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Office de la Propriété Intellectuelle du Canada

Innovation, Science and Economic Development Canada
Canadian Intellectual Property Office

CA 2921103 C 2021/06/15

(11)(21) **2 921 103**

(12) **BREVET CANADIEN**
CANADIAN PATENT

(13) **C**

(22) Date de dépôt/Filing Date: 2016/02/17
(41) Mise à la disp. pub./Open to Public Insp.: 2016/11/19
(45) Date de délivrance/Issue Date: 2021/06/15
(30) Priorité/Priority: 2015/05/19 (US14/716,409)

(51) Cl.Int./Int.Cl. *B64D 11/04* (2006.01)

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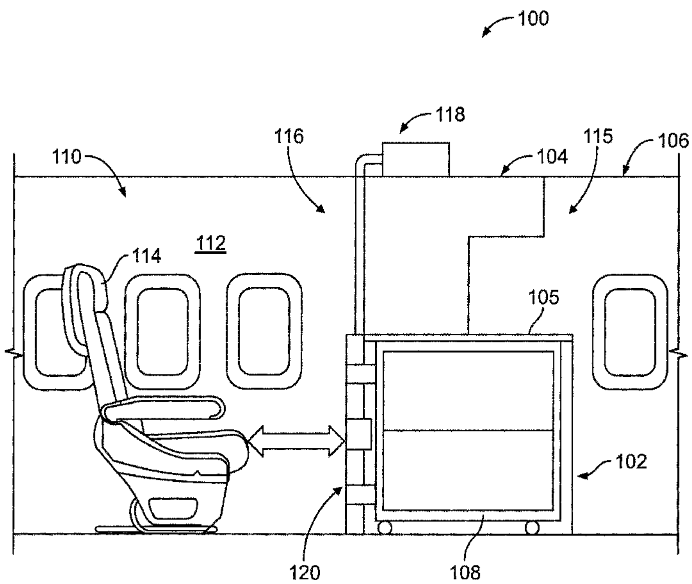
(54) Titre : SYSTEME DE REFRIGERATION D'OFFICE DANS UN AERONEF
(54) Title: GALLEY REFRIGERATION SYSTEM OF AN AIRCRAFT



(57) Abrégé/Abstract:
A galley refrigeration system includes a liquid heat exchange loop and an air heat exchange loop in thermal communication with the liquid heat exchange loop. The air heat exchange loop includes a heat exchanger configured to be coupled in flow communication with at least one galley cart. Optionally, the galley refrigeration system may include a control system in operative communication with the liquid heat exchange loop and the air heat exchange loop.

GALLEY REFRIGERATION SYSTEM OF AN AIRCRAFT

ABSTRACT

A galley refrigeration system includes a liquid heat exchange loop and an air heat exchange loop in thermal communication with the liquid heat exchange loop. The air heat exchange loop includes a heat exchanger configured to be coupled in flow communication with at least one galley cart. Optionally, the galley refrigeration system may include a control system in operative communication with the liquid heat exchange loop and the air heat exchange loop.

GALLEY REFRIGERATION SYSTEM OF AN AIRCRAFT

BACKGROUND

[0001] The present disclosure relates generally to systems and methods of refrigeration a galley of an aircraft.

[0002] Aircraft typically include multiple galleys to store food and beverages on the aircraft. The food and beverages are typically stored in galley carts which are transported to the aircraft and stored in refrigerated compartments or zones in the galleys. A refrigeration system is provided with heat exchanger at the top of the galley and air ducts and other components that supply cooled air from the heat exchanger to each of the galley carts in the compartments or zones. The air ducts are routed along the rear wall of the galley to the cart compartment to supply the cooled air to the cart compartment and the galley carts therein and to return the air to the heat exchanger. Typically, the single heat exchanger is used to supply cool air to all of the galley carts and thus cools all of the galley carts to the same temperature. Additionally, because the refrigeration system uses a single heat exchanger, the heat exchanger has a high capacity and uses a large blower or fan to move the air through the system. The large fan is loud and inefficient using a large amount of power.

[0003] Additionally, a large amount of space is required for the airflow supply and return components, such as the ducts and the valves that interface with the galley carts. The footprint of the galley is deep enough to accommodate the galley carts as well as the airflow supply and return components. The galleys occupy valuable space within the cabin of the aircraft, which limits the number of passenger seats that may be provided on the aircraft. For example, the airflow supply and return components may add approximately **4-5** inches (in) (**10-13** centimeters (cm)) of depth to the galleys, and some aircraft may have eight or more galleys, leading to a large amount of cabin space dedicated to the airflow supply and return components, which may be used for other purposes.

SUMMARY

[0004] In accordance with one embodiment, a galley refrigeration system is provided including a liquid heat exchange loop and an air heat exchange loop in thermal communication with the liquid heat exchange loop. The air heat exchange loop includes a heat exchanger configured to be coupled in flow communication with at least one galley cart. Optionally, the galley refrigeration system may include a control system in operative communication with the liquid heat exchange loop and the air heat exchange loop.

[0005] In accordance with a further embodiment, there is provided a galley system including the galley refrigeration system above and a galley having a rear wall. The galley system includes the liquid heat exchange loop in the galley and the air heat exchange loop in the galley. The air heat exchange loop extends in the galley and a heat exchanger is configured to be coupled in flow communication with a refrigerated compartment of the galley.

[0005a] In accordance with a further embodiment, there is provided a galley system including a galley having a rear wall, a liquid heat exchange loop in the galley, and an air heat exchange loop in the galley. The air heat exchange loop extends in the galley and is in thermal communication with the liquid heat exchange loop. The air heat exchange loop includes a heat exchanger configured to be coupled in flow communication with a refrigerated compartment of the galley.

[0005b] In accordance with a further embodiment, there is provided an aircraft including a cabin and at least one galley system described above, or any of its variants, positioned in the cabin.

[0005c] In one embodiment, there is provided a galley refrigeration system for a galley including a cart compartment. The galley refrigeration system includes a liquid heat exchange loop including a chiller, a liquid supply line coupled to the chiller, and an accumulator in the liquid supply line and configured to store a liquid of the liquid heat exchange loop. The galley refrigeration system further includes a first air heat exchange loop in thermal communication with the liquid heat exchange loop via the liquid supply line. The first air heat exchange loop includes a first air supply duct and a first air return duct, a first air supply sensor coupled to the first air supply duct and configured to sense a temperature of a fluid in the first air supply duct, a first air return sensor coupled to the first air return duct and configured to sense a temperature of a fluid in the first air return duct, and a first heat exchanger in the cart compartment and configured to be coupled in flow communication with a first galley cart in the cart compartment via the first air supply duct and the first air return duct. The galley refrigeration system further includes a second air heat exchange loop in thermal communication with the liquid heat exchange loop via the liquid supply line. The second air heat exchange loop includes a second air supply duct and a second air return duct, a second air supply sensor coupled to the second air supply duct and configured to sense a temperature of a fluid in the second air supply duct, a second air return sensor coupled to the second air return duct and configured to sense a temperature of a fluid in the second air return duct, and a second heat exchanger in the cart compartment and configured to be coupled in flow communication with a second galley cart in the cart compartment via the second air supply duct and the second air return duct. The galley refrigeration system further includes a control system in operative communication with the liquid heat exchange loop and the first and second air heat exchange loops. The control system is configured to: receive at least the temperatures of the fluid in the first air supply duct from the first air supply sensor, of the fluid in the first air return duct from the first air return sensor, of the fluid in the second air supply duct from the second air supply sensor, and of the fluid in the second air return duct from the second air return sensor; operate the first air heat exchange loop and the liquid heat exchange loop, based at least in part on the

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received temperatures of the fluid in the first air supply duct and the fluid in the first air return duct, to achieve a first desired temperature in the first galley cart; and operate the second air heat exchange loop and the liquid heat exchange loop, based at least in part on the temperatures of the fluid in the second air supply duct and the fluid in the second air return duct, to achieve a second desired temperature in the second galley cart.

