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(71) Applicant: **GENTHERM INC.** [US/US]; 21680 Haggerty Road, Suite 101, Northville, Michigan 48167 (US).

(72) Inventors: **YANG, Jun**; 2203 Mckay Ave., Windsor, Ontario N9B 3W9 (CA). **MYERS, Tyler**; 9116 Mayflower Drive, Plymouth, Michigan 48170 (US). **ARSENAULT, Jeff**; 45570 Moonlight Drive, Plymouth, Michigan 48170 (US). **CHEWTER, Alan**; 1995 Frances Way, Ypsilanti, Michigan 48198 (US).

(74) Agent: **BURCH, Stephen A.**; Carlson, Gaskey & Olds, P.C., 400 West Maple Road, Suite 350, Birmingham, Michigan 48009 (US).

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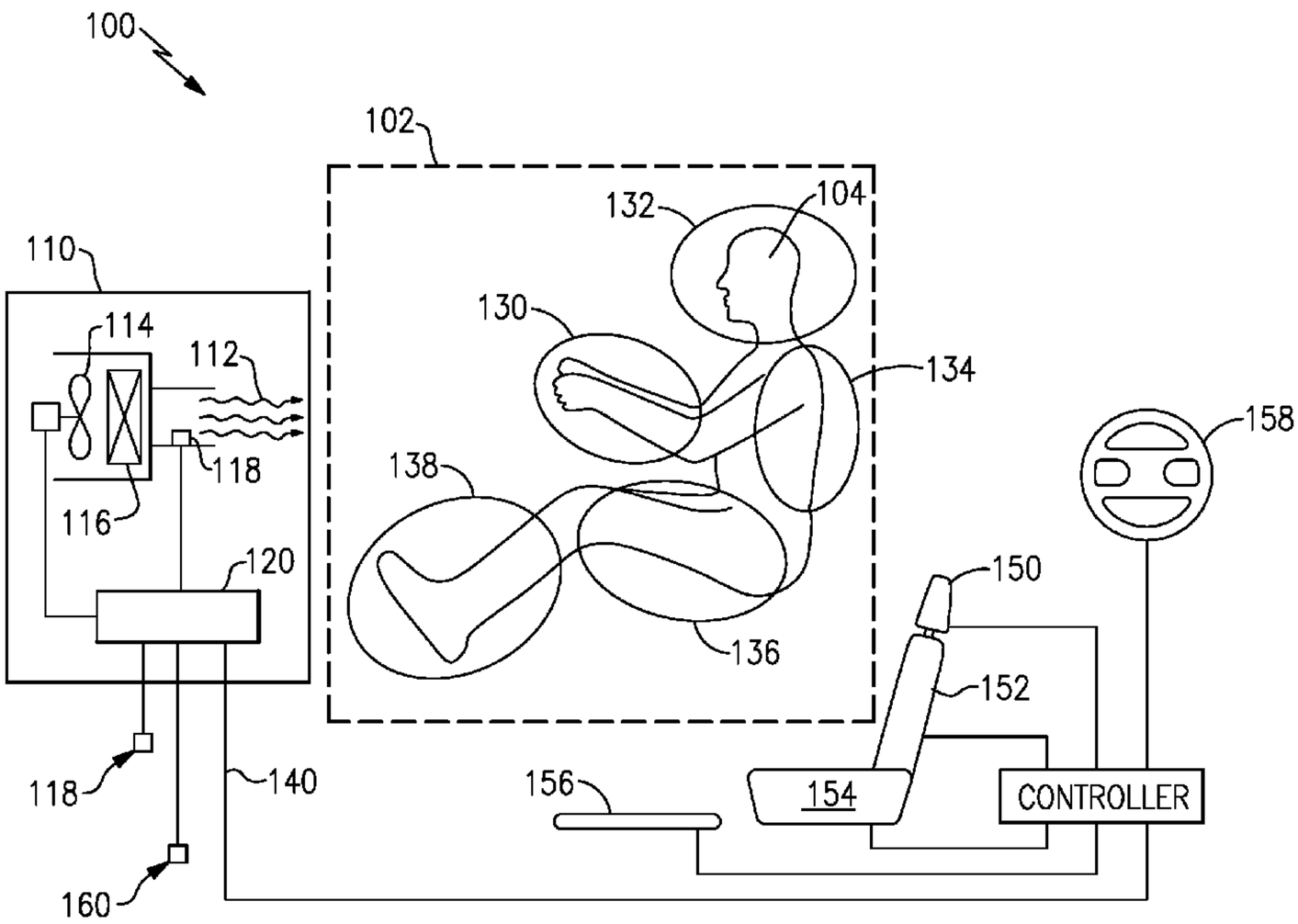


FIG.1

(57) Abstract: A method of controlling a microclimate system includes identifying a set of multiple microclimate thermal effectors configured to provide multiple occupant zones and determining a differential temperature between a local temperature at one of the microclimate thermal effectors and a preset temperature for the microclimate thermal effectors. The differential temperature is determined for each of the microclimate thermal effectors. A fuzzy set is generated for each of the microclimate thermal effectors based upon the respective differential temperature. A respective temperature set point for each of the microclimate thermal effectors is defined based upon the fuzzy set for the corresponding microclimate thermal effectors. Each microclimate thermal effector is commanded to the corresponding respective temperature set point.

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AUTOMOTIVE SEAT BASED MICROCLIMATE SYSTEM

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims priority to United States Provisional Application No. 62/937892 filed on November 20, 2019.

TECHNICAL FIELD

[0002] This disclosure relates to microclimate system that provides increased thermal comfort to the occupant using sensor fusion and fuzzy logic.

BACKGROUND

[0003] In traditional automotive HVAC or climate systems, the control system uses temperatures from sensors mounted in different locations within the cabin or calculates temperature using a mathematical cabin thermal model. In recent years, seat based microclimate systems have become more desirable because of their fast time to comfort and lower energy consumption compared to prior systems.

[0004] An automotive seat-based microclimate system has many conductive, convective and radiative devices, like heater mats, thermo-electric devices (TED)s, positive temperature coefficient thermistors (PTCs) and mini-compressor systems located in the seat and surrounding area. Calculating local temperature accurately for local heating/cooling device control is important for controlling local thermal comfort, but is difficult to achieve with current systems.

[0005] The current methods for automotive seat based microclimate systems are discrete ON/OFF or modulated power (PWM) control based on fixed temperature setpoints (typically 3 to 5 discrete levels). The occupant manually selects one of these predefined temperature setpoints to adjust for changing conditions in the vehicle and human body. Additionally, since levels are discrete, the user may be forced to change levels to "hunt" for an unobtainable setting.

[0006] Fuzzy logic has been disclosed as an option for bulk air heating and cooling in aircraft cabins. Fuzzy logic is an approach to algorithms that utilizes "degrees of truth" rather than the binary extremes of true (1) / false (0). Fuzzy logic includes the extreme cases, but also includes multiple states between true and false such that the comparison between two things can result in a value between true and false (e.g. the driver is comfortable is .45 (45%) true). Because the fuzzy

logic is used to regulate the bulk air temperature, the rate of change in cabin temperature is used to create the fuzzy set rather that another metric. Regulating based upon temperature rate of change prevents undesired oscillations in cabin temperature from overshooting the desired cabin temperature.

SUMMARY

[0007] An exemplary method of controlling a microclimate system includes identifying a set of multiple microclimate thermal effectors configured to provide multiple occupant zones, determining a differential temperature between a local temperature at one of the microclimate thermal effectors and a preset temperature for the one of the microclimate thermal effectors, the differential temperature being determined for each of the microclimate thermal effectors, and generating a fuzzy set for each of the microclimate thermal effectors based upon the respective differential temperature, defining a respective temperature set point for each of the microclimate thermal effectors based upon the fuzzy set for the corresponding microclimate thermal effectors, and commanding each microclimate thermal effector to the corresponding respective temperature set point.

[0008] In another example of the above described method of controlling a microclimate system the multiple occupant zones include at least two of a head zone, a seat back zone, a seat cushion zone, a hand/arm zone and a foot/leg zone.

[0009] In another example of any of the above described methods of controlling a microclimate system at least a portion of the set of multiple microclimate thermal effectors are conductive thermal devices that are configured to engage an occupant during use.

[0010] In another example of any of the above described methods of controlling a microclimate system the set of multiple microclimate thermal effectors includes microclimate thermal effectors selected from the group comprising climate controlled seats, head rest/neck conditioner, climate controlled headliner, steering wheel, heated gear shifter, heater mat, and mini-compressor system.

[0011] In another example of any of the above described methods of controlling a microclimate system the local temperature for at least one of the microclimate thermal effectors in the set of multiple microclimate thermal effectors is determined using a negative temperature coefficient element in the one of the microclimate thermal effectors.

[0012] In another example of any of the above described methods of controlling a microclimate system generating the fuzzy set for each of the microclimate thermal effectors uses fuzzy rules based upon an occupant thermal sensation scale for a population of occupants and their personal occupant thermal comfort for the multiple occupant zones.

[0013] Another example of any of the above described methods of controlling a microclimate system further including converting the fuzzy set to a fuzzy output corresponding to the temperature set point for each of the microclimate thermal effectors.

[0014] In another example of any of the above described methods of controlling a microclimate system further including providing a feedback loop from each of the microclimate thermal effectors, wherein the feedback loop is configured to determine the differential temperature based upon the commanded temperature set point and a measured local temperature.

[0015] In another example of any of the above described methods of controlling a microclimate system including the step of fusing temperature data to determine the local temperature, temperature data fusing step includes providing microclimate temperature data from each of the microclimate thermal effectors, receiving vehicle temperature data from a vehicle data bus, the vehicle temperature data including a cabin temperature and an outside air temperature, and fusing the microclimate temperature data with the vehicle temperature data to determine a local temperature for each of the microclimate thermal effectors.

[0016] In one exemplary embodiment a microclimate system for a vehicle occupant includes multiple microclimate thermal effectors configured to provide multiple occupant zones, a controller in communication with the microclimate thermal effectors, the controller configured to determine a differential temperature between a local temperature for one of the microclimate thermal effectors and a preset temperature for the one of the microclimate thermal effectors, the controller being further configured to determine the differential temperature for each of the microclimate thermal effectors, the controller being further configured to generate a respective fuzzy set for each of the microclimate thermal effectors based upon a respective differential temperature of each of the microclimate thermal effectors, the controller being further configured to define a temperature set point based upon the fuzzy set for each of the microclimate thermal effectors, and the controller configured to command the microclimate thermal effectors to its respective temperature set point.

