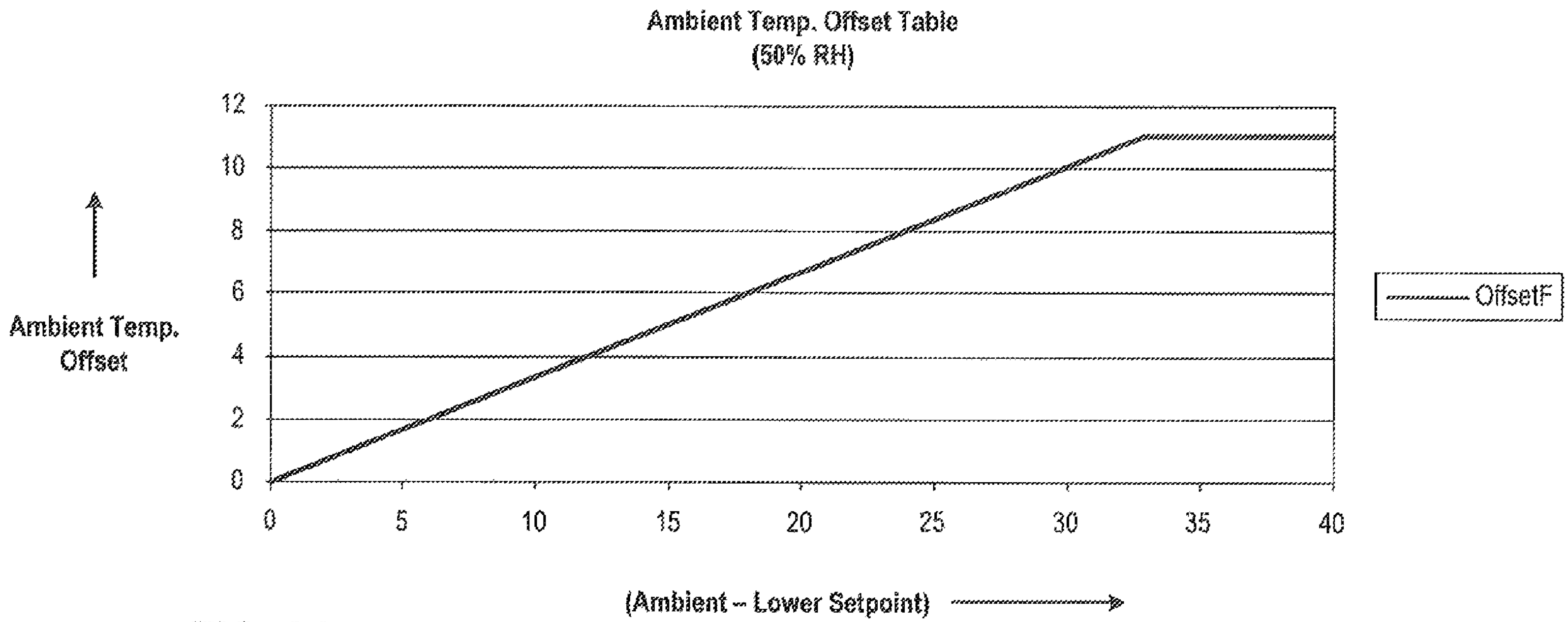


FIG. 6A

Ambient Temp. Offset Table
(50% RH)

(Ambient – Lower Setpoint)	Ambient Temp. Offset
0	0
33	11
255	11

FIG. 6B

Cabin Dewpoint Offset Table
(50% RH)

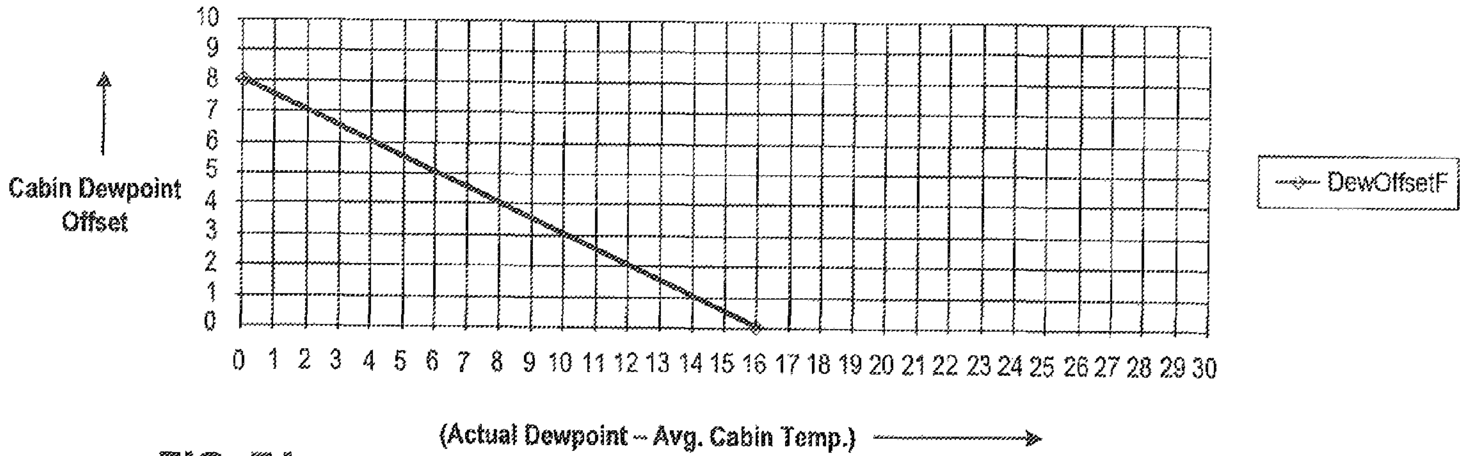


FIG. 7A

Cabin Dewpoint Offset Table
(50% RH)

