

14042 U.S. PTO  
051004

PTO/SB/16 (01-04)  
Approved for use through 07/31/2006. OMB 0851-0032  
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## PROVISIONAL APPLICATION FOR PATENT COVER SHEET

This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR 1.53 (c).

Express Mail Label No. EV 406 075 507 US (5/10/2004)

2264 U.S. PTO  
60/569581  
051004

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| <input type="checkbox"/> Additional inventors are being named on the _____ separately numbered sheets attached hereto                         |  |                                  |           |                                                         |                  |
| TITLE OF THE INVENTION (500 characters max)                                                                                                   |  |                                  |           |                                                         |                  |
| ANTI-CONDENSATION CONTROL SYSTEM                                                                                                              |  |                                  |           |                                                         |                  |
| Direct all correspondence to: CORRESPONDENCE ADDRESS                                                                                          |  |                                  |           |                                                         |                  |
| <input checked="" type="checkbox"/> Customer Number 27572                                                                                     |  |                                  |           |                                                         |                  |
| OR                                                                                                                                            |  |                                  |           |                                                         |                  |
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| ENCLOSED APPLICATION PARTS (check all that apply)                                                                                             |  |                                  |           |                                                         |                  |
| <input checked="" type="checkbox"/> Specification Number of Pages 9 <input type="checkbox"/> CD(s), Number _____                              |  |                                  |           |                                                         |                  |
| <input checked="" type="checkbox"/> Drawing(s) Number of Sheets 5 <input checked="" type="checkbox"/> Other (specify) Acknowledgment Postcard |  |                                  |           |                                                         |                  |
| <input checked="" type="checkbox"/> Application Data Sheet. See 37 CFR 1.76                                                                   |  |                                  |           |                                                         |                  |
| METHOD OF PAYMENT OF FILING FEES FOR THIS PROVISIONAL APPLICATION FOR PATENT                                                                  |  |                                  |           |                                                         |                  |
| <input type="checkbox"/> Applicant claims small entity status. See 37 CFR 1.27.                                                               |  |                                  |           |                                                         |                  |
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| <input type="checkbox"/> Payment by credit card. Form PTO-2038 is attached.                                                                   |  |                                  |           |                                                         |                  |
| The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government.       |  |                                  |           |                                                         |                  |
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Respectfully submitted,

SIGNATURE

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[Page 1 of 2]

Date

May 10, 2004

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Docket Number:

4731-000013

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EV 406 075 507 US

## ANTI-CONDENSATION CONTROL SYSTEM

### FIELD

**[0001]** A system and method for preventing condensation on refrigerated display case doors, and more particularly, a system and method for operating door heaters.

### BACKGROUND

**[0002]** Glass-door refrigerated display cases, which are frequently used in supermarkets and convenience stores, often include heaters in the glass doors to prevent condensation on the glass from humid air. The glass door is typically heated to a temperature above the dew point temperature of the air in the room in which the display cases are located to prevent condensation.

**[0003]** There are two common methods of controlling the amount of heat applied to the display case doors. One method is to apply full power (line voltage, typically) to the door heaters. This prevents condensation but wastes energy because more heat is applied than is necessary. The extra energy spent heating the doors has a cost, but some of that extra energy is dissipated into the refrigerated space and must be removed by the refrigeration system at considerable cost.

**[0004]** Other systems modulate the heat applied to the doors, reducing the door heat energy and related costs. Such systems use a measure of the room humid air dew point, i.e., the temperature at or below which condensation will occur.

These control systems adjust the amount of heat applied to the doors in proportion to the measured dew point temperature.

