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(54) **HEATING SYSTEM FOR A VEHICLE**

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(75) Inventors: **Dave Lyons**, Union City, CA (US);
Paul Knauer, Union City, CA (US); **Justin Dobbs**, Union City, CA (US); **Ethan Petersen**, Union City, CA (US)

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Correspondence Address:
FOLEY AND LARDNER LLP
SUITE 500
3000 K STREET NW
WASHINGTON, DC 20007 (US)

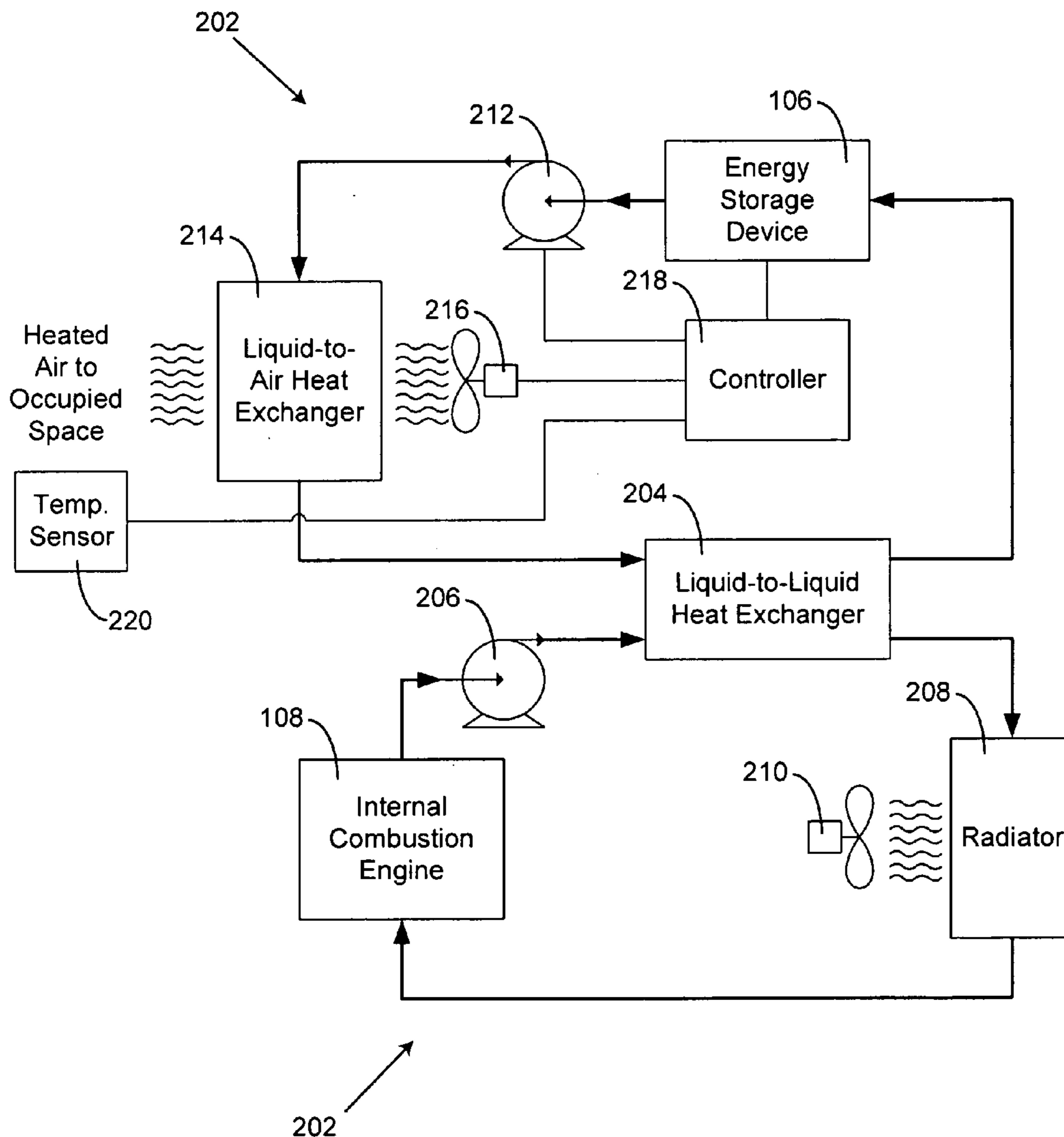
(57) **ABSTRACT**

A climate control system is configured to provide at least one of heating and cooling of air in an occupied space of a vehicle. The system includes a thermal energy storage device configured to receive heat from a waste heat source in the vehicle and a heat exchanger coupled between the thermal energy storage device and the occupied space of the vehicle by a coolant loop. The second heat exchanger is configured to transfer heat from at least one of the thermal energy storage device to the occupied space of the vehicle and the occupied space in the vehicle to the thermal energy storage device.