(Actual Dewpoint – Avg. Cabin Temp.)	Cabin Dewpoint Offset
0	8
16	0
255	0

FIG. 7B

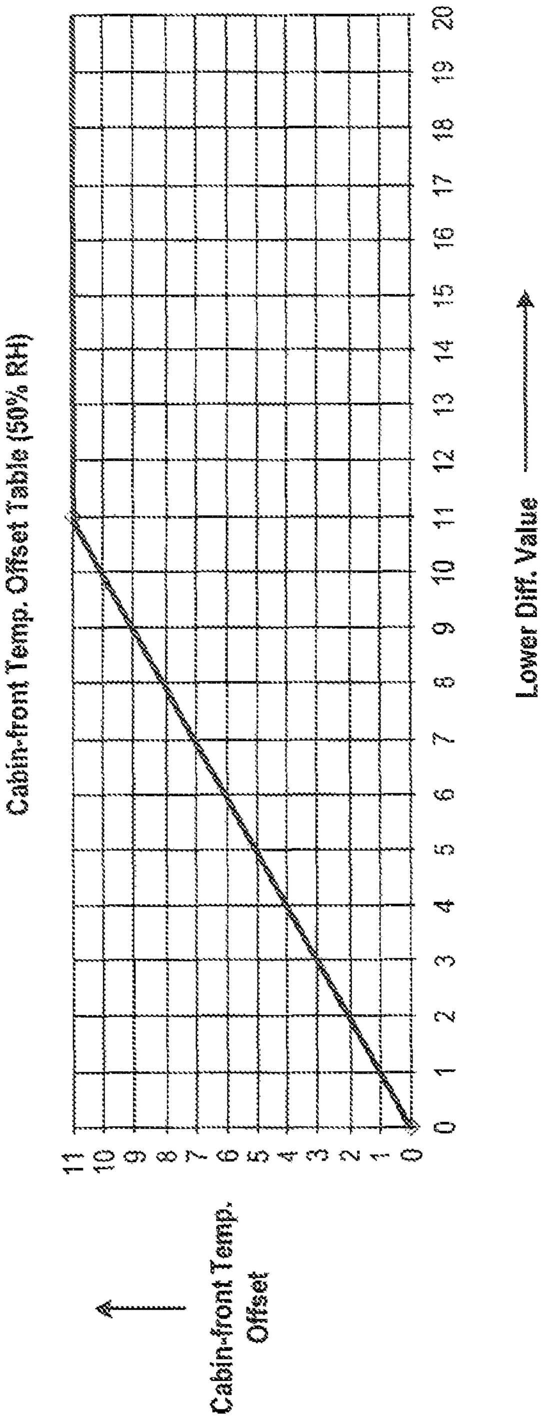


FIG. 8A

Cabin-front Temp. Offset Table (50% RH)

Lower Diff. Value	Cabin-front Temp. Offset
0	8
11	11
255	11

FIG. 8B

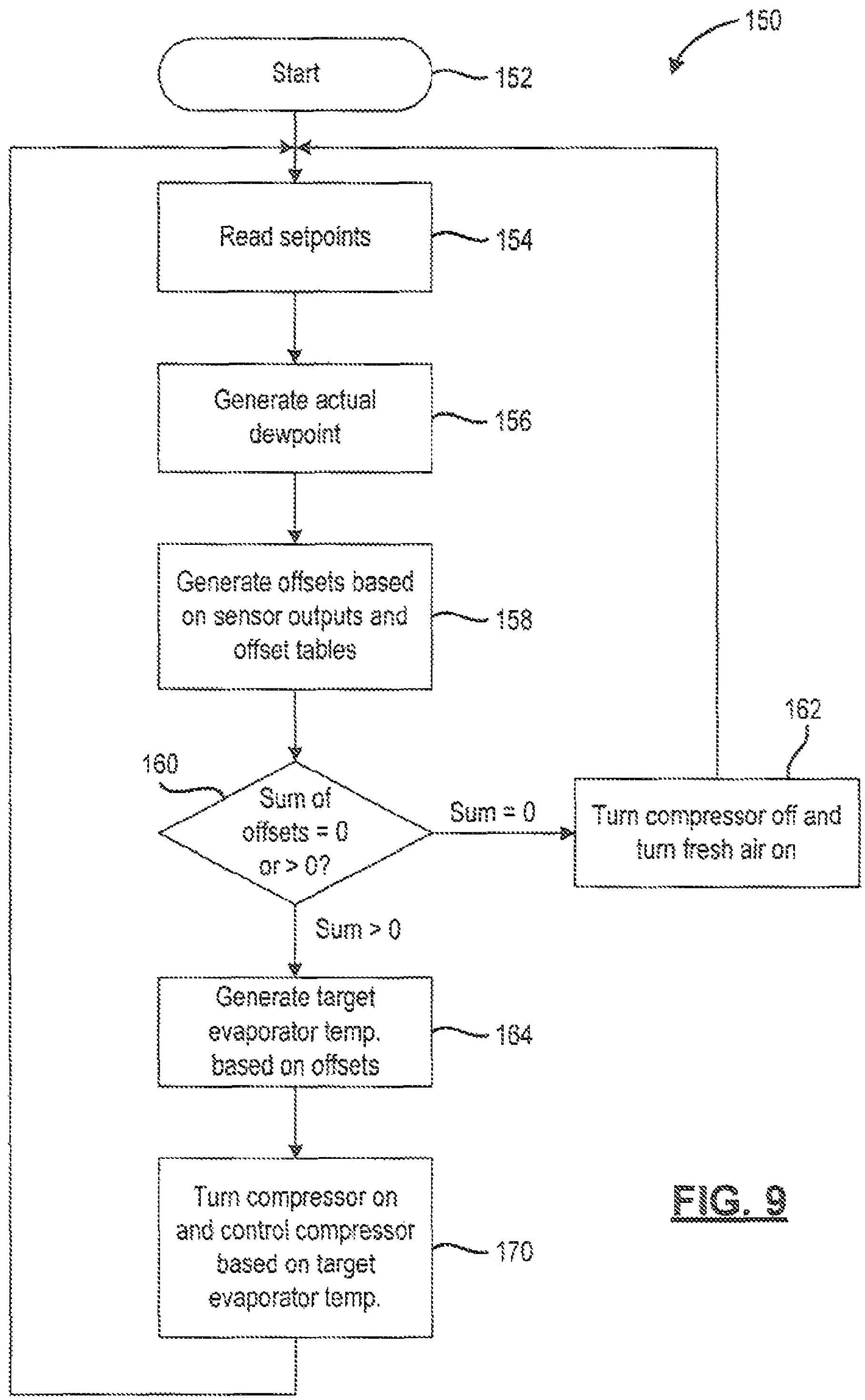

150
Start
152
Read setpoints
154
Generate actual dewpoint
156
Generate offsets based on sensor outputs and offset tables
158
160
Sum of offsets = 0 or > 0?
Sum = 0
Turn compressor off and turn fresh air on
162
Sum > 0
Generate target evaporator temp. based on offsets
164
Turn compressor on and control compressor based on target evaporator temp.
170