**[0005]** As illustrated in Figure 1, a prior art proportional controller has one or more adjustments to set the range of dew points over which the door heater goes from minimum to maximum. Some systems permit limiting the upper and lower limits of the heat modulation to values other than zero and 100 percent, e.g., limiting the heat to a 20 percent minimum and a 90 percent maximum. Others have a simple rotary dial that adjusts a gain or an offset. Still others define limits as endpoints of a line, as illustrated in Figure 2, which shows control over a 3-segment line. Segment 1, which is at a low dew point, shows modulation held at 20 percent. In segment 2, modulation varies with dew points between 25° and 50°F dew point. At segment 3, modulation is 100 percent, or full heat, for high dew points.

**[0006]** The prior art control systems apply heat to the glass doors in proportion to a measured dew point in an open-loop system. Manual intervention, in the form of manually adjusting the control scheme, is required to achieve condensation-free doors. The adjustment process is prone to human error, typically resulting in setting the heat too high and losing some of the promised energy savings. Also, such adjustments usually are made at a particular operating condition, and will not work correctly year around where climate changes are more drastic, as dew point and conditions change with the season. Further, the adjustment process is time consuming.

**[0007]** 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.

### DETAILED DESCRIPTION

**[0008]** The following description is merely exemplary in nature and is in no way intended to limit the invention, its application, or uses.

**[0009]** The control system and method according to the invention achieves a door temperature slightly higher than the dew point of the humid air adjacent the door. Thus, the relative humidity of the humid air adjacent the door—the air which has been cooled to door temperature—is relatively high but less than 100 percent. Because humid air has a dew point, or temperature at which relative humidity is 100 percent, cooling the humid air to a temperature below the dew point causes water vapor to condense. If the temperature of the glass door is below the dew point of the humid air in the room where the door is located, cooling the humid air at the door below the dew point will cause moisture to condense on the glass. But if the temperature of the glass door is slightly above the dew point of room air, the humid air touching the door will be cooled, but not to the point of causing condensation.

**[0010]** To achieve the system and method according to the invention, a relative humidity sensor may be mounted on the door such that the sensor itself, and the air it monitors, are cooled to door temperature (DT). Thus, the relative humidity

sensor indicates door temperature relative humidity (DTRH), which can be used as an anti-condensation control parameter and an energy-use minimizing control signal.

**[0011]** An anti-condensation control scheme employing DTRH is illustrated in Figure 3. The DTRH sensor provides an input to an adder-subtractor, which also receives a DTRH set point as an input. The set point may be provided at 90 percent, and the adder-subtractor determines an error, which is input to a proportional integral derivative (PID) controller to determine an output between zero and 100 percent. The output may be applied to a limiter having a percent minimum and percent maximum output to be applied to the heater modulator, which controls the door heater as the DTRH sensor at the door continues to supply an input to the adder-subtractor for comparison to the set point. Thus, the anti-condensation control scheme provides closed-loop control.

**[0012]** The DTRH sensor may be located on the door or door frame, or inside the door frame. The DTRH sensor may be arranged to sense air cooled by the door and the door temperature. The set point may never have to be adjusted, particularly if there is a control system for each door. Thus, if the set point may not need to be adjusted, then it does not have to be readily accessible without user intervention required to get the controller adjusted properly. This feature, in system design, would result in considerable cost savings.

**[0013]** The DTRH sensor may be arranged in a thin vertical tube having baffles near the sensor to prevent moisture or dust from falling on the sensor, and to prevent water or other cleaning solutions from dripping onto the sensor. The vertical tube would permit air flow vertically, so that air would pass by the relative humidity

sensor located inside the tube. The tube may be thermally in contact with the door, so that the tube is at the same temperature as the door. The tube may be long enough to cool air passing through the door temperature or close to door temperature, before passing over the sensor. The tube may have a path long enough for cooling air to pass above and below the sensor so that the air is cooled before reaching the sensor, regardless of the direction of air flow. That is, air currents in the room can cause flow in either direction.

**[0014]** The DTRH sensor may be located inside a door frame, such that it is out of sight and protected from moisture, dust or other liquids. For example, the sensor and appropriate drip protection or baffles may be arranged on a small plate, which is mounted in a hole cut into a door frame. The door frame may be further modified to include air vents, such as screens, louvers or small holes, above and below the sensor location. By locating the sensor somewhere in the middle portion of a vertical portion of a door frame, adequate air flow over the sensor may provide a reliable DTRH. Such arrangements are shown in Figures 4 and 5.