[0005d] In another embodiment, there is provided a galley system including a galley having a rear wall and a counter. The galley has a cart compartment below the counter for receiving at least one galley cart. The galley system further includes a liquid heat exchange loop coupled to the galley. The liquid heat exchange loop includes a chiller, a liquid supply line and a liquid return line along the rear wall extending from the chiller, and an accumulator in the liquid supply line and configured to store liquid of the liquid heat exchange loop. The galley system further includes an air heat exchange loop located on an interior of the galley inside of the cart compartment. The air heat exchange loop includes an air supply duct and an air return duct contained below the counter in the cart compartment, an air supply sensor coupled to the air supply duct and configured to sense a temperature of a fluid in the air supply duct, an air return sensor coupled to the air return duct and configured to sense a temperature of a fluid in the air return duct, and a heat exchanger configured to be coupled in flow communication with the liquid heat exchange loop via the liquid supply line and the liquid return line and configured to be coupled in flow communication with the at least one galley cart in the cart compartment via the air supply duct and the air return duct. The galley system further includes a control system in operative communication with the liquid heat exchange loop and the air heat exchange loop. The control system is configured to receive at least the temperatures of the fluid in the air supply duct from the air supply sensor and of the fluid in the air return duct from the air return sensor and operate the air heat exchange loop and the liquid heat exchange loop, based at least in part on the received temperatures of the fluids in the air supply duct and the air return duct, to achieve a desired temperature in the at least one galley cart.

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[0005e] In another embodiment, there is provided a galley refrigeration system for a galley of an aircraft including: a liquid heat exchange loop; a first air heat exchange loop in thermal communication with the liquid heat exchange loop, the first air heat exchange loop including a first heat exchanger and configured to be coupled in flow communication with a first galley cart in a cart compartment of the galley; and a second air heat exchange loop in thermal communication with the liquid heat exchange loop, the second air heat exchange loop including a second heat exchanger and configured to be coupled in flow communication with a second galley cart. The galley refrigeration system is arranged within the galley. The galley has a rear wall. The first and second heat exchangers are located within the rear wall of the galley. The liquid heat exchange loop includes supply and return lines and each of the first and second air heat exchange loops includes supply and return ducts. The supply and return lines and the supply and return ducts are provided in the rear wall. The liquid heat exchange loop further includes: a chiller, the supply line extending between the chiller and at least one of the first and second air heat exchange loops, and the return line extending between the chiller and the at least one of the first and second air heat exchange loops; and an accumulator in the supply line configured to store cold liquid. The chiller and the accumulator are provided at a top of the galley in a crown of the aircraft.

[0005f] In another embodiment, there is provided a galley system including the galley refrigeration system described above or any variants thereof. The galley system includes the liquid heat exchange loop in the galley and the first and second air heat exchange loops in the galley. The first and second air heat exchange loops extend in the galley, and the first and second heat exchangers are configured to be coupled in flow communication with a refrigerated compartment of the galley.

[0006] The features and functions that have been discussed can be achieved independently in various embodiments or may be combined in yet other embodiments, further details of which can be seen with reference to the following description and drawings.

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BRIEF DESCRIPTION OF THE DRAWINGS

[0007] Figure **1** is a schematic illustration of an exemplary galley system for an aircraft.

[0008] Figure **2** is a side cross-sectional view of a galley and galley refrigeration system of the galley system in accordance with an exemplary embodiment.

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[0009] Figure **3** is an opposite side cross-sectional view of the galley and galley refrigeration system.

[0010] Figure **4** is a schematic illustration of the galley system showing various components of the galley refrigeration system.

[0011] Figure **5** is a schematic illustration of a portion of the galley system showing the galley refrigeration system in accordance with an exemplary embodiment.

DETAILED DESCRIPTION

[0012] The following detailed description of certain embodiments will be better understood when read in conjunction with the appended drawings. It should be understood that the various embodiments are not limited to the arrangements and instrumentality shown in the drawings.

[0013] As used herein, an element or step recited in the singular and proceeded with the word "a" or "an" should be understood as not excluding plural of said elements or steps, unless such exclusion is explicitly stated. Furthermore, references to "one embodiment" are not intended to be interpreted as excluding the existence of additional embodiments that also incorporate the recited features. Moreover, unless explicitly stated to the contrary, embodiments "comprising" or "having" an element or a plurality of elements having a particular property may include additional such elements not having that property.

[0014] Described herein are various embodiments of a galley refrigeration system for an aircraft configured to supply refrigerated air to a cart compartment of a galley monument, or simply galley, for refrigerating galley carts. Various embodiments provide a liquid heat exchange loop and an air heat exchange loop in thermal communication with the liquid heat exchange loop. The galley refrigeration system includes components arranged to reduce a size or footprint of the galley monument, which may provide additional space in the passenger compartment, such as for adding additional room for passenger seating. Various embodiments provide an efficient refrigerated environment for the galley carts using air-through-cart refrigeration arrangements. Various embodiments provide individual galley cart temperature control.

[0015] Figure **1** is a schematic illustration of an exemplary galley system **100** for an aircraft **106**. The galley system **100** is used to cool galley carts **108** held in cart compartments **102** of a galley **104**. The galley **104** defines one or more cart compartments **102**, which are typically arranged below a counter **105** of the galley **104**. The galley **104** is positioned within a cabin **110** of the aircraft **106**, and the cabin of the aircraft **106** is divided into a passenger area **112**, where passenger seats **114** are located, and a galley area **115**, where the galley **104** is located. The passenger area **112** is the area exterior of the galley **104** within the aircraft **106** where passengers are able to be located. The galley area **115** has a working area for the galley crew forward of the galley **104** where the cart compartments **102**, counter **105** and cabinets or storage bins may be accessed. Space dedicated to the galley **104** is unusable for passenger seats **114** or other purposes such as lavatories, and thus it may be desirable for aircraft manufacturers to reduce the footprint of the galley area **115** in order to increase the passenger area **112** to increase revenue of each flight for aircraft operators.

[0016] As used herein a cart compartment is an insulated or uninsulated volume that is utilized to store one or more galley carts on the aircraft **106**. The cart compartment may define one or more refrigerated compartments that receives refrigerated cooling. A galley cart, as used herein, is a portable device that is used to store food and/or beverages that are transported from a caterer to the aircraft **106** or from the cart compartments **102** to other parts of the aircraft **106** for serving the food and/or beverages. The galley carts may include wheels, however some galley carts may be hand carried boxes in some embodiments. The galley carts may define refrigerated compartments.

[0017] The galley **104** may include any number of cart compartments **102** and the aircraft **106** may include any number of galleys **104**. The galleys **104** are typically arranged near the doors of the aircraft **106**, such as at the fore and/or aft of the cabin **110**, but may be located mid-cabin in some embodiments. Each cart compartment **102** may hold any number of galley carts **108**. For example, each cart compartment **102** may have multiple cart bays, which may be separated from other cart bays by divider walls within the cart compartment **102**. The galleys **104** may be used for the storage and/or preparation of food or beverages. Some galleys may be bar units used strictly for preparation of beverages. Some galleys may be incorporated into other monuments used for other purposes such as closets, workstations, lavatories, and the like.

[0018] The galley system **100** includes a galley refrigeration system **116** that provides cooled air for the galley **104**. Components of the galley refrigeration system **116** may be positioned above the galley **104** (e.g., in the crown of the aircraft **106**), may be positioned in the galley **104**, and/or may be positioned below the galley **104** (e.g., in the belly of the aircraft **106**). In an exemplary embodiment, the galley refrigeration system **116** includes a liquid heat exchange loop **118** and at least one air heat exchange loops **120** in flow communication with the liquid heat exchange loop **118**. The liquid heat exchange loop **118** is used to supply cold liquid to the air heat exchange loop(s) **120** for heat transfer. Optionally, the liquid heat exchange loop **118** may be a vapor cycle chiller. The air heat exchange loop(s) **120** are used to supply cold air to the cart compartment **102** (e.g., to form a refrigerated compartment) and the galley carts **108** in the cart compartment **102**.

