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United States Patent	12392529
Kind Code	B2
Date of Patent	August 19, 2025
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Air distribution system and method including a thermocouple device

Abstract

An air distribution system and method and an associated climate control device are provided for an aircraft in order to allow for more granular control of the temperature of the conditioned air distributed through the cabin of the aircraft. In one example, an air distribution system and method are configured to provide for individual temperature control within different zones of an aircraft, such as by associating a thermocouple device with a respective air distribution subsystem that delivers conditioned air to a respective zone. In another example, a climate control device is configured to allow individualized temperature control of the air discharged through a vent by associating a thermocouple device with the respective vent, thereby allowing for individual temperature control for a passenger onboard the aircraft.

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Appl. No.: **16/890698**

Filed: **June 02, 2020**

Prior Publication Data

Document Identifier	Publication Date
US 20210318036 A1	Oct. 14, 2021

Foreign Application Priority Data

IN	202011015959	Apr. 13, 2020

Publication Classification

Int. Cl.: **F25B21/04** (20060101); **B64D13/06** (20060101)

U.S. Cl.:

CPC **F25B21/04** (20130101); **B64D13/06** (20130101); B64D2013/0655 (20130101); F25B2321/0251 (20130101)

Field of Classification Search

CPC: F25B (21/04); F25B (2321/0251); B64D (13/06); B64D (2013/0655)

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Background/Summary

TECHNOLOGICAL FIELD

(1) An example embodiment of the present disclosure relates generally to an air distribution system and method and, more particularly, to an air distribution system and method that includes a

thermocouple device.

BACKGROUND

(2) Air distribution systems for controlling the temperature of a space oftentimes include a centralized source of conditioned air and a distribution network, such as a network of ducts, to distribute the conditioned air throughout the space. The temperature of the conditioned air is generally regulated by the source such that air of the same temperature is provided throughout the space. Thus, separate regulation of the temperature in different regions of a space is typically not provided if the conditioned air that is provided to the different regions originates with a common source.

(3) By way of example, commercial aircraft may include an air distribution system that routes conditioned air from a centralized source, through a plurality of air distribution subsystems to a plurality of vents through which the air is discharged. The temperature of the air is regulated at the source such that air of the same temperature is typically discharged through each vent. This provision of air having the same temperature throughout the cabin of an aircraft does not allow for individual temperature control by the passengers and, as such, does not readily accommodate the different temperatures that may be experienced in different regions of the cabin and the different temperature preferences of the passengers. Instead, passengers are commonly limited to controlling the quantity of air flow through the vent associated with their passenger seat without any ability to control the temperature of the air discharged through the vent. Moreover, while passengers who are cold-natured may dress warmly and/or use blankets, jackets or the like to stay warm onboard an aircraft, warm-natured passengers lack similar techniques to remain cool while onboard the aircraft.

BRIEF SUMMARY

(4) An air distribution system and method and an associated climate control device are provided for an aircraft in order to allow for more granular control of the temperature of the conditioned air distributed through the cabin of the aircraft. In an example embodiment, the air distribution system and method are configured to provide for individual temperature control within different zones of an aircraft. In another example embodiment, a climate control device is configured to allow individualized temperature control of the air discharged through a vent, thereby allowing for individual temperature control for a passenger onboard the aircraft. By providing for more individualized control with respect to the air temperature onboard an aircraft, passengers may be more comfortable and have an improved experience.

(5) In an example embodiment, an air distribution system is provided for an aircraft. The air distribution system includes a plurality of air distribution subsystems configured to separately provide conditioned air to different zones of the aircraft. At least one zone of the aircraft includes at least a passenger compartment including a plurality of seats and a plurality of associated air vents through which the respective air distribution subsystem delivers conditioned air to the passengers. The air distribution system also includes a plurality of thermocouple devices. Each thermocouple device is associated with a different respective air distribution subsystem. The air distribution system further includes a controller configured to separately control operation of the plurality of thermocouple devices in order to provide for individual temperature control within the different zones. The controller is configured to control at least one of a polarity or a magnitude of a voltage applied to a respective thermocouple device.

(6) At least one of the thermocouple devices of an example embodiment includes a thermocouple material having first and second opposed surfaces and first and second heat sinks in thermal communication with the first and second surfaces of the thermocouple material, respectively. In this example embodiment, the first surface of the thermocouple material may be maintained at a first temperature and the second surface of the thermocouple material may be maintained at a second temperature. The first temperature is greater than the second temperature. In this example embodiment, at least one of the thermocouple devices also includes a fan configured to circulate air across the thermocouple material. At least one of the thermocouple devices of an example

embodiment is a Peltier device. The air distribution system of an example embodiment also includes a power supply configured to provide the voltage to the respective thermocouple device. In an example embodiment, a respective air distribution subsystem for a respective zone includes a plurality of ducts that deliver conditioned air to different portions of the respective zone.

(7) In another example embodiment, a method is provided for distributing conditioned air throughout an aircraft. The method includes separately providing conditioned air through a plurality of air distribution subsystems to different zones of the aircraft. At least one zone of the aircraft includes at least a portion of the passenger compartment including a plurality of seats and a plurality of associated vents through with the respective air distribution subsystem delivers conditioned air to the passengers. The method also includes individually modifying the temperature of the air provided through the plurality of air distribution subsystems to the different zones of the aircraft by causing the air provided by a respective air distribution subsystem to be in thermal communication with a respective one of a plurality of thermocouple devices. The method further includes separately controlling operation of the plurality of the thermocouple devices in order to provide for individual temperature control within the different zones. By controlling the operation of a respective thermocouple device, the method controls at least one of a polarity or a magnitude of a voltage applied to the respective thermocouple device.