FIG. 9

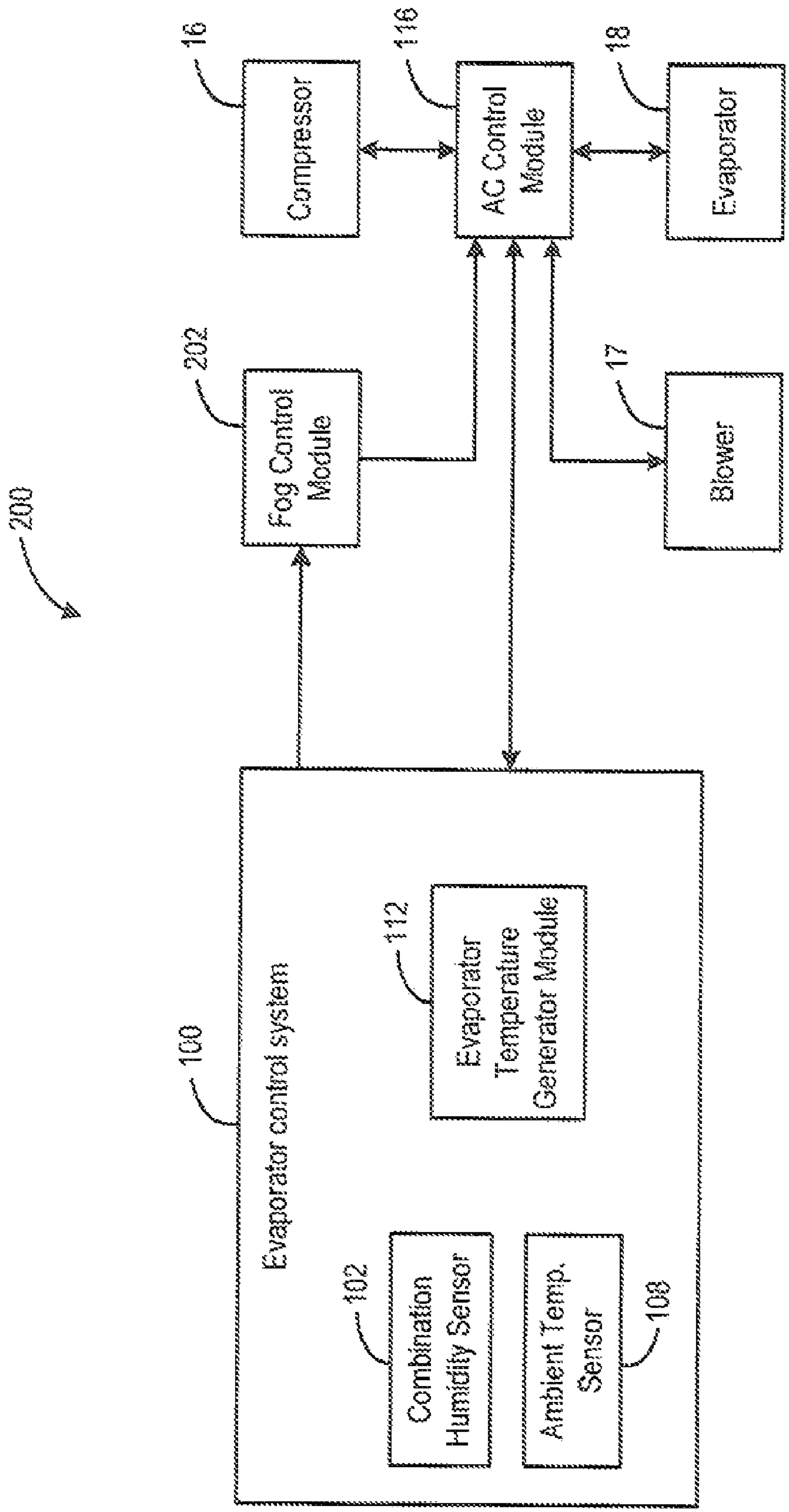
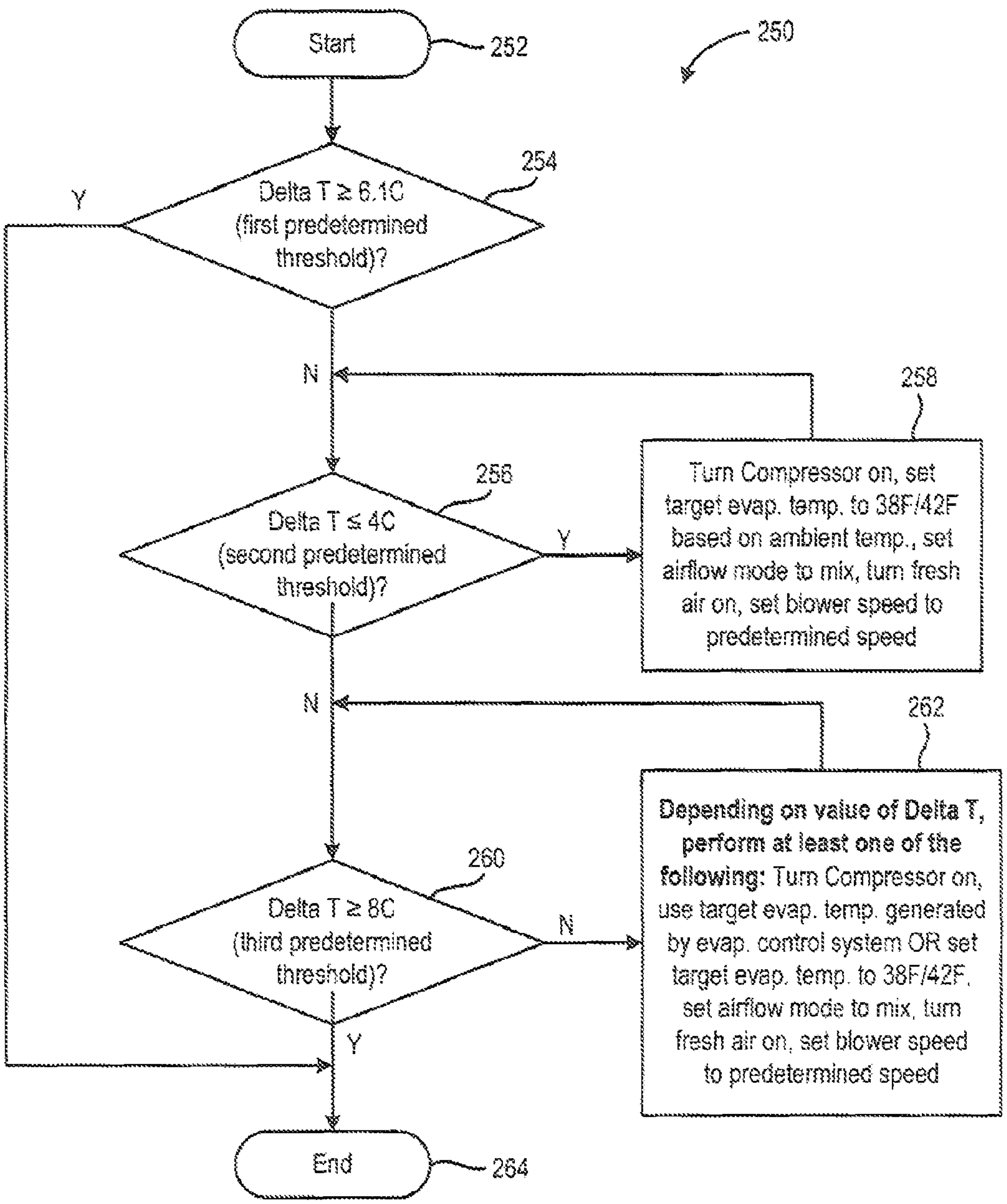