**[0015]** The control scheme according to the invention may have a set point at a relatively high RH value, such as 90 or 95 percent. The RH set point may be adjusted for lack of accuracy in the DTRH sensor. For example, if parts of the door are cooler than the air flowing over the DTRH sensor, a lower DTRH set point (DTRHSP) may be appropriate, such as lowering the DTRHSP to 80 percent.

**[0016]** With reference to Figure 6, operation of the control scheme can be illustrated by plotting an example on a psychrometric chart. The system control goal is to maintain relative humidity at the DTRH sensor at 90 percent relative humidity,

i.e., DTRHSP equaling approximately 90 percent. In a room having a dry bulb temperature of +68 degrees F and relative humidity of 36.9 percent (away from the refrigerated surfaces), the dew point is +40 degrees F, which is determined by extending a line horizontally from the air condition to a point on the 100 percent RH curve in Figure 6. The control point is where that same horizontal line intersects 90 percent RH, and the heater modulator will apply just enough heat to bring the door temperature to +42.7 degrees F, which is slightly above the dew point. Further, if the DTRH sensor indicates 95 percent relative humidity, the controller would apply more heat as the door temperature is +41.3 degrees F. If the DTRH sensor indicates 85 percent relative humidity, the controller would reduce the heat being applied, as the door temperature is +44.2 degrees F. Thus, the controller will adjust the heat applied until the DTRH sensor achieves 90 percent relative humidity.

**[0017]** Another psychometric chart is illustrated in Figure 7, where water vapor (i.e., airborne moisture, humidity) is present at twice the amount as in the example of Figure 6, which is noted on the vertical axis of the psychometric chart of Figure 7. Where Figure 6 included 0.0052 pounds of moisture per pound of dry air, Figure 7 illustrates 0.0107 pounds of moisture per pound of dry air. While in Figure 6, DT minus DP equals 2.7 degrees F, the differential in Figure 7 is 3.0 degrees F. In both situations, however, controlling the DTRH sensor at 90 percent relative humidity causes the door temperature to be about 3 degrees F above the dew point. This approximate differential is true over a wide variation of airborne moisture or humidity.

**[0018]** The apparatus and method according to the invention includes several advantages over prior systems. Particularly, the control system can be mounted in or near the door. Also, a relative humidity sensor is employed instead of a dew point sensor. True dew point sensors, such as chilled mirror devices or sensors with a wick coated or saturated with a lithium chloride solution, are relatively expensive or require frequent maintenance. Further, dew point calculating sensors, which measure both relative humidity and dry bulb temperature, and then determine the dew point, require great precision in the relative humidity sensor to achieve accuracy in the calculated dew point. With a relative humidity sensor, arranged as described to measure DTRH, application to each door is relatively economical. Further, it remains economical to apply a separate control system to each door of a refrigerated display case.

**[0019]** The system and method may include one controller to control heaters for a plurality of doors. For example, to control two doors, the DTRH sensor may be located in the side of one door that is closest to the other door sought to be controlled, i.e., adjacent doors. The heaters of both doors may be connected in parallel and be driven by the same controller. For three adjacent doors, the DTRH sensor may be mounted in the middle door. The heaters of all three doors may be connected in parallel and be driven by one controller. The system and method may include three different heater outputs, all modulated in the same way, but each output powered by a different phase of three-phase power.