(8) The method of an example embodiment also includes providing the plurality of thermocouple devices with at least one of the thermocouple devices including a thermocouple material having first and second opposed surfaces and first and second heat sinks in thermal communication with the first and second surfaces of the thermocouple material, respectively. In this example embodiment, the method may control operation of the respective thermocouple device by maintaining the first surface of the thermocouple material at a first temperature and maintaining the second surface of the thermocouple material at a second temperature. The first temperature is greater than the second temperature. The method of this example embodiment may control operation of the respective thermocouple device by causing a fan to circulate air across the thermocouple material. At least one of the thermocouple devices of an example embodiment includes a Peltier device. The method of an example embodiment may provide conditioned air by providing conditioned air to a respective zone via a respective air distribution subsystem that includes a plurality of ducts that deliver conditioned air to different portions of the respective zone.

(9) In a further example embodiment, a climate control device is provided for an aircraft. The climate control device includes a thermocouple device that includes a thermocouple material having first and second opposed surfaces. The thermocouple device also includes first and second heat sinks in thermal communication with the first and second surfaces of the thermocouple material, respectively. The first surface of the thermocouple material is maintained at a first temperature and the second surface of the thermocouple material is maintained at a second temperature in response to electrical actuation by a power supply. The first temperature is greater than the second temperature. The climate control device also includes a passenger air duct configured to deliver conditioned at to a passenger onboard the aircraft. The first surface of the thermocouple material and the first heat sink are in thermal communication with air passing through the passenger air duct. The climate control device also includes a return air duct. The second surface of the thermocouple material and the second heat sink are in thermal communication with air passing through the return air duct.

(10) The thermocouple device of an example embodiment includes a Peltier device. The climate control device of an example embodiment also includes the power supply configured to provide the electrical actuation to the thermocouple material. In this example embodiment, the climate control device may also include a controller configured to control a polarity and/or a magnitude of a voltage delivered by the power supply to the thermocouple material. The thermocouple device of an example embodiment also includes a fan configured to circulate air across the thermocouple

material. In an example embodiment, the passenger air duct is configured to deliver the conditioned air via a single vent associated with a respective passenger onboard the aircraft.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

(1) Having thus described certain example embodiments of the present disclosure in general terms, reference will hereinafter be made to the accompanying drawings, which are not necessarily drawn to scale, and wherein:

(2) FIG. **1** is a schematic representation of an aircraft depicting an air distribution system having a plurality of air distribution subsystems for separately providing conditioned air to different zones of the aircraft in accordance with an example embodiment of the present disclosure;

(3) FIG. **2** depicts a plurality of ducts that form an air distribution subsystem of an example embodiment;

(4) FIG. **3** depicts a subset of the plurality of ducts of FIG. **2** that distribute condition air to individual seats within a respective zone of the aircraft in accordance with an example embodiment;

(5) FIG. **4** is a block diagram of an air distribution system of an example embodiment;

(6) FIG. **5** is a flowchart illustrating the operations performed to modify an air distribution system in accordance with an example embodiment;

(7) FIG. **6** is a flowchart illustrating operations performed, such as by the air distribution system of FIG. **4**, in accordance with an example embodiment;

(8) FIGS. **7**A and **7**B are a side view and a cross-sectional view of a thermocouple device with a first heat sink disposed in a passenger air duct and a second heat sink disposed in a return air duct in accordance with an example embodiment;

(9) FIG. **8** is a block diagram of a climate control device in accordance with an example embodiment; and

(10) FIG. **9** is a schematic representation of a control device in an accordance with an example embodiment.

DETAILED DESCRIPTION

(11) The present disclosure now will be described more fully hereinafter with reference to the accompanying drawings, in which some, but not all aspects are shown. Indeed, the disclosure may be embodied in many different forms and should not be construed as limited to the aspects set forth herein. Rather, these aspects are provided so that this disclosure will satisfy applicable legal requirements. Like numbers refer to like elements throughout.

(12) An air distribution system and method as well as an associated climate control device are provided in order to allow for more individualized regulation of the temperature of the conditioned air discharged, in one embodiment, to a zone or, in another embodiment, through a vent, such as a vent in association with a respective seat. As shown in FIG. **1**, the air distribution system **10** and method may be deployed onboard an aircraft **12** in order to pressurize the cabin **14** and to regulate the temperature of the cabin. The air distribution system **10** includes a source **16** of conditioned air that is then distributed throughout the cabin **14** including throughout the cockpit **18** and the passenger compartment **20**.

(13) The source **16** of conditioned air onboard an aircraft **12** may be embodied in a variety of manners. In an example embodiment, the source **16** includes one, two or more air conditioning packs that produce a sufficient quantity of air having a desired temperature to maintain a desired cabin **14** environment.