[0017] In another example of the above described microclimate system for a vehicle occupant the multiple occupant zones include at least two of a head zone, a seat back zone, a seat cushion zone, a hand/arm zone and a foot/leg zone.

[0018] In another example of any of the above described microclimate systems for a vehicle occupant at least a portion of the multiple microclimate thermal effectors are conductive thermal devices configured to engage an occupant during use.

[0019] In another example of any of the above described microclimate systems for a vehicle occupant the microclimate thermal effectors include microclimate thermal effectors selected from the group comprising climate controlled seats, head rest/neck conditioner, climate controlled headliner, steering wheel, heated gear shifter, heater mat, and mini-compressor system.

[0020] In another example of any of the above described microclimate systems for a vehicle occupant the local temperature for at least one of the one of the microclimate thermal effectors is determined by the controller using a negative temperature coefficient element in the one of the microclimate thermal effectors.

[0021] In another example of any of the above described microclimate systems for a vehicle occupant the fuzzy sets are generated by the controller using fuzzy rules based upon an occupant thermal sensation scale for a population of occupants and their personal occupant thermal comfort for the multiple occupant zones.

[0022] In another example of any of the above described microclimate systems for a vehicle occupant the controller is configured to convert each fuzzy set to a fuzzy output corresponding to the temperature set point for of the corresponding microclimate thermal effectors.

[0023] In another example of any of the above described microclimate systems for a vehicle occupant the controller includes a feedback loop from the microclimate thermal effectors, wherein the feedback loop is configured to determine the differential temperature based upon the commanded temperature set point.

[0024] In another example of any of the above described microclimate systems for a vehicle occupant the controller includes an input configured to receive vehicle temperature data from a vehicle data bus, and wherein the vehicle temperature data includes a cabin temperature output from a cabin air sensor and an outside air temperature output from an outside air sensor.

[0025] In another example of any of the above described microclimate systems for a vehicle occupant the controller includes a fusion algorithm configured to fuse the microclimate

temperature data with the vehicle temperature data to determine an expected local temperature for each of the microclimate thermal effectors.

BRIEF DESCRIPTION OF THE DRAWINGS

[0026] The disclosure can be further understood by reference to the accompanying drawings, comprising Figures 1-9.

[0027] Figure 1 schematically illustrates a vehicle heating ventilation and cooling system.

[0028] Figure 2 schematically illustrates a sensor fusion processor for fusing microclimate sensor data and other vehicle sensor data into a single vehicle sensor set.

[0029] Figure 3 schematically illustrates an exemplary thermal comfort ASHRAE scale ranging from -3 to 3.

[0030] Figure 4A illustrates an equivalent temperature for multiple regions during the summer.

[0031] Figure 4B illustrates an equivalent temperature for multiple regions during the winter.

[0032] Figures 5 schematically illustrates a basic architecture of an exemplary microclimate control system .

[0033] Figure 6 schematically illustrates an exemplary fuzzy logic control.

[0034] Figure 7A schematically illustrates exemplary temperature environment fuzzy sets.

[0035] Figure 7B schematically illustrates exemplary temperature environment fuzzy sets.

[0036] Figure 8 schematically illustrates an example fuzzy set based upon ΔT for a give thermal comfort effector.

[0037] Figure 9 shows an exemplary fuzzy logic controller output plot for heating.

[0038] The embodiments, examples and alternatives of the claims, or the following description and drawings, including any of their various aspects or respective individual features, may be taken independently or in any combination. Features described in connection with one embodiment are applicable to all embodiments, unless such features are incompatible.

DETAILED DESCRIPTION

[0039] This disclosure relates to a microclimate system that provides increased thermal comfort to the occupant by controlling microclimate thermal effectors using sensor fusion and fuzzy logic.

[0040] Referring to Figure 1, a vehicle 100 has a heating, ventilation and air conditioning (HVAC) system 110 that is used to condition the air 112 and control the bulk temperature of the air within the vehicle cabin 102. A typical HVAC system 110 has ducting that supplies conditioned air 112 to the cabin 102 using a blower 114 moving air over a heat exchanger 116. A sensor 118 monitors the temperature of the conditioned cabin air 112, and a controller 120 regulates operation of the HVAC system 110 to a temperature set point that is typically manually adjusted by an occupant 104. The central HVAC 110 system is insufficient to achieve thermal comfort for each specific occupant 104 and location in many scenarios, such as those where multiple different occupants 104 are in the same cabin 102, so microclimate devices or thermal effectors are used to create a unique microclimate for each occupant 104 in the cabin 102, thereby providing improved overall thermal comfort for each occupant 104.

[0041] As a further challenge to providing an effective climate control system, each occupant 104 typically has unique personal comfort preferences. That is, a particular occupant 104 detects a level of thermal energy differently than another occupant 104. As a result, the exact same thermal environment within a vehicle 100 may be perceived as comfortable by one occupant 104, but as uncomfortable by another occupant 104. To this end, the vehicle 100 includes an integrated approach to human thermal management by controlling both the central HVAC system 110, or any other thermal control system in the vehicle 110, as well as various microclimate thermal effectors using fuzzy logic to coordinate and optimize comfort for each occupant 104 of the vehicle 100.

[0042] With continuing reference to Figure 1, an example microclimate system may have multiple discrete occupant microclimate zones. According to ISO 145045-2:2006 (E), a human body can be divided into different body segments, such as hand, head or chest, and each segment has a different thermal comfort temperature range. The five example microclimate zones in Figure 1 are: head 132, back 134, cushion 136 (thigh and buttocks), foot/leg 138, and arm/hand 130. Fewer, more and/or different zones may be used if desired, depending on the specific microclimate system and the needs of a given vehicle. In the disclosed microclimate system an

estimated local equivalent temperature T_{local} is calculated on a per device/body region basis, i.e., by individual zones 130, 132, 134, 135, 136, 138.

[0043] Microclimate thermal effectors are localized components that can adjust or maintain a desired microclimate in a corresponding zone 130, 132, 134, 136, 138. The microclimate thermal effectors can include, for example, climate controlled seats (e.g., U.S. Patent Nos. 5,524,439 and 6,857,697), a head rest/neck conditioner (e.g., U.S. Provisional App. No. 62/039,125), a climate controlled headliner (e.g., U.S. Provisional App. No. 61/900334), a steering wheel (e.g., U.S. Patent No. 6,727,467 and U.S. Pub. No. 2014/0090513), a heated gear shifter (e.g., U.S. Pub. No. 2013/0061603, etc.), heater mats, a mini-compressor system, and/or any other systems configured to achieve a personalized microclimate. The enumerated microclimate thermal effectors are exemplary in nature and are non-limiting. The microclimate system provides a corresponding occupant 104 personal comfort in an automated manner with little or no input from the corresponding occupant 104. All or some of the microclimate thermal effectors can be arranged to optimally control the thermal environment around an occupant of a seat located anywhere inside a passenger vehicle. In addition, the microclimate thermal effectors can be used to regulate thermal comfort separately for individual segments of the occupant's body.

[0044] Occupant variables such as activity level and clothing are also considered by a local equivalent homogeneous temperature (EHT) model by considering the season, outside air temperature (determined via an outside air sensor 118) and/or the region. User information such as gender, height, weight and age may also be provided to a sensor fusion processor in the controller 120. By combining the data from a vehicle data bus 140 (e.g., CAN, LIN, PWM HVAC signal, or any other data bus) and feedback from local conductive, radiative or convective heating/cooling microclimate thermal effectors within a headrest 150, a seat back 152, a seat cushion 154, a floormat 156, a steering wheel 158, each microclimate system accurately estimates the local equivalent homogenous temperature, or estimated local equivalent temperature, T_{local}, for the corresponding zone 130, 132, 134, 136, 138 which is then used for local thermal comfort prediction and heating/cooling control. Thus, a discrete local temperature can be obtained with the microclimate thermal effectors at each of the five regions of the occupant's body.

[0045] The sensor fusion method provides an efficient and accurate way to estimate local environment temperatures at each of the microclimate zones 130, 132, 134, 136, 138. Referring to Figure 2, a sensor fusion processor 200 acquires vehicle cabin temperature/velocity

202, outside air temperature 204, sun load 206, vehicle speed and/or other data from a vehicle data bus 210 or from any available in vehicle sensors 160 (see Figure 1) and includes a sensor fusion controller 210.

[0046] The sensor fusion controller 210 acquires temperature feedback from each thermal effector (i.e. each local heating/cooling device). Exemplary automotive seat-based occupant thermal comfort control systems can utilize many conductive, convective or radiative heating and cooling devices to achieve optimal occupant comfort.

[0047] In the example microclimate system, multiple microclimate thermal effectors are configured to thermally condition multiple occupant zones 130, 132, 134, 136, 138. Each of the microclimate thermal effectors generates microclimate temperature data, which is provided by a temperature sensor (e.g., a negative temperature coefficient (NTC) element) that is incorporated into each of the microclimate thermal effectors 220. Non-limiting examples of microclimate thermal effectors 220 include climate controlled seats, head rest/neck conditioners, climate controlled headliners, steering wheels, heated gear shifters, heater mats, other heated surfaces and mini-compressor systems. Other example microclimate thermal effectors include radiative console and/or door surfaces, radiant heater panels, and liquid loop based cooling devices (devices which convert conditioned glycol to localized cooling).

[0048] One or more controllers 230 within the sensor fusion controller 200 are in communication with each of the microclimate thermal effectors 220. The controller 230 includes one or more inputs 212 configured to receive vehicle temperature data from a vehicle data bus 210. The controller 230 fuses the microclimate temperature data 222 received from the microclimate thermal effectors 220 with the vehicle temperature data received from the vehicle data bus 210 using an algorithm (e.g. Equation 1) to determine an estimated local equivalent temperature T_{local} for each of the microclimate thermal regions/zones. The controller provides a temperature command 224 to each of the microclimate thermal effectors 220 based upon its estimated local equivalent temperature T_{local} to achieve occupant thermal comfort at each individual zone 130, 132, 134, 136, 138.