(73) Assignee: **GLACIER BAY, INC.**

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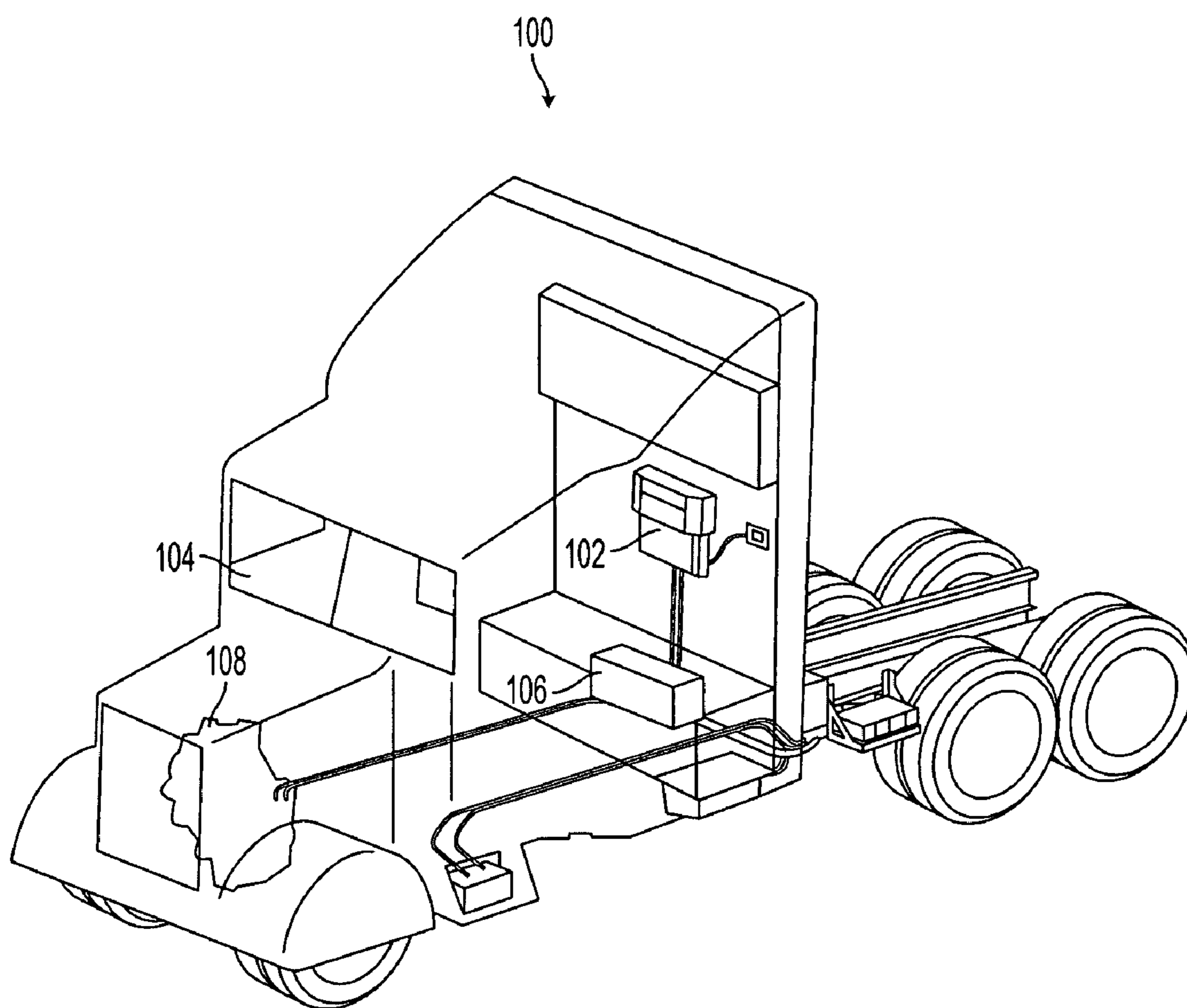
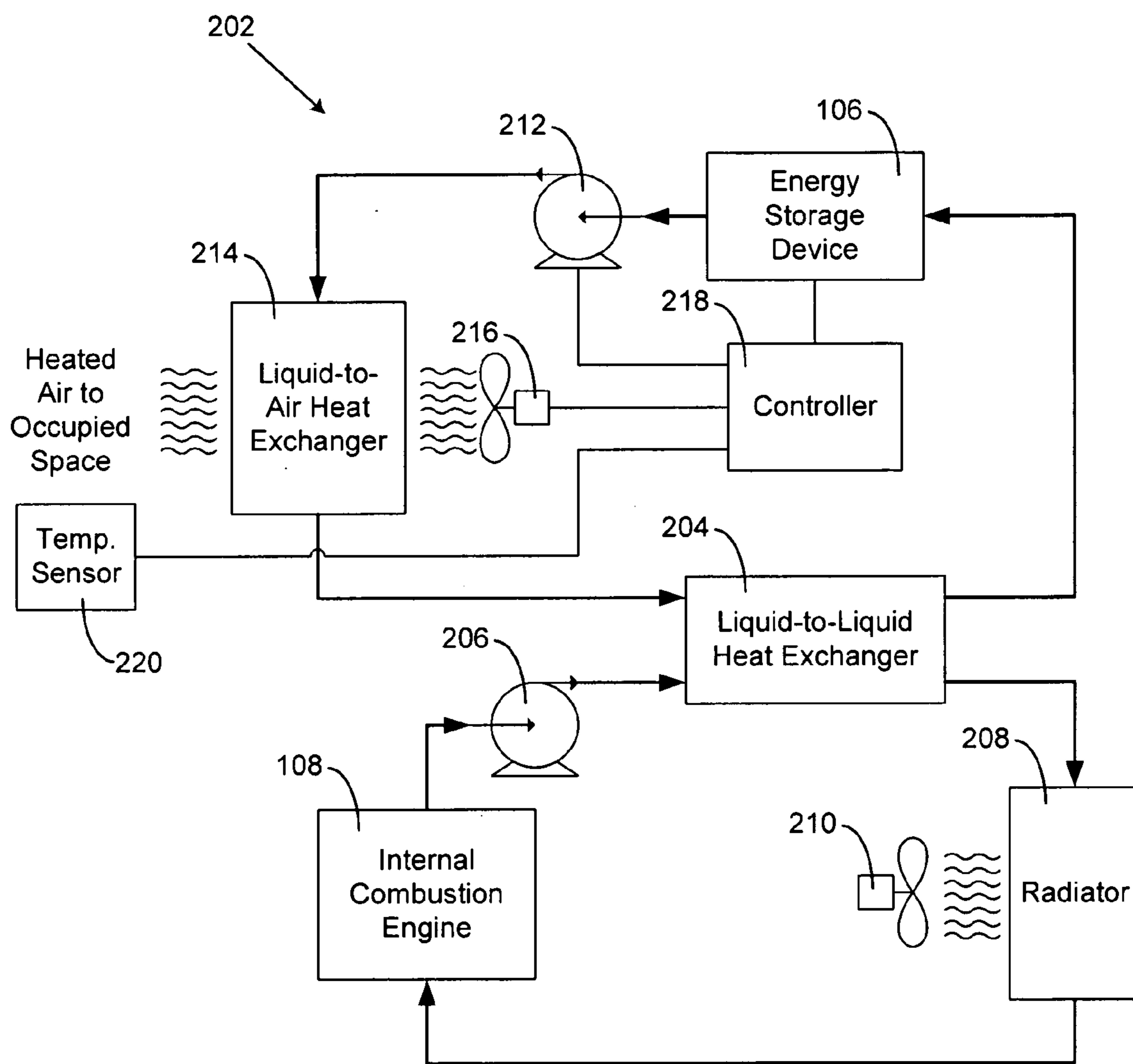