(14) The air distribution system **10** includes a plurality of air distribution subsystems **22** configured to separately provide conditioned air from the source **16** to different zones **24** of the aircraft **12**. In

the illustrated embodiment, the air distribution system **10** includes six air distribution subsystems **22**, one of which provides conditioned air to the cockpit **18** and five of which provide conditioned air to different zones **24** of the passenger compartment **20**. The number of air distribution subsystems **22** and, as a result, the number of different zones **24** can be varied in order to provide more or fewer zones onboard the aircraft **12** and may be dependent upon the type of aircraft, the size of the aircraft, the layout or configuration of the aircraft or other factors. Correspondingly, the relative locations of the zones **24** and the relative sizes of the different zones within the cabin **14**, such as within the passenger compartment **20**, may also be varied with the air distribution subsystems **22** and the corresponding zones of FIG. **1** depicted by way of illustration, but not of limitation. Regardless of the number of air distribution subsystems **22**, the source **16** of the conditioned air may include one or more manifolds **26** in order to separately provide the conditioned air to the plurality of air distribution subsystems.
(15) An air distribution subsystem **22** generally includes a plurality of ducts **28** that deliver conditioned air to different portions of the respective zone **24**. The ducts **28** that comprise the air distribution subsystem **22** may be of different types and may be configured in different manners depending upon the relative locations of the source **16** of the conditioned air and the zone **24** to which the conditioned air is to be provided by the respective air distribution subsystem, as well as the size and configuration of the zone within the aircraft **12** that the air distribution subsystem is to service.
(16) Although a plurality of air distribution subsystems **22** having a plurality of ducts **28** are schematically depicted in FIG. **1** by way of example, one of the air distribution subsystems is illustrated in more detail than FIG. **2**, again by way of example, but not of limitation. As shown in FIG. **2**, this example of an air distribution subsystem **22** includes a primary duct **28***a* that carries the conditioned air from the source **16** of the conditioned air, such as from the manifold **26** of FIG. **1** that provides the conditioned air to the respective air distribution subsystem, to a location within or at least closer to the zone **24** within the cabin **14** to which the conditioned air is to be provided. The air distribution subsystem **22** of the illustrated embodiment also includes a plurality of secondary ducts **28***b* in fluid communication with the primary duct **28***a*. The secondary ducts **28***b* extend from the primary duct **28***a* to different locations within or proximate the zone **24** to which the conditioned air is to be distributed. In the embodiment depicted in FIG. **2**, the secondary ducts **28***b* branch outwardly from the primary duct **28***a* at different locations along the primary duct. However, all of the secondary ducts **28***b* may alternatively be connected to and branch outwardly from the same portion of the primary duct **28***a*, such as from a distal end of the primary duct, opposite the source **16**. In the illustrated embodiment, the air distribution subsystem **22** also includes one or more tertiary ducts **28***c* that are in fluid communication with a respective secondary duct **28***b* and that extend to different regions within the zone **24**.
(17) By way of example, a zone **24** onboard an aircraft **12** may include a portion of the passenger compartment **18** that includes two rows **38** of passenger seats with each row including four seats **39***a*, **39***b*, **39***c*, **39***d*, as shown in FIG. **3**. The air distribution subsystem **22** that serves an example zone **24** may include one primary duct **28***a* that splits into two secondary ducts **28***b*, each of which supplies air to one row **38** of passenger seats **39***a*, **39***b*, **39***c*, **39***d*. In order to separately deliver conditioned air via the vents **30** associated with each seat **39***a*, **39***b*, **39***c*, **39***d* of a respective row **38**, the air distribution subsystem **22** of this example embodiment may include four tertiary ducts **28***c* that extend from each respective secondary duct **28***b* to the vents associated with respective seats within the row served by the respective secondary duct. Thus, the primary duct **28***a* of this example of an air distribution subsystem **22** is configured to carry the conditioned air from the source **16** toward the zone **24** of the aircraft **12** to which the conditioned air will be discharged, while the secondary ducts **28***b* are configured to carry the conditioned air to different regions within the zone of the aircraft and the tertiary ducts **28***c* are configured to carry the conditioned air to individual vents **30** of the aircraft, such as the vents associated with respective passenger seats

39*a*, **39***b*, **39***c*, **39***d* through which the conditioned air will be discharged. It is noted, however, that the air distribution subsystem **22** depicted in FIGS. **2** and **3** and described herein is provided by way of an example, but not as a limitation as the number and type of ducts that comprise a respective air distribution subsystem may be varied in other embodiments.

(18) The air distribution system **10** also includes one or more thermocouple devices **32** configured to controllably regulate the temperature of the air that is proximate to, in the vicinity of or otherwise passing by the thermocouple device. In one embodiment, a thermocouple device **32** is associated with a respective air distribution subsystem **22** and, as a result, is configured to regulate the temperature of the conditioned air discharged by the air distribution subsystem throughout the zone **24** of the aircraft **12** serviced by the respective air distribution subsystem. In this example embodiment, the air distribution system **10** includes a plurality of thermocouple devices **32**, at least one of which is associated with each respective air distribution subsystem **22**. In order to provide for uniform regulation of temperature within a zone **24** but separate regulation between the zones, the thermocouple devices(s) **32** of a respective air distribution subsystem **22** of an example embodiment may be associated with, e.g., positioned within, the primary duct **28***a* of the air distribution subsystem as indicated by the location designated **32***a* in FIG. **2** and/or upstream of the secondary ducts **28***b*. Alternatively, a plurality of thermocouple devices **32** may be associated with, e.g., positioned within, the ducts downstream of the primary duct **28***a*, such as at locations designated **32***b* and **32***c* within the secondary and tertiary ducts **28***b*, **28***c*, respectively, with each of the thermocouple devices of the air distribution subsystem **22** controlled to regulate the temperature delivered throughout the zone in the same manner. In either of these embodiments, since each thermocouple device **32** may be separately controlled in order to individually regulate the temperature of the air in thermal communication with a respective thermocouple device, the air distribution system **10** of this example embodiment provides for separate temperature control of the different zones **24** within the cabin **14** of an aircraft **12**, while maintaining a uniform temperature within a respective zone.