[0049] One example sensor fusion equation (Equation 1) calculates estimated local equivalent temperature T_{local} for each microclimate thermal region/zone, as follows.

$$T_{local} = W_1 \times (T_{cabin} + b_{tv}) + W_2 \times T_{outside} + W_3 \times SL_{nor} + W_4 \times V + W_5 \times T_{lf}$$

Where:
W_i i = 1, 2, 3, 4, 5; calibratable weighting factor
T_{cabin} cabin temperature
b_{tv} temperature vertical stratification factor or offset
$T_{outside}$ outside temperature
SL_{nor} normalized sunload
V vehicle speed
T_{lf} local effector temperature feedback

[0050] The vehicle temperature data includes cabin temperature T_{cabin}, outside air temperature $T_{outside}$, vehicle solar load SL_{nor} and vehicle speed V. The weighting factors W_i may be different based upon the particular microclimate thermal effector 220. A skilled artisan can select the particular weighting factor to be used for each control portion (i) based on the particular microclimate thermal effectors 220 and the expected/experienced conditions of the thermal effector(s) 220 affecting the control potion (i).

[0051] Most vehicles have a single interior air temperature sensor, but if one were to measure local temperatures inside the vehicle at any given time the temperatures would be very different, especially if you have a sunny day (i.e. the vehicle has a high solar load). The algorithm allows adjustments based on how well the interior cabin sensor actually correlates to local temperatures and is unique for each car. The temperature vertical stratification or offset b_{tv} adjusts the cabin air temperature for the level of stratification in a particular zone e.g. "breath level" would be used in the zone around the head of the occupant 104. Similarly, if the cabin air temperature sensor is located at approximately the same level as the steering wheel, then there may be no offset for back zone 134 and the hand/arm zone 130. However, there may be a negative offset for the foot/leg zone 138 or the seat zone 136, and a positive offset for the head zone 132. The weighting factor W_1 provides further adjustments for each microclimate thermal region/zone 130, 132, 134, 136, 138. For example, the cabin temperature in the head zone 132 may have a greater weighting factor W_1 than the hand/arm zone 130.

[0052] Weighting factor W_2 adjusts the outside temperature and its effects on each microclimate thermal effector. For example, the outside temperature in the hand/arm zone 130 may have a bigger weighting factor than in the seat zone 136. In a cold ambient when the vehicle is travelling quickly, additional "work" is needed from the door heaters to overcome the loss of heat through the door and side glass.

[0053] The vehicle solar load SL_{nor} is normalized, and a weighting factor W_3 is applied to the vehicle solar load SL_{nor} to account for a particular body segment which has direct sun exposure. For example, with a panoramic sun roof more solar radiant heating would enter the cabin and impact comfort. Conversely, the impact of sun could be reduced if the vehicle has special solar glazing, which reflects sun load.

[0054] Weighting factor W_4 adjusts for the effects of vehicle speed on the particular zone. The foot/leg zone 138 is particularly susceptible to effects of vehicle speed on local temperature. For example, the foot/leg zone 138 becomes particularly cold at high speeds in cold temperatures, so a larger weighting factor may be used for the foot/leg zone 138. The vehicle speed may have negligible effects on the back zone 134, for example, so the weighting factor may be used to zero-out the vehicle speed for the seat back thermal effector(s).

[0055] The microclimate temperature data 222 includes thermal effector feedback T_{lf} that may also be adjusting using a weighting factor W_5. For example, the hand/arm zone 130 thermal effector(s) 220 may be given increased weight when a steering wheel heater is used, as that can have a large impact on occupant comfort in the hand/arm zone 130.

[0056] The effectiveness of the disclosed system is, in some examples, further enhanced by using fuzzy logic to predict the human body's thermal sensation and thereby the comfort of the human body in real time. By employing fuzzy logic control, each device in the system is automatically tuned to the correct temperature and flow rate set point based on the local environmental condition to meet the occupant's local body segment's thermal comfort expectations. Since each occupants' thermal expectations are unique, fuzzy logic is used to define a temperature set point for each thermal effector in such a manner that takes into account thermal comfort variations in an occupant population.

[0057] In one example, an occupant thermal condition is expressed as the degree to which an occupant senses a hot or cold temperature, or changes and variations in temperature. These hot and cold sensations are represented using an ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers) thermal sensation scale 310 from 3 (hot) to -3 (cold), as shown in Figure 3, according to a predicted mean vote (PMV) methodology 320. In the disclosed system, the PMV calculation assigns a "hotness"/"coldness" value for each microclimate zone.

[0058] As an alternative to the hot and cold sensation scale shown in Figure 3, an occupant thermal condition can be expressed using the Berkeley Sensation and Comfort Scale ("Berkeley scale"), described in, for example, Arens E. A., Zhang H. & Huizenga C. (2006) Partial- and whole-body thermal sensation and comfort, Part I: Uniform environmental conditions. *Journal of Thermal Biology*, 31, 53-59. It should be understood that other approaches can be used to quantify an occupant's thermal condition.

[0059] The season may significantly affect the perceived occupant thermal comfort such that the PMV 320 outcome is different. So, the predicted occupant thermal comfort 400 may be adjusted based upon the season, as shown in Figures 4A and 4B, with Figure 4A illustrated an equivalent temperature for multiple regions 410A during summer and Figure 4B illustrating an equivalent temperature for the multiple regions 410B during the winter. Although only a five-value thermal scale is shown in Figures 4A and 4B ("too cold," "cold but comfortable," "neutral," "hot but comfortable," and "too hot"), it is appreciated that the thermal comfort can be further refined to correlate to the seven-value ASHRAE thermal sensation scale 310 (3 to -3) shown in Figure 3.

[0060] Figures 5 schematically illustrates the basic architecture of an exemplary microclimate control system 500 that uses both sensor fusion 510 and fuzzy logic control 520 (illustrated in more detail in Figure 6) to regulate each of the microclimate thermal effectors 530. The sensor fusion control scheme 500 compensates for important factors that affect occupant comfort including both environmental conditions 512 external to the vehicle and environmental conditions 514 within specific stratified layers of the cabin volume. The local effector temperature feedback T_{LF} 532 (Feedback T) is provided in one example by a negative thermal coefficient (NTC) temperature sensor that is integrated into each thermal effector within each zone. The values from the local fuzzy logic controller 520 and NTC feedback 532 are provided to the PWM controller 540 to regulate the thermal effector 530. Other control functions may be used such as overheat protection, maximum temperature limits from the PWM controller, maximum holding times for a given temperature setpoint and the like, according to conventional control methodologies.

[0061] Referring to Figures 5-6, the local fuzzy logic controller 520 establishes temperature based fuzzy sets which are related to each local body segments' temperature range for comfort. Fuzzy rules are created according to each physical heating/cooling device's characteristics and location, and the fuzzy controller applies "fuzzy logic" in the automotive seat

based occupant thermal comfort system (including other microclimate thermal effectors) to control each individual heating/cooling device's temperature dynamically.

[0062] As explained above in connection with the sensor fusion algorithm, the occupant thermal comfort system is divided into multiple comfort control zones (e.g., five) based on up to nineteen body segments and corresponding effectors in each seat location. The number of control zones can be more than five and up to nineteen (defined in ASHRAE model) according to unique conditions around the body. Approximately five zones are desirable in some examples from a perspective of user input to the system for customization and control due to the reduced complexity while the relationship between five comfort control zones and nineteen, for example, can be established mathematically, in order to translate from comfort related parameters to control related parameters.

[0063] There may be several heating and/or cooling devices impinging on the climate in each of the comfort control zones. Each of these devices may have its own control module. Figure 5 shows the major functional subsystems within a typical heating and/or cooling control module 500.

[0064] After collecting the vehicle data and feedback from all comfort control devices, the system generates localized temperature information for each control module based on the device location. The control module calculates ΔT 550 based on the local temperature and desired comfort temperature for the zone. In particular, ΔT 550 corresponds to the local temperature based upon the vehicle temperature data minus the desired, preset local comfort temperature for the given thermal effector. The fuzzy logic controller 520 takes ΔT 550 as the input and converts ΔT 550 into a fuzzy membership function through fuzzification. According to ASHRAE thermal sensation scale, ISO 14505-2:2006 and each individual heating/cooling device's physical characteristics, location and corresponding body segments the exemplary system 500 defines four environment temperature fuzzy sets 560, 562, 564, 566 (member functions) for each zone, as shown in Figure 7A, and 4 fuzzy sets 570, 572, 574, 576 for heating/cooling set temperatures, as shown in Figure 7B. The fuzzy logic controller 520 applies fuzzy rules and decides the output value, i.e., the inference mechanism. Through defuzzification, the control module 540 converts the fuzzy output to real life data value which is used as a temperature set point for the device. Figure 6 is a typical control flowchart for designing a fuzzy logic controlled heating/cooling device.

[0065] The temperature set point 552 is provided to the controller 540, which uses any suitable control scheme to provide a pulse width modulation (PWM) signal 542 to the given thermal effector 530 controlling the thermal effector 530 to the setpoint. The NTC within the thermal effector 530 provides feedback to the sensor fusion algorithm 510, as well as a summing junction 534 between the temperature set point to provide a corrected signal to the control scheme.

[0066] The fuzzy sets account for the uncertainty relating to the application of the ASHRAE thermal sensation scale to any given occupant. The "1" value indicates 100% certainty that the entire population would agree with the indicated thermal sensation, and the "0" value indicates that the entire population would disagree with the indicated thermal sensation. An example of the fuzzy sets based upon ΔT 550 for a give thermal comfort effector 530 is shown in Figures 7A and the left side of Figure 8. The sloped lines reflect the variation within the population as to whether the indicated thermal sensation applies to the population of occupants. Where sloped lines overlap at a given ΔT 550, the population is divided as to its perceived thermal comfort. For example, at -10 ΔT 550, 50% of the population would feel "slightly cool", and 50% of the population would feel "neutral." The fuzzy sets are determined using the ΔT 550 to produce the temperature set point 552 for the given thermal effector, as shown in Figure 7B and the right side of Figure 8. The specific values illustrated in Figures 7A, 7B and 8 are exemplary only and the values will vary depending on the specifics of the system 500 and the thermal effector 530.