FIG. 1



202
 FIG. 2

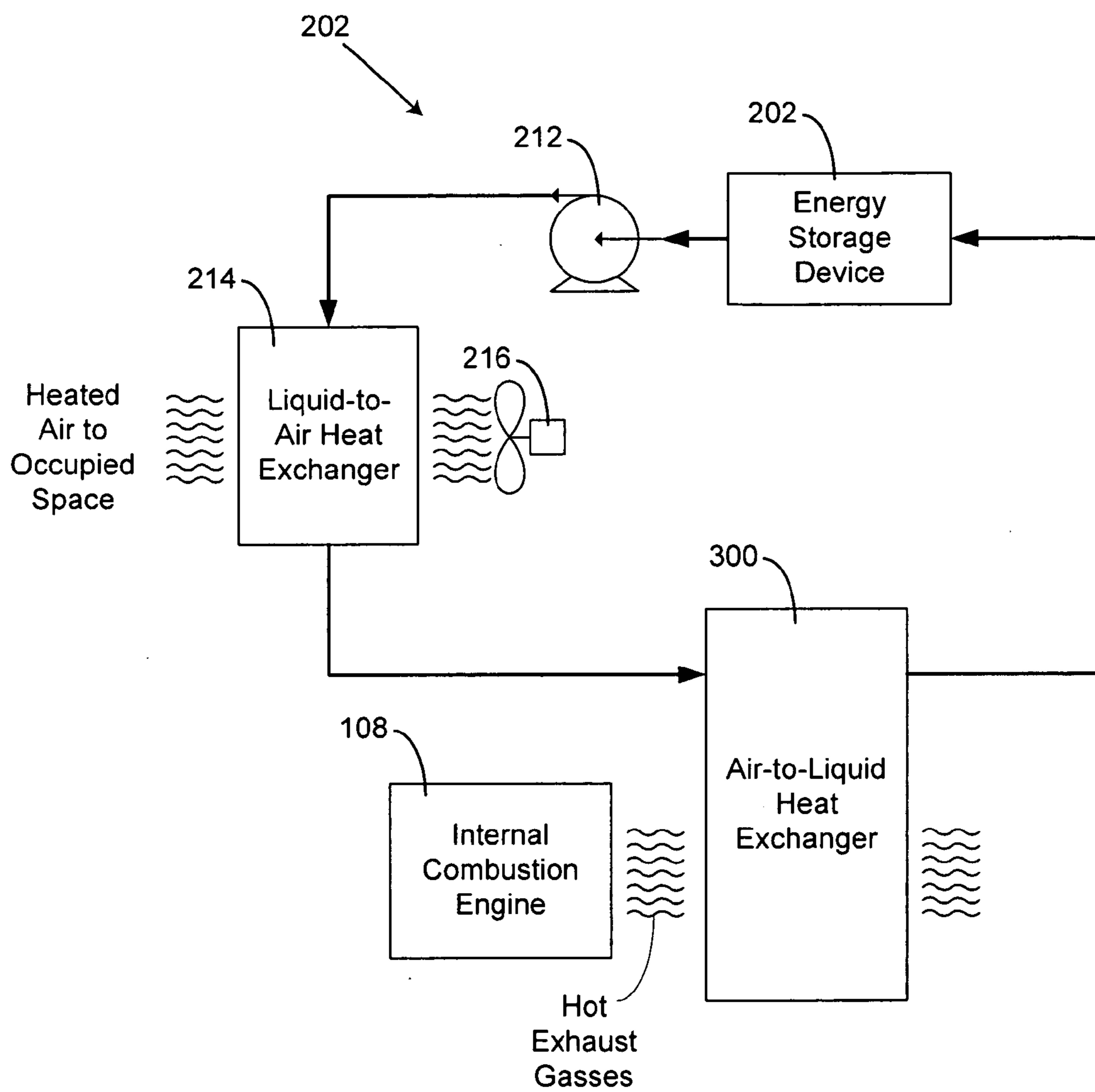


FIG. 3

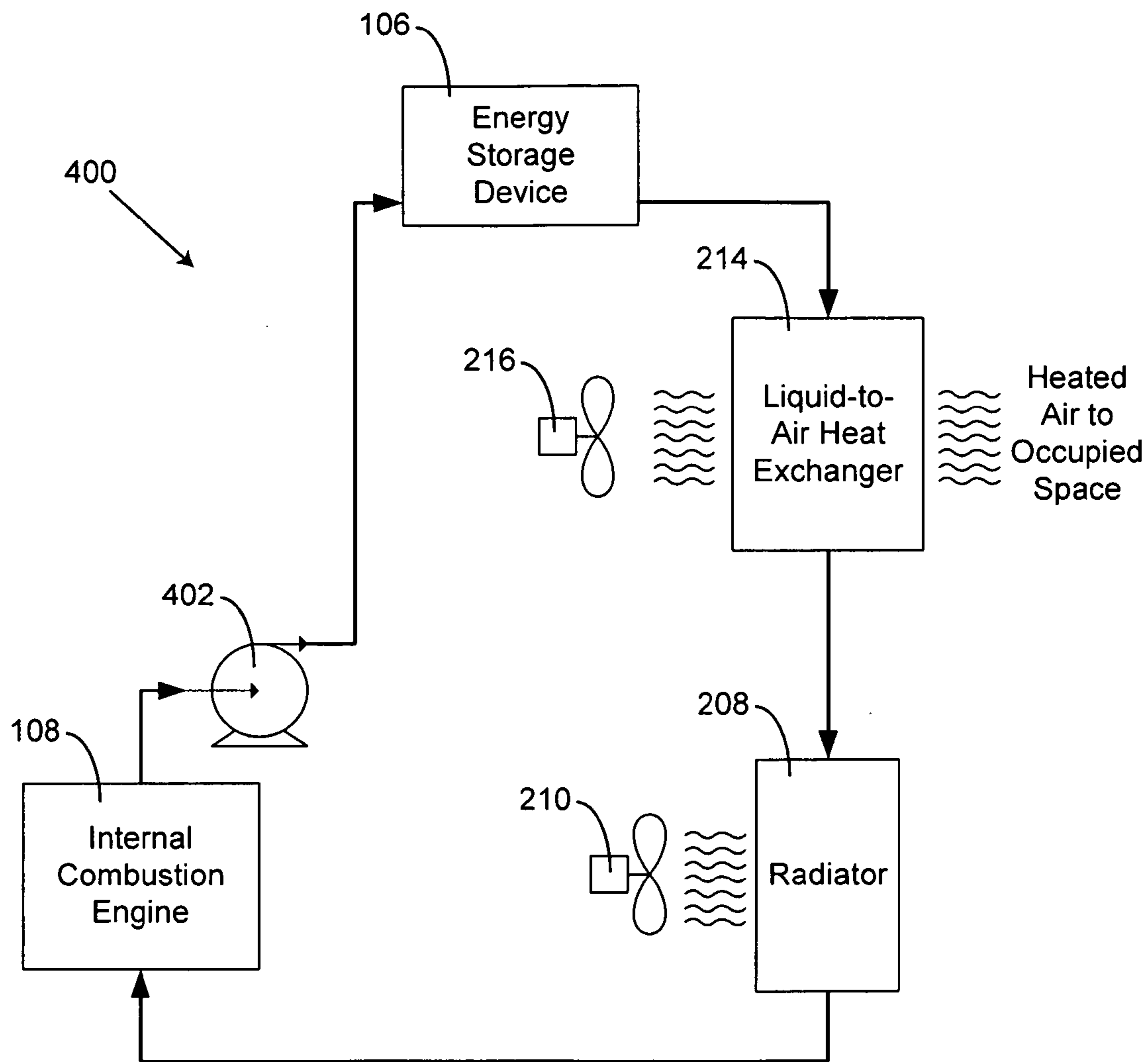


FIG. 4

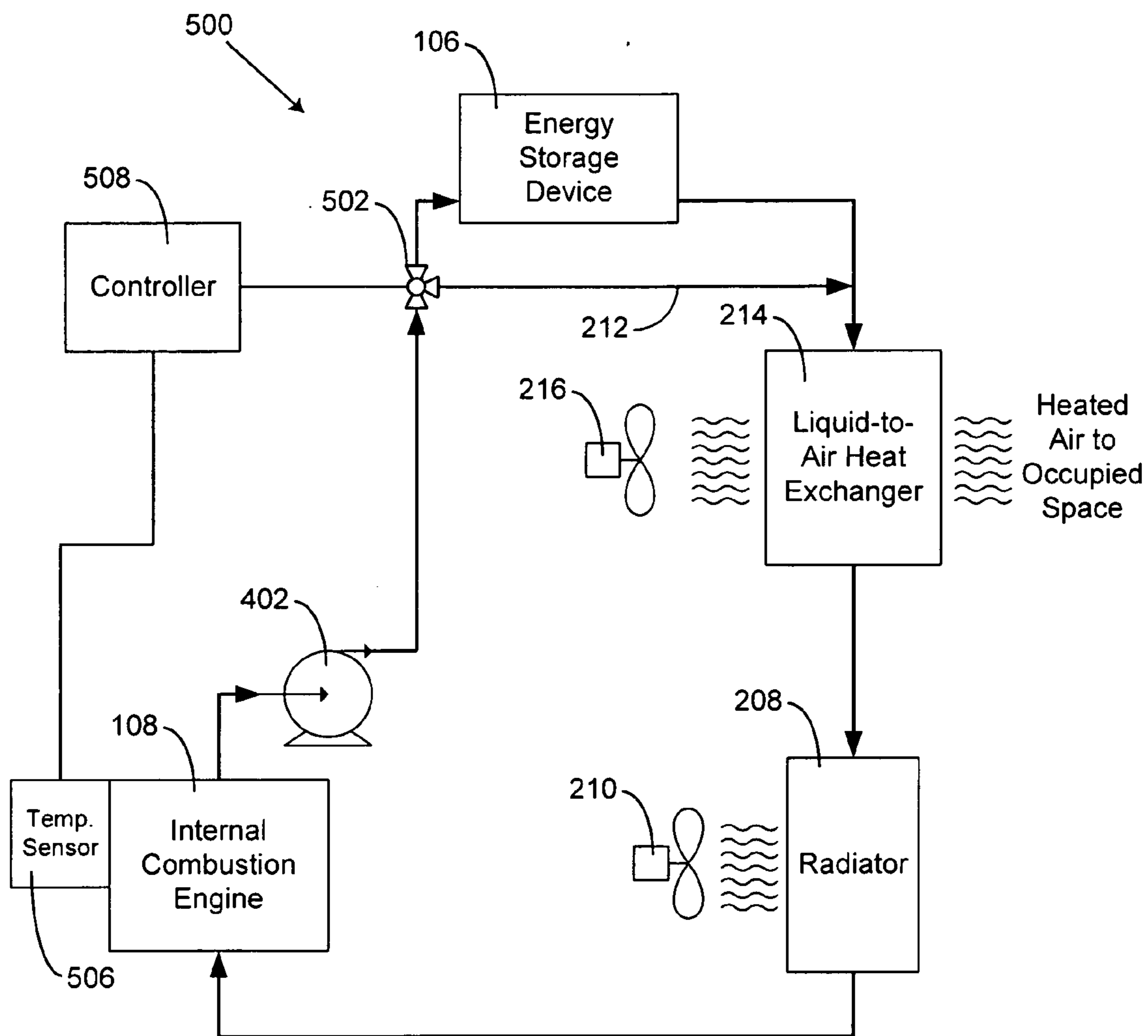


FIG. 5

HEATING SYSTEM FOR A VEHICLE

CROSS-REFERENCE TO RELATED PATENT APPLICATIONS

[0001] This application claims priority to and the benefit of U.S. Provisional Application No. 61/202,615, filed Mar. 18, 2009, which is herein incorporated by reference in its entirety.

BACKGROUND

[0002] The present invention relates generally to the field of heating systems for vehicles. Some vehicles are required to turn their engines off during mandatory or voluntary resting periods. With the engine off, waste heat is not used to provide cabin heating. In hybrid-electric vehicles or marine vessels, cabin heat may be required at times when the vehicle or vessel is operating in “all-electric” mode or “quiet” mode. In these modes, waste heat from the internal combustion engine is not available to provide heat to the occupant cabin. Generator powered buildings or structures may require supplemental or primary heat during periods of non-operation of the primary generator.

SUMMARY

[0003] According to one exemplary embodiment, a climate control system is configured to provide at least one of heating and cooling of air in an occupied space of a vehicle. The system includes a thermal energy storage device configured to receive heat from a waste heat source in the vehicle and a heat exchanger coupled between the thermal energy storage device and the occupied space of the vehicle by a coolant loop. The second heat exchanger is configured to transfer heat from at least one of the thermal energy storage device to the occupied space of the vehicle and the occupied space in the vehicle to the thermal energy storage device.