200
16
Compressor
116
AC Control Module
18
Evaporator
202
Fog Control Module
17
Blower
100
Evaporator control system
112
Evaporator Temperature Generator Module
102
Combination Humidity Sensor
Ambient Temp. Sensor
108

FIG. 10



Start
252
250
Delta T ≥ 6.1C
(first predetermined
threshold)?
254
Y
N
258
Turn Compressor on, set
target evap. temp. to 38F/42F
based on ambient temp., set
airflow mode to mix, turn fresh
air on, set blower speed to
predetermined speed
256
Delta T ≤ 4C
(second predetermined
threshold)?
Y
N
262
**Depending on value of Delta T,
perform at least one of the
following:** Turn Compressor on,
use target evap. temp. generated
by evap. control system OR set
target evap. temp. to 38F/42F,
set airflow mode to mix, turn
fresh air on, set blower speed
to predetermined speed
260
Delta T ≥ 8C
(third predetermined
threshold)?
N
Y
End
264

FIG. 11

EFFICIENT AC OPERATION USING DEW-POINT TEMPERATURE

CROSS REFERENCE TO RELATED APPLICATION

This application claims the benefit of U.S. Provisional Application No. 61/056,512 filed May 28, 2008.

FIELD OF THE INVENTION

The present invention relates to vehicle air-conditioning (AC) systems, and more particularly to systems and methods for efficient operation of vehicle AC systems using dew-point temperature.

BACKGROUND OF THE INVENTION

Referring now to FIGS. **1**A and **1**B, different temperature control systems used in vehicles to control cabin temperature are shown. In FIG. **1**A, a manual temperature control (MTC) system **10** is shown. The MTC system **10** comprises user controls **12**, an air-conditioning (AC) control module **14**, a compressor **16**, a blower **17**, and an evaporator **18**.

An occupant uses user controls **12** to manually set and adjust the cabin temperature. For example, the occupant can set a desired cabin temperature, adjust a speed of the blower **17**, and/or turn the AC on or off. The AC control module **14** controls the compressor **16** based on the settings input by the occupant and by sensing the temperature of the evaporator **18**. When the user turns the blower **17** on, the blower **17** blows fresh air from outside the vehicle into the cabin or recirculates the air in the cabin depending on an airflow mode selected by the user.

In FIG. **1**B, an automatic temperature control (ATC) system **20** is shown. The ATC system **20** comprises the user controls **12**, an AC control module **22**, the compressor **16**, the blower **17** and the evaporator **18**.

The occupant initially sets the desired cabin temperature. Thereafter, the ATC system **20** automatically maintains the desired cabin temperature based on inputs received from interior and exterior of the cabin and by sensing the temperature of the evaporator **18**. Additionally, the AC control module **22** controls the blower **17** and selects the airflow mode. When the AC control module **22** turns the blower **17** on, the blower **17** blows fresh air from outside the vehicle into the cabin or recirculates the cabin air depending on the airflow mode selected.

Typically, the ATC system **20** maintains the desired cabin temperature by turning the compressor **16** on and by maintaining an evaporator temperature at a low value (e.g., 35 F to 38 F). When the evaporator temperature is maintained at the low value, however, the compressor **16** is turned on at all times. Consequently, the ATC system **20** increases energy consumption and decreases fuel efficiency of the vehicle.

SUMMARY OF THE INVENTION

A system for controlling air-conditioning of a vehicle controls a compressor by operating an evaporator in a predetermined temperature range. The system includes an input, a plurality of sensors, an offset module, an evaporator temperature control module, and an air-conditioning (AC) control module.

The input receives an input temperature desired by an occupant. The sensors measure a plurality of parameters including a psychrometric parameter of the air inside the vehicle. The offset module generates a plurality of offsets based on outputs generated by the sensors. The evaporator temperature control module generates a target evaporator temperature based on a predetermined evaporator temperature and the offsets.

The AC control module controls at least one of a compressor, a blower, and a mode of airflow inside the vehicle based on the target evaporator temperature. The AC control module turns the compressor on until the evaporator reaches the target evaporator temperature. The AC control module turns the compressor off when a sum of the offsets is zero.

The system further includes a fog control module that communicates with the AC control module and the evaporator temperature control module. The fog control module controls defogging of the windshield based on a difference between the psychrometric parameter and a glass temperature of the windshield measured by one of the sensors.

Further areas of applicability of the present invention will become apparent from the detailed description provided hereinafter. It should be understood that the detailed description and specific examples, while indicating the preferred embodiment of the invention, are intended for purposes of illustration only and are not intended to limit the scope of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will become more fully understood from the detailed description and the accompanying drawings, wherein:

FIG. **1**A is a functional block diagram of an exemplary manual temperature control system according to the prior art;

FIG. **1**B is a functional block diagram of an exemplary automatic temperature control system according to the prior art;

FIG. **2**A is a functional block diagram of an exemplary automatic temperature control system according to the present invention;

FIG. **2**B is an exemplary graph of target evaporator temperature versus ambient temperature according to the present invention;

FIG. **2**C is an exemplary table showing points of the graph of FIG. **2**B according to the present invention;

FIG. **3**A is a table showing dewpoint temperatures corresponding to different desired temperatures at different percentages of relative humidity;

FIG. **3**B is an exemplary graph of user dewpoint offset versus user dewpoint difference according to the present invention;

FIG. **3**C is an exemplary user dewpoint offset table showing points of the graph of FIG. **3**B according to the present invention;

FIG. **4** is a graph of dewpoint temperature versus desired temperature (i.e., setpoint temperature) at different percentages of relative humidity;

FIG. **5**A is an exemplary graph of sunload offset versus sunload sum according to the present invention;

FIG. **5**B is an exemplary sunload offset table showing points of the graph of FIG. **5**A according to the present invention;

