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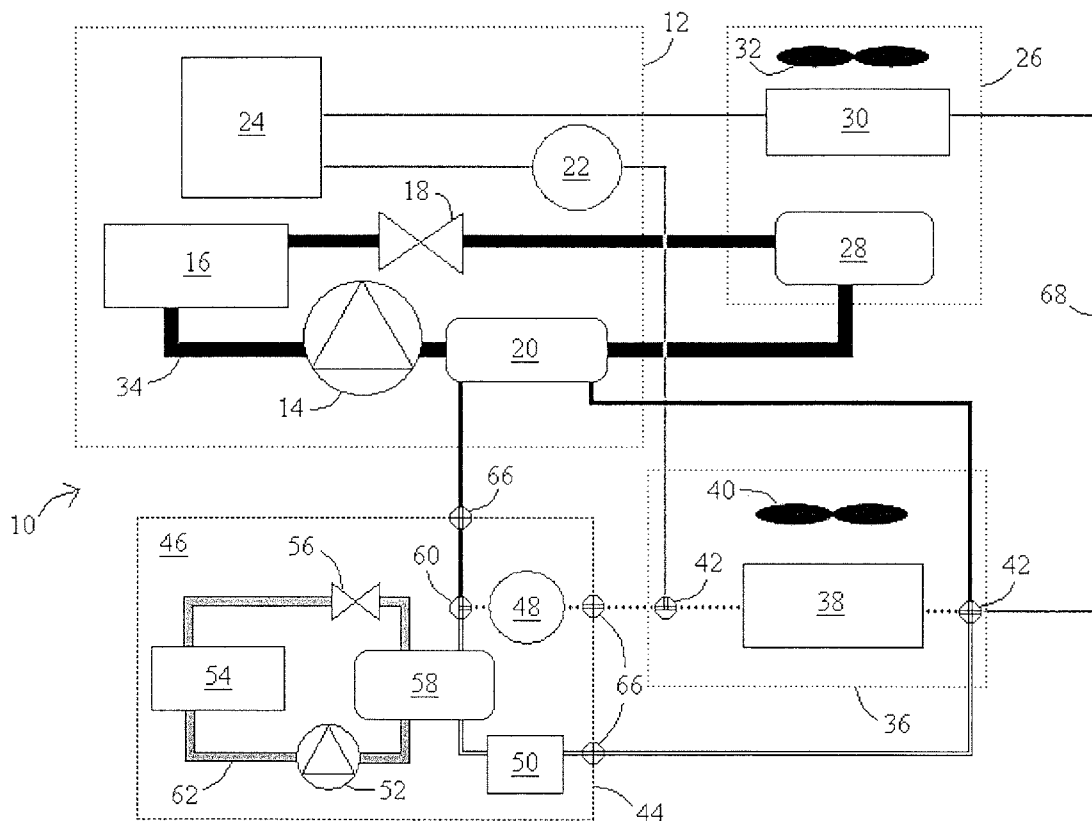
(19) **United States**(12) **Patent Application Publication**
Wilson et al.(10) **Pub. No.: US 2008/0245503 A1**(43) **Pub. Date: Oct. 9, 2008**(54) **HEAT EXCHANGE SYSTEM FOR VEHICLES
AND METHOD OF OPERATING THE SAME****Related U.S. Application Data**

(60) Provisional application No. 60/922,544, filed on Apr. 9, 2007.

(76) Inventors: **Michael J. Wilson**, Racine, WI (US); **Stephen B. Memory**, Kenosha, WI (US); **Jianmin Yin**, Racine, WI (US); **Jonathan P. Wattlelet**, Gurnee, IL (US); **Samuel J. Collier**, Danville, KY (US); **Kevin Traeger**, Chicago, IL (US); **Todd Bandhauer**, Avondale Estates, GA (US)**Publication Classification**(51) **Int. Cl.**
B61D 27/00 (2006.01)(52) **U.S. Cl.** **165/42**(57) **ABSTRACT**

The present invention provides a heat exchange system for a vehicle. The heat exchange system can include a first heat exchange circuit supported by the vehicle and fluidly connecting a condenser, a compressor, an evaporator, and an expansion device, a module removably secured to the vehicle, the module housing a pump, and a second heat exchange circuit fluidly connecting a liquid-to-air heat exchanger, the pump, and the evaporator. The first exchange circuit can be operable to condition a first passenger space, and the second heat exchange circuit can be operable to condition a second passenger space spaced apart from the first passenger space.

Correspondence Address:

MICHAEL BEST & FRIEDRICH LLP
100 E WISCONSIN AVENUE, Suite 3300
MILWAUKEE, WI 53202 (US)(21) Appl. No.: **12/099,828**(22) Filed: **Apr. 9, 2008**