(19) FIG. **4** is a block diagram of an air distribution system **10** having a plurality of air distribution subsystems **22** and a plurality of thermocouple devices **32**, each of which is associated with a different respective air distribution subsystem. As shown in FIG. **4**, the air distribution system **10** of this example embodiment also includes a controller **34** configured to separately control operation of the plurality of thermocouple devices **32**. By providing for separate control of the thermocouple devices **32**, the controller **34** is configured to provide, in one embodiment, for individual temperature control within the different zones **24** of the aircraft **12** or, in another embodiment, for individual temperature control of the air delivered via the different vents **30** associated with the passenger seats. As described below, the controller **34** is configured to separately control at least one of a polarity and/or a magnitude of a voltage applied to the different thermocouple devices.

(20) The controller **34** may be embodied in various manners, such as by being embodied by one or more microprocessors, one or more coprocessors, one or more multi-core processors, one or more controllers, one or more computers, various other processing elements including integrated circuits or other specially configured hardware such as, for example, an ASIC (application specific integrated circuit) or FPGA (field programmable gate array), or some combination thereof for conducting one or more operations described herein. In some example embodiments, the controller **34** is configured to execute instructions stored in a memory device or otherwise accessible thereto in order to perform one or more of the functionalities described herein.

(21) A method **40** of modifying an air distribution system **10** of an aircraft **12** to facilitate temperature control is depicted in FIG. **5** in accordance with an example embodiment. As shown in block **42**, a plurality of thermocouple devices **32** are installed in association with different air distribution subsystems **22**. For example, the plurality of thermocouple devices **32** may be installed in different ducts **28**, such as different secondary ducts **28**b or different tertiary ducts **28**c so as to appropriately and independently condition the air passing therethrough. As shown in block **44**, the

thermocouple devices **32** are then operably connected to a controller **34**. As shown in blocks **46**, the controller **34** may also be operably connected to one or more fans **36** to control the flow of air over one or more thermocouple devices **32**. The controller **34** may also be operably connected to a power supply **72** that is configured to provide voltage, under control of the controller, to the plurality of thermocouple devices **32**. See block **48**. Further, as shown in block **49**, the controller **34** is configured to separately control operation of the plurality of thermocouple devices **32**. By configuring the controller **34** to separately control the thermocouple devices **32**, such as by configuring the controller to separately control at least one of the polarity and/or the magnitude of a voltage applied to the respective thermocouple devices, the controller may be configured to independently control the heating or cooling provided by the different thermocouple devices.
Referring now to Figure **6**, a method **50** performed, such as following construction and during operation of the air distribution system **10** of FIG. **4**, is illustrated. As shown in block **42**, conditioned air is separately provided through a plurality of air distribution subsystems **22** to different zones **24** of an aircraft **12**. As also described above, at least one zone **24** of the aircraft **12** includes a portion of the passenger compartment **20** including a plurality of seats and a plurality of associated air vents **30** through which the respective air distribution subsystem **22** delivers conditioned air to the passengers.

(22) As shown in block **54** of FIG. **6**, the temperature of the air provided through the plurality of air distribution subsystems **22** to the different zones **24** of the aircraft **12** is individually modified. In this regard, the temperature of the air provided by a respective air distribution subsystem **22** is caused to be in thermal communication with a respective one of the plurality of thermocouple devices **32** which, in turn, is capable of modifying the temperature of the air prior to discharge within the respective zone **24** of the aircraft **12**. With reference to block **56** of FIG. **6**, the operation of the plurality of thermocouple devices **32** is separately controlled in order to provide for individual temperature control of the different zones **24**. In this regard, the operation of a respective thermocouple device **32** may be controlled by controlling, such as with a controller **34**, at least one of the polarity and/or the magnitude of a voltage applied to the respective thermocouple device.

(23) Although a thermocouple device **32** may be configured in different manners, one example of the thermocouple device is depicted in FIGS. **7**A and **7**B. In this example embodiment, the thermocouple device **32** may be a Peltier device. However, the other types of thermocouple devices **32** may be employed in accordance with other example embodiments of the present disclosure. In the illustrated embodiment, the thermocouple device **32** includes a thermocouple material **58**, such as comprised of two dissimilar electrically conductive materials that form an electrical junction, having first and second opposed surfaces **60***a*, **60***b*, such as first and second opposed major surfaces. The thermocouple device **32** of the illustrated embodiment also includes first and second heat sinks **62***a*, **62***b* in thermal communication with the first and second surfaces **60***a*, **60***b* of the thermocouple material **58**, respectively. The heat sinks **62***a*, **62***b* may be configured in different manners and, in one embodiment, may include a plurality of fins **64***a*, **64***b* to facilitate heat transfer. Although the fins **64***a*, **64***b* of a heat sink may be configured in various manners, the heat sinks **62***a*, **62***b* may include folded fins that are bonded, brazed or soldered to the respective surface **60***a*, **60***b* of the thermocouple material **58**. The fins **64***a*, **64***b* of a heat sink **62***a*, **62***b* may be formed of any of a variety of thermally conductive materials including, for example, aluminum, copper or carbon based materials. In other example embodiments, the heat sinks **62***a*, **62***b* may include heat pipes, thermosiphons, heat spreaders or the like and/or may be disposed in vapor chambers to facilitate the thermal capacity of the heat sinks.