FIG. **6**A is an exemplary graph of ambient temperature offset versus a difference between ambient and setpoint temperatures according to the present invention;

FIG. **6**B is an exemplary ambient temperature offset table showing points of the graph of FIG. **6**A according to the present invention;

FIG. 7A is an exemplary graph of cabin dewpoint offset versus a difference between actual dewpoint and average cabin temperature according to the present invention;

FIG. 7B is an exemplary cabin dewpoint offset table showing points of the graph of FIG. 7A according to the present invention;

FIG. 8A is an exemplary graph of cabin-front temperature offset versus a lower difference value between actual dewpoint and average cabin temperature according to the present invention;

FIG. 8B is an exemplary cabin-front temperature offset table showing points of the graph of FIG. 8A according to the present invention;

FIG. 9 is a flowchart of an exemplary method for generating a target evaporator temperature according to the present invention;

FIG. 10 is a functional block diagram of an exemplary defogging system according to the present invention; and

FIG. 11 is a flowchart of an exemplary method for defogging a windshield of a vehicle according to the present invention.

DETAILED DESCRIPTION

The present invention discloses an ATC system that maintains the desired cabin temperature by maintaining the evaporator temperature at a highest possible value at which occupants feel comfortable. Additionally, the compressor **16** can be turned off by determining when running the compressor **16** is unnecessary to maintain the desired cabin temperature.

Specifically, instead of maintaining the evaporator temperature at a predetermined low value, the evaporator **18** is operated within a predetermined or targeted temperature range. A target evaporator temperature is determined based on a plurality of inputs. The inputs include psychrometric parameters of the air inside the cabin. For example, the inputs include a dewpoint temperature of the air inside the vehicle. The psychrometric parameters are measured by psychrometric sensors. For example, the dewpoint temperature is accurately measured (i.e., not estimated) by a combination humidity sensor mounted adjacent to a windshield of the vehicle (e.g., at a base of a rear view mirror). The compressor **16** is turned on only until the temperature of the evaporator **18** reaches the target evaporator temperature. Thereafter, the compressor **16** is turned off.

Referring now to FIGS. **2A**-**2C**, an ATC system **90** according to the present invention is shown. In FIG. **2A**, the ATC system **90** comprises the user controls **12**, an evaporator control system **100**, an AC control module **116**, the compressor **16**, the blower **17**, and the evaporator **18**. The evaporator control system **100** generates the target evaporator temperature. The AC control module **116** controls the compressor **16** based on the target evaporator temperature. Additionally, the AC control module **116** controls the blower **17**.

The evaporator control system **100** comprises a user input module **101**, a psychrometric sensor **102**, infrared sensors **104**, sunload sensors **106**, an ambient temperature sensor **108**, an offset generator module **110**, and an evaporator temperature generator module **112**. As an example, the psychrometric sensor **102** includes a combination humidity sensor **102**. As an example, the offset generator module **110** comprises a user dewpoint offset module **120**, a sunload offset module **124**, an ambient temperature offset module **126**, a cabin dewpoint offset module **128**, and a cabin-front temperature offset module **130**. The offset generator module **110** can include fewer or additional offset modules.

The user input module **101** receives inputs from occupants via the user controls **12**. The sensors sense respective parameters and generate output signals. The offset generator module **110** generates one or more offsets based on the inputs received by the user input module **101** and the output signals received from the sensors. The evaporator temperature generator module **112** generates the target evaporator temperature for the evaporator **18** based on one or more of the offsets.

The AC control module **116** senses the temperature of the evaporator **18**, turns the compressor **16** on, and controls the speed of the compressor **16** until the temperature of the evaporator **18** reaches the target evaporator temperature. The AC control module **116** turns the compressor **16** off when the temperature of the evaporator **18** is substantially equal to the target evaporator temperature (i.e., when a sum of the offsets is zero). Additionally, the AC control module **116** senses and controls the speed of the blower **17** and selects the airflow mode.

Specifically, the evaporator temperature generator module **112** generates the target evaporator temperature during each proportional integral derivative (PID) control loop of the compressor **16**. The evaporator temperature generator module **112** generates the target evaporator temperature by subtracting one or more offsets from a predetermined evaporator temperature. As an example, the target evaporator temperature ranges between a maximum of 52 F and a minimum of 38 F. An exemplary graph of the target evaporator temperature versus ambient temperature is shown in FIG. **2B**, and a table corresponding to the graph is shown in FIG. **2C**.

More specifically, the user input module **101** receives one or more desired temperature settings set by one or more occupants (e.g., a driver and a front passenger) of the vehicle using user controls **12**. The temperature settings are hereinafter referred to as driver and passenger setpoints (collectively setpoints). The input module **101** generates output signals indicating the driver and passenger setpoints.

The combination humidity sensor **102** measures a windshield glass temperature, a windshield air temperature, and a relative humidity (RH) of the air proximate to the combination humidity sensor **102**. The combination humidity sensor **102** calculates the dewpoint temperature of the air proximate to the combination humidity sensor **102** (hereinafter actual dewpoint or measured dewpoint) based on the windshield glass temperature, the windshield air temperature, and the RH of the air. The combination humidity sensor **102** generates output signals indicating the windshield glass temperature, the windshield air temperature, the RH, and the actual dewpoint.

The infrared sensors **104** are mounted at various locations inside the cabin (e.g., in driver, passenger, and/or rear area of the cabin). The infrared sensors **104** sense the temperature of the air inside the cabin and generate output signals indicating the temperature of the air on the driver and passenger sides of the cabin.

One or more sunload sensors **106** are mounted on a dashboard of the vehicle (e.g., one on driver side and another on passenger side). The sunload sensors **106** measure sunload on the dashboard by sensing solar radiation. The sunload sensors **106** generate output signals indicating the sunload on the driver and passenger sides of the dashboard.

The ambient temperature sensor **108** senses the ambient temperature outside the vehicle. The ambient temperature sensor **108** generates an output signal indicating the ambient temperature.

On receiving the output signals generated by the input module **101** and the sensors, the offset generator module **110** generates one or more offsets. Specifically, the user dewpoint offset module **120** generates a user dewpoint offset. The sunload offset module **124** generates a sunload offset. The ambient temperature offset module **126** generates the ambient temperature offset. The cabin dewpoint offset module **128** generates a cabin dewpoint offset. The cabin-front temperature offset module **130** generates a cabin-front temperature offset. A description of each offset follows.

Referring now to FIGS. **3**A-3C, the user dewpoint offset module **120** generates the user dewpoint offset as follows. In FIG. **3**A, a temperature table is shown. The temperature table shows dewpoint temperatures corresponding to different setpoints at different percentages of RH according to American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) standards.