**[0020]** As previously described, the DTRH sensor mounted within the door frame may include air inlets and outlets at the top and bottom of the door frame to

accommodate air flow. A variation of the invention includes air inlets located on the front or the sides, which lessens the opportunity for water to drip into the sensor assembly or dust to collect on the assembly. Such an arrangement is particularly useful where the DTRH sensor is not mounted inside the door frame. Possible arrangements are shown in Figures 8, 9 and 10. Figures 8 and 9 illustrate air entering exit holes on the front surface of the door frame. Figure 10 illustrates air entry and exit holes on the sides of the door frame. Note, however, that the air entry and exit holes may be on both sides or, if mounted on a door frame, preferably on the side toward the door glass only. The DTRH sensor may be made as thin as practical, measuring from front to back, to sense air as close to the door surface as possible, and thus nearly at door temperature. This may be particularly appropriate for DTRH sensors not mounted inside a door frame.

**[0021]** 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.

## CLAIMS

What is claimed is:

1. An anti-condensation control apparatus comprising:
  - a relative humidity sensor operable to sense a relative humidity at door temperature;
  - an adder/subtractor receiving an input from said sensor and operable to compare said input to a set point and output an error;
  - a proportional integral derivative (PID) controller receiving said error and operable to determine an output between zero and 100 percent;
  - a limiter operable to modify said output between a percent minimum and percent maximum; and
  - a heater modulator operable to control a door heater based on said modified output.

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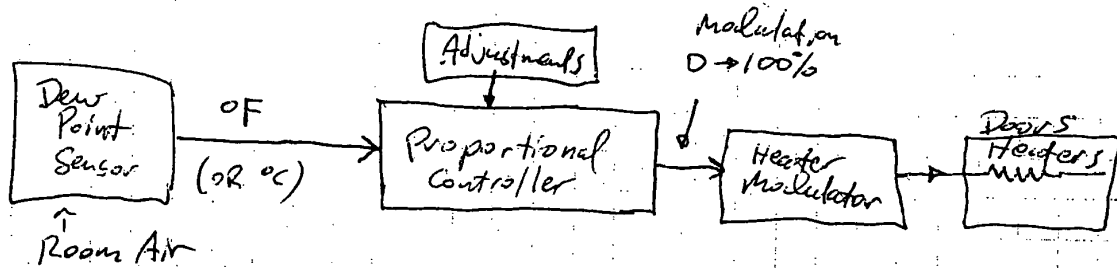