[0019] Figure **2** is a side cross-sectional view of the galley **104** and galley refrigeration system **116** in accordance with an exemplary embodiment. Figure **3** is an opposite side cross-sectional view of the galley **104** and galley refrigeration system **116**. The galley **104** includes a bottom **122**, which may be the airplane floor or the galley area floor, a top **124**, a front **126** and a rear **128** opposite the front **126**, and may include at least one side (not shown). The rear **128** may be fore or aft facing, depending on the orientation of the galley **104** within the cabin **110**. The rear **128** may face the passenger area **112** (e.g., passenger seats **114** may be located behind the rear **128**, in front of the rear **128**, and the like); however in alternative embodiments, the rear **128** may be positioned against a bulkhead.

[0020] In an exemplary embodiment, the galley refrigeration system **116** is positioned at the top **124** and along the rear **128**; however the components of the galley refrigeration system **116** may be positioned at other locations in alternative embodiments. The components of the galley refrigeration system **116** may extend into the cart compartment **102** to interface with the galley carts **108** to supply cool air to the galley carts **108** in an air-through-cart supply arrangement. Alternatively, the galley refrigeration system **116** may supply air by an air-over-cart arrangement. In the illustrated embodiment, the liquid heat exchange loop **118** includes components along the top **124** and along the rear **128** that extend to the cart compartment **102**, while the air heat exchange loop(s) **120** include components along the rear **128**, such as in the cart compartment **102**, that interface with and provide cold air to the galley carts **108**.

[0021] Figure **4** is a schematic illustration of the galley system **100** showing various components of the galley refrigeration system **116**. The galley refrigeration system **116** includes the liquid heat exchange loop **118** and a plurality of air heat exchange loops **120** in thermal communication with the liquid heat exchange loop **118**.

[0022] The liquid heat exchange loop **118** includes a chiller **130**, a supply line **132** in flow communication with the chiller **130** and a return line **134** in flow communication with the chiller **130**. Cold liquid is forced through the liquid heat exchange loop **118** for refrigerating the air heat exchange loops **120**. In an exemplary embodiment, the liquid heat exchange loop **118** includes a plurality of heat exchange coils **136** associated with corresponding air heat exchange loops **120**. The heat exchange coils **136** connect between the supply line **132** and the return line **134**. In an exemplary embodiment, the heat exchange coils **136** are arranged in parallel between the supply line **132** and the return line **134**. The heat exchange coils **136** may be connected to a manifold at the supply line **132** and/or the return line **134**. Cold liquid is supplied from the chiller **130** through the supply line **132** to each of the heat exchange coils **136**. The liquid is then transferred from the heat exchange coils **136** to the chiller **130** in the return line **134**.

[0023] While a plurality of air heat exchange loops **120** are illustrated in Figure **4**, any number of air heat exchange loops **120**, including a single air heat exchange loop **120**, may be provided in the galley refrigeration system **116**. In an exemplary embodiment, a separate air heat exchange loop **120** is provided for each galley cart **108**. Alternatively, one or more of the air heat exchange loops **120** may be in flow communication with and configured to supply refrigerated airflow to multiple galley carts **108**. Optionally, at least one air heat exchange loop **120** may supply cool air to a refrigerated compartment **148**, such as a cartless refrigerated compartment that does not receive a galley cart.

[0024] Each air heat exchange loop **120** includes a heat exchanger **140**, a supply duct **142** in flow communication with the heat exchanger **140** and a return duct **144** in flow communication with the heat exchanger **140**. The supply and return ducts **142**, **144** are configured to be coupled in flow communication with one or more of the refrigerated compartments **148**, such as with at least one galley cart **108** in such refrigerated cart compartment or with one of the cartless refrigerated compartments **148**. Optionally, the interior of the galley cart **108** may define a refrigerated compartment, wherein the air heat exchange loop **120** supply the air directly into the galley cart **108** as opposed to the space of the cart compartment **102** around the galley cart **108**.

[0025] The heat exchanger **140** includes a fan **146** for circulating air in the air heat exchange loop **120**. The fan **146** forces airflow past the heat exchange coils **136** to cool the air supplied to the galley carts **108**. In an exemplary embodiment, the fan **146** is a variable speed fan to control the airflow in the air heat exchange loop **120**. In an exemplary embodiment, each fan **146** of the various air heat exchange loops **120** may be independently controlled, such as to control or vary the temperature of the air in the corresponding air heat exchange loop **120**. As such, the galley carts **108** may have independent or separate temperature control.

[0026] Figure **5** is a schematic illustration of a portion of the galley system **100** showing the galley refrigeration system **116** in accordance with an exemplary embodiment. The galley refrigeration system **116** includes the liquid heat exchange loop **118** and a plurality of the air heat exchange loops **120**. In the illustrated embodiment, one of the air heat exchange loops **120** is used to provide cold air to the refrigerated compartment **148** while another of the air heat exchange loops **120** is configured to supply cold air to a corresponding galley cart **108**.

[0027] In the illustrated embodiment, the air heat exchange loop **120** is provided with a fan **146** in the supply duct **142**; however the fan **146** may be positioned elsewhere, such as in the return duct **144** or in the heat exchanger **140**. Other types of air moving devices other than a fan may be used in alternative embodiments to transfer the air in the air heat exchange loop **120**. The heat exchanger **140** includes an air filter **150** in the return duct **144**. The air filter **150** filters the air prior to the air flowing through the heat exchanger **140**.

[0028] The air heat exchange loop **120** includes one or more temperature sensors **152** to measure a temperature of the air in the air heat exchange loop **120**. For example, one temperature sensor **152** may measure the supply air temperature in the supply duct **142** while another temperature sensor **152** may measure the return air temperature in the return duct **144**. The fan speed of the fan **146** may be controlled based on temperature readings from one or more of the temperature sensors **152**.

[0029] The liquid heat exchange loop **118** includes a pump **160** for circulating the liquid in the liquid heat exchange loop **118**. The liquid may be a non-freezing coolant fluid, such as propylene glycol or other type of refrigerant. The pump **160** circulates the fluid through the supply line **132** and the return line **134**. The pump

160 circulates the fluid through the chiller **130**. Other types of liquid moving devices other than the pump **160** may be used in other embodiments. In some various embodiments, the liquid heat exchange loop **118** may use convection to move the liquid through the loop.

[0030] In the illustrated embodiment, the liquid heat exchange loop **118** includes a coolant accumulator **162** in the supply line **132**. The accumulator **162** may be insulated. The accumulator **162** allows for coolant thermal expansion and contraction. The accumulator **162** provides a reservoir of cold fluid available for use in the liquid heat exchange loop **118**.

[0031] Optionally, the liquid heat exchange loop **118** may include an accumulator bypass valve **164** upstream of the coolant accumulator **162**. The bypass valve **164** allows the liquid heat exchange loop **118** to bypass the accumulator **162**. The coolant may flow from the chiller **130** through the supply line **132** to the heat exchangers **140** without flowing through the accumulator **162**. The bypass valve **164** may be used in a defrost mode for sending warm liquid to the heat exchangers **140** to defrost the heat exchangers **140**. For example, the chiller **130** may be turned off during the defrost mode and the warm liquid may defrost the heat exchangers **140**.

[0032] In the illustrated embodiment, the liquid heat exchange loop **118** includes one or more temperature sensors **166** for sensing temperature of the liquid in the liquid heat exchange loop **118**. For example, one temperature sensor **166** may measure the supply liquid temperature in the supply line **132** while another temperature sensor **166** may measure the return liquid temperature in the return line **134**.

[0033] In an exemplary embodiment, the galley refrigeration system **116** includes a control system **170** in operative communication with the liquid heat exchange loop **118** and the air heat exchange loops **120**. The control system **170** may be used to control operation of one or more components of the liquid heat exchange loop **118** and/or one or more components of the air heat exchange loops **120**. Optionally, more than one control system may be provided, such as a control system for the liquid heat exchange loop **118** and a different control system(s) for the air heat exchange loops **120**.

[0034] The control system **170** includes a controller **172** operably coupled to the corresponding components. In an exemplary embodiment, the controller **172** is operably coupled to the pump **160**, the chiller **130** and the bypass value **164** of the liquid heat exchange loop **118**. The pump **160** may be a variable speed pump and the controller **172** may control the speed or output of the pump **160** based on refrigeration demand of the galley refrigeration system **116**. The controller **172** may control operation of the chiller **130** to control a temperature of the liquid in the liquid heat exchange loop **118**.