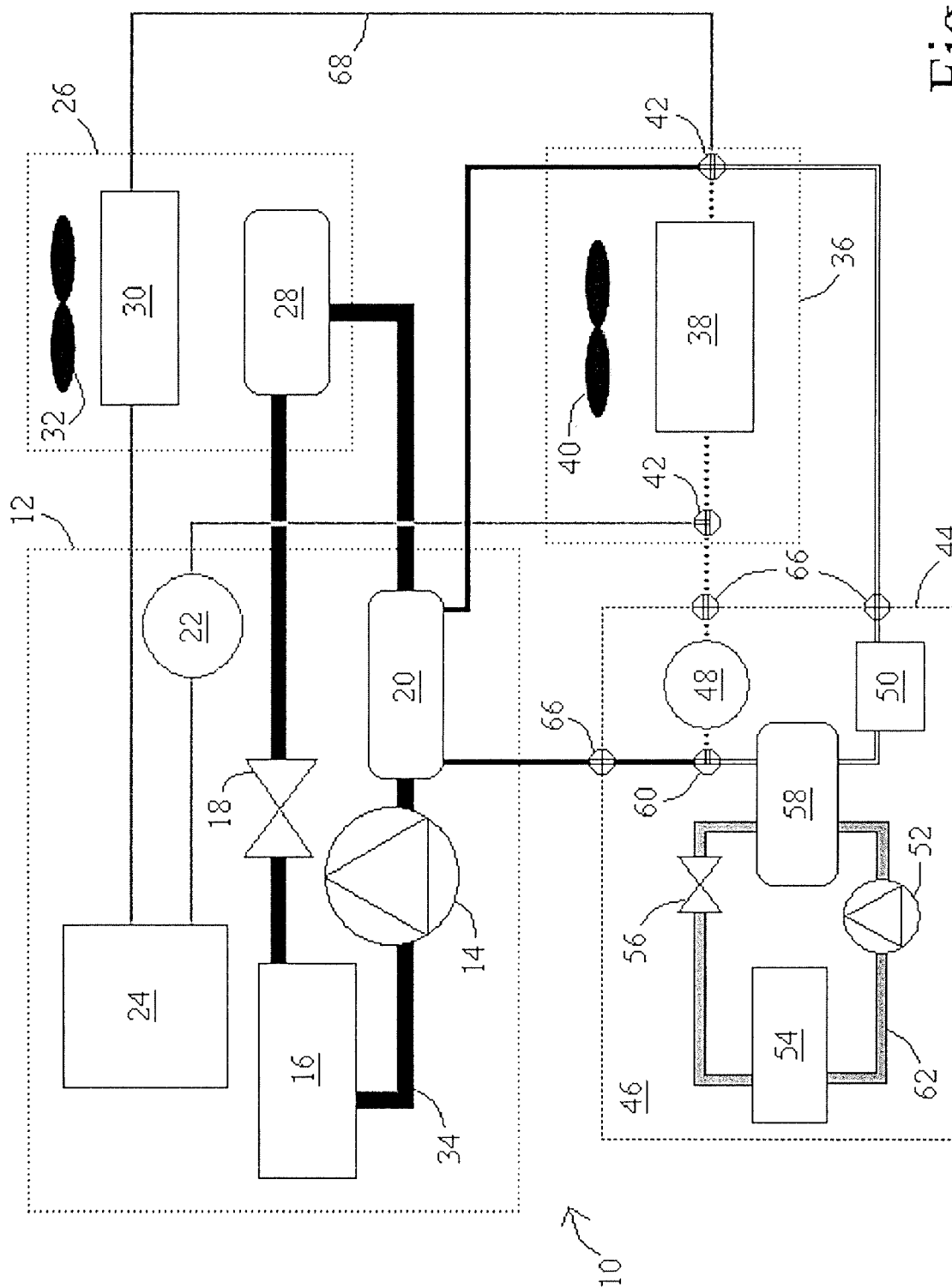


Fig. 1

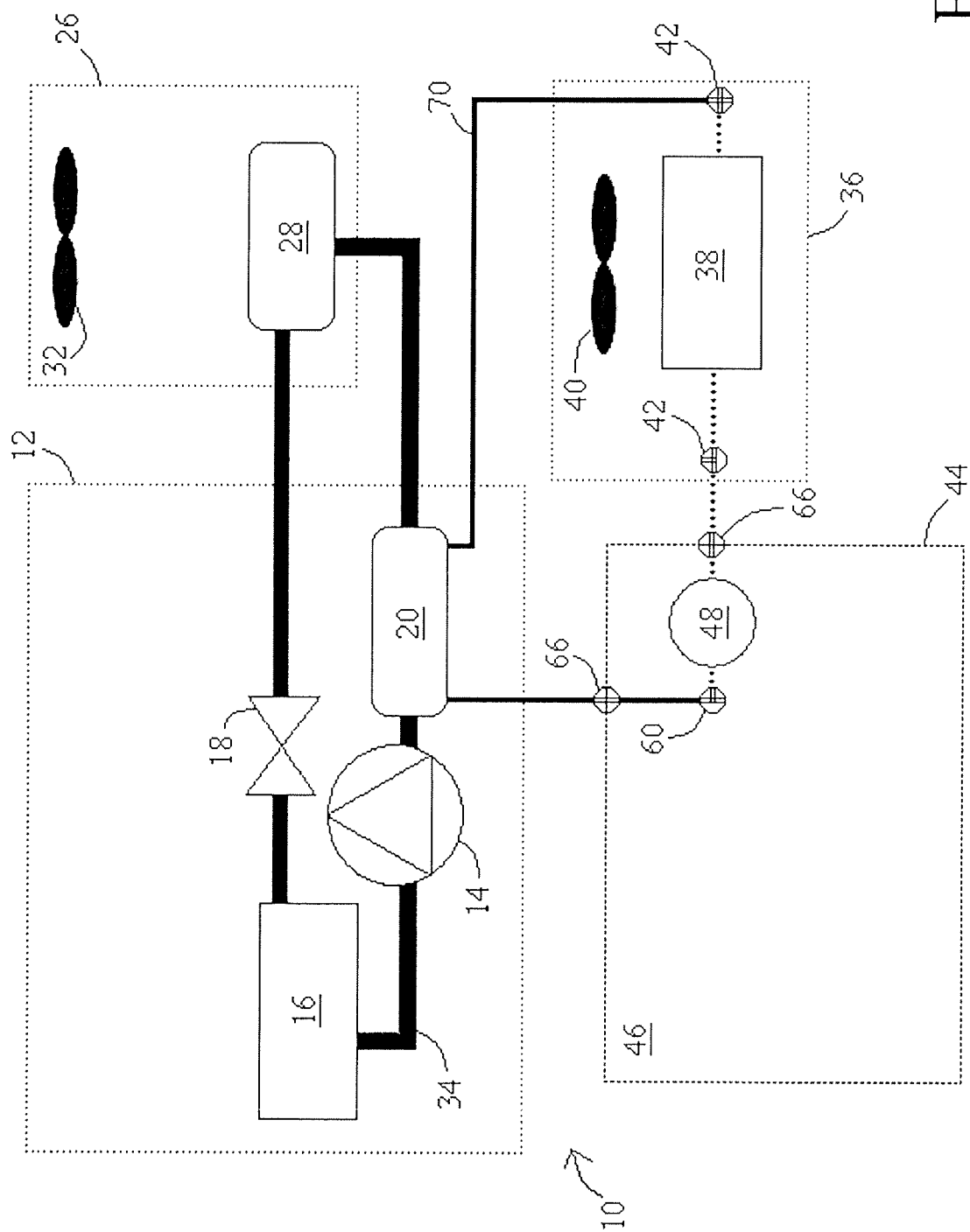


Fig. 2

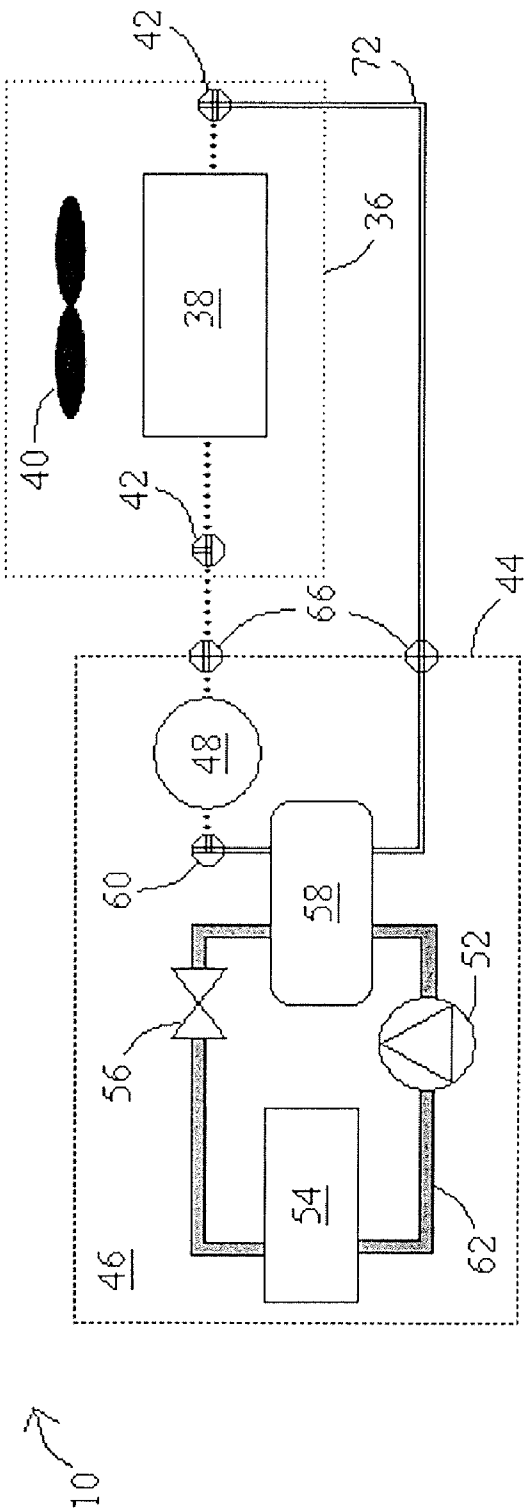


Fig. 3

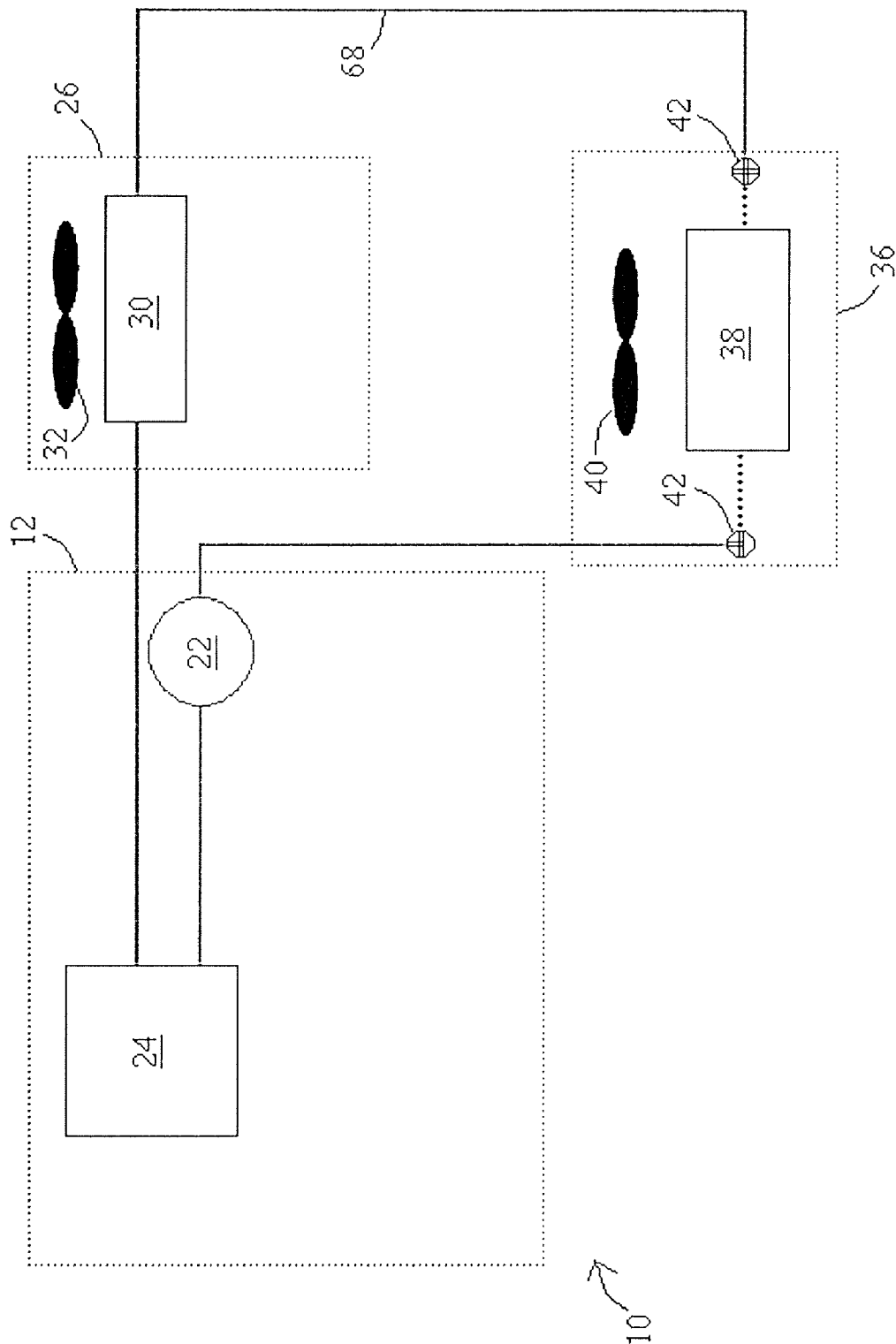


Fig. 4

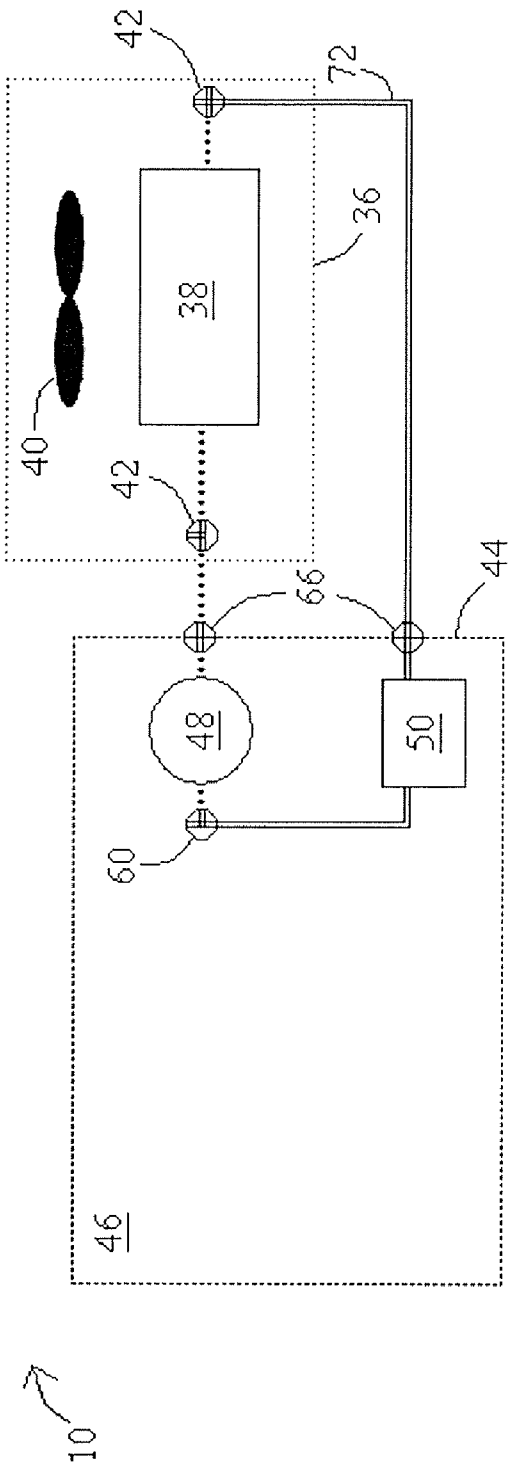


Fig. 5

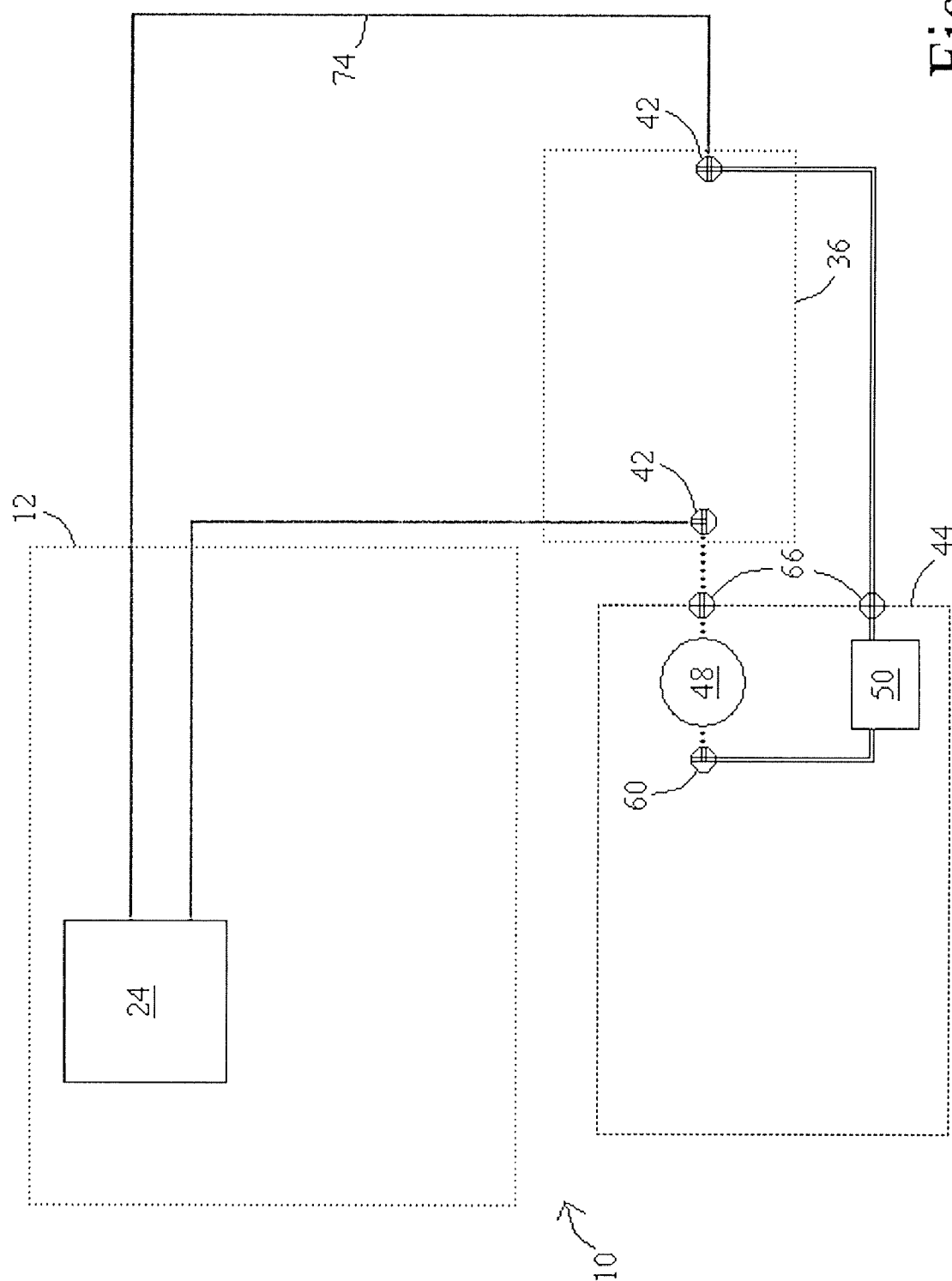


Fig. 6

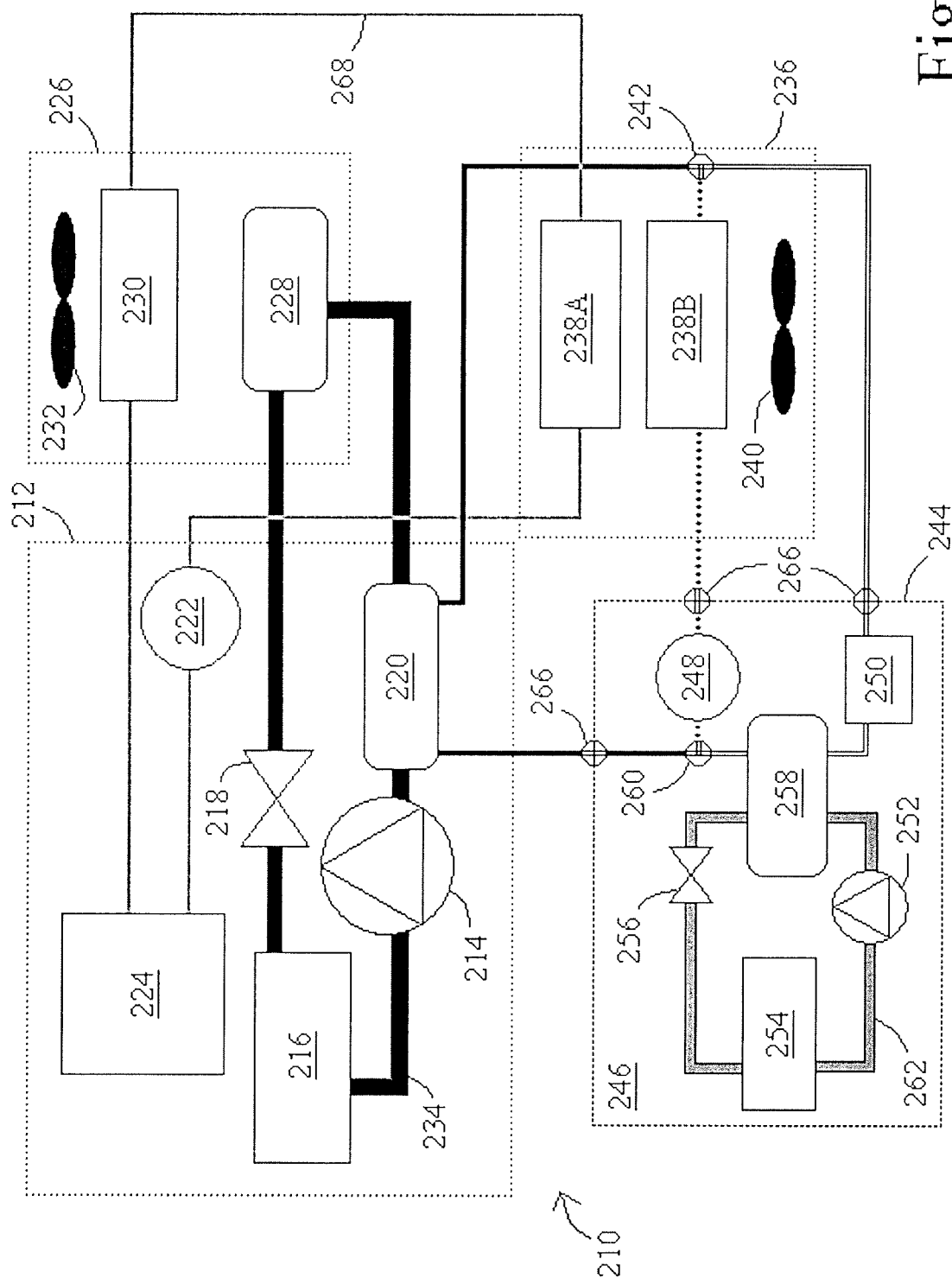


Fig. 7

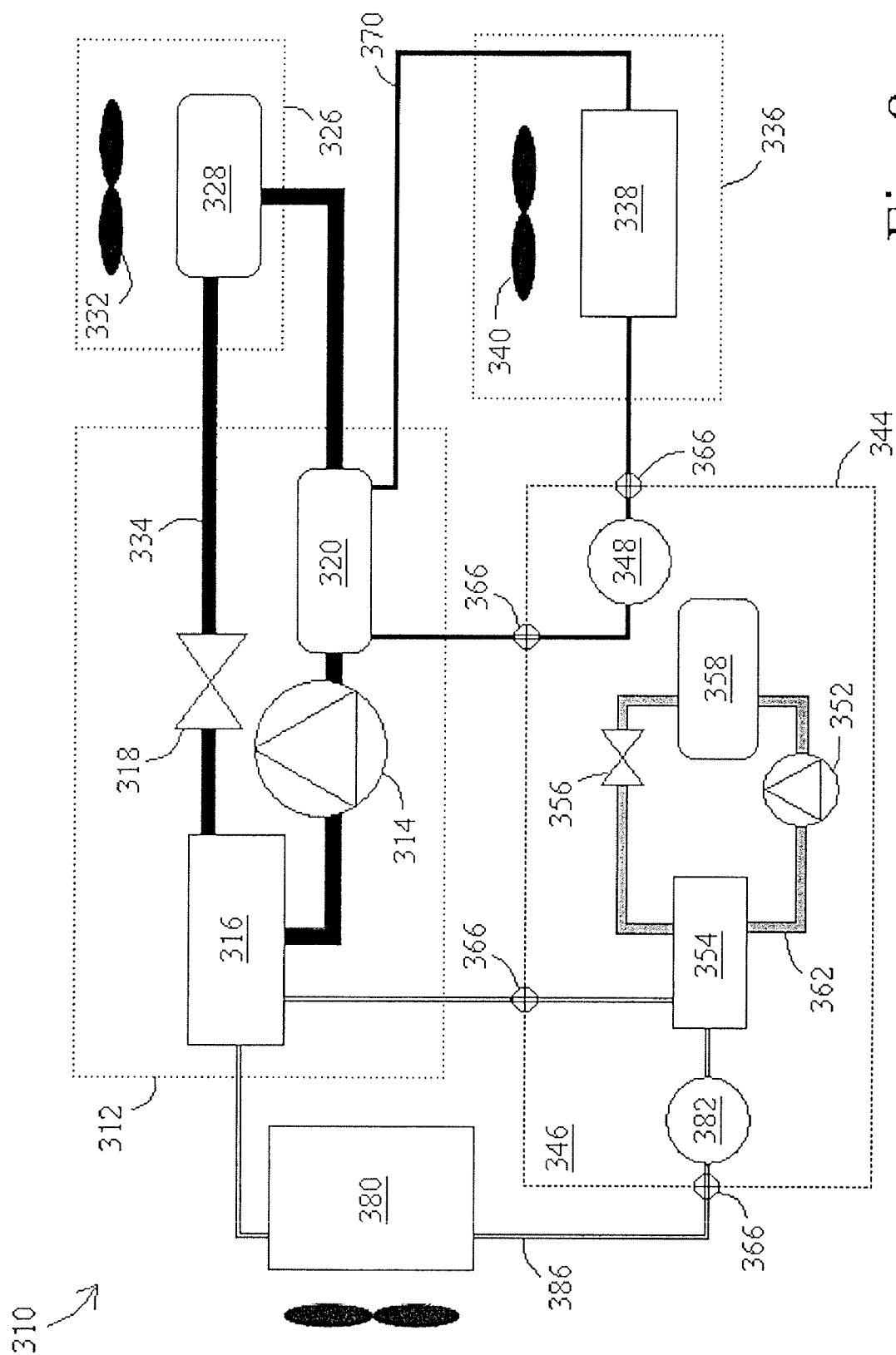


Fig. 8

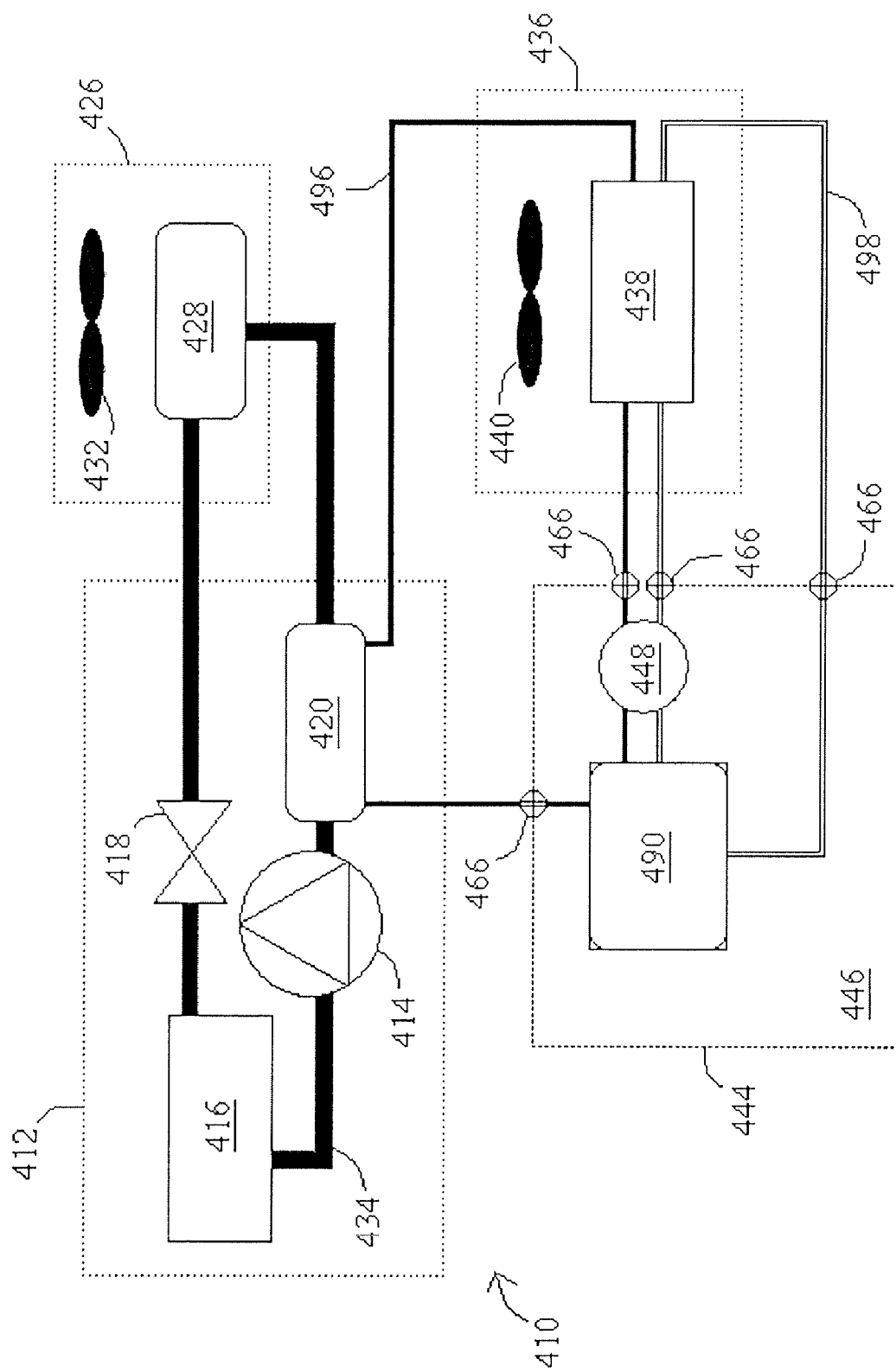


Fig. 9

HEAT EXCHANGE SYSTEM FOR VEHICLES AND METHOD OF OPERATING THE SAME

RELATED APPLICATIONS

[0001] This application claims priority to co-pending provisional patent application Ser. No. 60/922,544 filed on Apr. 9, 2007, the entire content of which is incorporated herein by reference.

FIELD OF THE INVENTION

[0002] The present invention relates to vehicle mounted heat exchangers and, more particularly, to a supplemental heat exchange module for a vehicle passenger space and a method of operating the same.

SUMMARY

[0003] In some embodiments, the present invention provides a heat exchange system for a vehicle. The heat exchange system can include a first heat exchange circuit supported by the vehicle and fluidly connecting a condenser, a compressor, an evaporator, and an expansion device, a module removably secured to the vehicle, the module housing a pump, and a second heat exchange circuit fluidly connecting a liquid-to-air heat exchanger, the pump, and the evaporator. The first exchange circuit can be operable to condition a first passenger space, and the second heat exchange circuit can be operable to condition a second passenger space spaced apart from the first passenger space.

[0004] The present invention also provides a method of operating a heat exchange system in a vehicle. The method can include the acts of directing a first working fluid through a first heat exchange circuit fluidly connecting a first compressor, a first condenser, a first expansion device, and a first evaporator. The first heat exchange circuit can extend through a first passenger space and can be supported in the vehicle. The method can also include the act of securing a removable module housing a pump to the vehicle. In addition, the method