[0004] According to another exemplary embodiment, a method for providing at least one of heating and cooling of air in an occupied space of a vehicle includes transferring heat from a waste heat source to a thermal energy storage device and transferring heat from at least one of the thermal energy storage device to the occupied space of the vehicle and the occupied space in the vehicle to the thermal energy storage device using a heat exchanger coupled between the thermal energy storage device and the occupied space.

[0005] According to another exemplary embodiment, a climate control system is configured to provide heating air in an occupied space of a vehicle. The system includes a first coolant loop configured to transfer waste heat away from a heat source in the vehicle. The first coolant loop includes a first heat exchanger configured to transfer heat away from the heat source. The system also includes a second coolant loop configured to store waste heat from the first coolant loop for use in heating the occupied space. The second coolant loop includes a thermal energy storage device configured to store heat from first heat exchanger and a second heat exchanger coupled between the thermal energy storage device and the occupied space of the vehicle. The second heat exchanger is configured to transfer heat from the thermal energy storage device to the occupied space of the vehicle.

[0006] It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory only, and are not restrictive of the invention as claimed.

BRIEF DESCRIPTION OF DRAWINGS

[0007] These and other features, aspects, and advantages of the present invention will become apparent from the following description, appended claims, and the accompanying exemplary embodiments shown in the drawings, which are briefly described below.

[0008] FIG. 1 is an isometric view of a vehicle including a heating system with a thermal energy storage device according to an exemplary embodiment.

[0009] FIGS. 2-5 are block diagrams of a heating system according to several exemplary embodiments.

DETAILED DESCRIPTION

[0010] Hereinafter, various embodiments of the present invention will be described in detail with reference to the drawings.

[0011] Referring to FIG. 1, according to various exemplary embodiments, a vehicle 100 may include an HVAC system 102 configured to provide climate control of a vehicle cabin 104. In situations where the primary engine or generator is not operating, the vehicle 100, a building, or a structure may rely on stored power from a variety of sources to provide heating and/or cooling for the occupied space when the primary system is not running (e.g., battery system, fuel system (chemical energy), phase-change material system, or various other systems). According to one exemplary embodiment, the HVAC system 100 may be an HVAC system installable in the vehicle 100 and having an energy storage module or device 106 connected to the vehicle's existing power system 108 (e.g., an engine in an engine compartment). The HVAC system 102 may be controlled in a way that makes optimized use of stored power in module 106 to condition the air for the occupied space of the cabin 104.