FIGURE 1

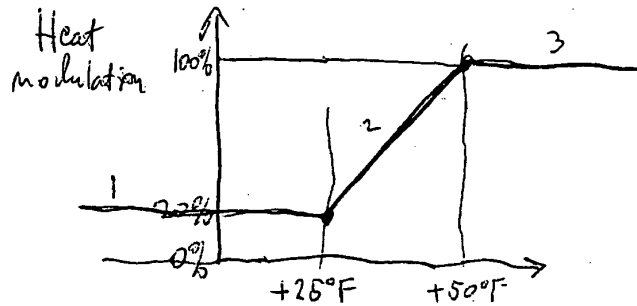


FIGURE 2

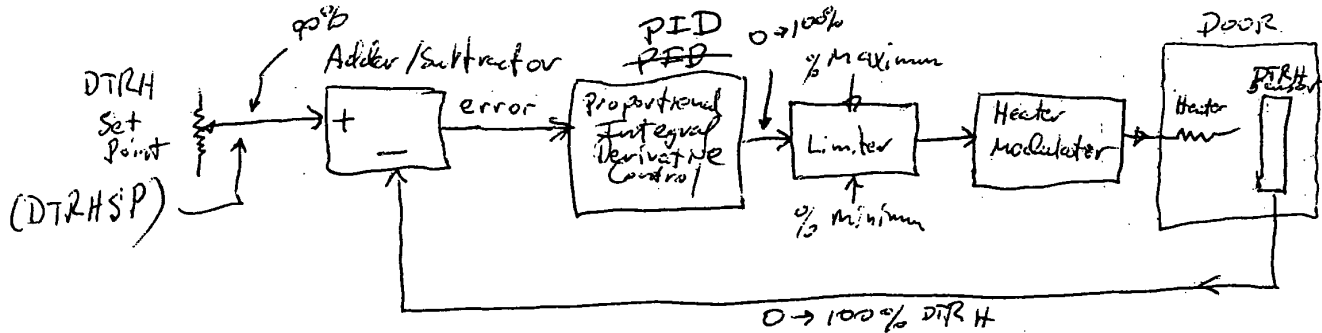


FIGURE 3

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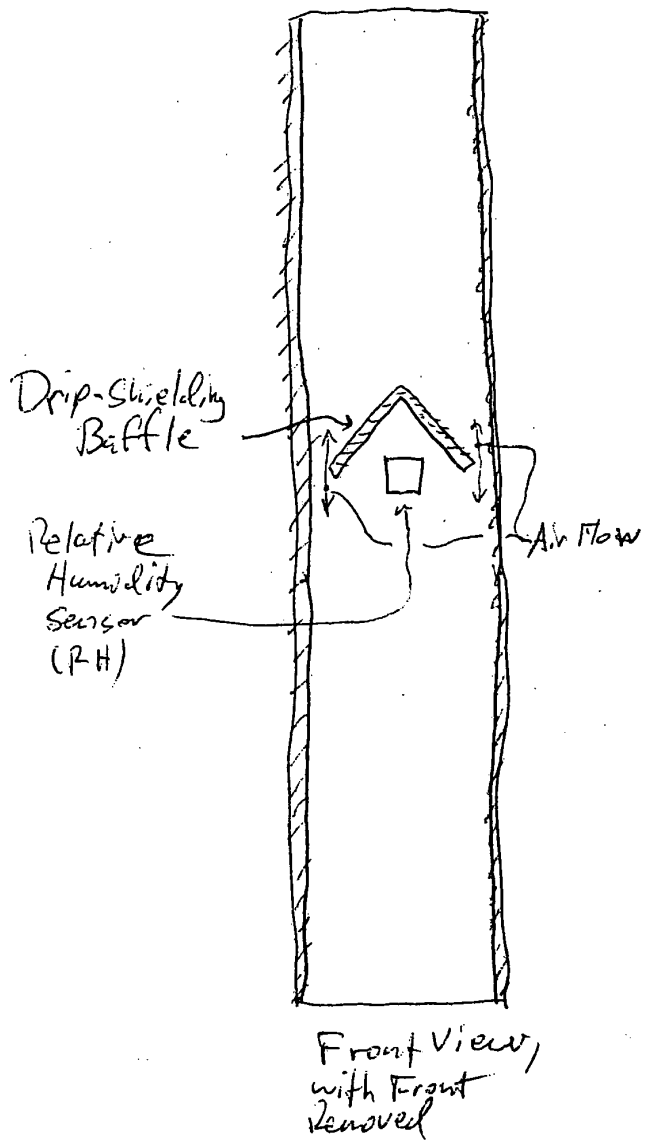