can include the acts of conveying a second working fluid through a second heat exchange circuit which extends through a second passenger space using the pump, and transferring heat from one of the first passenger space and the second passenger space to the second working fluid to condition the one of the first passenger space and the second passenger space when an engine of the vehicle is not in operation.

[0005] In some embodiments, the present invention provides a modular heat exchange system for a vehicle. The modular heat exchange system can include a first heat exchange circuit extending between and connecting a first module and a second module. The first heat exchange circuit can be operable to provide one of heating and cooling capacity to a first passenger space of the vehicle. The heat exchange system can also include a second heat exchange circuit extending between and connecting the first module, a third module, and a fourth module. The second heat exchange circuit can be operable to provide one of heating and cooling capacity to a second passenger space of the vehicle. The second passenger space can be spaced apart from the first passenger space. In addition, the heat exchange system can include a third heat exchange circuit extending between and connecting the third and fourth modules. The third heat exchange circuit can be operable to provide one of heating

and cooling capacity to the second passenger space of the vehicle. The fourth module can be removably supported on the vehicle.

[0006] The present invention also provides a modular unit for a heat exchange system in a vehicle. The vehicle can have a heat exchange circuit for conditioning a passenger space of the vehicle. The modular unit can include a conduit that forms a portion of a fluid flow path, a first disconnect valve at a first end of the conduit, a second disconnect valve at a second end of the conduit, the first and second disconnect valves being connectable to the heat exchange circuit of the vehicle, and a pump for conveying a working fluid along the fluid flow path and through the heat exchange circuit of the vehicle. The first and second disconnect valves can prevent substantial loss of working fluid from the fluid flow path when the modular unit is removed from the vehicle.