For example, when 50% RH is desired (since humans are generally comfortable when the RH is between 45% and 55%), the dewpoint temperature corresponding to a setpoint of 70 F is 50.5 F. The dewpoint temperature 50.5 F is referred to as a target dewpoint for the setpoint of 70 F at 50% RH. The user dewpoint offset module **120** includes memory and stores the temperature table in memory.

When used, the user dewpoint offset module **120** receives the output signals generated by the user input module **101** indicating the driver and passenger setpoints. The user dewpoint offset module **120** generates the target dewpoint corresponding to a lower of the driver and passenger setpoints at a predetermined RH (e.g., 50%) based on the temperature table.

Additionally, the user dewpoint offset module **120** receives the output signal generated by the combination humidity sensor **102** indicating the actual dewpoint. The user dewpoint offset module **120** generates a difference between the target and actual dewpoints. The difference is called a user dewpoint difference.

The user dewpoint offset module **120** stores a user dewpoint offset table for a predetermined RH in memory. An exemplary user dewpoint offset table for 50% RH is shown in the form of a graph of user dewpoint offset versus the user dewpoint difference in FIG. **3**B and in a corresponding table in FIG. **3**C. The user dewpoint offset module **120** generates the user dewpoint offset corresponding to the user dewpoint difference based on the user dewpoint offset table. The user dewpoint offset module **120** generates an output signal indicating the user dewpoint offset.

Referring now to FIG. **4**, the user dewpoint offset module **120** can store multiple user dewpoint offset tables. For example, the user dewpoint offset module **120** can store user dewpoint offset tables for 45%, 50%, and 55% RH. The user dewpoint offset module **120** can generate the user dewpoint offset for any RH between 45% and 55%. Accordingly, the evaporator temperature generator module **112** can generate different target evaporator temperatures corresponding to different values of RH. The evaporator temperature generator module **112** can receive feedback from the AC control module **116**. Based on the feedback, the evaporator temperature generator module **112** can select the RH at which the compressor **16** operates most efficiently.

Referring now to FIGS. **5**A and **5**B, the sunload offset module **124** generates the sunload offset as follows. The sunload offset module **124** receives the output signals generated by the sunload sensors **106** indicating the sunload on the driver and passenger sides of the dashboard. The sunload offset module **124** generates a sum of normalized values of the output signals, filters the sum, and generates a sunload sum.

The sunload offset module **124** includes memory and stores a sunload offset table for a predetermined RH in memory. An example of the sunload offset table for 50% RH is shown in the form of a graph of the sunload offset versus the sunload sum in FIG. **5**A an in a table in FIG. **5**B. The sunload offset module **124** generates the sunload offset corresponding to the sunload sum based on the sunload offset table. The sunload offset module **124** generates an output signal indicating the sunload offset.

Referring now to FIGS. **6**A and **6**B, the ambient temperature offset module **126** generates the ambient temperature offset as follows. The ambient temperature offset module **126** receives the output signal generated by the ambient temperature sensor **108** indicating the ambient temperature. Additionally, the ambient temperature offset module **126** receives the output signals generated by the user input module **101** indicating the driver and passenger setpoints. The ambient temperature offset module **126** generates a difference between the ambient temperature and a lower of the driver and passenger setpoints.

The ambient temperature offset module **126** includes memory and stores an ambient temperature offset table for a predetermined RH in memory. An example of the ambient temperature offset table for 50% RH is shown in the form of a graph of the ambient temperature offset versus the difference in FIG. **6**A and in a table in FIG. **6**B. The ambient temperature offset module **126** generates the ambient temperature offset corresponding to the difference based on the ambient temperature offset table. The ambient temperature offset module **126** generates an output signal indicating the ambient temperature offset.

Referring now to FIGS. **7**A and **7**B, the cabin dewpoint offset module **128** generates the cabin dewpoint offset as follows. The cabin dewpoint offset module **128** receives the output signal generated by the combination humidity sensor **102** indicating the actual dewpoint. Additionally, the cabin dewpoint offset module **128** receives the output signals generated by the infrared sensors **104** indicating the temperatures of the air on the driver and passenger sides of the cabin. The cabin dewpoint offset module **128** generates an average cabin temperature by averaging the temperatures. The cabin dewpoint offset module **128** generates a difference between the actual dewpoint and the average cabin temperature.

The cabin dewpoint offset module **128** includes memory and stores a cabin dewpoint offset table for a predetermined RH in memory. An example of the cabin dewpoint offset table for 50% RH is shown in the form of a graph of the cabin dewpoint offset versus the difference in FIG. **7**A and in a table in FIG. **7**B. The cabin dewpoint offset module **128** generates the cabin dewpoint offset corresponding to the difference based on the cabin dewpoint offset table. The cabin dewpoint offset module **128** generates an output signal indicating the cabin dewpoint offset.

Referring now to FIGS. **8**A and **8**B, the cabin-front temperature offset module **130** generates the cabin-front temperature offset as follows. The cabin-front temperature offset module **130** receives the output signals generated by the infrared sensors **104** indicating the temperatures of the air on the driver and passenger sides of the cabin-front. Additionally, the cabin-front temperature offset module **130** receives the output signals generated by the user input module **101** indicating the driver and passenger setpoints.

The cabin-front temperature offset module **130** generates a first difference between the temperature of the air on the driver side and the driver setpoint. The cabin-front temperature offset module **130** generates a second difference between the temperature of the air on the passenger side and the passenger setpoint. The cabin-front temperature offset module **130** selects a lower difference value of the first and second differences.

The cabin-front temperature offset module **130** includes memory and stores a cabin-front temperature offset table for a predetermined RH in memory. An example of the cabin-front temperature offset table for 50% RH is shown in the form of a graph of the cabin-front temperature offset versus the lower difference value in FIG. **8**A and in a table in FIG. **8**B. The cabin-front temperature offset module **130** generates the cabin-front temperature offset corresponding to the lower difference value based on the cabin-front temperature offset table. The cabin-front temperature offset module **130** generates an output signal indicating the cabin-front temperature offset.

The evaporator temperature control module **112** generates the sum by adding some or all of the offsets, subtracts the sum from the predetermined evaporator temperature, and generates the target evaporator temperature. For example, if the user dewpoint offset is 2, the sunload offset is 1, the ambient temperature offset is 1, the cabin dewpoint offset is 2, and the cabin-front temperature offset is 0, the sum of the offsets is 6. If the predetermined evaporator temperature is 52 F, the target evaporator temperature is (52 F−6)=46 F. Accordingly, the AC control module **116** adjusts the compressor **16** until the evaporator temperature reaches the target evaporator temperature of 46 F. If the sum of the offsets is zero, the AC control module **116** will turn the compressor **16** off until the sum of the offsets is non-zero again. The AC control module **116** does not keep the compressor **16** turned on until the evaporator temperature reaches the fixed low value of 38 F.