[0035] In an exemplary embodiment, the controller **172** receives inputs from the temperature sensors **166** to determine the temperature of the liquid in the supply line **132** and the temperature of the liquid in the return line **134**. A comparison of the temperature of the liquid upstream of the heat exchangers **140** and downstream of the heat exchangers **140** corresponds to demand or load on the galley refrigeration system **116**. The controller **172** may increase refrigeration or decrease refrigeration based on the temperatures measured in the supply line **132** and/or the return line **134**.

[0036] The controller **172** is operably coupled to the fans **146** of the air heat exchange loops **120**. The controller **172** may control the speed of the fans **146** based on refrigeration demand of the galley refrigeration system **116**. The controller **172** may independently control operation of the fans **146** of the various air heat exchange loops **120** to achieve different temperatures in different galley carts **108**. The control system **170** may control the heat exchanger **140** and/or the fan **146** to achieve a predetermined temperature in the corresponding galley cart **108**. The controller **172** may receive inputs from a user input or control panel **174** relating to a desired temperature. For example, the control panel **174** may be associated with the galley **104** and may have user selectable inputs to adjust the temperature of the individual galley carts **108** and/or galley compartments **102**. The control panel **174** may have a display. The control panel **174** may be a touchscreen.

[0037] In an exemplary embodiment, the controller **172** receives inputs from the temperature sensors **152** to determine the temperature of the air in the supply duct **142** and the temperature of the air in the return duct **144** of the corresponding air heat exchange loop **120**. A comparison of the temperature of the air upstream of the galley cart **108** and downstream of the galley cart **108** corresponds to demand or load on the galley refrigeration system **116**. The controller **172** may increase refrigeration or decrease refrigeration based on the temperatures measured in the supply duct **142** and/or the return duct **144**.

[0038] In an exemplary embodiment, the control system **170** is configured to monitor operation of the components of the galley refrigeration system **116** and diagnose problems with components of the galley refrigeration system **116**. For example, the control system **170** may diagnose problems with operation of the heat exchangers **140**. By measuring the temperature of the supply and return air in the air heat exchange loop **120**, the control system **170** may diagnose problems with the heat exchanger **140**, which may be a problem with the fan **146**. For example, if the temperature in the return air duct **144** is higher than expected or above a threshold, the control system **170** may determine that the heat exchanger **140** and/or the fan **146** are not working properly. The control system **170** may diagnose problems with the fan **146** using other types of sensors, such as a flow meter to measure airflow through the air heat exchange loop **120**. The control system **170** may diagnose problems with the galley cart **108**. For example, the control system **170** may diagnose problems with the insulation of the galley cart **108** by monitoring the temperature of the air in the air heat exchange loop **120**. For example, if the temperature downstream of the galley cart **108**, such as in the air return duct **144**, is higher than expected or above a threshold, the efficiency of the galley cart **108** may be compromised. The control system **170** may provide feedback to the operator, such as at the control panel **174**, indicating a problem with the galley refrigeration system **116** or the galley cart **108**. For example, a message, such as "cart in compartment M**106** is underperforming - please inspect door seal or insulation for damage", may be provided on the display.

[0039] Returning to Figures **2** and **3**, the galley refrigeration system **116** is arranged within the galley **104**. Components of the liquid heat exchange loop **118** may be routed in various portions of the galley **104** to supply and return the liquid as needed. Components of the air heat exchange loop **120** may be routed in various portions of the galley **104** to supply and return the air as needed. In the illustrated embodiment, components of the galley refrigeration system **116** are generally arranged along the rear of the galley **104**, such as behind the cabinets, cart compartments **102**, galley carts **108** and other compartments of the galley **104**.

[0040] In an exemplary embodiment, the components of the galley refrigeration system **116** are routed in areas to reduce a depth of at least a portion of the galley **104**. For example, the supply and return lines **132**, **134** (Figures **2** and **3**, respectively) of the liquid heat exchange loop **118** may be relatively thin as compared to air ducts of conventional galley systems (e.g., ½ in (**1**.**3** cm) liquid lines versus **3** - **4** in (**7**.**5**-**10** cm) wide air ducts) and routed along the rear **128** of the galley **104**, which may considerably reduce the depth of the galley **104** along the rear **128** of the galley **104**. Such reduction in depth may decrease the footprint or volume of the galley area **115**, and thus increase the footprint or volume of the passenger area **112**. Optionally, the supply and return ducts **142**, **144** (Figures **2** and **3**, respectively) of the air heat exchange loop **120** may be relatively thin as compared to air ducts of conventional galley systems (e.g., **1**-**2** in (**2**.**5**-**5** cm) air ducts versus **3**-**4** in (**7**.**5**-**10** cm) wide air ducts) because the volume of airflow in the individual air heat exchange loops **120** is considerably less than the volume of airflow in conventional supply and return systems. The thinner air ducts considerably reduce the depth of the galley **104** along the rear **128** of the galley **104**.

Such reduction in depth may decrease the footprint or volume of the galley area **115**, and thus increase the footprint or volume of the passenger area **112**.

[0041] In an exemplary embodiment, at least some of the components of the liquid heat exchange loop **118** are provided at the top **124** of the galley **104** (e.g., in the crown of the aircraft **106**). For example, the chiller **130** and accumulator **162** may be provided at the top **124**. The supply and return lines **132**, **134** are routed in a rear wall **180** of the galley **104** at the rear **128**. The supply and return lines **132**, **134** are routed to the heat exchangers **140**. The heat exchangers **140** may be located within the cart compartment **102**, such as below the counter **105**. Alternatively, the heat exchangers **140** may be located at other locations, such as in a dedicated compartment (shown in phantom) above the counter **105**. The heat exchangers **140** may be located within the rear wall **180** in other various embodiments.

[0042] In an exemplary embodiment, at least some of the components of the air heat exchange loop **120** are provided near the galley carts **108**. For example, the heat exchanger **140** may be provided in or near the cart compartment **102**. The supply and return ducts **142**, **144** are routed in or along the rear wall **180** to interface with the galley carts **108**. The supply and return ducts **142**, **144** are in flow communication with the galley cart **108**, such as via supply and return valves, vents or other interface devices that interface with corresponding supply and return ports **190**, **192** and/or valves, vents or other interface devices of the galley cart **108**. Optionally, the supply duct **142** may interface with the galley cart **108** near the top of the galley cart **108** and the return duct **144** may interface with the galley cart **108** near the bottom of the galley cart **108** such that the cool air flows through the galley cart **108** past the trays, food, beverages and the like in the galley cart **108**. The supply and return ducts **142**, **144** may be located at other locations, such as adjacent to each other at the top or at the bottom.

[0043] Other arrangements of the components, supply and return lines **132**, **134** and supply and return ducts **142**, **144** are possible in alternative embodiments.

For example, rather than providing components at the top **124**, at least some of the components may be provided below the galley **104**, such as below the deck or floor of the cabin and routed to the cart compartment **102** and galley cart **108**. Some of the components may be routed under the counter **105** as opposed to along the rear wall **180** to reduce the depth of the cart compartment **102**.

[0044] In an exemplary embodiment, at least a portion of the rear wall **180** is shifted forward, as compared to conventional galley monuments that provide large airflow supply or return components along the rear wall **180**, to reduce the footprint of the galley **104**. At least a portion of the rear wall **180** is shifted toward the galley cart **108** to reduce the depth of the cart compartment **102**. Such reduction in depth (shown by arrow A in Figure **3**) of the galley **104** as compared to conventional galleys equates to an increase in volume of the passenger area **112**. For example, more space may be provided for passenger seats **114**. For example, more leg room may be provided for passengers in the passenger seats **114**.

[0045] A galley refrigeration system is provided for an aircraft that supplies refrigeration air to a compartment of a galley for refrigeration galley carts. The galley refrigeration system includes a liquid heat exchange loop that provides cold liquid supply to one or more air heat exchange loops. The air heat exchange loops provide cold air for a limited number of galley carts, such as a single galley cart. As such, the air heat exchange loops may be sized smaller than conventional heat exchange loops that provide refrigeration for the entire cart compartment and all of the galley carts. The reduced size of the components of the air heat exchange loop, such as thinner ducts, decreases the size of the galley. Additional space is provided in the passenger compartment by shifting the walls of the cart compartment inward (e.g., closer to the galley cart), such as for adding additional room for passenger seating. Additionally, the components, such as the fan, may be smaller than conventional fans, thus reducing the weight of the galley refrigeration system.