FIGURE 4

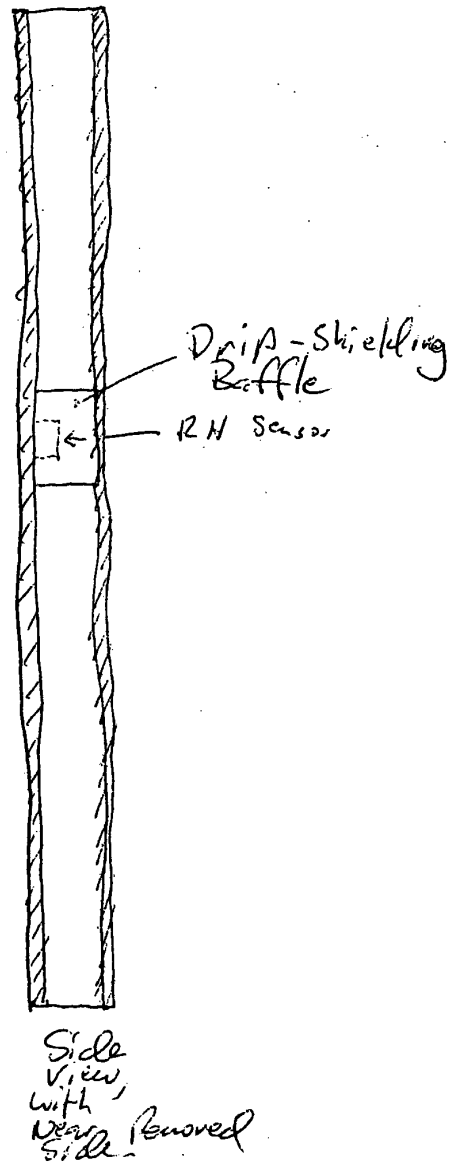


FIGURE 5

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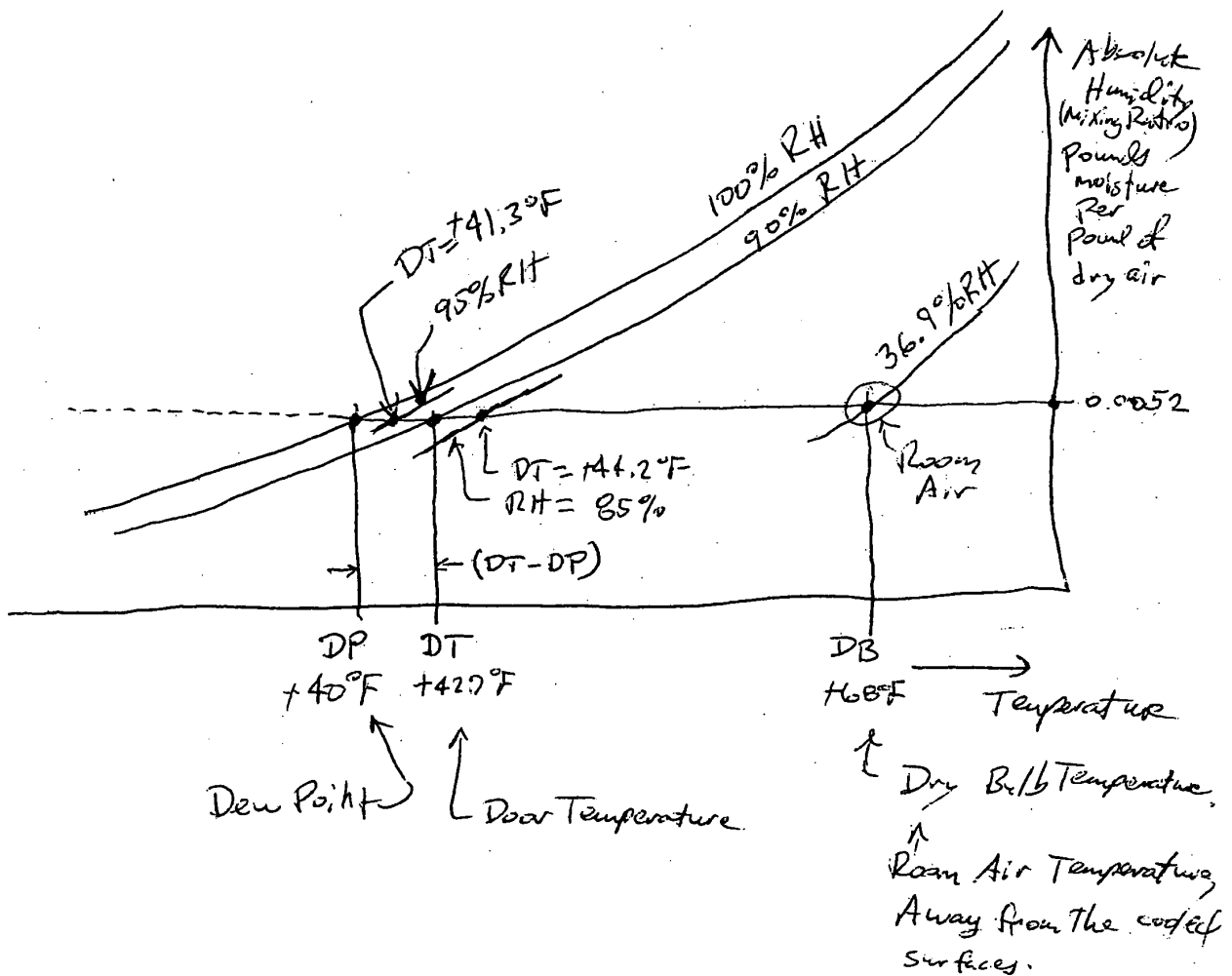