[0012] It may be advantageous for the HVAC system 100 to be at least partially powered by the waste heat of the vehicle from a waste heat source (e.g., from an engine, an exhaust system, a drivetrain, etc.) and to store excess energy from the waste heat in the energy storage device 106, which may also power other components of the HVAC system 100. It may be advantageous for the HVAC system 100 to be powered by the waste heat and the energy storage device 106 such that the HVAC components and system operate efficiently.

[0013] The engine 108 (e.g., an internal combustion engine) may include a system to cool the engine 108. According to one exemplary embodiment, the cooling system comprises a closed loop through which flows a cooling fluid, such as a mixture of water and glycol. The cooling fluid absorbs heat as it passes through the engine 108 and transfers heat to the surrounding environment (e.g., the surrounding air and/or water) with a heat exchanger, such as a radiator.

[0014] At least a portion of the waste heat generated by the engine 108 may be transferred to the storage device 106. The waste heat may be transferred to the storage device 106 directly (e.g., with the closed cooling loop) or with a secondary loop. As described below, according to some exemplary embodiments, the stored energy may be used to heat the vehicle cabin 104. However, according to other exemplary

embodiments, the stored energy may be used for other purposes, such as cooling the vehicle cabin **104**.

[0015] The vehicle **100** includes occupied space, such as the cabin **104** or other rooms. The occupied rooms are generally heated by powered equipment while the engine **108** is running. As described in more detail below, the vehicle may include a heating system and the energy storage device **106** may be a thermal energy storage device. The storage device **106** absorbs thermal energy when the engine **108** is operating and releases the energy when the engine **108** is off to heat air supplied to the occupied areas of the vehicle **100**. In other exemplary embodiments, the storage device **106** may be a battery charged by an alternator driven by the engine or any other suitable energy storage device.

[0016] The storage device **106** may use the stored energy when the engine **108** is off to heat or cool air supplied to the occupied areas of the vehicle, for example the cabin **104**. The heating and cooling system **102** may include an intelligent control system configured to optimize performance to the cabin occupants based on their situational needs and comfort levels. The heating and cooling system **102** may be a “hybrid” heating system that combines multiple forms of heating in an optimized system. For example, a radiant panel and a fuel-fired heater may be used together such that the panel warms the driver while he or she is in the bunk, while a motion sensor turns on the fuel-fired heater when the driver gets up to heat the remainder of the cabin **104**.

[0017] The energy to drive the heating and cooling system **102** is stored in the energy storage module **106**, as described above. Because the amount of stored energy in the energy storage system **106** is finite, the heating and cooling ability of the system **102** is, in turn, also finite. For example, on especially cold or hot nights the heating or cooling load needed to maintain the desired interior cabin temperature may exceed the amount of heating or cooling that can be provided with the stored energy. To make efficient use or consumption of the stored energy, the heating and cooling system **102** may be configured to make trade-offs between system power (energy consumption rates) and system performance (heating or cooling output) under certain high temperature difference conditions.

[0018] According to various exemplary embodiments, the energy storage device **106** may be a system that utilizes phase change materials where the heat is released or absorbed by a chemical substance during a change of state (i.e., solid, liquid, or gas) or a phase transition (e.g., water, salt hydrates, etc.). For example, the heat from the secondary working fluid may cause the material to transform from a solid to a liquid or vice versa. The energy storage device **106** functions as a heat exchanger for the secondary loop **202**, transferring heat from or to a flue in the secondary loop **202**.

[0019] According to some exemplary embodiments, the energy storage device **106** may comprise a plurality of storage panels. For example, the energy storage device **106** may be an energy storage device described in U.S. Pat. No. 5,901,572, which is herein incorporated by reference in its entirety. Heated air is blown over the panels with a fan, causing the material in the panel to undergo phase change and store thermal energy (e.g., when the engine is running). Such a material may be, for example, water, a linear alkyl hydrocarbon, or a mix of alkyl hydrocarbons and paraffin wax. Likewise, air may be blown over the panels after the engine is off causing the opposite effect, with the phase change material giving up the stored thermal energy to heat the air (e.g., after

the engine has been turned off). According to other exemplary embodiments, and as described herein, instead of a forced air system similar to the system disclosed in U.S. Pat. No. 5,901,572, the heat transfer between the energy storage device **106** and the heating and cooling system **102** may be directly between the phase change material and a primary or secondary loop of fluid.

[0020] While the heating and cooling system **102** as generally described herein may be configured so that energy storage module **106** serves as a secondary power source, according to other exemplary embodiments, the energy storage module **106** may not be limited to use as a backup power source. In some exemplary embodiments, the system may be configured so that the energy storage module **106** is the main source of energy for the heating and cooling system **102**. For example, the heating and cooling system **102** may be powered in most situations by energy from the energy storage module **106**. In exemplary embodiments where the energy storage module provides primary power, an engine powered generator or an off truck power source (i.e., shore power) system may be used to charge the energy storage module **106**.

[0021] According to various exemplary embodiments, the features described herein may be employed with an HVAC system disclosed in U.S. patent application Ser. No. 12/320,213, filed Jan. 21, 2009, or in U.S. patent application Ser. No. 11/560,160, filed on Nov. 15, 2006, each of which is incorporated herein by reference in its entirety.

[0022] Referring to FIG. 2, according to one exemplary embodiment, heat is transferred from an engine cooling loop **200** (e.g., a primary loop) to a secondary loop **202** with a liquid-to-liquid heat exchanger **204** (e.g., counter flow or parallel flow double pipe heat exchanger, cross flow heat exchanger, shell-and-tube heat exchanger, etc.).