[0046] It is to be understood that the above description is intended to be illustrative, and not restrictive. For example, the above-described embodiments (and/or aspects thereof) may be used in combination with each other. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the various embodiments without departing from the scope thereof. Dimensions, types of materials, orientations of the various components, and the number and positions of the various components described herein are intended to define parameters of certain embodiments, and are by no means limiting and are merely exemplary embodiments. Many other embodiments and modifications within the spirit and scope of the claims will be apparent to those of skill in the art upon reviewing the above description. The scope of the various embodiments should, therefore, be determined with reference to the appended claims, along with the full scope of equivalents to which such claims are entitled. In the appended claims, the terms "including" and "in which" are used as the plain-English equivalents of the respective terms "comprising" and "wherein." Moreover, in the following claims, the terms "first," "second," and "third," etc. are used merely as labels, and are not intended to impose numerical requirements on their objects.

EMBODIMENTS IN WHICH AN EXLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. A galley refrigeration system for a galley comprising a cart compartment, the galley refrigeration system comprising:

a liquid heat exchange loop comprising:

a chiller;

a liquid supply line coupled to the chiller; and

an accumulator in the liquid supply line and configured to store a liquid of the liquid heat exchange loop;

a first air heat exchange loop in thermal communication with the liquid heat exchange loop via the liquid supply line, the first air heat exchange loop comprising:

a first air supply duct and a first air return duct;

a first air supply sensor coupled to the first air supply duct and configured to sense a temperature of a fluid in the first air supply duct;

a first air return sensor coupled to the first air return duct and configured to sense a temperature of a fluid in the first air return duct; and

a first heat exchanger in the cart compartment and configured to be coupled in flow communication with a first galley cart in the cart compartment via the first air supply duct and the first air return duct;

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a second air heat exchange loop in thermal communication with the liquid heat exchange loop via the liquid supply line, the second air heat exchange loop comprising:

a second air supply duct and a second air return duct;

a second air supply sensor coupled to the second air supply duct and configured to sense a temperature of a fluid in the second air supply duct;

a second air return sensor coupled to the second air return duct and configured to sense a temperature of a fluid in the second air return duct; and

a second heat exchanger in the cart compartment and configured to be coupled in flow communication with a second galley cart in the cart compartment via the second air supply duct and the second air return duct; and

a control system in operative communication with the liquid heat exchange loop and the first and second air heat exchange loops, wherein the control system is configured to:

receive at least the temperatures of the fluid in the first air supply duct from the first air supply sensor, of the fluid in the first air return duct from the first air return sensor, of the fluid in the second air supply duct from the second air supply sensor, and of the fluid in the second air return duct from the second air return sensor;

operate the first air heat exchange loop and the liquid heat exchange loop, based at least in part on the received temperatures of the fluid in the first air supply duct and the fluid

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in the first air return duct, to achieve a first desired temperature in the first galley cart; and

operate the second air heat exchange loop and the liquid heat exchange loop, based at least in part on the temperatures of the fluid in the second air supply duct and the fluid in the second air return duct, to achieve a second desired temperature in the second galley cart.

2. The galley refrigeration system of claim **1**, wherein the first heat exchanger and the second heat exchanger are located in an interior of the cart compartment.

3. The galley refrigeration system of claim **1** or **2**, wherein the liquid heat exchange loop comprises a liquid return line between the chiller and the first and second air heat exchange loops.

4. The galley refrigeration system of any one of claims **1** to **3**, further comprising at least one other air heat exchange loop, wherein at least one other heat exchanger of the at least one other air heat exchange loop is in thermal communication with the liquid heat exchange loop via the liquid supply line.

5. The galley refrigeration system of claim **4**, wherein the at least one other heat exchanger is configured to be coupled in flow communication with a refrigerated compartment.

6. The galley refrigeration system of any one of claims **1** to **5**, wherein the first heat exchanger is in flow communication with a first plurality of galley carts, the first plurality of galley carts comprising the first galley cart.

7. The galley refrigeration system of any one of claims **1** to **6**, wherein the second heat exchanger is in flow communication with a second plurality of

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galley carts, the second plurality of galley carts comprising the second galley cart.

8. The galley refrigeration system of any one of claims **1** to **4**, wherein at least one of the first and second heat exchangers is further configured to be coupled in flow communication with a refrigerated compartment.

9. The galley refrigeration system of any one of claims **1** to **8**, wherein the liquid heat exchange loop further comprises an accumulator bypass configured to bypass the accumulator to transfer the liquid of the liquid heat exchange loop to at least one of the first and second air heat exchange loops.

10. The galley refrigeration system of claim **9**, wherein the accumulator bypass is configured to transfer the liquid of the liquid heat exchange loop to the at least one of the first and second air heat exchange loops to defrost a corresponding at least one of the first and second heat exchangers.

11. The galley refrigeration system of any one of claims **1** to **10**, wherein the control system is further configured to:

receive at least one of a liquid supply temperature and a liquid return temperature; and

control operation of the liquid heat exchange loop based on at least one of the received liquid supply temperature and the received liquid return temperature.

12. The galley refrigeration system of any one of claims **1** to **11**, wherein the liquid heat exchange loop comprises a pump and the control system is operatively coupled to the pump, wherein the control system is further configured to control the pump based on a temperature of the liquid of the liquid heat exchange loop.

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13. The galley refrigeration system of any one of claims **1** to **11**, wherein the control system is further configured to control operation of at least one of the first and second heat exchangers based on a temperature of the liquid of the liquid heat exchange loop.

14. The galley refrigeration system of any one of claims **1** to **13**, wherein the first air heat exchange loop includes a variable speed fan and wherein the control system is further configured to operate the first air heat exchange loop by controlling a speed of the variable speed fan to achieve the first desired temperature in the first galley cart.

15. The galley refrigeration system of any one of claims **1** to **14**, wherein the control system is configured to identify problems associated with operation of the first heat exchanger based on at least one of the received temperature of the fluid in the first air supply duct and the received temperature of the fluid in the first air return duct.

16. The galley refrigeration system of any one of claims **1** to **15**, wherein the control system is configured to identify problems associated with operation of the second heat exchanger based on at least one of the received temperature of the fluid in the second air supply duct and the received temperature of the fluid in the second air return duct.

17. The galley refrigeration system of any one of claims **1** to **16**, wherein the control system is configured to determine an insulation efficiency of the first galley cart based on at least one of the received temperature of the fluid in the first air supply duct and the received temperature of the fluid in the first air return duct.

18. The galley refrigeration system of any one of claims **1** to **17**, wherein the control system is configured to determine an insulation efficiency of the second galley cart based on at least one of the received temperature of the

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fluid in the second air supply duct and the received temperature of the fluid in the second air return duct.

19. The galley refrigeration system of claim **1**, wherein at least one of the first and second air heat exchange loops is located in an interior of the cart compartment.

20. The galley refrigeration system of any one of claims **1** to **19**, wherein the galley has a rear wall, and the liquid supply line is routed in the rear wall.

21. The galley refrigeration system of any one of claims **1** to **20**, wherein the chiller is located in a crown of an aircraft above the galley.

22. The galley refrigeration system of claim **21**, wherein the accumulator is located proximate the chiller in the crown of the aircraft.

23. A galley system comprising:

a galley having a rear wall and a counter, the galley having a cart compartment below the counter for receiving at least one galley cart;

a liquid heat exchange loop coupled to the galley, the liquid heat exchange loop comprising:

a chiller;

a liquid supply line and a liquid return line along the rear wall extending from the chiller; and

an accumulator in the liquid supply line and configured to store liquid of the liquid heat exchange loop; and

an air heat exchange loop located on an interior of the galley inside of the cart compartment, the air heat exchange loop comprising:

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an air supply duct and an air return duct contained below the counter in the cart compartment;

an air supply sensor coupled to the air supply duct and configured to sense a temperature of a fluid in the air supply duct;

an air return sensor coupled to the air return duct and configured to sense a temperature of a fluid in the air return duct; and

a heat exchanger configured to be coupled in flow communication with the liquid heat exchange loop via the liquid supply line and the liquid return line and configured to be coupled in flow communication with the at least one galley cart in the cart compartment via the air supply duct and the air return duct;

a control system in operative communication with the liquid heat exchange loop and the air heat exchange loop, wherein the control system is configured to:

receive at least the temperatures of the fluid in the air supply duct from the air supply sensor and of the fluid in the air return duct from the air return sensor; and

operate the air heat exchange loop and the liquid heat exchange loop, based at least in part on the received temperatures of the fluids in the air supply duct and the air return duct, to achieve a desired temperature in the at least one galley cart.