[0067] Figure 9 shows an exemplary fuzzy logic controller output plot 600 for heating. The output plot 600 discloses multiple exemplary regions 610, 620, 630, 640, 650 with 610 representing the "0" value where no users would be comfortable and 650 representing the "1" value where every user is comfortable. Intervening regions 620, 630, 640 represent intermediate regions where some users are expected to be comfortable and other users are expected to be uncomfortable.

[0068] The fuzzy logic control temperature can be based on SISO (single input single output) 1D control or MIMO (multiple inputs multiple outputs) multi- dimensional control. Additional inputs and outputs can be included, such as fan airflow rate, humidity etc. and the controls can be implemented according to any SISO or MIMO control scheme.

[0069] It should also be understood that although a particular component arrangement is disclosed in the illustrated embodiment, other arrangements will benefit herefrom. Although particular step sequences are shown, described, and claimed, it should be understood that steps

may be performed in any order, separated or combined unless otherwise indicated and will still benefit from the present invention.

[0070] Although the different examples have specific components shown in the illustrations, embodiments of this invention are not limited to those particular combinations. It is possible to use some of the components or features from one of the examples in combination with features or components from another one of the examples.

[0071] Although an example embodiment has been disclosed, a worker of ordinary skill in this art would recognize that certain modifications would come within the scope of the claims. For that reason, the following claims should be studied to determine their true scope and content.

CLAIMS

What is claimed is:

1. A method of controlling a microclimate system comprising:

identifying a set of multiple microclimate thermal effectors configured to provide multiple occupant zones;

determining a differential temperature between a local temperature at one of the microclimate thermal effectors and a preset temperature for the one of the microclimate thermal effectors, the differential temperature being determined for each of the microclimate thermal effectors;

generating a fuzzy set for each of the microclimate thermal effectors based upon the respective differential temperature;

defining a respective temperature set point for each of the microclimate thermal effectors based upon the fuzzy set for the corresponding microclimate thermal effectors; and

commanding each microclimate thermal effector to the corresponding respective temperature set point.

2. The method of claim 1, wherein the multiple occupant zones include at least two of a head zone, a seat back zone, a seat cushion zone, a hand/arm zone and a foot/leg zone.

3. The method of claim 2, wherein at least a portion of the set of multiple microclimate thermal effectors are conductive thermal devices that are configured to engage an occupant during use.

4. The method of claim 3, wherein the set of multiple microclimate thermal effectors includes microclimate thermal effectors selected from the group comprising climate controlled seats, head rest/neck conditioner, climate controlled headliner, steering wheel, heated gear shifter, heater mat, and mini-compressor system.

5. The method of claim 3, wherein the local temperature for at least one of the microclimate thermal effectors in the set of multiple microclimate thermal effectors is determined using a negative temperature coefficient element in the one of the microclimate thermal effectors.

6. The method of claim 2, wherein generating the fuzzy set for each of the microclimate thermal effectors uses fuzzy rules based upon an occupant thermal sensation scale for a population of occupants and their personal occupant thermal comfort for the multiple occupant zones.

7. The method of claim 6, further comprising converting the fuzzy set to a fuzzy output corresponding to the temperature set point for each of the microclimate thermal effectors.

8. The method of claim 1, further comprising providing a feedback loop from each of the microclimate thermal effectors, wherein the feedback loop is configured to determine the differential temperature based upon the commanded temperature set point and a measured local temperature.

9. The method of claim 8, comprising the step of fusing temperature data to determine the local temperature, temperature data fusing step includes:

providing microclimate temperature data from each of the microclimate thermal effectors;

receiving vehicle temperature data from a vehicle data bus, the vehicle temperature data including a cabin temperature and an outside air temperature; and

fusing the microclimate temperature data with the vehicle temperature data to determine a local temperature for each of the microclimate thermal effectors.

10. A microclimate system for a vehicle occupant comprising:

multiple microclimate thermal effectors configured to provide multiple occupant zones;

a controller in communication with the microclimate thermal effectors, the controller configured to determine a differential temperature between a local temperature for one of the microclimate thermal effectors and a preset temperature for the one of the microclimate thermal effectors, the controller being further configured to determine the differential temperature for each of the microclimate thermal effectors, the controller being further configured to generate a respective fuzzy set for each of the microclimate thermal effectors based upon a respective differential temperature of each of the microclimate thermal effectors, the controller being further configured to define a temperature set point based upon the fuzzy set for each of the microclimate thermal effectors, and the controller configured to command the microclimate thermal effectors to its respective temperature set point.

11. The microclimate system of claim 10, wherein the multiple occupant zones include at least two of a head zone, a seat back zone, a seat cushion zone, a hand/arm zone and a foot/leg zone.

12. The microclimate system of claim 11, wherein at least a portion of the multiple microclimate thermal effectors are conductive thermal devices configured to engage an occupant during use.

13. The microclimate system of claim 12, wherein the microclimate thermal effectors include microclimate thermal effectors selected from the group comprising climate controlled seats, head rest/neck conditioner, climate controlled headliner, steering wheel, heated gear shifter, heater mat, and mini-compressor system.

14. The microclimate system of claim 12, wherein the local temperature for at least one of the one of the microclimate thermal effectors is determined by the controller using a negative temperature coefficient element in the one of the microclimate thermal effectors.

15. The microclimate system of claim 11, wherein the fuzzy sets are generated by the controller using fuzzy rules based upon an occupant thermal sensation scale for a population of occupants and their personal occupant thermal comfort for the multiple occupant zones.

16. The microclimate system of claim 15, wherein the controller is configured to convert each fuzzy set to a fuzzy output corresponding to the temperature set point for of the corresponding microclimate thermal effectors.

17. The microclimate system of claim 10, wherein the controller includes a feedback loop from the microclimate thermal effectors, wherein the feedback loop is configured to determine the differential temperature based upon the commanded temperature set point.

18. The microclimate system of claim 17, wherein the controller includes an input configured to receive vehicle temperature data from a vehicle data bus, and wherein the vehicle temperature data includes a cabin temperature output from a cabin air sensor and an outside air temperature output from an outside air sensor.

19. The microclimate system of claim 18, wherein the controller includes a fusion algorithm configured to fuse the microclimate temperature data with the vehicle temperature data to determine an expected local temperature for each of the microclimate thermal effectors.

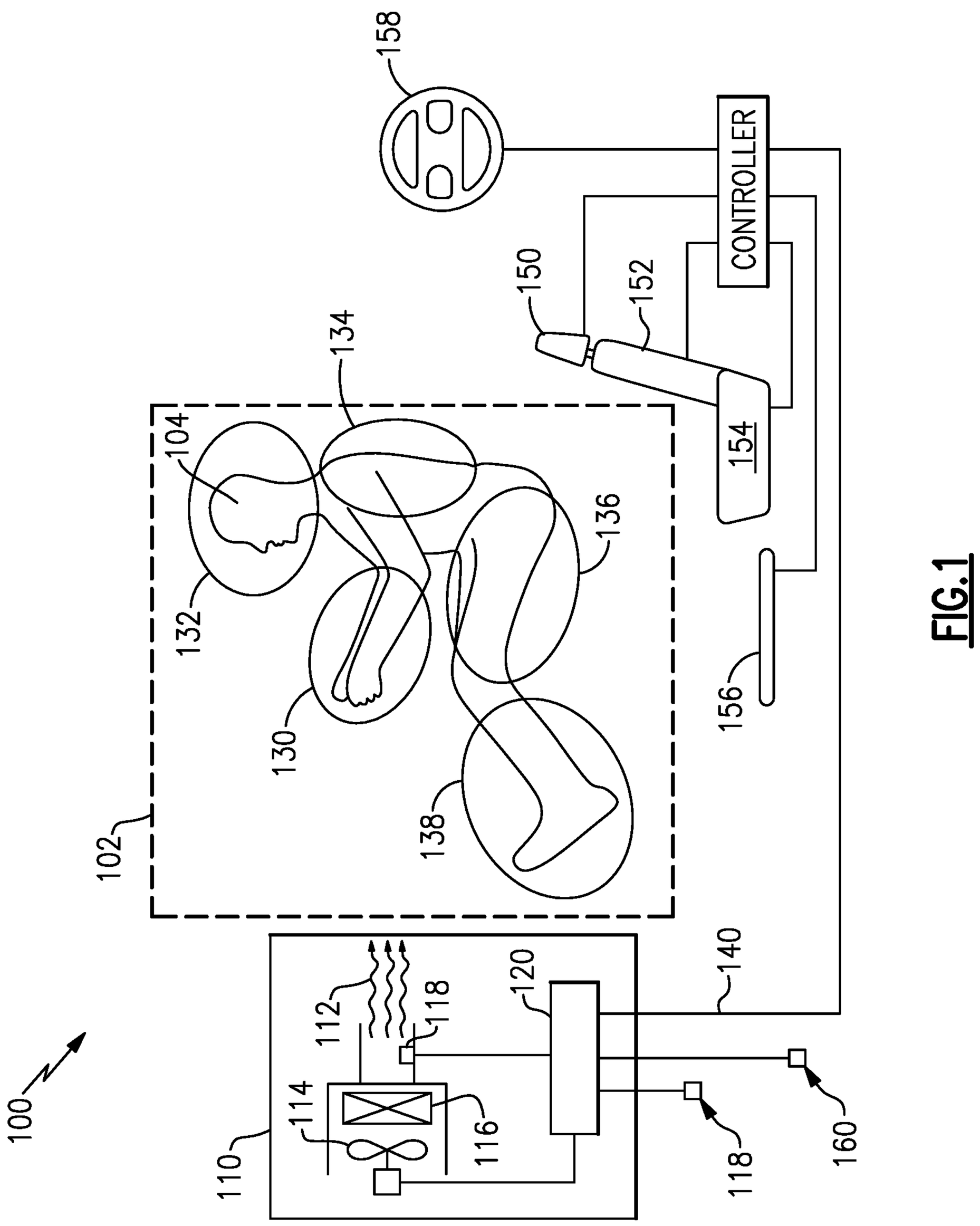

100
102
104
110
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114
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134
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158
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CONTROLLER