[0007] Other aspects of the invention will become apparent by consideration of the detailed description and accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] FIG. 1 is a schematic view of a heat exchange system according to some embodiments of the present invention.

[0009] FIG. 2 is a schematic view of the heat exchange system shown in FIG. 1 operating in a first mode.

[0010] FIG. 3 is a schematic view of the heat exchange system shown in FIG. 1 operating in a second mode.

[0011] FIG. 4 is a schematic view of the heat exchange system shown in FIG. 1 operating in a third mode.

[0012] FIG. 5 is a schematic view of the heat exchange system shown in FIG. 1 operating in a fourth mode.

[0013] FIG. 6 is a schematic view of the heat exchange system shown in FIG. 1 operating in a fifth mode.

[0014] FIG. 7 is a schematic view of a heat exchange system according to another embodiment of the present invention.

[0015] FIG. 8 is a schematic view of a heat exchange system according to yet another embodiment of the present invention.

[0016] FIG. 9 is a schematic view of a heat exchange system according to still another embodiment of the present invention.

DETAILED DESCRIPTION

[0017] Before any embodiments of the invention are explained in detail, it is to be understood that the invention is not limited in its application to the details of construction and the arrangement of components set forth in the following description or illustrated in the following drawings. The invention is capable of other embodiments and of being practiced or of being carried out in various ways. Also, it is to be understood that the phraseology and terminology used herein is for the purpose of description and should not be regarded as limiting. The use of "including," "comprising," or "having" and variations thereof herein is meant to encompass the items listed thereafter and equivalents thereof as well as additional items.