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24. The galley system of claim **23**, wherein at least one of the liquid supply line and the liquid return line extends through the rear wall into the cart compartment.

25. The galley system of claim **23** or **24**, wherein the air supply and air return ducts extend along the rear wall in the cart compartment for flow communication with the at least one galley cart, and wherein the air supply and air return ducts are located entirely in the rear wall in the cart compartment.

26. The galley system of claim **23** or **24**, wherein the liquid supply and liquid return lines and the air supply and air return ducts are provided in the rear wall.

27. The galley system of any one of claims **23** to **26**, wherein the at least one galley cart comprises at least one insulated galley cart having supply and return ports in flow communication with the air heat exchange loop, the air heat exchange loop configured to supply air in an air-through-cart supply arrangement.

28. The galley system of any one of claims **23** to **27**, wherein the at least one galley cart comprises a single galley cart received in the cart compartment.

29. The galley system of any one of claims **23** to **27**, wherein the at least one galley cart comprises a plurality of galley carts received in the cart compartment.

30. The galley system of any one of claims **23** to **27**, wherein the cart compartment comprises a plurality of cart bays, each cart bay configured to receive a corresponding galley cart.

31. The galley system of claim **30**, wherein the galley system comprises a plurality of air heat exchange loops including the air heat exchange loop, and

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each air heat exchange loop is associated with a cart bay of the plurality of cart bays and the corresponding galley cart.

32. The galley system of claim **31**, wherein the control system is configured to operate each air heat exchange loop of the plurality of air heat exchange loops differently to achieve different desired temperatures in the corresponding galley cart.

33. The galley system of any one of claims **1** to **32**, wherein the chiller is located in a crown of an aircraft above the galley.

34. The galley system of claim **33**, wherein the accumulator is located proximate the chiller in the crown of the aircraft.

35. A galley refrigeration system for a galley of an aircraft comprising:

a liquid heat exchange loop;

a first air heat exchange loop in thermal communication with the liquid heat exchange loop, the first air heat exchange loop comprising a first heat exchanger and configured to be coupled in flow communication with a first galley cart in a cart compartment of the galley; and

a second air heat exchange loop in thermal communication with the liquid heat exchange loop, the second air heat exchange loop comprising a second heat exchanger and configured to be coupled in flow communication with a second galley cart, and

wherein the galley refrigeration system is arranged within the galley, the galley having a rear wall,

wherein the first and second heat exchangers are located within the rear wall of the galley,

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wherein the liquid heat exchange loop comprises supply and return lines and each of the first and second air heat exchange loops comprises supply and return ducts, the supply and return lines and the supply and return ducts being provided in the rear wall,

wherein the liquid heat exchange loop further comprises:

a chiller, the supply line extending between the chiller and at least one of the first and second air heat exchange loops, and the return line extending between the chiller and the at least one of the first and second air heat exchange loops, and

an accumulator in the supply line configured to store cold liquid, and

wherein the chiller and the accumulator are provided at a top of the galley in a crown of the aircraft.

36. The galley refrigeration system of claim **35**, wherein the first and second air heat exchange loops are operated differently to achieve different temperatures in the first and second galley carts.

37. The galley refrigeration system of claim **35** or **36**, wherein the supply line is in thermal communication with a plurality of heat exchangers, the plurality of heat exchangers including the first and second heat exchangers.

38. The galley refrigeration system of any one of claims **35** to **37**, further comprising a control system in operative communication with the liquid heat exchange loop and the first and second air heat exchange loops.

39. The galley refrigeration system of claim **38**, wherein the control system is configured to at least one of:

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receive at least one of a liquid supply temperature and a liquid return temperature, the control system controlling operation of the liquid heat exchange loop based on the received at least one of the liquid supply and liquid return temperatures; and

receive at least one of an air supply temperature and an air return temperature, the control system controlling operation of at least one of the first and second air heat exchange loops based on the received at least one of the air supply and air return temperatures.

40. The galley refrigeration system of claim **39**, wherein the control system is configured to diagnose problems associated with operation of at least one of the first and second heat exchangers based on the received at least one of the air supply and air return temperatures.

41. The galley refrigeration system of claim **39** or **40**, wherein the control system is configured to diagnose an insulation efficiency of at least one of the first and second galley carts based on the received at least one of the air supply and air return temperatures.

42. The galley refrigeration system of any one of claims **38** to **41**, wherein the liquid heat exchange loop comprises a pump, the control system is operatively coupled to the pump and the control system is configured to control the pump based on a temperature of the liquid of the liquid heat exchange loop.

43. The galley refrigeration system of any one of claims **38** to **41**, wherein the control system is configured to control at least one of the first and second heat exchangers based on a temperature of the liquid of the liquid heat exchange loop.

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44. The galley refrigeration system of any one of claims **38** to **43**, wherein the control system is configured to control the first heat exchanger to achieve a predetermined temperature within the first galley cart.

45. The galley refrigeration system of any one of claims **38** to **44**, wherein the control system is configured to control the second heat exchanger to achieve a predetermined temperature within the second galley cart.

46. The galley refrigeration system of any one of claims **38** to **43**, wherein at least one of the first and second heat exchangers include a variable speed fan and the control system is configured to control a speed of the variable speed fan to achieve a predetermined temperature in a corresponding at least one of the first and second galley carts.

47. The galley refrigeration system of any one of claims **38** to **46**, further comprising at least one temperature sensor configured to sense a temperature of at least one of the liquid heat exchange loop, the first air heat exchange loop, and the second air heat exchange loop, the at least one temperature sensor being in operative communication with the control system.

48. The galley refrigeration system of any one of claims **35** to **47**, wherein the supply line is in flow communication with the chiller, and the return line is in flow communication with the chiller, and further comprising an accumulator bypass valve configured to bypass the accumulator to transfer liquid to at least one of the first air heat exchange loop for defrosting the first heat exchanger and the second air heat exchange loop for defrosting the second heat exchanger.

49. A galley system including the galley refrigeration system of any one of claims **35** to **48**, the galley system comprising:

the liquid heat exchange loop in the galley; and

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the first and second air heat exchange loops in the galley, the first and second air heat exchange loops extending in the galley, and the first and second heat exchangers configured to be coupled in flow communication with a refrigerated compartment of the galley.

50. The galley system of claim **49**, wherein the liquid heat exchange loop extends through the rear wall to the refrigerated compartment.

51. The galley system of claim **49** or **50**, wherein the at least one of the first and second air heat exchange loops comprise the supply duct in flow communication with a corresponding at least one of the first and second heat exchangers and the return duct in flow communication with the corresponding at least one of the first and second heat exchangers.

52. The galley system of claim **51**, wherein the corresponding at least one of the first and second heat exchangers, the supply duct, and the return duct is in or near the refrigerated compartment for flow communication therewith.

53. The galley system of any one of claims **49** to **52**, further comprising:

a counter oriented with respect to the rear wall; and

the cart compartment, wherein the cart compartment is at least partially defined by the rear wall and the counter.

54. The galley system of claim **53**, wherein the cart compartment is configured to receive the first and second galley carts.

55. The galley system of claim **53** or **54**, wherein at least one of the first and second heat exchangers are located within the rear wall positioned above the counter, and the supply and return ducts of a corresponding at least one of the first and second air heat exchange loops extend from the at least one of the first and second heat exchangers above the counter into the cart compartment.

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56. The galley system of claim **53**, wherein the cart compartment comprises a plurality of cart bays, each cart bay receiving a corresponding galley cart.