FIG.1

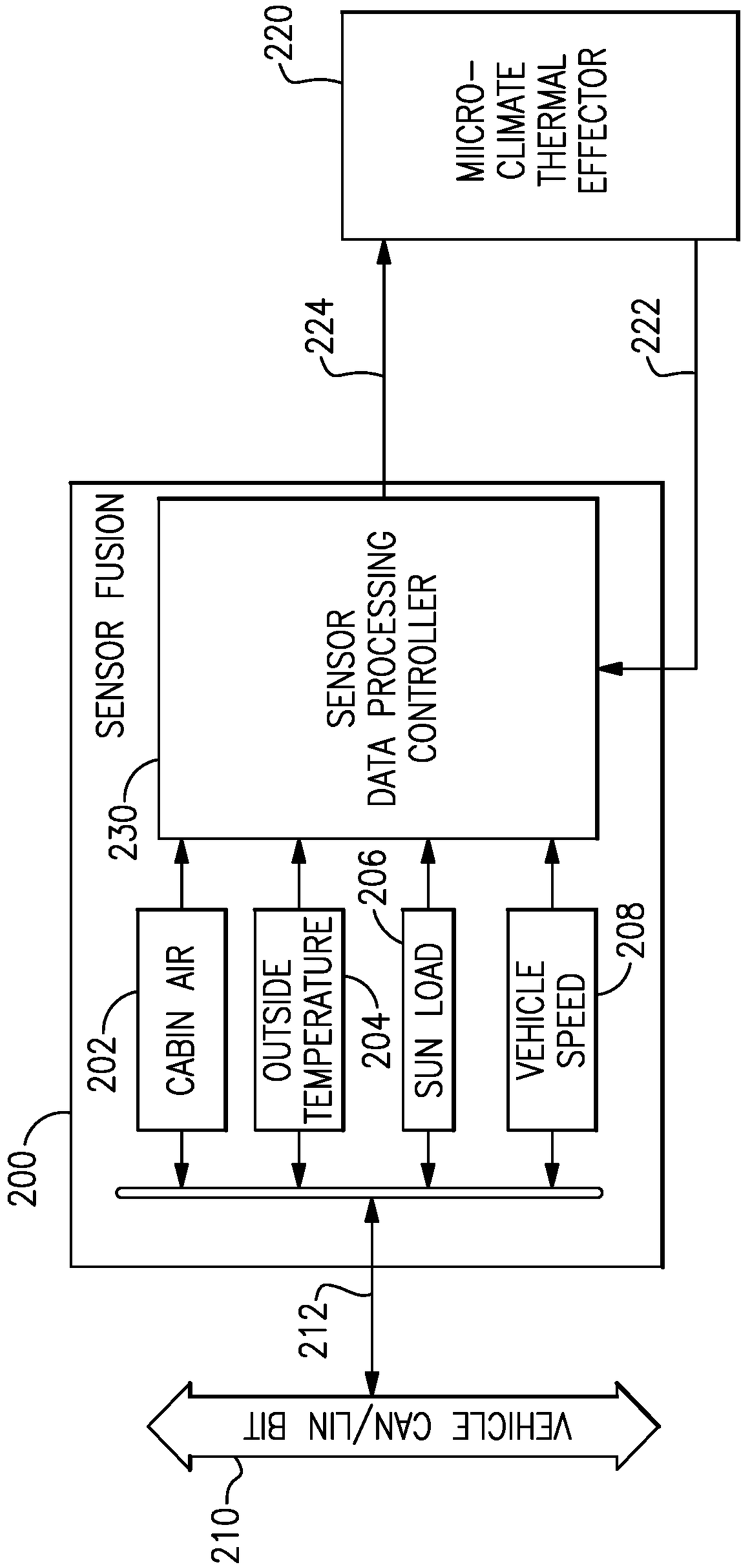


FIG.2

$$T_{local} = W_1 \times (T_{cabin} + b_{tv}) + W_2 \times T_{outside} + W_3 \times SL_{nor} + W_4 \times V + W_5 \times T_{lf}$$

Where:

W_i	i=1,2,3,4,5: calibratable weighting factor
T_{cabin}	cabin temperature
b_{tv}	temperature vertical stratification factor/offset
$T_{outside}$	outside temperature
SL_{nor}	normalized sunload
V	vehicle speed
T_{lf}	local effector temperature feedback

EQUATION 1:

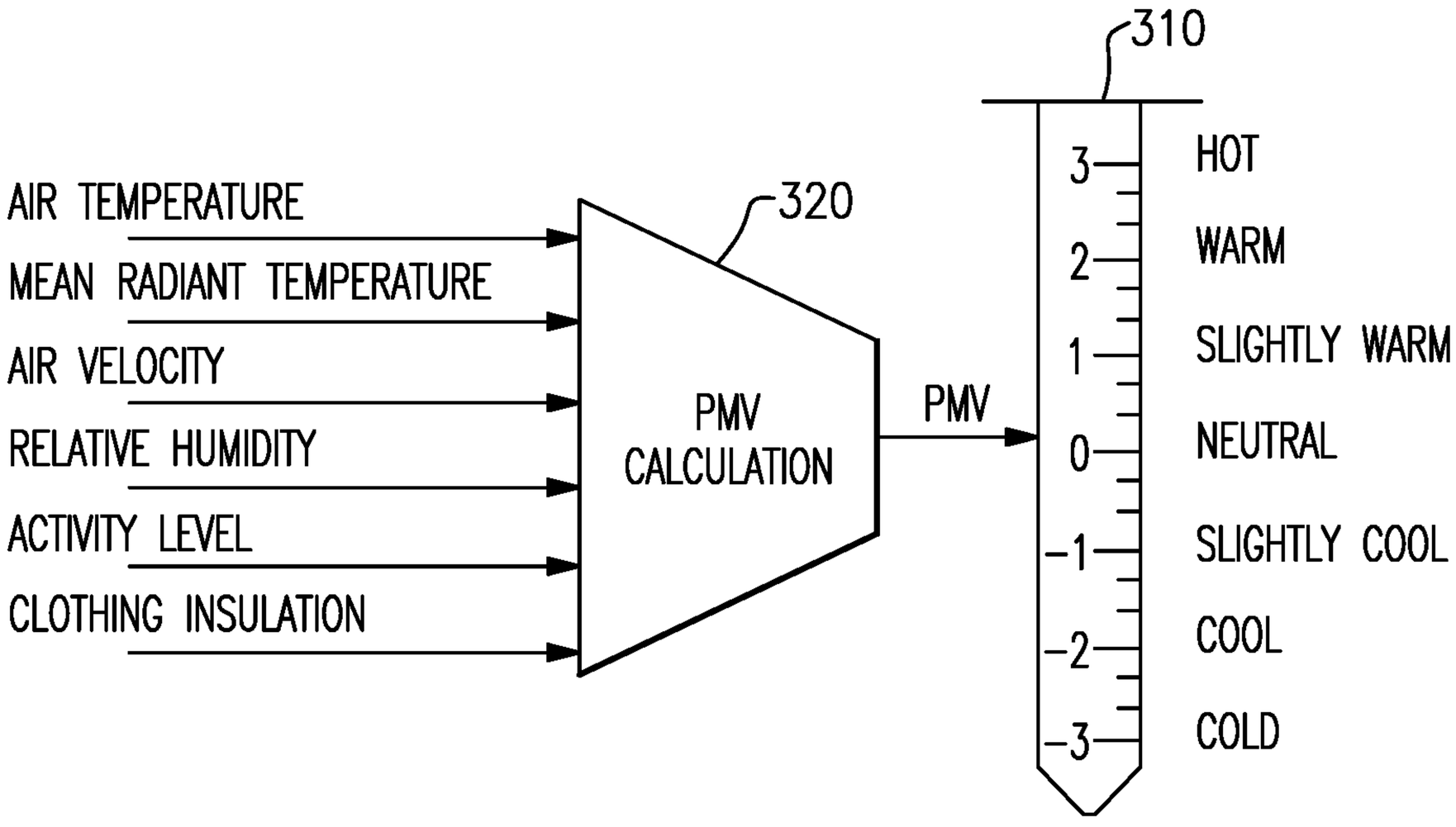

310
320
AIR TEMPERATURE
MEAN RADIANT TEMPERATURE
AIR VELOCITY
RELATIVE HUMIDITY
ACTIVITY LEVEL
CLOTHING INSULATION
PMV CALCULATION
PMV
3
HOT
2
WARM
1
SLIGHTLY WARM
0
NEUTRAL
-1
SLIGHTLY COOL
-2
COOL
-3
COLD