[0018] Unless specified or limited otherwise, the terms "mounted," "connected," "supported," and "coupled" and variations thereof are used broadly and encompass both direct and indirect mountings, connections, supports, and couplings. Further, "connected" and "coupled" are not restricted to physical or mechanical connections or couplings. In addi-

tion, terms such as “first,” “second,” “third,” and “fourth” are used herein for purposes of description and are not intended to indicate or imply relative importance or significance.

[0019] Also, it should be understood that the term “evaporator” is used herein to refer to heat exchange elements which operate to transfer heat between two or more working fluids. As such, the term “evaporator” as used herein is not limited to elements or locations wherein a working fluid changes state.

[0020] FIGS. 1-6 illustrate a heat exchange system 10 for use in a vehicle, such as, for example, a truck, tractor-trailer combination, bus, van, etc. In some embodiments of the present invention, the heat exchange system 10 can include a first portion or module 12, at least a part of which can be located in or adjacent to an engine compartment of the vehicle. The first module 12 can include a compressor 14 (e.g., a mechanical, electrical, or other compressor), a condenser 16, an expansion device 18 (e.g., a valve, channel, chamber, etc.), a first evaporator 20, and a pump 22 (e.g., an electrical, mechanical, or other pump).

[0021] In some embodiments, the condenser 16 is an air-cooled condenser. The condenser 16 can also include a fan for moving air through the condenser 16. In other embodiments, other condensers, including liquid-cooled condensers can also or alternatively be used. In some embodiments, the condenser 16 is a liquid-cooled condenser, having a low temperature loop extending through the vehicle radiator. In some such embodiments, the condenser 16 can include a remote cooler/radiator.

[0022] The compressor 14 and the pump 22 can be driven by a vehicle engine 24, an electric motor, a power take-off arrangement, a vehicle battery, or other prime-movers. In some embodiments, the compressor 14, condenser fan, and the pump 22 can utilize the same driving arrangement or power source. Alternatively, or in addition, one or more of these components can have a distinct drive arrangement or power source.