57. The galley system of any one of claims **49** to **56**, further comprising the first and second galley carts, wherein at least one of the first and second galley carts comprise an insulated galley cart having supply and return ports in flow communication with a corresponding at least one of the first and second air heat exchange loops, the corresponding first and second air heat exchange loops configured to supply air in an air-through-cart supply arrangement.

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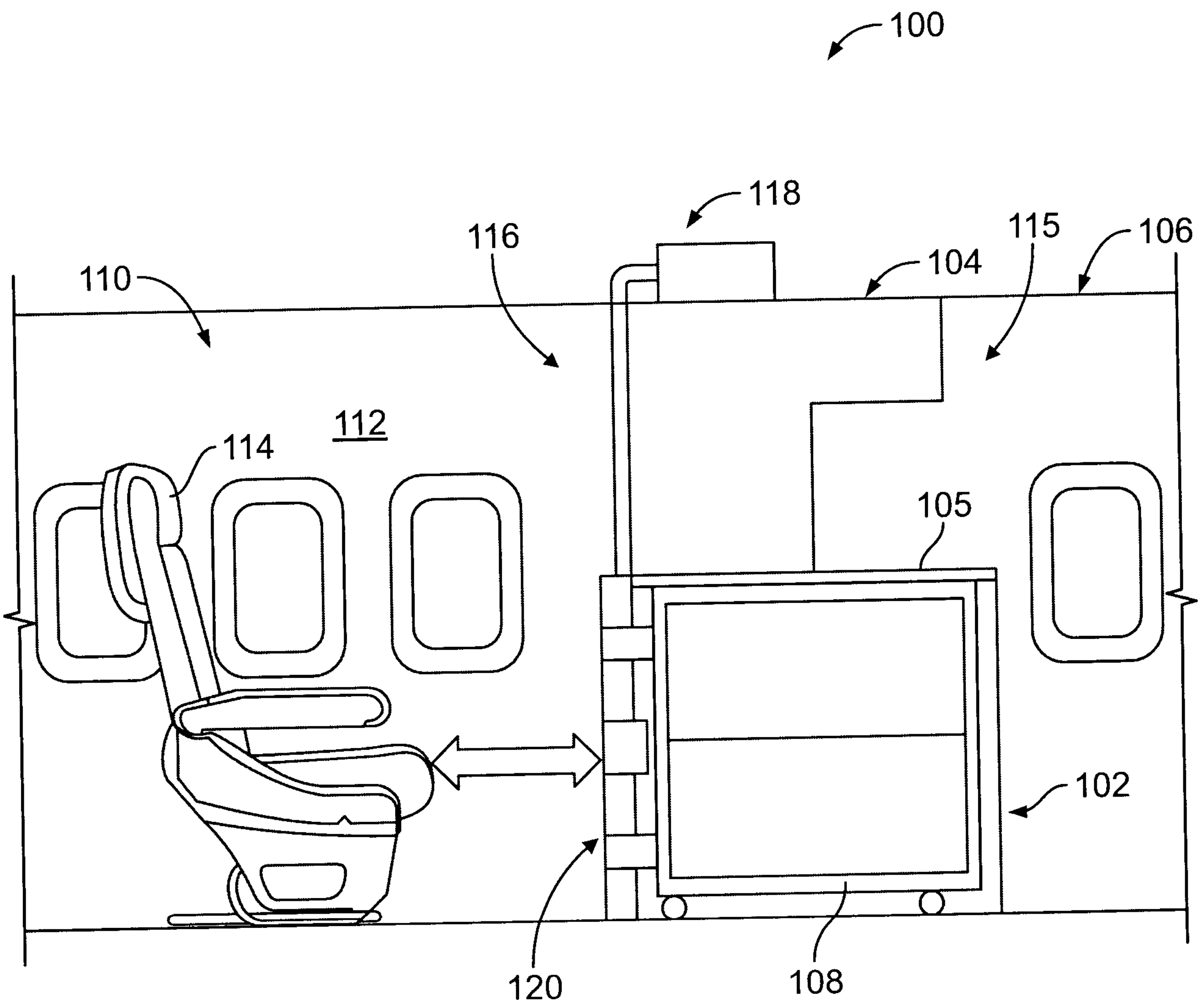

FIG. 1

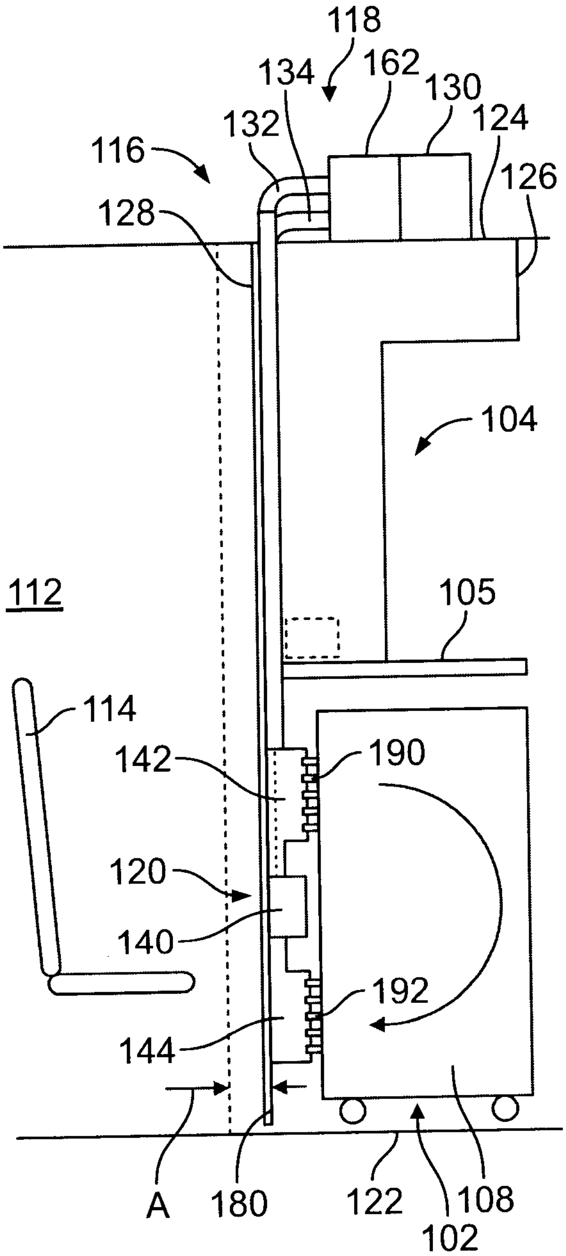
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FIG. 2

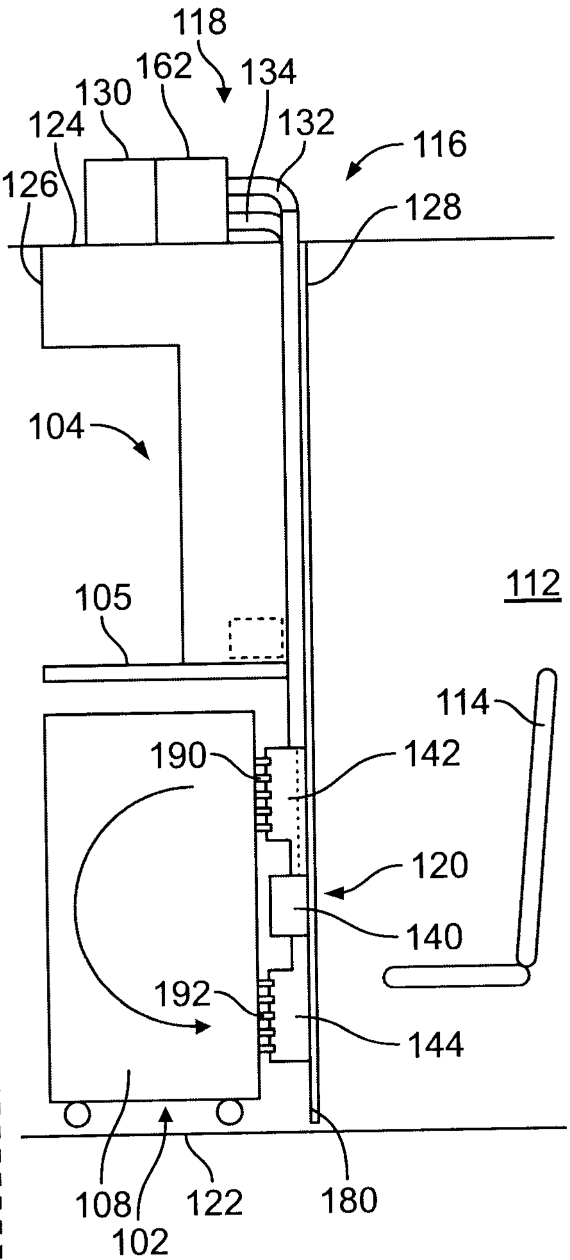
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FIG. 3