FIG.3

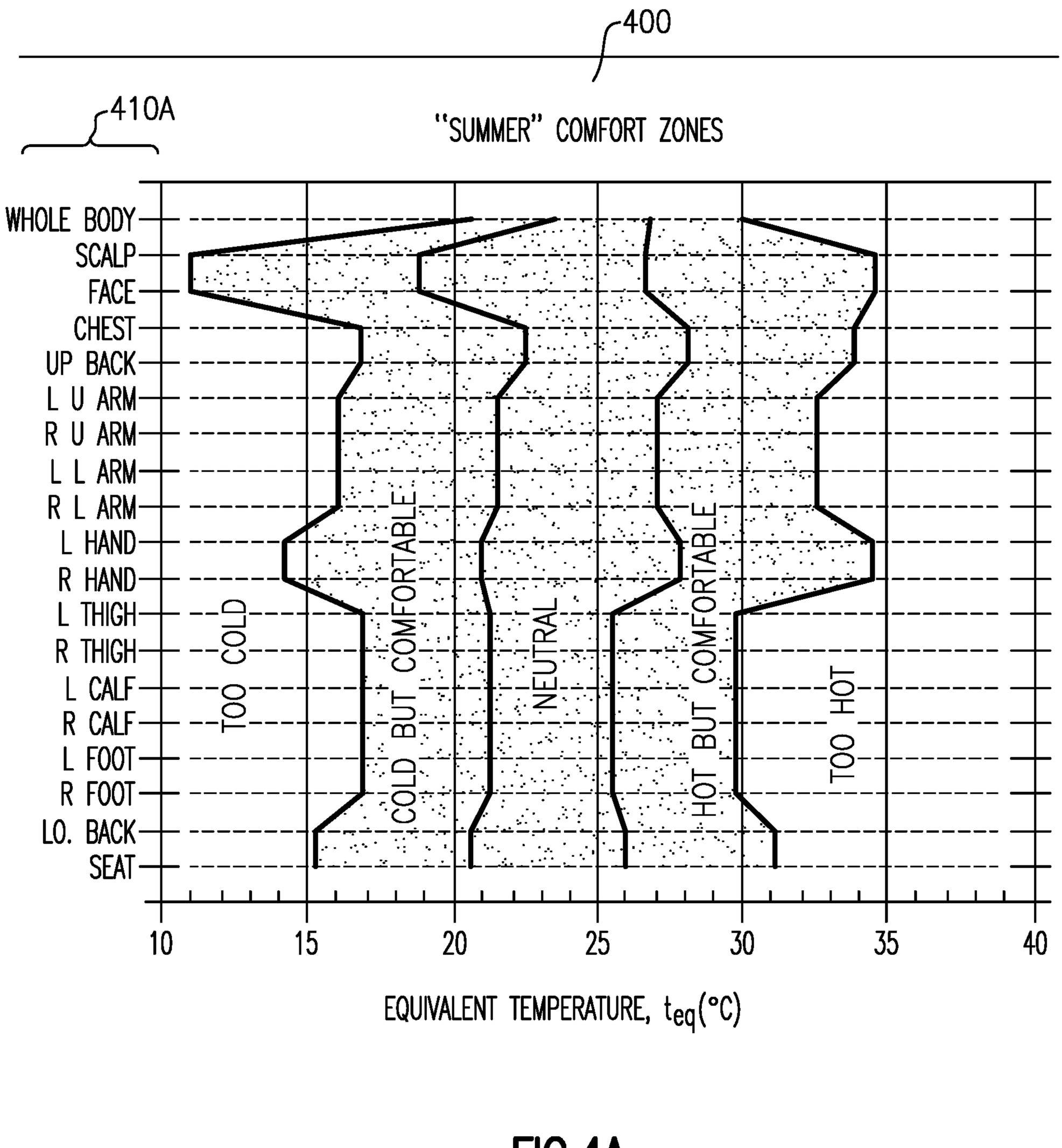

400
410A
"SUMMER" COMFORT ZONES
WHOLE BODY
SCALP
FACE
CHEST
UP BACK
L U ARM
R U ARM
L L ARM
R L ARM
L HAND
R HAND
L THIGH
R THIGH
L CALF
R CALF
L FOOT
R FOOT
LO. BACK
SEAT
TOO COLD
COLD BUT COMFORTABLE
NEUTRAL
HOT BUT COMFORTABLE
TOO HOT
10
15
20
25
30
35
40
EQUIVALENT TEMPERATURE, t_{eq}(°C)

FIG.4A

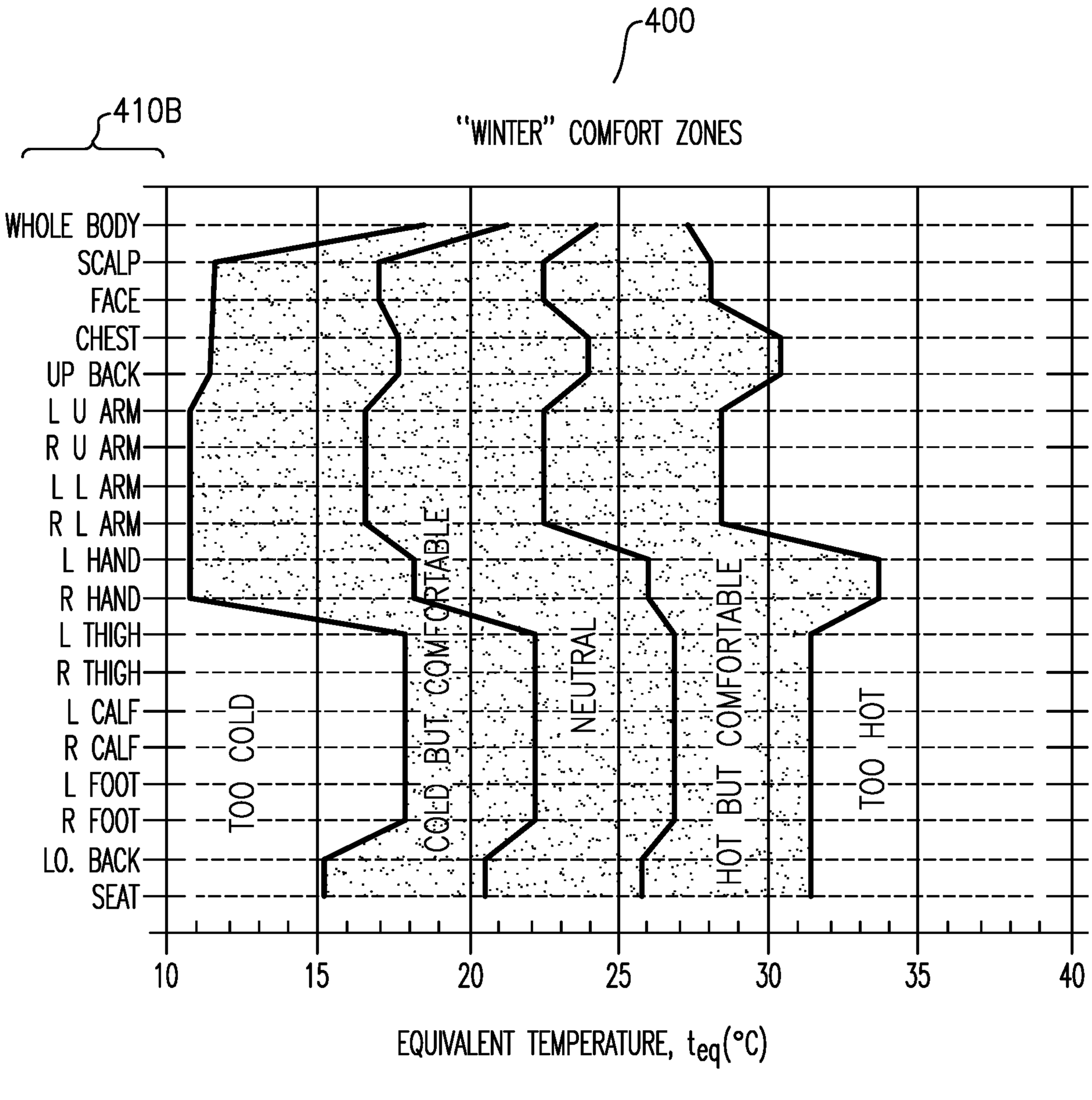

400
410B
"WINTER" COMFORT ZONES
WHOLE BODY
SCALP
FACE
CHEST
UP BACK
L U ARM
R U ARM
L L ARM
R L ARM
L HAND
R HAND
L THIGH
R THIGH
L CALF
R CALF
L FOOT
R FOOT
LO. BACK
SEAT
TOO COLD
COLD BUT COMFORTABLE
NEUTRAL
HOT BUT COMFORTABLE
TOO HOT
10
15
20
25
30
35
40
EQUIVALENT TEMPERATURE, t_{eq}(°C)

FIG.4B

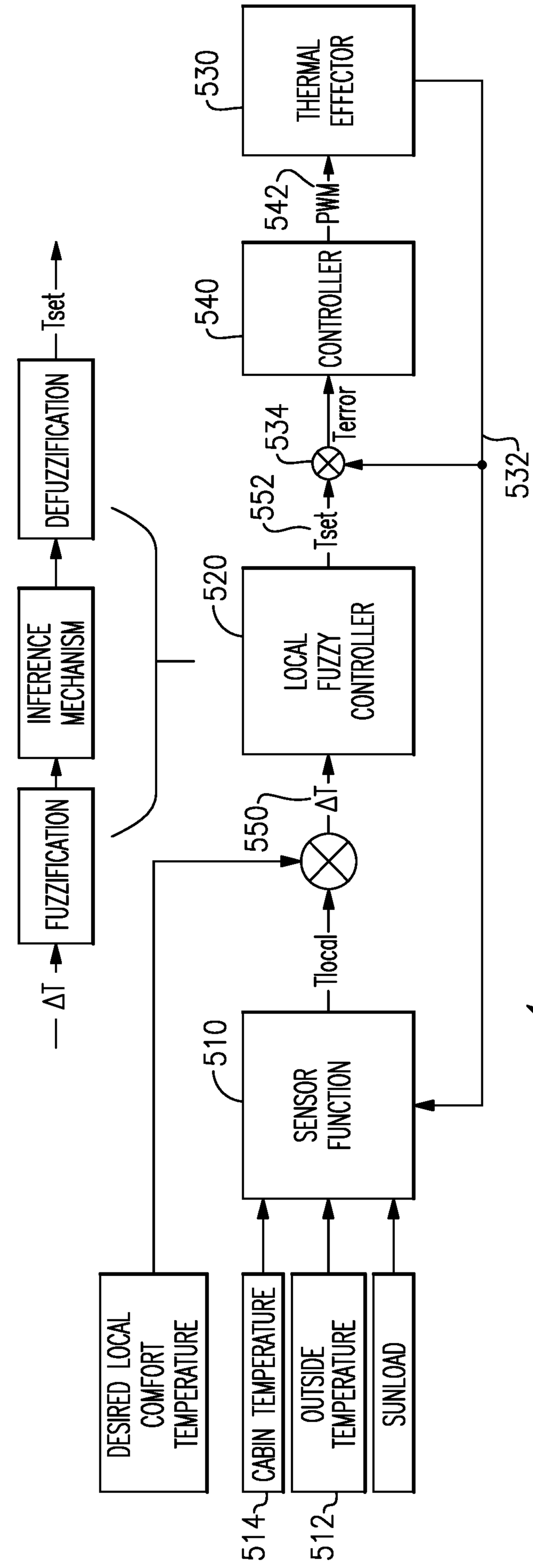

530
THERMAL EFFECTOR
542
PWM
540
CONTROLLER
534
Terror
552
Tset
532
520
LOCAL FUZZY CONTROLLER
550
ΔT
Tlocal
DEFUZZIFICATION
Tset
INFERENCE MECHANISM
FUZZIFICATION
ΔT
510
SENSOR FUNCTION
500
DESIRED LOCAL COMFORT TEMPERATURE
CABIN TEMPERATURE
514
OUTSIDE TEMPERATURE
512
SUNLOAD