[0023] As shown in the illustrated embodiment of FIGS. 1-6, the heat exchange system 10 also includes a second portion or module 26, at least a part of which can be located in or adjacent to a first passenger space of the vehicle (e.g., under the dashboard, in a console, under a seat, etc.). In another embodiment, the second module 26 can be located remotely from and yet be in fluid communication with the first passenger space of the vehicle. The second module 26 can include a second evaporator 28, a liquid-to-air heat exchanger or heater core 30, and a blower or fan 32.

[0024] In the illustrated embodiment, the first evaporator 20, compressor 14, condenser 16, and expansion device 18 of the first module 12, and the second evaporator 28 of the second module 26 can be fluidly connected along a first heat exchange circuit 34. While the first heat exchange circuit 34 extends between and connects the first and second modules 12, 26 in this embodiment, it can have other configurations and include other elements in other embodiments.

[0025] As shown in FIGS. 1-6, the heat exchange system 10 can also include a third portion or module 36, at least a part of which can be located in or adjacent to the first passenger space, or alternatively, can be located in a second passenger or cargo space (e.g., a sleeping area of the vehicle, a rear seat area of the vehicle, etc.), which is at least partially separated from the first passenger space. In another embodiment, the third module 36 can be located remotely from and yet be in fluid communication with the second passenger space of the vehicle. In some embodiments, the third module 36 can

include a liquid-to-air heat exchanger or heater/cooling core 38 and a blower or fan 40. As shown in the illustrated embodiment of FIGS. 1-6, the third module 36 can also include one or more valves 42. The valves 42 provide a means for selectively directing a working fluid along a certain path within the heat exchange system 30.

[0026] The heat exchange system 10 can also include a fourth portion or module 44, at least a part of which can be removably supported in or by the vehicle. In some embodiments, the fourth module 44 or a portion of the fourth module 44 can be housed in a cassette or modular unit 46, which can be secured to the vehicle and can be removed from the vehicle for servicing or replacement.

[0027] As shown in FIGS. 1-6, the fourth module 44 can include a pump 48 (e.g., an electrical, mechanical, or other pump), a heating element 50 (e.g., an electric heater, a diesel heater, a propane heater, a heating coil supplied with high-temperature engine coolant from the vehicle engine, etc.), a compressor 52 (e.g., a mechanical, electrical, or other compressor), a condenser 54, an expansion device 56, and a third evaporator 58. In some embodiments, the compressor 52, condenser 54, expansion device 56 (e.g., a valve, channel, chamber, etc.), and third evaporator 58 can be fluidly connected along a second heat exchange circuit 62. As shown in the illustrated embodiment of FIGS. 1-6, the fourth module 44 can also include one or more valves 60. Though none are shown, first and second modules can also include valves 60 for selectively directing a working fluid along a certain path within the heat exchange system 30.

[0028] In some embodiments, the condenser 54 is an air-cooled condenser. The condenser 54 can also include a fan for moving air through the condenser 54. In other embodiments, other condensers, including liquid-cooled condensers can also or alternatively be used. In some embodiments, the condenser 54 is a liquid-cooled condenser, having a low temperature loop extending through the vehicle radiator. In some such embodiments, the condenser 54 can include a remote cooler/radiator.

[0029] The compressor 54 and the pump 48 can be powered by the vehicle engine 24, an electric motor, a power take-off arrangement, battery, a fuel cell, or another prime mover. In some embodiments, the compressor 14, condenser fan, and the pump can utilize the same driving means. Alternatively, or in addition, one or more of these components can have distinct driving means.

[0030] In some embodiments, the condenser 54 is an air-cooled condenser. The condenser 54 can also include a fan for moving air through the condenser 54. In other embodiments, other condensers, including liquid-cooled condensers can also or alternatively be used. In some embodiments, the condenser 54 is a liquid-cooled condenser, having a low temperature loop extending through the vehicle radiator. In some such embodiments, the condenser can include a remote cooler/radiator.

[0031] In embodiments, such as the illustrated embodiment of FIGS. 1-6, in which the fourth module 44 is removably supported in the vehicle, the heat exchange system 10 can include quick-disconnect valves 66 positioned on the cassette 46. Alternatively or in addition, the heat exchange system 10 can include quick-disconnect valves 66 positioned in one or more of the first, second, or third modules 12, 26, 36, 44, elsewhere in the vehicle, and/or along the first heat exchange circuit 34. In these embodiments, when the cassette 46 is

removed, quick-disconnect valves 66 are closed to prevent the working fluid from escaping from the heat exchange system 10.

[0032] As shown in FIGS. 1-6, the heat exchange system 10 can include a heating circuit 68 extending between and fluidly connecting the first, second, and third modules 12, 26, 36. In some embodiments, such as the illustrated embodiment of FIGS. 1-6, the heating circuit 68 extends between and fluidly connects the coolant system of the vehicle engine and the pump 22 in the first module 12, the heater core 30 in the second module 26, and the liquid-to-air heat exchanger 38 in the third module 36. In other embodiments, the heating circuit 68 can have other constructions and arrangements, can fluidly connect other elements of the heat exchange system 10, and can extend through one, two, or four of the first, second, third, and fourth modules 12, 26, 36, 44.

[0033] In some embodiments, the heat exchange system 10 can operate in a first mode, a second mode, a third mode, a fourth mode, and a fifth mode. In other embodiments, the heat exchange system 10 can operate in one, two, three, four, six, or more modes. Alternatively or in addition, the heat exchange system 10 can include a controller for controlling operation of the heat exchange system 10. In some such embodiments, the controller can be operable to initiate operation in and to switch between operation in each of the first, second, third, fourth, and fifth modes. In other embodiments, the heat exchange system 10 can be manually operated.

[0034] During operation in the first mode, the heat exchange system 10 can transfer heat from the first passenger space of the vehicle (e.g., the front seat area of the vehicle) to a working fluid flowing through the second evaporator 28. This function can be performed by the first heat exchange circuit 34 in order to cool the first passenger space. During operation in the first mode, the heat exchange system 10 can also or alternatively transfer heat from the second passenger space (e.g., a sleeping area of the vehicle, a rear seat area of the vehicle, etc.) to a working fluid flowing through the liquid-to-air heat exchanger 38. This function can be performed by a combination of the first heat exchange circuit 34 and a third heat exchange circuit 70 in order to cool the first passenger space.

[0035] In some embodiments, when cooling is required in one or both of the first and second passenger areas of the vehicle, the controller can activate the compressor 14 and adjust the valves positioned along the first heat exchange circuit 34 to direct a working fluid into one or both of the evaporators 20, 28. In some embodiments and as shown in FIG. 2, the pump 48 in the cassette 46 can operate to direct a working fluid through the third heat exchange circuit 70 (see FIG. 2). In some such embodiments, the third heat exchange circuit 70 can extend between and fluidly connect the first evaporator 20 in the first module 12, the pump 48 in the fourth module, and the liquid-to-air heat exchanger 38 in the third module 36. During operation, heat can be transferred from the air in the second passenger space to working fluid (e.g., glycol, a water-glycol mix, and the like) traveling through the liquid-to-air heat exchanger 38. The working fluid can then travel to the first evaporator 20 and transfer heat to the working fluid traveling through the first heat exchange circuit 34.

[0036] During operation in the second mode, the heat exchange system 10 can transfer heat from the air in the second passenger space of the vehicle (e.g., a sleeping area of the vehicle, a rear seat area of the vehicle, etc.) to a working fluid flowing through the liquid-to-air heat exchanger 38. This

function can be performed by a combination of the second heat exchange circuit 62 and a fourth heat exchange circuit 72 (see FIG. 3) in order to cool the second passenger space. In some embodiments and as shown in FIG. 3, the pump 48 in the cassette 46 can operate to direct the working fluid through the fourth heat exchange circuit 72. In some such embodiments, the fourth heat exchange circuit 72 can extend between and fluidly connect the pump 48, third evaporator 58, and heating element 50 (see FIG. 1), in the fourth module 44 and the liquid-to-air heat exchanger 38 in the third module 36. The heating element 50 can be either deactivated or bypassed when the system 10 is operating in the second mode.

[0037] The heat from the air in the second passenger space can be transferred to working fluid (e.g., glycol, a water-glycol mix, and the like) traveling through the liquid-to-air heat exchanger 38. The working fluid can then travel through the fourth heat exchange circuit 72 to the third evaporator 58 and transfer heat to the working fluid flowing through the second heat exchange circuit 62. The working fluid traveling through the second heat exchange circuit 62 can be cooled and compressed in a conventional manner as the working fluid flows through the compressor 52, the condenser, 54 and the expansion device 56 of the second heat exchange circuit 62.