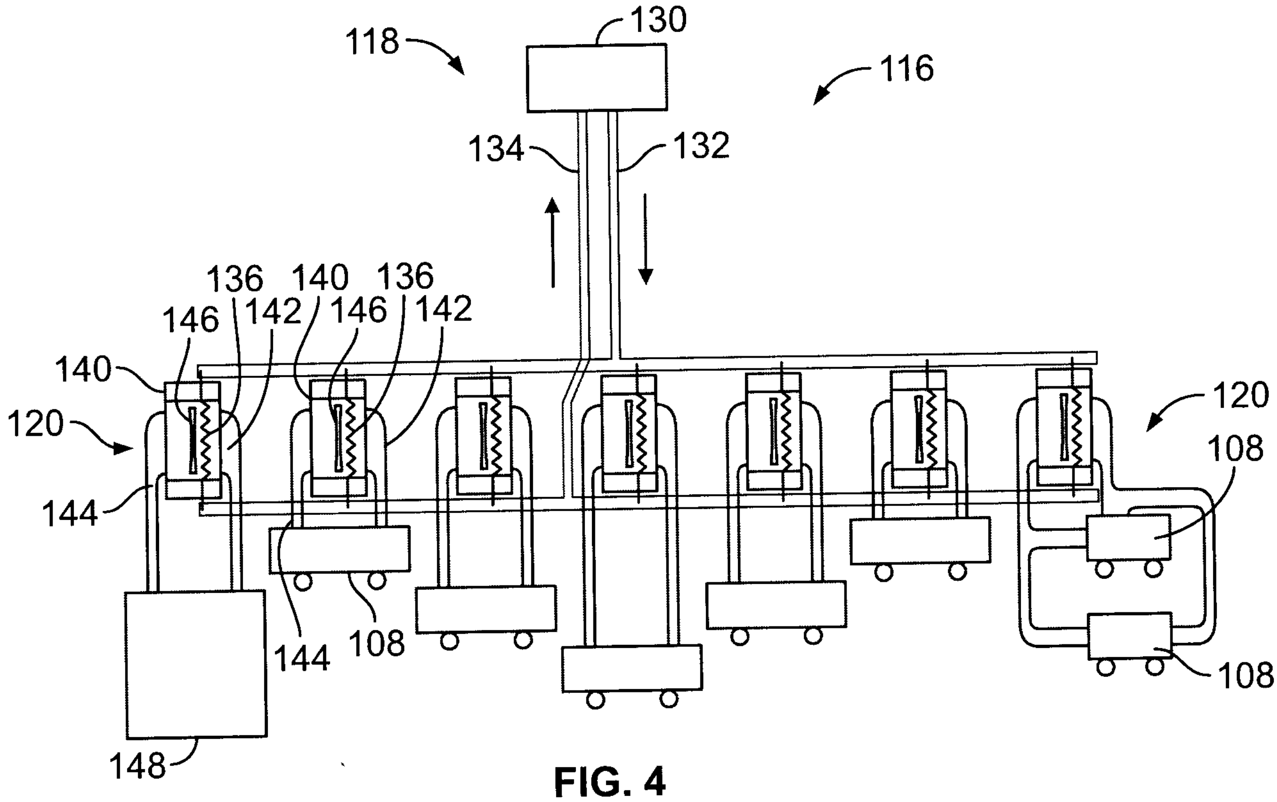

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FIG. 4

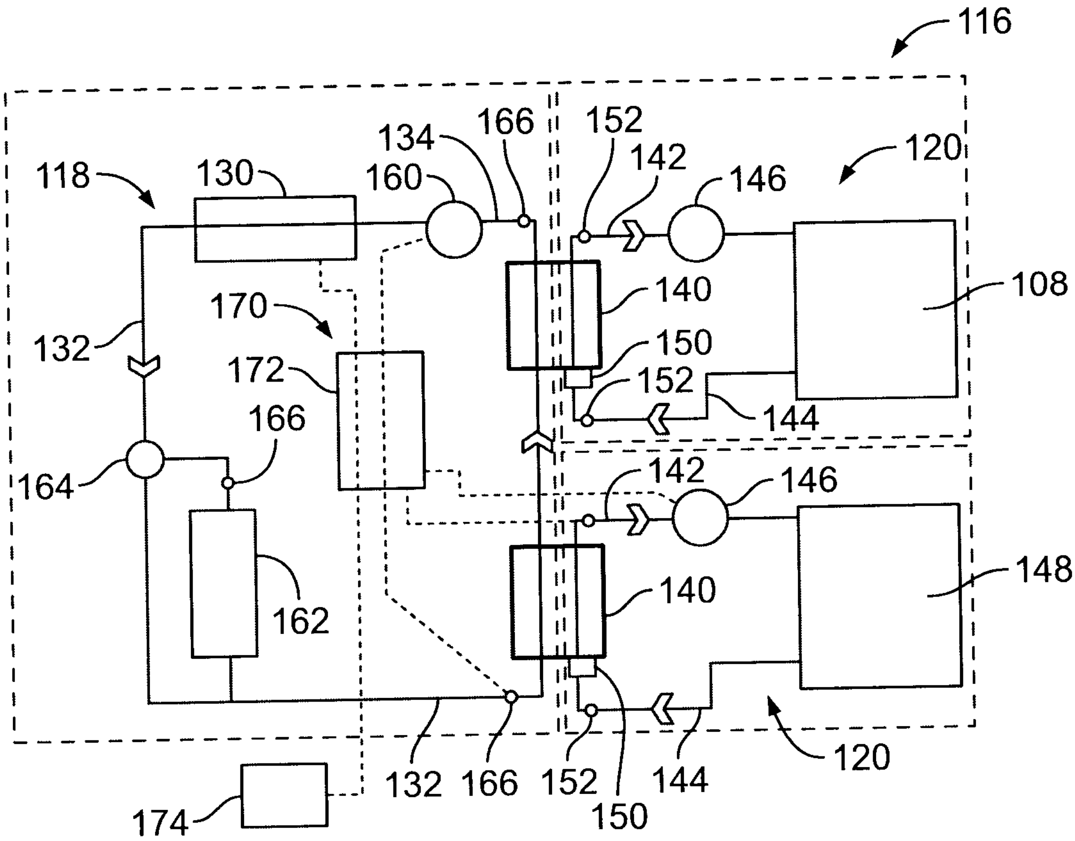

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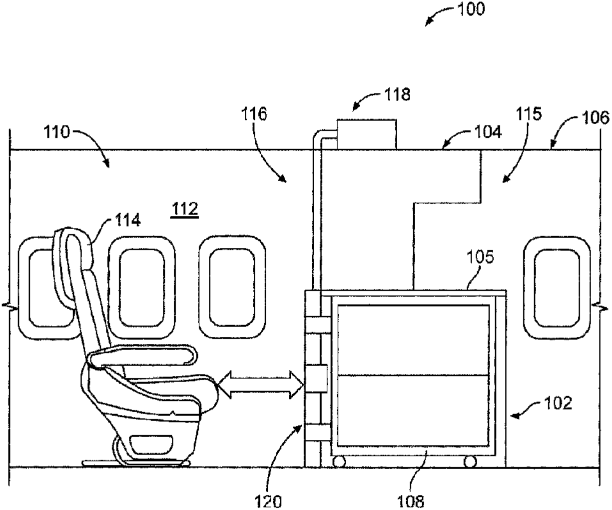
FIG. 5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