(24) The thermocouple device **32** and, in particular, the thermocouple material **58** is responsive to electrical actuation, such as provided by a power supply **72** (see FIG. **8**). In this regard, in response to a voltage applied by the power supply and the resulting current through the thermocouple material **58**, a temperature differential will be created between the first and second opposed surfaces **60***a*, **60***b* of the thermocouple material. For example, a voltage of a first polarity, such as a

positive voltage, may cause the first surface **60***a* to be heated and the second surface **60***b* to be cooled such that the first surface of the thermocouple material is maintained at a first temperature and the second surface of the thermocouple material is maintained at a second temperature with the first temperature being greater than the second temperature. Conversely, a voltage of a second polarity, such as a negative voltage, may cause the first surface **60***a* to be cooled and the second surface **60**b to be heated such that the first surface of the thermocouple material is maintained at a first temperature and the second surface of the thermocouple material is maintained at a second temperature with the first temperature being less than the second temperature. Thus, the polarity of the voltage controls which surface is heated and which surface is cooled.

(25) By varying the magnitude of the voltage applied to the thermocouple material **58**, the extent of the temperature differential and, as a result, the first and second temperatures at which the first and second opposed surfaces **60***a*, **60***b*, respectively, are maintained may be modified. For example, by increasing the magnitude of the voltage of the first polarity applied to the thermocouple material **58**, the first temperature at which the first surface **60***a* is maintained may be increased and the second temperature at which the second surface **60***b* is maintained is decreased. Alternatively, by reducing the magnitude of the voltage applied to the thermocouple material **58**, the first temperature at which the first surface **60***a* is maintained may be decreased, while the second temperature at which the second surface **60***b* is maintained may be increased, thereby reducing the temperature differential therebetween although the first temperature continues to be greater than the second temperature in this example embodiment. As the foregoing examples demonstrate, the thermocouple device **32** of an example embodiment may be configured such that the temperature of both of the opposed surfaces **60***a*, **60***b* are altered with one surface increasing in temperature and the other temperature decreasing in temperature. Not only may the temperatures of the opposed surfaces both be altered in opposite directions, but the temperatures of the opposed surfaces may be altered in an inversely proportional manner, that is, by equal, but opposite amounts, e.g., +5 degrees for the first surface **60***a* and −5 degrees for the second surface **60***b*. By switching the polarity of the voltage applied to the thermocouple material **58**, such as by applying a negative voltage to the thermocouple material, a temperature differential is still established between the first and second opposed surfaces **60***a*, **60***b* of the thermocouple material, but the second temperature at which the second surface is maintained is now greater than the first temperature at which the first surface is maintained.

(26) The thermocouple device **32** may be associated with a passenger air duct, such as a duct of an air distribution subsystem **22**, that provides conditioned air to a passenger or crew member. In an example embodiment in which the air distribution system **10** provides for zone-based temperature regulation, the thermocouple device **32** may be associated with, such as by being at least partially positioned within an air duct, such as a primary air duct **28***a*, e.g., at location **32***a*, that delivers the conditioned air for the entire zone. As shown in FIGS. **7**A and **7**B, the thermocouple device may be configured such that the first heat sink **62***a* and, in some embodiments, the first surface **60***a* are disposed within or at least in thermal communication with the air passing through the passenger air duct. In this example embodiment, the first temperature at which the first surface **60***a* of the thermocouple material **58** is maintained may be controlled as described below in order to correspondingly modify the temperature of the air flowing through the primary air duct and across the first surface and the first heat sink of the thermocouple device **32**. Thus, in an instance in which the first temperature at which the first surface **60***a* of the thermocouple material **58** is maintained is greater than the temperature of the conditioned air, the temperature of the conditioned air is increased prior to delivery to the respective zone **24**, the respective vent **30** associated with a passenger seat or the like. Alternatively, in an instance in which the first temperature at which the first surface **60***a* is maintained is less than the temperature of the conditioned air, the temperature of the conditioned air is reduced prior to delivery to the respective zone **24** or the respective vent **30** associated with a passenger seat.