[0023] The engine cooling loop **200** (e.g., a closed loop through) circulates a cooling fluid, such as a mixture of water and glycol, using a pump **206**. The cooling fluid absorbs heat as it passes through the engine **108** and transfers heat to the surrounding environment (e.g., the surrounding air and/or water) with a heat exchanger **208**, such as a radiator. A fan **210** may blow air across the radiator **208** to increase heat transfer from the fluid to the surrounding air.

[0024] The secondary loop **202** contains a working fluid that is configured to efficiently absorb and transfer heat from the engine cooling loop **200** to the storage device **106**. The working fluid may be, for example, a mixture of water and glycol. The working fluid is circulated by a pump **212** from the energy storage device **106** to a heat exchanger **214**, for example a liquid to air heat exchanger, to provide heated air to the occupied space, for example the cabin **104**. A variable speed or fixed speed fan **216** may blow air across the heat exchanger **214** to increase heat transfer from the fluid to the surrounding air.

[0025] When the engine **108** is running, heat energy is stored in the energy storage device **106** via the phase transition of the storage material. During periods when the engine **108** is turned off, the stored energy can be released by the storage device **106** to the working fluid secondary loop **202**. The energy is carried by the secondary loop **202** to the liquid-to-air heat exchanger **214**. The air absorbs heat from the secondary fluid and is provided to the cabin **104** or other occupied space.

[0026] An electronic controller **218** is provided to control the storage device **106**, the pump **212**, and the fan **216** in the secondary loop **202**. Alternatively, separate controllers may

be provided for one or more components. The electronic controller **218** is configured to monitor sensors (e.g., state sensors) for various systems, for example a temperature sensor **220**. The controller **218** is configured to provide climate control based on system feedback control algorithms. The sensors may be sensors positioned and configured to sense a condition of the vehicle. For example, the sensors may include a sensor to detect the temperature of a compartment (i.e., engine compartment or passenger compartment).

[0027] According to another exemplary embodiment, the system could work on simple open-loop user set controls. A user may select the fan **216** speed (e.g., “low,” “medium,” and “high”) based on their preference. The fan **216** speed may be adjusted or the fan **216** may be turned off if the user feels the temperature is too warm or too cold in the occupied space.

[0028] Referring to FIG. 3, according to another exemplary embodiment, exhaust gases from the engine **108** may be directed to an air-to-liquid heat exchanger **300** (e.g., counter flow or parallel flow double pipe heat exchanger, cross flow heat exchanger, shell-and-tube heat exchanger, etc.). Heat is transferred from the exhaust gases to a secondary loop **302**. Similar to the exemplary embodiment of FIG. 2, the secondary loop **302** transfers the heat from the heat exchanger **300** to the storage device **106** for use in heating air of the occupied space.

[0029] Referring to FIG. 4, according to still another exemplary embodiment, a heating system **400** may not include a secondary loop. Instead, the coolant in the cooling loop may be routed directly to the storage device **106** by a pump **402** before passing through the heat exchanger **214** configured to provide heat to the occupied space and the engine **108** heat exchanger **208** (e.g., a radiator).

[0030] Because of space and material limitations, the energy storage device **106** may only be capable of storing enough energy to heat the cabin **104** or other occupied space for a certain amount of time. To extend the amount of time the cabin **104** may be heated after the engine **108** has been turned off, the engine block itself may be used as a storage device. In the exemplary embodiment of FIG. 4, a working fluid such as water or a water and glycol mix may be circulated through the engine block for a few hours after shutting down the engine **108**.

[0031] Referring to FIG. 5, according to an exemplary embodiment similar to the system shown in FIG. 4, a cooling loop **500** provides a working fluid. Instead of transferring heat to the storage device **106**, the fluid may be directed to the liquid-to-air heat exchanger **214**, bypassing the storage device **106**. A valve **502** may control the flow of the fluid through the main line or a bypass line **504** based on the temperature of the engine **108** block. The temperature of the engine block may be read by a temperature sensor **506**, which sends temperature readings to a controller **508**. Controller **508** is configured to control actuation of the valve **502**. The length of time the engine **108** block may provide heat to the heating system may be dependent on how long the block stays hot due to external temperatures, etc. However, using the engine **108** block heat may contribute additional heating time for the cabin **104** in addition to what the energy stored in the storage device **106** can provide.

[0032] As described above, the heating and cooling system **102** may capture waste heat from the vehicle’s internal combustion engine **108**. The heat source may be the engine block or other component of the internal combustion engine **108**. The heat exchanger **204**, **300**, transferring the waste heat to

the secondary loop **202** may be constructed in a manner similar to conventional well known examples of heat exchangers utilizing the heat from the engine **108** or engine exhaust to heat a fluid. According to various exemplary embodiments, the heat exchanger **204**, **300** may be a heat exchanger disclosed in U.S. Pat. Nos. 4,003,344 and 7,013,644, each of which is incorporated by reference herein in its entirety.

[0033] While the heating and cooling system **102** is described above as being used to capture waste heat from a propulsion or power generation engine **108** in a vehicle **100**, it should be understood that the concepts are applicable to other environments as well. For example, the heating system may also be used to heat a building structure or shelter by extracting waste heat of an power generating internal combustion engine.

[0034] While the thermal energy stored in the storage device **106** is generally described as being used to heat the air for occupied areas of the vehicle **100**, such stored energy may be used for other purposes. For example, according to another exemplary embodiment, the stored thermal energy may be used as part of a refrigeration cycle to cool air.