FIGURE 6

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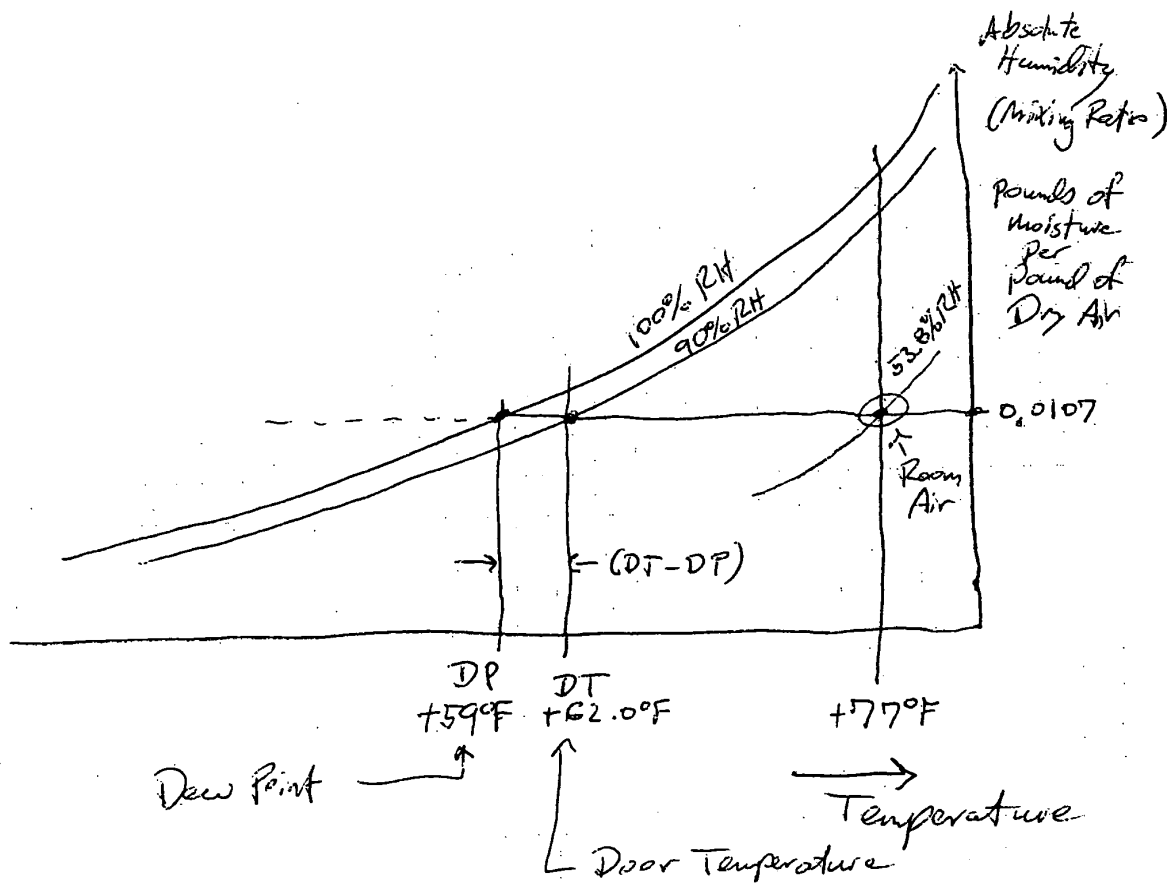