[0038] In some embodiments, the heat exchange system 10 can be operated in the second mode when the vehicle engine is shut down and/or not operating. In these embodiments, the pump 48 and other elements of the heat exchange system 10 can receive electrical power from the vehicle battery. Alternatively, the pump 48 and other elements of the heat exchange system 10 can receive electrical power from one or more batteries supported in the cassette 46 and/or an external power supply. In these embodiments, the heat exchange system 10 can maintain a relatively low temperature and/or pull the temperature down in the second passenger space without requiring the vehicle engine to be in operation, thereby significantly reducing vehicle emissions.

[0039] During operation in the third mode, the heat exchange system 10 can transfer heat from the vehicle engine to one or both the first and second passenger spaces. This function can be performed by the heating circuit 68 in order to heat the first and/or second passenger space. In these embodiments, the pump 22 in the first module 12 can direct high-temperature engine coolant through the heating circuit 68 to the heater core 30 and/or the liquid-to-air heat exchanger 38. In some embodiments, such as the illustrated embodiment of FIGS. 1-6, fans 32, 40 can be operated to direct air from the first and second passenger spaces across the heater core 30 and the liquid-to-air heat exchanger 38.

[0040] As illustrated in the embodiment of FIGS. 1-6, the heating circuit 68 can be oriented such that the heater core 30 and the liquid-to-air heat exchanger 38 are arranged in series so that working fluid exiting the heater core 30 enters the liquid-to-air heat exchanger 38, or alternatively, so that working fluid exiting the liquid-to-air heat exchanger 38 enters the heater core 30. In other embodiments, the heating circuit 68 can have other orientations and configurations. For example, in some such embodiments, the heater core 30 and the liquid-to-air heat exchanger 38 can be oriented in parallel along the heating circuit 68.

[0041] During operation in the fourth mode, the heat exchange system 10 can transfer heat from a working fluid traveling through the liquid-to-air heat exchanger 38 to air in the second passenger space. This function can be performed

by the fourth heat exchange circuit 72 (see FIG. 5) in order to heat the second passenger space. In some embodiments, the third evaporator 58 (see FIG. 1) can be bypassed when the system 10 is operating in the second mode.

[0042] As shown in FIG. 5, the heating element 50 in the cassette 46 can heat working fluid traveling through the fourth heat exchange circuit 72. The pump 48 in the cassette 46 can then direct the heated working fluid out of the cassette 46 and along the fourth heating circuit 72 toward the liquid-to-air heat exchanger 38 where heat can be transferred from the working fluid to the air in the second passenger space.

[0043] In some embodiments, the heat exchange system 10 can operate in the fourth mode to heat the second passenger space without requiring the vehicle engine to be in operation. In these embodiments, the vehicle battery, a battery or fuel cell supported in the cassette 46, or another on-board power supply can supply electrical power to the pump 48 and/or the heating element 50. In some embodiments, the heating element can be a diesel heater. In other embodiments, the heating element 50 can be an electrically-powered heating coil.

[0044] During operation in the fifth mode, the heating element 50 can be activated to heat engine coolant or another working fluid, and the pump 48 in the cassette 46 can be activated to direct the heated engine coolant or other working fluid along a warming circuit 74 (see FIG. 6). The warming circuit 74 can extend between and fluidly connect the vehicle engine 24 in the first module 12, and the pump 48 and heating element 50 in the fourth module 44, bypassing the liquid-to-air heat exchanger 38 via the valves 42 in the third module 36. In some embodiments, such as the illustrated embodiment of FIG. 6, the heat exchange system 10 can maintain the engine temperature above a threshold temperature for an extended time period without requiring the vehicle engine 24 to be in operation.

[0045] FIG. 7 illustrates an alternate embodiment of a heat exchange system 210 according to the present invention. The heat exchange system 210 shown in FIG. 7 is similar in many ways to the illustrated embodiments of FIGS. 1-6 described above. Accordingly, with the exception of mutually inconsistent features and elements between the embodiment of FIG. 7 and the embodiments of FIGS. 1-6, reference is hereby made to the description above accompanying the embodiments of FIGS. 1-6 for a more complete description of the features and elements (and the alternatives to the features and elements) of the embodiment of FIG. 7 corresponding to features and elements in the embodiments of FIGS. 1-6 are numbered in the 200 series.

[0046] As shown in the illustrated embodiment of FIG. 7, the third module 236 can include a first liquid-to-air heat exchanger or heater core 238A and a second liquid-to-air heat exchanger or heater/cooling core 238B. The first liquid-to-air heat exchanger 238A of the third module 236 can be connected to the heating circuit 268, and the second liquid-to-air heat exchanger 238B of the third module 236 can be connected to the third and fourth heat exchange circuits 270, 272. In this configuration, debris and residue circulating in the engine coolant fluid can be isolated within one circuit and therefore travel through only two heat exchangers 230, 238A.

[0047] FIG. 8 illustrates an alternate embodiment of a heat exchange system 310 according to the present invention. The heat exchange system 310 shown in FIG. 8 is similar in many ways to the illustrated embodiments of FIGS. 1-7 described above. Accordingly, with the exception of mutually inconsis-

tent features and elements between the embodiment of FIG. 8 and the embodiments of FIGS. 1-7, reference is hereby made to the description above accompanying the embodiments of FIGS. 1-7 for a more complete description of the features and elements (and the alternatives to the features and elements) of the embodiment of FIG. 8. Features and elements in the embodiment of FIG. 8 corresponding to features and elements in the embodiments of FIGS. 1-7 are numbered in the 300 series.

[0048] As shown in the illustrated embodiment of FIG. 8, the heat exchange system 310 can include a radiator 380, which can be located on the vehicle remotely from one or both the first and fourth modules 312, 344. In some such embodiments, the radiator 380 can provide supplemental cooling to working fluid traveling through the condenser 316 in the first module 312 and/or working fluid traveling through the condenser 354 in the fourth module 344. As shown in FIG. 8, the heat exchange system 310 can also or alternatively include a pump 382 operable to move working fluid through a supplemental cooling circuit 386. The cooling circuit 386 can extend between and fluidly connect the radiator 380, the pump 382, the condenser 316 in the first module 312, and/or the condenser 354 in the fourth module 344. In some embodiments, such as the illustrated embodiment of FIG. 8, the pump 382 can be positioned in the cassette 346.

[0049] In embodiments, such as the illustrated embodiment of FIG. 8, in which the radiator 380 is located remotely from the first and fourth modules 312, 344, the heat exchange system 310 can include quick-disconnect valves 366 positioned on the cassette 346 along the supplemental cooling circuit 386 so that the cassette 346 can be removed from the vehicle without accidentally spilling working fluid.

[0050] While FIG. 8 does not illustrate the heating circuit 368, heat exchange circuit 372, and some of the associated heat exchange system components, it should be readily understood that further embodiments can include any or all of these elements without departing from the scope of the present invention. Further, the dual liquid-to-air heat exchangers and separate heating circuit 268 utilized in the embodiment of FIG. 7 can also be implemented in further embodiments of the invention which also include aspects of the illustrated embodiment of FIG. 8.

[0051] FIG. 9 illustrates an alternate embodiment of a heat exchange system 410 according to the present invention. The heat exchange system 410 shown in FIG. 9 is similar in many ways to the illustrated embodiments of FIGS. 1-8 described above. Accordingly, with the exception of mutually inconsistent features and elements between the embodiment of FIG. 9 and the embodiments of FIGS. 1-8, reference is hereby made to the description above accompanying the embodiments of FIGS. 1-8 for a more complete description of the features and elements (and the alternatives to the features and elements) of the embodiment of FIG. 9. Features and elements in the embodiment of FIG. 9 corresponding to features and elements in the embodiments of FIGS. 1-8 are numbered in the 400 series.

[0052] As shown in the illustrated embodiment of FIG. 9, the heat exchange system 410 or a portion of the heat exchange system 410 can operate as a cold storage device. In some such embodiments, working fluid is cooled during normal operation and during vehicle operation. In some such embodiments, the cooled working fluid is directed through

the liquid-to-air heat exchanger **438** and the second evaporator **428** to condition air in the first and/or second passenger spaces.

[0053] As shown in FIG. 9, the heat exchange system **410** can also or alternatively include a cold battery **490**, which can store thermal capacity. In some embodiments, such as the illustrated embodiment of FIG. 9, the cold battery **490** can be located in the fourth module **444**. In other embodiments, the cold battery **490** can be located in other locations throughout the vehicle.