(27) The opposite surface of the thermocouple material **58**, that is, the surface of the thermocouple material that is not exposed to the conditioned air being delivered to the zone **24** within the aircraft **12**, such as the second surface **60***b* of the thermocouple material, is configured to dissipate the heat generated thereby. In this regard, the second heat sink **62***b* may be in thermal communication with a thermal mass, that is, the thermal capacity of the material forming the second heat sink to store thermal energy, sufficient to discharge the heat generated thereby. Alternatively, as shown in FIGS. **7**A and **7**B, the air distribution system **10** may include a return air duct **74** and the second surface **60***b* of the thermocouple material **58** and the second heat sink **62***b* may be in thermal communication with the air passing through the return air duct. The return air duct **74** serves to recirculate air for ventilation. In this example embodiment, the air passing through the return air duct **74** dissipates the heat generated by the second surface **60***b* of the thermocouple material **58** and withdrawn by the second heat sink **62***b*. Thus, the thermocouple device **32** may remain operational by appropriately managing the temperature of the thermocouple device with heat generated by one surface of the thermocouple material **58**, such as the first surface **60***a*, being utilized to regulate the temperature of the air supplied to the respective zone **24** of the cabin **14** of the aircraft **12**, while the heat generated via the opposite surface, such as the second surface **60***b* of the thermocouple material, is dissipated by air being discharge through the return air duct **74**.
(28) In an example embodiment depicted in FIG. **8**, a climate control device **70** is provided that includes the thermocouple device **32** as well as a power supply **72** and, in some example embodiments, a controller **34**. As described above, the power supply **72** is configured to provide the electrical actuation to the thermocouple material **58**, with the controller **34** being configured to provide a control signal so as to control the polarity and/or the magnitude of the voltage delivered by the power supply to the thermocouple material. The controller **34** may be embodied as described above. In other embodiments, however, the controller **34** may be embodied by a control device that enables a person, such as a passenger, a crew member or the like, to set the desired temperature to a zone **24**, to a vent **30** for discharge to a passenger seat or the like. For example, the control device may be a manual knob as described below that may be turned in opposite directions to increase or decrease the temperature. Alternatively, the control device may be embodied by a user interface that permits a passenger, a crew member of the like to input the desired temperature of the air that is provided to a zone, to a passenger or the like. Still further, the control device may include a temperature sensor that senses the temperature of the a zone **24**, of the air delivered via a vent **30** or the like and an associated feedback circuit that provides control signals in response to the sensed temperature in order to controllably increase or decrease the temperature of the air in order to cause the temperature to be adjusted to a desired temperature level.
(29) As such, in an embodiment in which the thermocouple device **32** is associated with a zone **24** of an aircraft **12**, such as by being positioned at least partially within an air duct, such as a primary air duct **28***a*, that delivers the conditioned air for the entire zone, the first temperature at which the first surface **60***a* of the thermocouple material **58** is maintained may be modified, such as by input via a control device provided by a crew member. Thus, the temperature of the air flowing through the primary air duct **28***a* may be correspondingly regulated based upon the temperature of the first surface **60***a* and the first heat sink **62***a* of the thermocouple device **32**, as modified by crew member input.
(30) In the embodiment described above, the thermocouple device **32** is positioned, such as at location **32***a* in a primary duct **28***a* of an air distribution subsystem **22**, so as to allow for common regulation of the temperature within a zone **24**. In another embodiment, however, the thermocouple device **32** is positioned further downstream relative to an air distribution subsystem **22** and is associated with and configured to allow for the individual control the temperature of the conditioned air discharged via a respective vent **30**, such as a vent associated with a respective passenger seat onboard the aircraft **12**. Thus, the air distribution system **10** of this example embodiment includes a plurality of thermocouple devices **32** associated with different vents **30**

onboard the aircraft **12**, such as by including one or more of the plurality of thermocouple devices in association with, e.g., positioned within, a tertiary duct **28***c* that supplies air to a respective one of the vents, such as at a location designated **32***c* in FIG. **2**. Since each thermocouple device **32** of this example embodiment may be separately controlled, such as by controller **34**, in order to individually regulate the temperature of the air in thermal communication with a respective thermocouple device. The air distribution system **10** of this example embodiment therefore provides for individualized control of the temperature of the conditioned air discharged through the vents **30**, such as by permitting individualized temperature control by each respective passenger onboard an aircraft **12**, such as via a respective control device **60** as shown, for example, in FIG. **8**.

(31) In an embodiment in which the thermocouple device **32** is associated with a vent **30** which, in turn, is associated with a respective passenger seat, a plurality of climate control devices **70**, with each coupled to a respective thermocouple device **32**, enables each passenger individualized control of the air temperature for their respective seat. As such, the passenger of this example embodiment is enabled to regulate the temperature of the air provided via the vent **30** associated with the passenger seat, such as by providing input via a control device, such as a rotatable knob **80** as shown in FIG. **9**. As described above and as shown in FIGS. **7**A and **7**B, the first surface **60***a* of the thermocouple material **58** and the first heat sink **62***a* may be in thermal communication with air passing through the passenger air duct, such as a tertiary duct **28***c*. As such, the resulting first temperature of the first surface **60***a* of the thermocouple material **58** causes the temperature of the conditioned air delivered to the passenger to be correspondingly modified, such as by increasing the temperature of the air delivered to the passenger in an instance in which the first temperature is greater than the temperature of the air supplied by the source **16** or by decreasing the temperature of the air delivered to the passenger in an instance in which the first temperature is less than the temperature of the air supplied by the source. As also described and as shown in FIGS. **7**A and **7**B, the second surface **60***b* of the thermocouple material **58** and the second heat sink **62***a* may be in thermal communication with air passing through a return air duct **74** in order to remove heat from the second surface.

(32) As noted above, either in conjunction with the control of the temperature of the air delivered to a respective passenger or a respective zone or more generally to the cabin **14** in an embodiment that employs centralized air, the controller **34** may be embodied by a feedback circuit that may be utilized to provide control signals in response to a sensed temperature in order to controllably increase or decrease the temperature of the air in order to cause the temperature to be adjusted to a desired and consistent temperature level. In terms of centralized temperature control, the temperature of the air delivered to locations closer to the source **16** of the air may be of a different, e.g., greater, temperature than the temperature of the air delivered to locations much further from the source. By sensing the temperature of the air delivered to different portions of the cabin **14**, a feedback circuit of the controller **34** may control the operation of one or more thermocouple devices **32** in order to regulate the temperature of the air throughout the cabin so as to maintain the temperature more consistent. For example, the thermocouple device(s) may be responsive to a feedback circuit of the controller **34** to control the temperature of the air delivered to locations further from the source, such as by increasing the air temperature so as to be consistent, e.g., approximately the same, with the temperature of the air delivered to locations closer to the source **16**.