FIGURE 7

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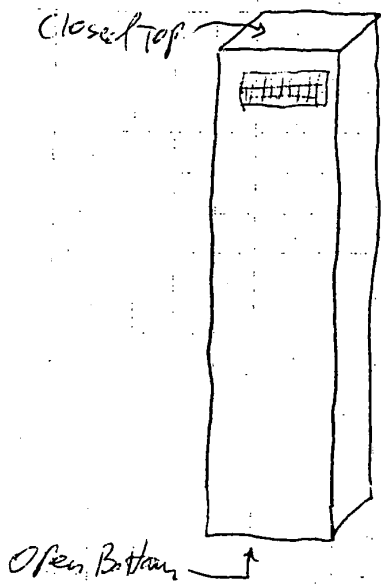


FIGURE 8

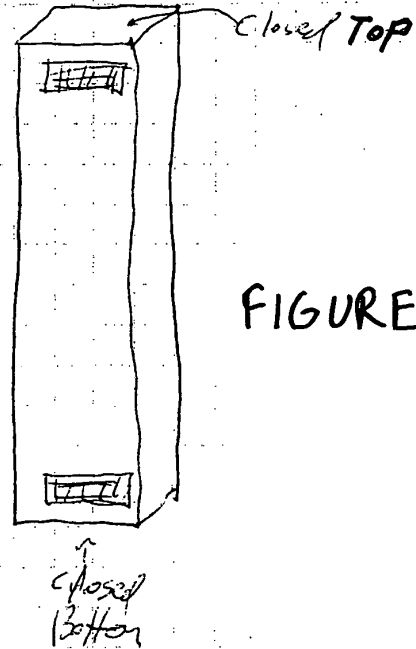


FIGURE 9

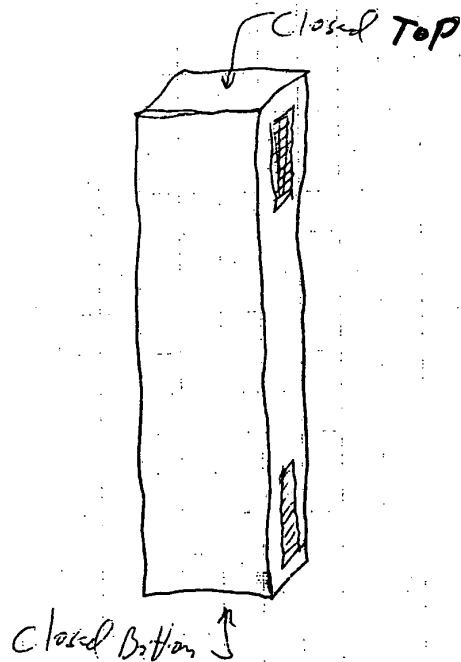


FIGURE 10

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#### CORRESPONDENCE INFORMATION

Correspondence Customer Number:: 27572  
Fax One:: (248) 641-0270

#### APPLICATION INFORMATION

Title Line One:: ANTI-CONDENSATION CONTROL SYSTEM  
Total Drawing Sheets:: 5  
Formal Drawings?: No  
Application Type:: Provisional  
Docket Number:: 4731-000013  
Secrecy Order in Parent Appl.?: No

#### REPRESENTATIVE INFORMATION

Representative Customer Number:: 27572  
Source:: PrintEFS Version 1.0.1

PATENT APPLICATION SERIAL NO. \_\_\_\_\_

U.S. DEPARTMENT OF COMMERCE  
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FEE RECORD SHEET

05/12/2004 TBESHAHI 00000057 60569581

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PTO-1556  
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\*U.S. Government Printing Office: 2002 — 489-267/69033