[0054] In some embodiments, the cold battery **490** or a working fluid stored in the cold battery **490** can be cooled as working fluid flows through a fifth heat exchange circuit **496** during normal operation of the heat exchange system **410** and during operation of the vehicle engine. The fifth heat exchange circuit **496** can extend between and fluidly connect the first evaporator in the first module **412**, the air-to-liquid heat exchanger **438** in the third module **436**, and the pump **448** and cold battery **490** in the fourth module **444**. When the vehicle engine is shut down, the cooled working fluid can be directed out of the cold battery **490** to the liquid-to-air heat exchanger **438** along a sixth heat exchange circuit **498** to cool air in the second passenger space. The sixth heat exchange circuit **496** can extend between and fluidly connect the air-to-liquid heat exchanger **438** in the third module **436**, and the pump **448** and cold battery **490** in the fourth module **444**.

[0055] Alternatively or in addition, the heat exchange system **410** can include a hot battery for storing heat. In some such embodiments, the hot battery can be located in the fourth module **444** and can be fluidly connected to an engine cooling circuit of the vehicle. In other embodiments, the hot battery can be located in other locations throughout the vehicle. In some embodiments, the hot battery or a working fluid stored in the hot battery can be heated during normal operation of the heat exchange system **410** and during operation of the vehicle engine. When the vehicle engine is shut down, the heated working fluid can be directed out of the hot battery to the liquid-to-air heat exchanger **438** along the sixth heat exchange circuit **498** to heat air in the second passenger space.

[0056] While FIG. 9 does not illustrate all the heat exchange circuits and associated heat exchange system components discussed with respect to other embodiments, it should be readily understood that further embodiments can include any or all of these elements and/or aspects of alternate embodiments without departing from the scope of the present invention.

[0057] The embodiments described above and illustrated in the figures are presented by way of example only and are not intended as a limitation upon the concepts and principles of the present invention. As such, it will be appreciated by one having ordinary skill in the art that various changes in the elements and their configuration and arrangement are possible without departing from the spirit and scope of the present invention. For example, while reference is made herein to a heat exchange system **10** having a first heat exchange circuit **34**, a second heat exchange circuit **62**, a third heat exchange circuit **70**, a fourth heat exchange circuit **72**, a heating circuit **68**, and a warming circuit **74**, in other embodiments, the heat exchange system **10** can have any other number of heat exchange circuits. Alternatively or in addition, the heat exchange circuits of the present invention can include one or more common elements, or alternatively, one or more of the heat exchange circuits can include one or more dedicated elements.

[0058] In addition, while reference is made herein to conduits, valves, and expansion devices, it should be understood that in alternate embodiments, the heat exchange system can also or alternatively include additional conduits, valves, and expansion devices distributed throughout the heat exchange system **10**. For example, in some embodiments, the heat exchange system **10** can include two or more thermal expansion valves, one or more of which can be electronically controlled, or alternatively, one or more of the valves, conduits, and expansion devices can be operated manually. Further, some heat exchangers, conduits, and other system components presented as distinct units in the illustrated embodiments can be combined or replaced by a single integrated unit, while a single unit presented in the illustrated embodiments can be replaced by multiple units (e.g., single-stage, remotely positioned, independently functioning, and other units) as circumstances suggest without departing from the scope of the invention.

What is claimed is:

1. A heat exchange system for a vehicle, the heat exchange system comprising:

a first heat exchange circuit supported by the vehicle and fluidly connecting a condenser, a compressor, an evaporator, and an expansion device;

a module removably secured to the vehicle, the module housing a pump; and

a second heat exchange circuit fluidly connecting a liquid-to-air heat exchanger, the pump, and the evaporator;

wherein the first exchange circuit is operable to condition a first passenger space, and the second heat exchange circuit is operable to condition a second passenger space spaced apart from the first passenger space.

2. The heat exchange system of claim 1, and further comprising a third heat exchange circuit operable to condition the second passenger space when an engine of the vehicle is not in operation.

3. The heat exchange system of claim 2, wherein the module houses a thermal storage component, and the third heat exchange circuit fluidly connects the pump, the thermal storage unit, and the liquid-to-air heat exchanger.

4. The heat exchange system of claim 2, wherein the module houses a heating element, and the third heat exchange circuit fluidly connects the pump, the heating element, and the liquid-to-air heat exchanger.

5. The heat exchange system of claim 2, wherein the module houses a fourth heat exchange circuit fluidly connecting a second condenser, a second compressor, a second evaporator, and a second expansion device, and the third heat exchange circuit fluidly connects the pump, the second evaporator, and the liquid-to-air heat exchanger, and wherein the second evaporator is operable to transfer heat between a fluid traveling along the third heat exchange circuit and a working fluid traveling along the fourth heat exchange circuit.

6. The heat exchange system of claim 1, wherein the heat exchange system further comprises a third heat exchange circuit fluidly connecting the liquid-to-air heat exchanger, a second liquid-to-air heat exchanger, a vehicle engine, and a second pump.

7. The heat exchange system of claim 6, and further wherein the third heat exchange circuit is operable to condition at least one of the first and second passenger spaces.

8. A method of operating a heat exchange system in a vehicle, the method comprising the acts of:

directing a first working fluid through a first heat exchange circuit fluidly connecting a first compressor, a first condenser, a first expansion device, and a first evaporator, the first heat exchange circuit extending through a first passenger space and being supported in the vehicle; securing a removable module housing a pump to the vehicle;

conveying a second working fluid through a second heat exchange circuit which extends through a second passenger space using the pump; and

transferring heat from one of the first passenger space and the second passenger space to the second working fluid to condition the one of the first passenger space and the second passenger space when an engine of the vehicle is not in operation.

9. The method of claim 8, and further comprising transferring heat from the second heat exchange circuit to the first heat exchange circuit through the evaporator.

10. The method of claim 8, and further comprising directing a third working fluid through a third heat exchange circuit fluidly connecting a second compressor, a second condenser, a second expansion device, and a second evaporator housed within the removable module.

11. The method of claim 10, and further comprising transferring heat from the second heat exchange circuit to the third heat exchange circuit through the second evaporator when the engine of the vehicle is not in operation.

12. The method of claim 8, and further comprising charging a thermal storage component with thermal potential energy supplied by one of the first and second heat exchange circuits.

13. The method of claim 12, and further comprising supporting the thermal storage component in the removable module.

14. The method of claim 8, wherein the second heat exchange circuit fluidly connects an air-to-liquid heat exchanger and the pump.

15. A modular heat exchange system for a vehicle, the modular heat exchange system comprising:

a first heat exchange circuit extending between and connecting a first module and a second module, the first heat exchange circuit being operable to provide one of heating and cooling capacity to a first passenger space of the vehicle;

a second heat exchange circuit extending between and connecting the first module, a third module, and a fourth module, the second heat exchange circuit being operable to provide one of heating and cooling capacity to a second passenger space of the vehicle, the second passenger space being spaced apart from the first passenger space; and

a third heat exchange circuit extending between and connecting the third and fourth modules, the third heat exchange circuit being operable to provide one of heating and cooling capacity to the second passenger space of the vehicle, the fourth module being removably supported on the vehicle.

16. The modular heat exchange system of claim 15, wherein the first module includes an evaporator positioned along the first and second heat exchange circuits.

17. The modular heat exchange system of claim 15, wherein the third module includes an air-to-liquid heat exchanger positioned along the second and third heat exchange circuits.

18. The modular heat exchange system of claim 15, wherein the fourth module includes a pump operable to circulate a working fluid in the second and third heat exchange circuits.

19. The modular heat exchange system of claim 15, and further comprising a fourth heat exchange circuit supported within the fourth module.

20. The modular heat exchange system of claim 19, wherein the fourth module includes an evaporator positioned along the third and fourth heat exchange circuits.

21. A modular unit for a heat exchange system in a vehicle, the vehicle having a heat exchange circuit for conditioning a passenger space of the vehicle, the modular unit comprising:

a conduit that forms a portion of a fluid flow path;

a first disconnect valve at a first end of the conduit;

a second disconnect valve at a second end of the conduit, the first and second disconnect valves being connectable to the heat exchange circuit of the vehicle; and

a pump for conveying a working fluid along the fluid flow path and through the heat exchange circuit of the vehicle;

wherein the first and second disconnect valves prevent substantial loss of working fluid from the fluid flow path when the modular unit is removed from the vehicle.

22. The modular unit of claim 21, and further comprising a thermal storage component positioned along the fluid flow path.

23. The modular unit of claim 21, and further comprising a heating element positioned along the fluid flow path/conduit.

24. The modular unit of claim 21, wherein the fluid flow path is a first fluid flow path, and further comprising a second fluid flow path connecting a compressor, a condenser, an expansion device, and an evaporator.

25. The modular unit of claim 24, wherein the evaporator is positioned along the first fluid flow path.

26. The modular unit of claim 21, and further comprising a prime mover operable to drive the pump.

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