[0035] It is important to note that the construction and arrangement of the heating system as shown in the various exemplary embodiments is illustrative only. Although only a few embodiments of the present application have been described in detail in this disclosure, those skilled in the art who review this disclosure will readily appreciate that many modifications are possible (e.g., variations in sizes, dimensions, structures, shapes and proportions of the various elements, values of parameters, mounting arrangements, use of materials, colors, orientations, etc.) without materially departing from the novel teachings and advantages of the subject matter recited in the application. For example, elements shown as integrally formed may be constructed of multiple parts or elements, the position of elements may be reversed or otherwise varied, and the nature or number of discrete elements or positions may be altered or varied. Accordingly, all such modifications are intended to be included within the scope of the present application. The order or sequence of any process or method steps may be varied or re-sequenced according to alternative embodiments. Any means-plus-function clause is intended to cover the structures described herein as performing the recited function and not only structural equivalents but also equivalent structures. Other substitutions, modifications, changes and omissions may be made in the design, operating conditions and arrangement of the exemplary embodiments without departing from the scope of the present application.

[0036] The foregoing description of embodiments of the application has been presented for purposes of illustration and description. It is not intended to be exhaustive or to limit the application to the precise form disclosed, and modifications and variations are possible in light of the above teachings, or may be acquired from practice of the application. The embodiments were chosen and described in order to explain the principles of the application and its practical application to enable one skilled in the art to utilize the application in various embodiments and with various modifications as are suited to the particular use contemplated.

[0037] Although the description contains many specificities, these specificities are utilized to illustrate some of the preferred embodiments of this application and should not be construed as limiting the scope of the application. The scope

of this application fully encompasses other embodiments which may become apparent to those skilled in the art. All structural, chemical, and functional equivalents to the elements of the above-described application that are known to those of ordinary skill in the art are expressly incorporated herein by reference and are intended to be encompassed by the present application. A reference to an element in the singular is not intended to mean one and only one, unless explicitly so stated, but rather it should be construed to mean at least one. Furthermore, no element, component or method step in the present disclosure is intended to be dedicated to the public.

What is claimed is:

1. A climate control system configured to provide at least one of heating and cooling of air in an occupied space of a vehicle, comprising:

- a thermal energy storage device configured to receive heat from a waste heat source in the vehicle; and
- a heat exchanger coupled between the thermal energy storage device and the occupied space of the vehicle by a coolant loop, the second heat exchanger configured to transfer heat from at least one of the thermal energy storage device to the occupied space of the vehicle and the occupied space in the vehicle to the thermal energy storage device.

2. The system of claim **1**, wherein the waste heat source comprises at least one of a vehicle engine, exhaust gas, and the occupied space.

3. The system of claim **1**, further comprising:
a second heat exchanger coupled to the thermal energy storage device by the coolant loop, the second heat exchanger configured to transfer waste heat from the heat source to the thermal energy storage device.

4. The system of claim **3**, further comprising:
a second coolant loop coupling the heat source to the second heat exchanger.

5. The system of claim **1**, wherein the second heat exchanger comprises a liquid-to-liquid heat exchanger or an air-to-liquid heat exchanger.

6. The system of claim **1**, wherein the heat source is coupled to the thermal energy storage device by the coolant loop.

7. The system of claim **4**, further comprising:
a valve; and
a bypass coolant line configured to bypass the thermal energy storage device and couple the heat source to the heat exchanger based on the position of the valve.

8. The system of claim **1**, further comprising:
a pump configured to circulate coolant through the coolant loop; and
a fan configured to heat across the heat exchanger and into the occupied space.

9. The system of claim **1**, further comprising:
an electronic controller configured to control operation of the climate control system based on electronic input from at least one sensor configured to sense a condition of the vehicle.

10. The system of claim **1**, wherein the at least one sensor comprises at least one temperature sensor for mounting in the occupied space or in an engine compartment.

11. The system of claim **1**, wherein the heat exchanger comprises a liquid-to-air heat exchanger.

12. A method for providing at least one of heating and cooling of air in an occupied space of a vehicle, comprising:
transferring heat from a waste heat source to a thermal energy storage device; and
transferring heat from at least one of the thermal energy storage device to the occupied space of the vehicle and the occupied space in the vehicle to the thermal energy storage device using a heat exchanger coupled between the thermal energy storage device and the occupied space.

13. The method of claim **12**, wherein the waste heat is transferred from at least one of a vehicle engine, exhaust gas, and the occupied space.

14. The method of claim **12**, further comprising:
transferring waste heat from the heat source to the thermal energy storage device using a second heat exchanger coupled to the thermal energy storage device by the coolant loop.

15. The method of claim **14**, further comprising:
transferring heat from the heat source to the second heat exchanger using a second coolant loop.

16. The method of claim **12**, further comprising:
transferring heat from the heat source to the thermal energy storage device using the coolant loop.

17. The method of claim **16**, further comprising:
actuating a valve to transfer heat from the heat source to the heat exchanger over a bypass coolant line to bypass the thermal energy storage device.

18. The method of claim **12**, further comprising:
receiving an electrical signal at an electronic controller from the at least one sensor; and
controlling operation of the climate control system based on the electrical signal using the electronic controller.

19. The method of claim **18**, wherein the electronic controller receives the electrical signal from at least one temperature sensor mounted in the occupied space or in an engine compartment.

20. A climate control system configured to provide heating air in an occupied space of a vehicle, comprising:
a first coolant loop configured to transfer waste heat away from a heat source in the vehicle, the first coolant loop comprising a first heat exchanger configured to transfer heat away from the heat source; and
a second coolant loop configured to store waste heat from the first coolant loop for use in heating the occupied space, the second coolant loop comprising:
a thermal energy storage device configured to store heat from first heat exchanger; and
a second heat exchanger coupled between the thermal energy storage device and the occupied space of the vehicle, the second heat exchanger configured to transfer heat from the thermal energy storage device to the occupied space of the vehicle.

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