The ATC system **90** offers several benefits. Since the evaporator control system **100** measures the actual dewpoint and does not estimate the actual dewpoint, the evaporator control system **100** generates the target evaporator temperature precisely and accurately. Since the evaporator control system **100** generates the target evaporator temperature based on the actual and target dewpoints, the ATC system **90** ensures the comfort of the occupants while operating at the highest possible evaporator temperature.

Additionally, when the sum of the offsets is zero, the evaporator temperature generator module **112** generates a control signal. On receiving the control signal, the AC control module **116** can turn the compressor **16** off and blend fresh air from outside the vehicle into the cabin. Thus, the ATC system **90** decreases the energy consumption and increases the fuel efficiency of the vehicle without sacrificing the comfort of the occupants.

In some implementations, the AC control module **116** can set the target evaporator temperature and control the speed of the compressor **16** based on other factors in conjunction with the target evaporator temperature generated by the evaporator control system **100**.

Referring now to FIG. **9**, a method **150** for generating the target evaporator temperature according to the present invention is shown. The method **150** begins at step **152**. The user input module **101** reads the setpoints in step **154**. The combination humidity sensor **102** measures the windshield glass temperature, the windshield air temperature, and the RH of the air at the combination humidity sensor **102** and generates the actual dewpoint in step **156**. In step **158**, the offset generator module **110** generates offsets based on the setpoints, the actual dewpoint, the output signals generated by the sensors, the temperature table, and the offset tables.

In step **160**, the evaporator temperature generator module **112** determines if the sum of the offsets is zero or greater than zero. When the sum of the offsets is zero, the evaporator temperature generator module **112** outputs the control signal to the AC control module **116** based on which the AC control module **116** turns the compressor **16** off and blends fresh air into the cabin in step **162**. The method **150** returns to step **154**.

When the sum of the sum of the offsets is greater than zero, the evaporator temperature generator module **112** generates the target evaporator temperature in step **164**. In step **166**, the AC control module **116** turns the compressor **16** on and controls the compressor **16** based on the target evaporator temperature in step **170**. For example, the AC control module **116** turns the compressor **16** on and controls the speed of the compressor **16** to reach the target evaporator temperature. The method **150** returns to step **154**.

Referring now to FIG. **10**, a defogging system **200** that defogs the windshield according to the present invention is shown. Fogging occurs when the actual dewpoint of the air at the windshield is greater than the windshield glass temperature and approaches the windshield glass temperature. Defogging can be achieved by increasing a difference between the windshield glass temperature and the actual dewpoint. The difference is called Delta T and is given by the following equation.

$$\text{Delta } T = \text{Windshield glass temperature} - \text{Actual Dewpoint}$$

Delta T can be increased (i.e., defogging can be achieved) by decreasing the actual dewpoint. The actual dewpoint can be decreased by increasing the air temperature or by decreasing the RH of the air in the cabin. The defogging system **200** increases Delta T by decreasing the RH using AC as follows.

The defogging system **200** comprises the evaporator control system **100**, a fog control module **202**, the AC control module **116**, the compressor **16**, the blower **17**, and the evaporator **18**. The fog control module **202** communicates with the evaporator control system **100** and the AC control module **116**. The fog control module **202** receives the windshield glass temperature and the actual dewpoint from the combination humidity sensor **102**. The fog control module **202** generates Delta T.

When power is applied, the fog control module **202** determines if Delta T is greater than or equal to a first predetermined threshold (e.g., 6.1 C). If Delta T is greater than or equal to the first predetermined threshold, the fog control module **202** generates a control signal and outputs the control signal to the AC control module **116** indicating that defogging is unnecessary.

If, however, Delta T is less than or equal to a second predetermined threshold (e.g., 4 C), the fog control module **202** generates a control signal and outputs the control signal to the AC control module **116**. On receiving the control signal, the AC control module **116** begins defogging as follows.

The AC control module **116** turns the compressor **16** on. The AC control module **116** receives the ambient temperature from the ambient temperature sensor **108**. The AC control module **116** sets the target evaporator temperature to 38 F or 42 F when the ambient temperature is below or above 60 F, respectively. The AC control module **116** sets the airflow mode to mix mode (e.g., floor and defrost mode). The AC control module **116** turns recirculation off and fresh air on. The AC control module **116** turns the blower **17** on and sets the blower speed to a predetermined speed. The actual dewpoint begins to decrease, and Delta T begins to increase.

As Delta T increases, the fog control module **202** compares Delta T to a plurality of predetermined thresholds. For example, the fog control module **202** determines if Delta T≦5 C, Delta T≦6 C, and so on. The fog control module **202** generates control signals indicating the values of Delta T relative to the predetermined thresholds.

Alternatively, when power is applied, if Delta is not greater than or equal to the first predetermined threshold and not less than or equal to the second predetermined threshold (e.g., 4 C≦Delta T≦6 C), the fog control module **202** determines if Delta T is less than or equal to the plurality of predetermined thresholds. For example, the fog control module **202** determines if Delta T≦4.3 C, Delta T≦5 C, and so on. The fog control module **202** generates control signals indicating the values of Delta T relative to the respective predetermined thresholds.

Based on the control signals (i.e., depending on the values of Delta T), the AC control module **116** performs one or more of the following functions to complete defogging. The AC control module **116** turns the compressor **16** on. The AC control module **116** uses the target evaporator temperature generated by the evaporator control system **100** or sets the target evaporator temperature to 38 F or 42 F when the ambient temperature is below or above 60 F. The AC control module **116** sets the airflow mode to mix mode (e.g., floor and defrost mode). The AC control module **116** turns recirculation off and fresh air on. The AC control module **116** turns the blower **17** on and sets the blower speed to the predetermined speed.

When Delta T is greater than or equal to a third predetermined threshold (e.g., 8 C), the fog control module **202** generates a control signal and outputs the control signal to the AC control module **116** indicating that the defogging is complete. The AC control module **116** stops the functions relative to defogging.

Referring now to FIG. **11**, a method **250** for defogging the windshield according to the present invention is shown. The method **250** begins at step **252**. The fog control module **202** determines in step **254** if Delta T is greater than or equal to the first predetermined threshold (e.g., 6.1 C). If the result of step **254** is true, the method **250** ends in step **264**. If the result of step **254** is false, the fog control module **202** determines in step **256** if Delta T is less than or equal to the second predetermined threshold (e.g., 4 C).