FIG.5

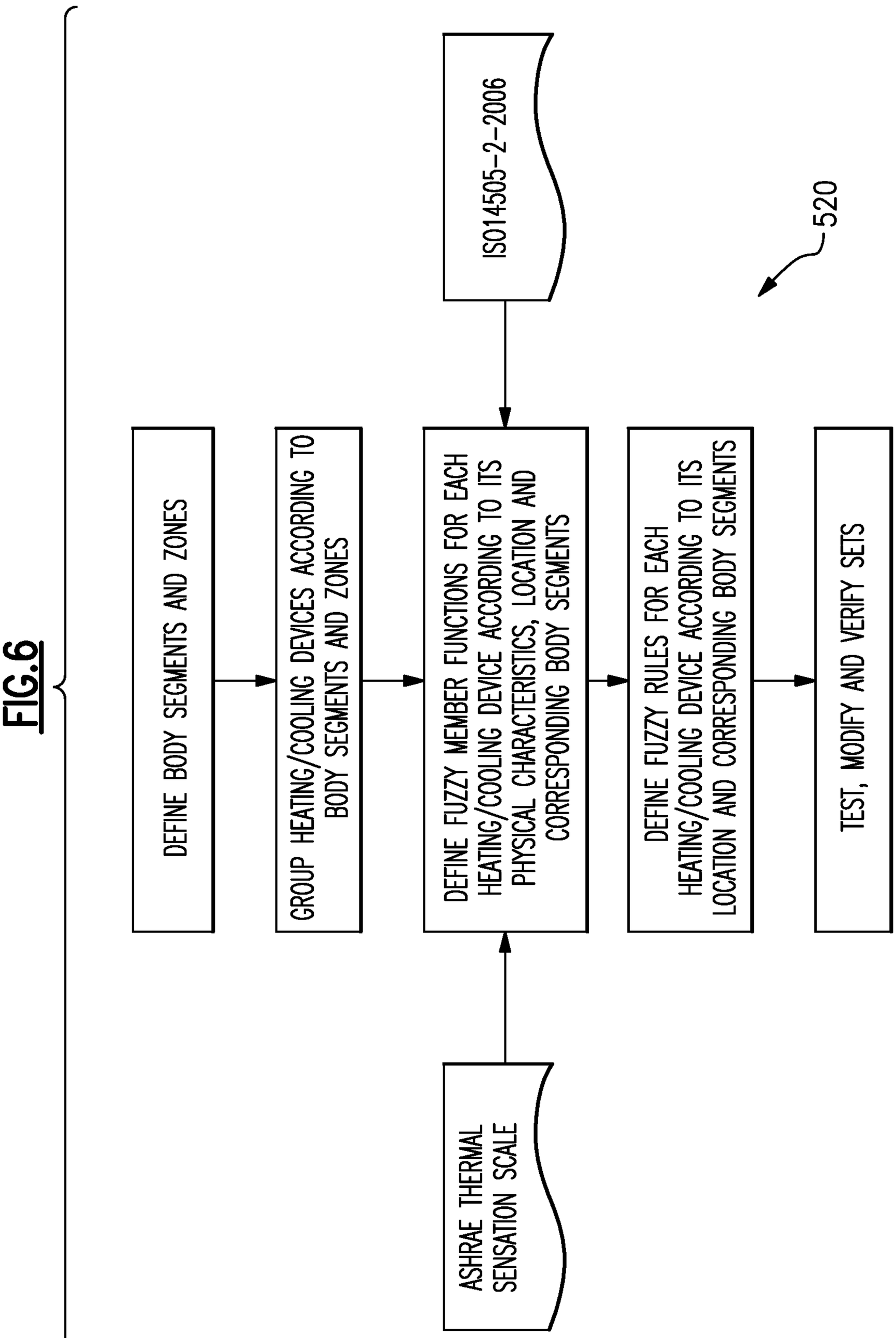

ISO14505-2-2006
520
DEFINE BODY SEGMENTS AND ZONES
GROUP HEATING/COOLING DEVICES ACCORDING TO BODY SEGMENTS AND ZONES
DEFINE FUZZY MEMBER FUNCTIONS FOR EACH HEATING/COOLING DEVICE ACCORDING TO ITS PHYSICAL CHARACTERISTICS, LOCATION AND CORRESPONDING BODY SEGMENTS
DEFINE FUZZY RULES FOR EACH HEATING/COOLING DEVICE ACCORDING TO ITS LOCATION AND CORRESPONDING BODY SEGMENTS
TEST, MODIFY AND VERIFY SETS
ASHRAE THERMAL SENSATION SCALE

FIG.6

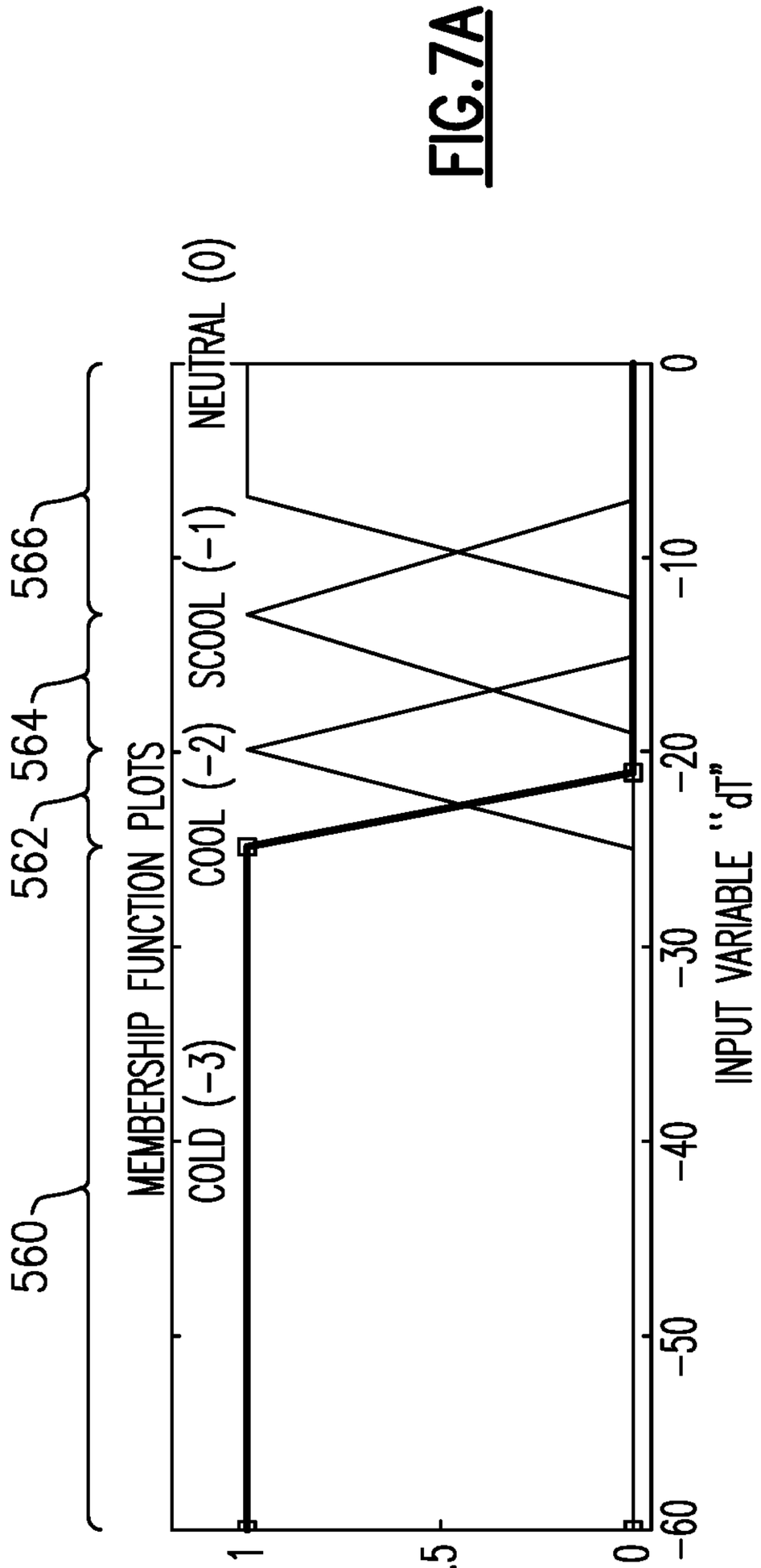

560
562
564
566
MEMBERSHIP FUNCTION PLOTS
COLD (−3)
COOL (−2)
SCOOL (−1)
NEUTRAL (0)
1
.5
0
−60
−50
−40
−30
−20
−10
0
INPUT VARIABLE "dT"