(33) Another example of a controller **34** and, more particularly, a control device that may be utilized to control the temperature of the air delivered to a zone or delivered to a particular passenger is depicted in FIG. **9**. As shown, the control device of this example embodiment includes a knob **80** that may be manually turned clockwise or counterclockwise from a neutral (N) position in which the thermocouple device **32** is inactive to increase or decrease, respectively, the temperature of the air. In addition to merely increasing or decreasing the air temperature, the magnitude of the increase or decrease is also controlled by the extent of the rotation of the knob **80**.

Relative to the scale provided by FIG. **9**, rotation of the knob **80** to be aligned with greater numbers, e.g., **4** or **5**, on the scale provides for a greater increase or decrease in the air temperature than rotation of the knob to be in alignment with smaller numbers, e.g., **1** or **2**, on the scale.
(34) In terms of operation, the control device of FIG. **9** controls the voltage delivered to the thermocouple device **32** from the power supply **72**, embodied as a voltage source **82** in this example embodiment. In particular, the control device includes a switch **84**, such as a relay switch, to switch the polarity of the voltage delivered to the thermocouple device **32** depending upon the direction, that is, clockwise or counterclockwise, that the knob **80** is rotated. For example, the switch **84** may be configured to cause a positive voltage to be delivered to the thermocouple device **32** in an instance in which the knob **80** is rotated in a clockwise direction so as to increase the air temperature that is delivered. Conversely, the switch **84** may be configured to cause a negative voltage to be delivered to the thermocouple device **32** in an instance in which the knob **80** is rotated in a counterclockwise direction so as to decrease the air temperature that is delivered.
(35) The control device of this example embodiment also includes a voltage regulator **86**, such as a variable resistor, to control the magnitude of the voltage delivered to the thermocouple device **32** depending upon the extent to which the knob **80** is rotated. In this regard, in response to smaller angular rotations of the knob **80**, the voltage regulator **86** may introduce a smaller resistance to allow the magnitude of the voltage delivered to the thermocouple device **32** to be larger. Conversely, in response to larger angular rotations of the knob **80**, the voltage regulator **86** may introduce a larger resistance to allow the magnitude of the voltage delivered to the thermocouple device **32** to be smaller. Thus, the control device of the example of FIG. **9** permits the temperature of the air that is delivered to be selectively controlled.
(36) As shown in FIGS. **2** and **7**A, the air distribution system **10** of an example embodiment includes one or more fans **36** positioned in respective ducts **28** in order to facilitate circulate of air therethrough. In relation to the air distribution system **10** including one or more thermocouple devices **32**, the thermocouple devices may impede the flow of air through the respective duct **28**. Thus, a fan **36** may be positioned upstream of a thermocouple device **32** as shown in solid lines to force air through the thermocouple device, and/or downstream of the thermocouple device as shown in dashed lines in FIG. **2** to pull air through the thermocouple device. Similarly, with reference to FIG. **7**A, a fan **36** may be positioned upstream and/or downstream of a thermocouple device **32** as shown in solid and dashed lines, respectively, in order to facilitate air flow through the thermocouple device.
(37) As described an air distribution system **10** and method and an associated climate control device **70** are provided for an aircraft **12** to allow for more granular control of the temperature of the conditioned air distributed through the cabin **14** of the aircraft. As such, passengers and crew members may be more comfortable and have an improved experience onboard the aircraft **12**.
(38) Many modifications and other aspects of the disclosure set forth herein will come to mind to one skilled in the art to which this disclosure pertains having the benefit of the teachings presented in the foregoing descriptions and the associated drawings. For example, although described herein with respect to a single thermocouple device **32** positioned within a respective air duct, the air distribution system **10** of other example embodiments may include a plurality of thermocouple devices positioned within a respective air duct, either at the same location within the air duct or at different locations with the air duct, and configured to collectively regulate the temperature of the air passing therethrough in the manner described herein. Therefore, it is to be understood that the disclosure is not to be limited to the specific aspects disclosed and that modifications and other aspects are intended to be included within the scope of the appended claims. Although specific terms are employed herein, they are used in a generic and descriptive sense only and not for purposes of limitation.