If the result of step **256** is true, the AC control module **116** performs the following functions in step **258**. The AC control module **116** turns the compressor **16** on, sets the target evaporator temperature to 38 F or 42 F when the ambient temperature is below or above 60 F, sets the airflow mode to mix mode (e.g., floor and defrost mode), turns recirculation off and fresh air on, turns the blower **17** on, and sets the blower speed to the predetermined speed. The method **250** repeats step **256**.

If the result of step **256** is false, the fog control module **202** determines in step **260** if Delta T is greater than or equal to the third predetermined threshold (e.g., 8 C). If the result of step **260** is false, the AC control module **116** performs one or more of the following functions in step **258**. The AC control module **116** turns the compressor **16** on, uses the target evaporator temperature generated by the evaporator control system **100** or sets the target evaporator temperature to 38 F or 42 F when the ambient temperature is below or above 60 F, sets the airflow mode to mix mode (e.g., floor and defrost mode), turns recirculation off and fresh air on, turns the blower **17** on, and sets the blower speed to the predetermined speed. The method **250** repeats step **260**. If the result of step **260** is true, the method **250** ends in step **164**.

The description of the invention is merely exemplary in nature and, thus, variations that do not depart from the gist of the invention are intended to be within the scope of the invention. Such variations are not to be regarded as a departure from the spirit and scope of the invention.

What is claimed is:

1. A system for controlling air-conditioning of a vehicle, comprising:

an input that receives an input temperature;

an offset generator module that receives a psychrometric parameter of air inside said vehicle and that generates offsets based on said input temperature and said psychrometric parameter;

an evaporator temperature control module that generates a target evaporator temperature based on said offsets; and

an air-conditioning (AC) module operative to control a compressor by turning off said compressor when a difference between said psychrometric parameter and a vehicle windshield glass temperature is greater than or equal to a first threshold temperature and by turning on said compressor when a difference between said psychrometric parameter and said glass temperature is less than or equal to a second threshold temperature.

2. The system of claim **1** wherein said psychrometric parameter includes a dewpoint temperature of air adjacent to a windshield of said vehicle generated by measuring a temperature and a relative humidity (RH) of said air adjacent to said windshield and a glass temperature of said windshield.

3. The system of claim **1** wherein said offset generator module generates said offsets at a predetermined relative humidity (RH), and wherein said offsets include at least one of:

a first offset based on a difference between an ambient temperature outside said vehicle and said input temperature;

a second offset based on a sunload inside said vehicle;

a third offset based on a difference between said psychrometric parameter and a temperature inside said vehicle; and

a fourth offset based on a difference between said input temperature and said temperature inside said vehicle.

4. The system of claim **3** wherein said evaporator temperature control module generates said target evaporator temperature by subtracting a sum of at least one of said first, second, third, and fourth offsets from a predetermined evaporator temperature.

5. The system of claim **4** wherein said predetermined RH includes RH between 45% and 55%, said predetermined evaporator temperature includes a temperature of 52 F, and wherein said target evaporator temperature includes a temperature between 38 F and 52 F.

6. The system of claim **1** wherein said (AC) module additionally controls at least one of a blower, and a mode of airflow inside said vehicle based on said target evaporator temperature, wherein said AC module turns off said compressor when one of a sum of said offsets is zero and a temperature of said evaporator is substantially equal to said target evaporator temperature.

7. The system of claim **1** further comprising a fog control module that controls defogging of a windshield of said vehicle based on said psychrometric parameter and said glass temperature of said windshield of said vehicle.

8. The system of claim **1** wherein said first threshold temperature includes a temperature of 6.1 degrees Celsius, and wherein said second threshold temperature includes a temperature of 4 degrees Celsius.

9. The system of claim **1** wherein when a difference between said psychrometric parameter and said glass temperature is between third and fourth thresholds, said AC module controls at least one of said compressor, a blower, and a mode of airflow by generating said target evaporator temperature based on an ambient temperature outside said vehicle.

10. The system of claim 9 wherein said third and fourth thresholds include 4 and 8 degrees Celsius, respectively.

11. A method for controlling air-conditioning of a vehicle, comprising:

receiving an input temperature;

receiving a psychrometric parameter of air inside said vehicle;

generating offsets based on said input temperature and said psychrometric parameter;

generating a target evaporator temperature based on said offsets; and

controlling a compressor by turning off said compressor when a difference between said psychrometric parameter and a vehicle windshield glass temperature is greater than or equal to a first threshold temperature and by turning on said compressor when a difference between said psychrometric parameter and said windshield glass temperature is less than or equal to a second threshold temperature.

12. The method of claim 11 further comprising, when said psychrometric parameter includes a dewpoint temperature of air adjacent to a windshield of said vehicle, generating said dewpoint temperature by measuring a temperature and a relative humidity (RH) of said air adjacent to said windshield and said windshield glass temperature.

13. The method of claim 11 further comprising generating said offsets at a predetermined relative humidity (RH), and wherein said offsets include at least one of:

a first offset based on a difference between an ambient temperature outside said vehicle and said input temperature;

a second offset based on a sunload inside said vehicle;

a third offset based on a difference between said psychrometric parameter and a temperature inside said vehicle; and

a fourth offset based on a difference between said input temperature and said temperature inside said vehicle.

14. The method of claim 13 further comprising generating said target evaporator temperature by subtracting a sum of at least one of said first, second, third, and fourth offsets from a predetermined evaporator temperature.

15. The method of claim 14 wherein said predetermined RH includes RH between 45% and 55%, said predetermined evaporator temperature includes a temperature of 52 F, and wherein said target evaporator temperature includes a temperature between 38 F and 52 F.

16. The method of claim 11 further comprising:

controlling at least one of said compressor, a blower, and a mode of airflow inside said vehicle based on said target evaporator temperature; and

turning off said compressor when one of a sum of said offsets is zero and a temperature of said evaporator is substantially equal to said target evaporator temperature.

17. The method of claim 16 further comprising:

controlling defogging of a windshield of said vehicle based on said psychrometric parameter and said glass temperature of said windshield of said vehicle.

18. The method of claim 11 wherein said first threshold temperature includes a temperature of 6.1 degrees Celsius, and wherein said second threshold temperature includes a temperature of 4 degrees Celsius.

19. The method of claim 11 further comprising, when a difference between said psychrometric parameter and said glass temperature is between third and fourth thresholds, controlling at least one of said compressor, a blower, and a mode of airflow by generating said target evaporator temperature based on an ambient temperature outside said vehicle.

20. The method of claim 19 wherein said third and fourth thresholds include 4 and 8 degrees Celsius, respectively.

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