FIG.7A

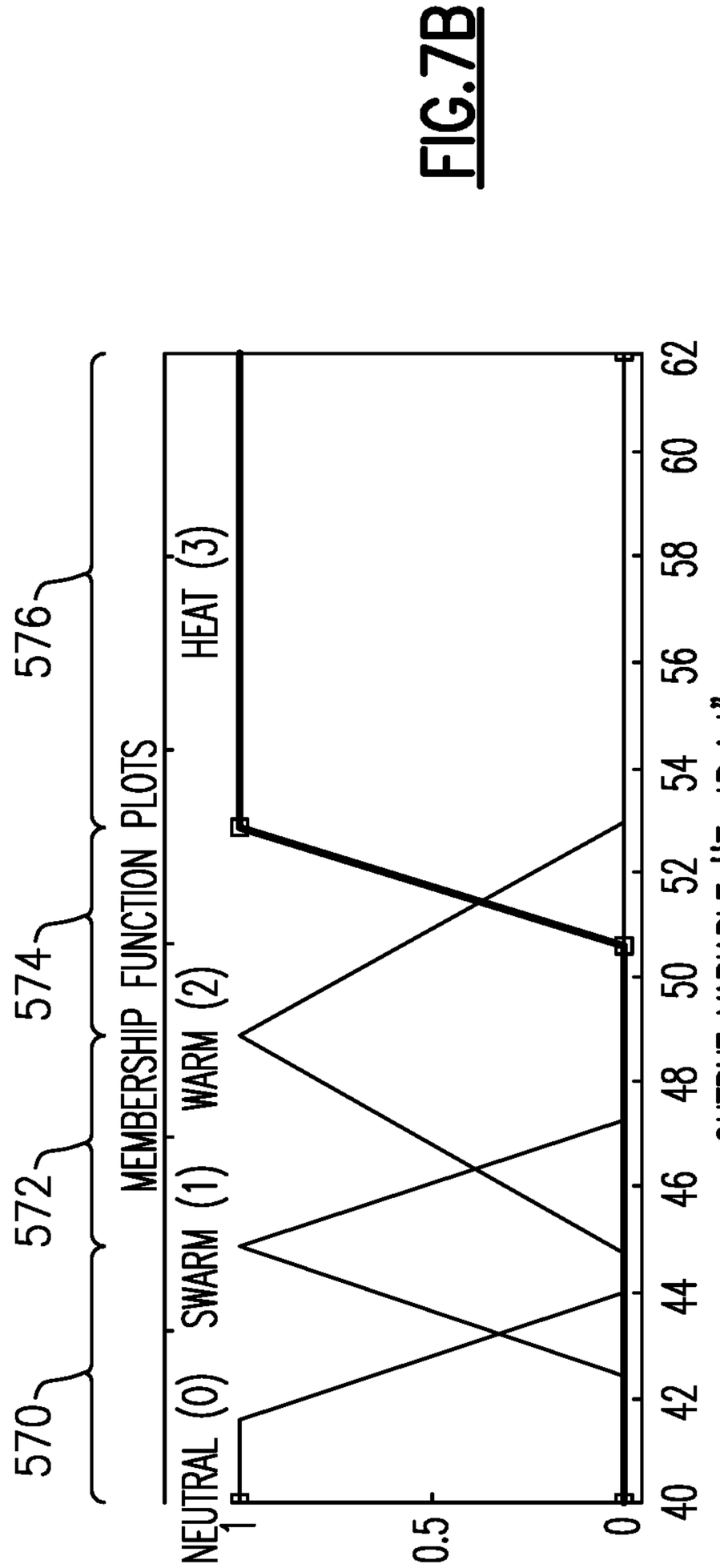

570
572
574
576
MEMBERSHIP FUNCTION PLOTS
NEUTRAL (0)
SWARM (1)
WARM (2)
HEAT (3)
1
0.5
0
40
42
44
46
48
50
52
54
56
58
60
62
OUTPUT VARIABLE "TsetPoint"

FIG.7B

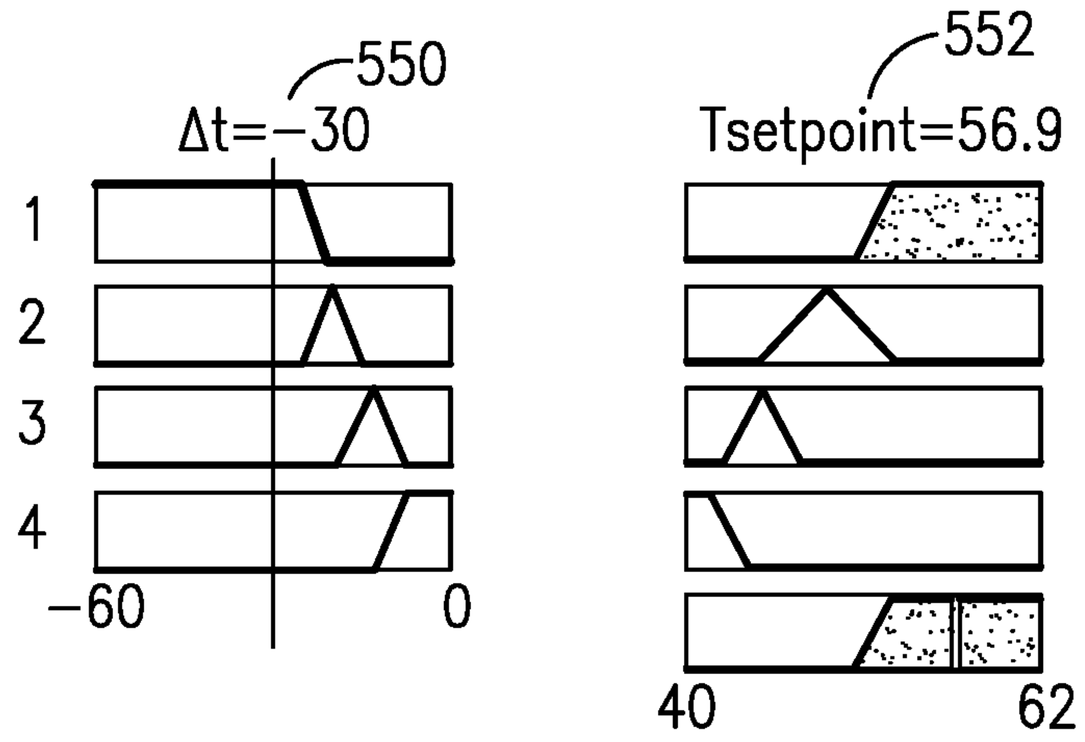

550
Δt=−30
1
2
3
4
−60
0
552
Tsetpoint=56.9
40
62

FIG.8

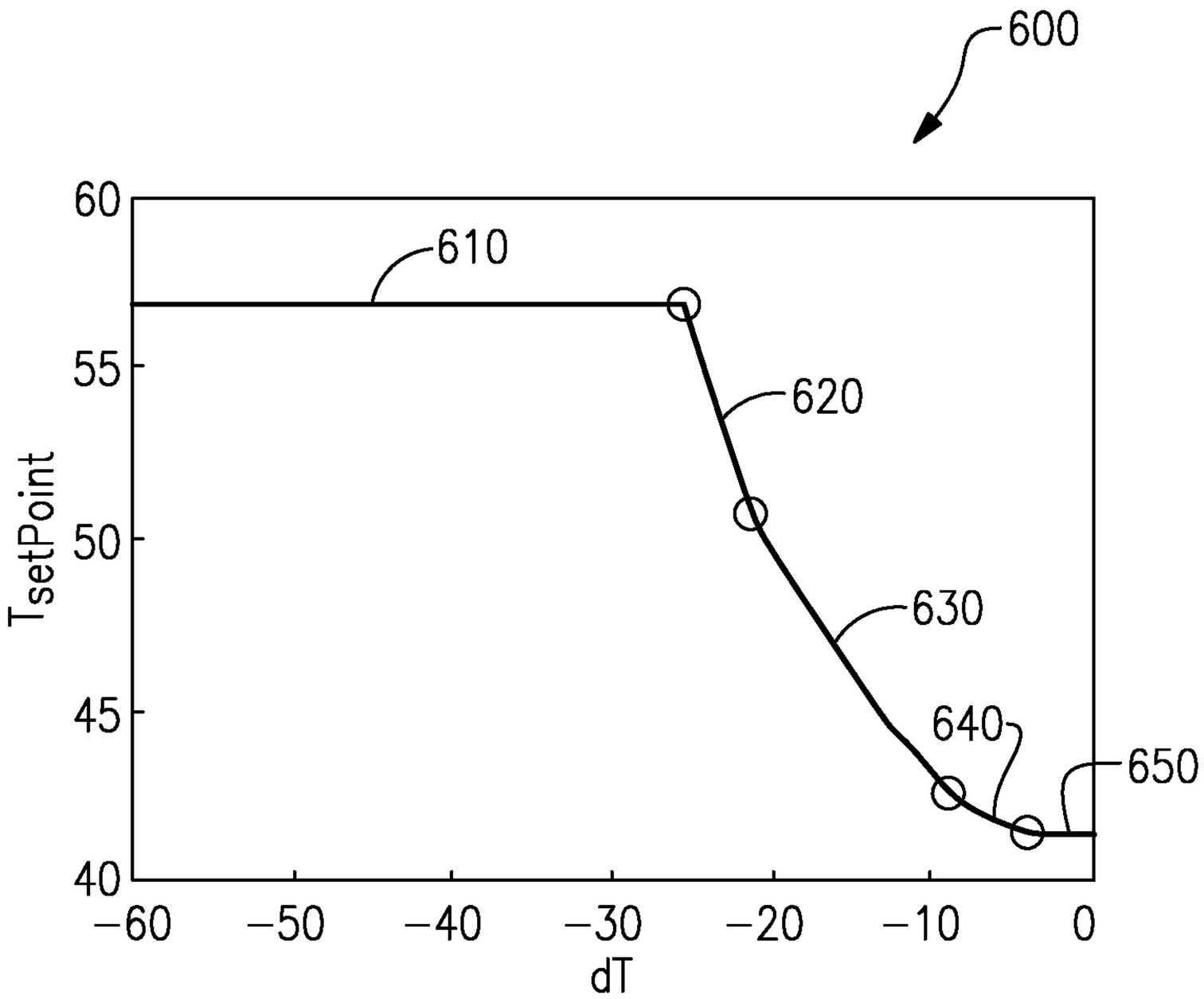

600
610
620
630
640
650
60
55
50
45
40
TsetPoint
−60
−50
−40
−30
−20
−10
0
dT

FIG.9

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2020/063358

A. CLASSIFICATION OF SUBJECT MATTER
INV. B60H1/00 B60H1/22
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B60H

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 1 236 593 A2 (BEHR GMBH & CO [DE]) 4 September 2002 (2002-09-04) paragraphs [0002], [0014] - [0024], [0032]; claims; figures -----	1-19
A	DE 11 2015 002482 T5 (DENSO CORP [JP]) 2 March 2017 (2017-03-02) paragraphs [0020] - [0025], [0045], [0071] - [0076]; figures -----	1-19
A	DE 197 45 427 A1 (VALEO CLIMATISATION [FR]) 30 April 1998 (1998-04-30) the whole document -----	1-19
A	US 5 579 994 A (DAVIS JR LEIGHTON I [US] ET AL) 3 December 1996 (1996-12-03) column 4; figures 2-5 -----	1-19
	-/--	

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
12 February 2021	22/02/2021
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Authorized officer Chavel, Jérôme

2

Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2020/063358

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2020/063358

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