Claims

1. An air distribution system for an aircraft, the air distribution system comprising: a source of air; a plurality of air distribution subsystems, wherein each air distribution subsystem of the plurality of air distribution subsystems is associated with a corresponding zone of a plurality of zones of the aircraft, wherein each zone of the plurality of zones comprises a plurality of passenger seats, wherein each air distribution subsystem of the plurality of air distribution subsystems is configured to receive air from the source of air and provide conditioned air to the corresponding zone of the plurality of zones, wherein each air distribution subsystem of the plurality of air distribution subsystems comprises a plurality of air vents, and wherein each air vent of the plurality of air vents of a corresponding air distribution subsystem of the plurality of air distribution subsystems delivers a corresponding portion of the air to a corresponding single passenger seat of the plurality of passenger seats of the corresponding zone of the plurality of zones; a plurality of thermocouple devices, wherein each thermocouple device of the plurality of thermocouple devices is configured to interact with the corresponding portion of the air delivered from a corresponding air vent of the plurality of air vents of a corresponding air distribution subsystem of the plurality of air distribution subsystems; and a controller configured to separately control operation of the plurality of thermocouple devices in order to provide for individual temperature control of the corresponding portion of the air delivered to each single passenger seat of the plurality of passenger seats of each zone of the plurality of zones, wherein the controller is configured to control at least one of a polarity or a magnitude of a voltage applied to each thermocouple device of the plurality of a thermocouple devices.
2. An air distribution system according to claim 1, wherein at least one of the thermocouple devices comprises: a thermocouple material having a first surface and a second surface opposing the first surface; and first and second heat sinks in thermal communication with the first surface and the second surface of the thermocouple material, respectively.
3. An air distribution system according to claim 2, wherein the first surface of the thermocouple material is maintained at a first temperature and the second surface of the thermocouple material is maintained at a second temperature, and wherein the first temperature is greater than the second temperature.
4. An air distribution system according to claim 3, wherein the first surface of the thermocouple material is maintained at the first temperature and the second surface of the thermocouple material is maintained at the second temperature in response to the controlled operation by the controller.
5. An air distribution system according to claim 2, wherein at least one of the thermocouple devices further comprises a fan configured to circulate air across the thermocouple material.
6. An air distribution system according to claim 2, wherein each air vent of the plurality of air vents is fluidically coupled with a corresponding passenger air duct of comprises a plurality of passenger air ducts, wherein the first surface of the thermocouple material and the first heat sink are in thermal communication with air passing through a corresponding passenger air duct of the plurality of passenger air ducts.
7. An air distribution system according to claim 6, wherein each thermocouple device of the plurality of thermocouple devices is located within a corresponding passenger air duct of the plurality of passenger air ducts.
8. An air distribution system according to claim 6, further comprising a return air duct, wherein the second surface of the thermocouple material and the second heat sink are in thermal communication with air passing through the return air duct.
9. An air distribution system according to claim 1, wherein the at least one of the polarity or the magnitude of the voltage comprises the magnitude of the voltage, wherein the air distribution system further comprises a power supply configured to provide the voltage to the plurality of

respective thermocouple devices.
10. An air distribution system according to claim 1, wherein each air distribution subsystem of the plurality of air distribution subsystems further comprises a plurality of ducts, wherein each air vent of the plurality of air vents is fluidically coupled with a corresponding duct of the plurality of ducts, and wherein each thermocouple device of the plurality of thermocouple devices is located within a corresponding duct of the plurality of ducts.
11. An air distribution system according to claim 1, wherein the source of air is a centralized source of air comprising a primary duct, and wherein each air distribution subsystems of the plurality of air distribution subsystems is configured to receive air from the centralized source via the primary duct.
12. An air distribution system according to claim 11, wherein a return air duct returns air to the centralized source.
13. A method for modifying an air distribution system of an aircraft to facilitate temperature control, the method comprising: installing a thermocouple device of a plurality of thermocouple devices in each air duct of a plurality of air ducts of an air distribution subsystem; receiving a corresponding portion of air from a source of air in each air duct of the plurality of air ducts; distributing the corresponding portion of air to a corresponding vent of a plurality of vents of the air distribution subsystem; delivering the corresponding portion of air from each vent of the plurality of vents to a corresponding single passenger seat of a plurality of passenger seats of the aircraft; operably connecting the plurality of thermocouple devices to a controller; and configuring the controller to separately control operation of the plurality of thermocouple devices in order to provide for individual temperature control of the corresponding portion of the air delivered to each single passenger seat of the plurality of passenger seats, wherein the controller is configured to control at least one of a polarity or a magnitude of a voltage applied to each thermocouple device of the plurality of the thermocouple devices.
14. A method according to claim 13, wherein at least one of the plurality of thermocouple devices comprises: a thermocouple material having a first surface and a second surface opposing the first surface; and first and second heat sinks in thermal communication with the first surface and the second surface of the thermocouple material, respectively.
15. A method according to claim 14, wherein the installing the thermocouple device of the plurality of thermocouple devices in each air duct of the plurality of air ducts comprises installing the thermocouple device such that the second surface of the thermocouple material of the thermocouple device and the second heat sink of the thermocouple device are in thermal communication with air passing through a return air duct.
16. A method according to claim 14, wherein the thermocouple device of the plurality of thermocouple devices is installed in each air duct of the plurality of air ducts such that the first surface of the thermocouple material and the first heat sink are in thermal communication with air passing through a corresponding air duct of the plurality of air ducts.
17. A method according to claim 13, further comprising operably connecting the controller to one or more fans to control circulation of air across the plurality of thermocouple devices.
18. A method according to claim 13, wherein at least one of the plurality of thermocouple devices comprises a Peltier device.
19. A method according to claim 13, wherein the at least one of the polarity or the magnitude of the voltage applied to the plurality of thermocouple device comprises the magnitude of the voltage applied to the plurality of thermocouple devices, wherein the method further comprises operably connecting the controller to a power supply that is configured to provide the voltage, under control of the controller, to each thermocouple device of the plurality of thermocouple devices.
20. A method according to claim 13, wherein the source of air is a centralized source of air comprising a primary duct, and the air distribution subsystem is configured to receive air from the centralized source via the primary duct.