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(54) **METHOD AND SYSTEM FOR PACKAGING HVAC COMPONENTS**

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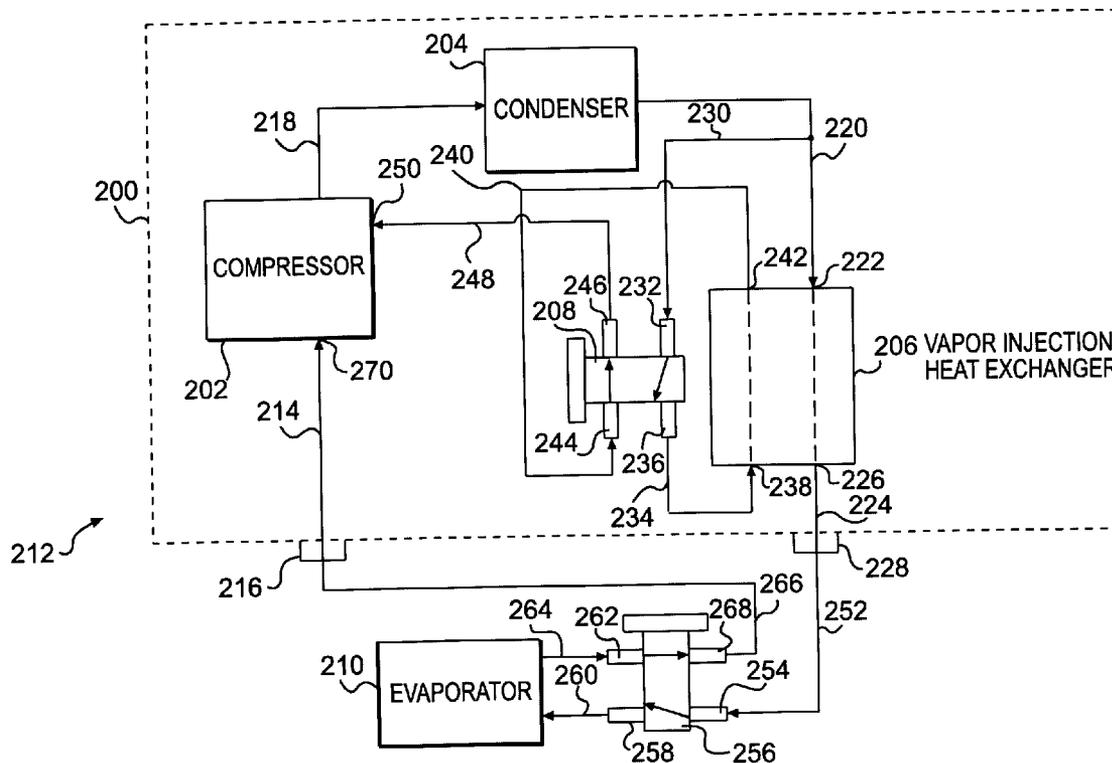
(57) **ABSTRACT**

An apparatus and method of controlling a heating and cooling system may include utilizing a heating, ventilation, and air conditioning (HVAC) module for an HVAC system. The HVAC module may include an input port, a compressor connected to the input port, a condenser connected to the compressor, a heat exchanger connected to the compressor, an output port connected to the heat exchanger, and a thermostatic expansion valve connected to the condenser, the compressor, and the heat exchanger.

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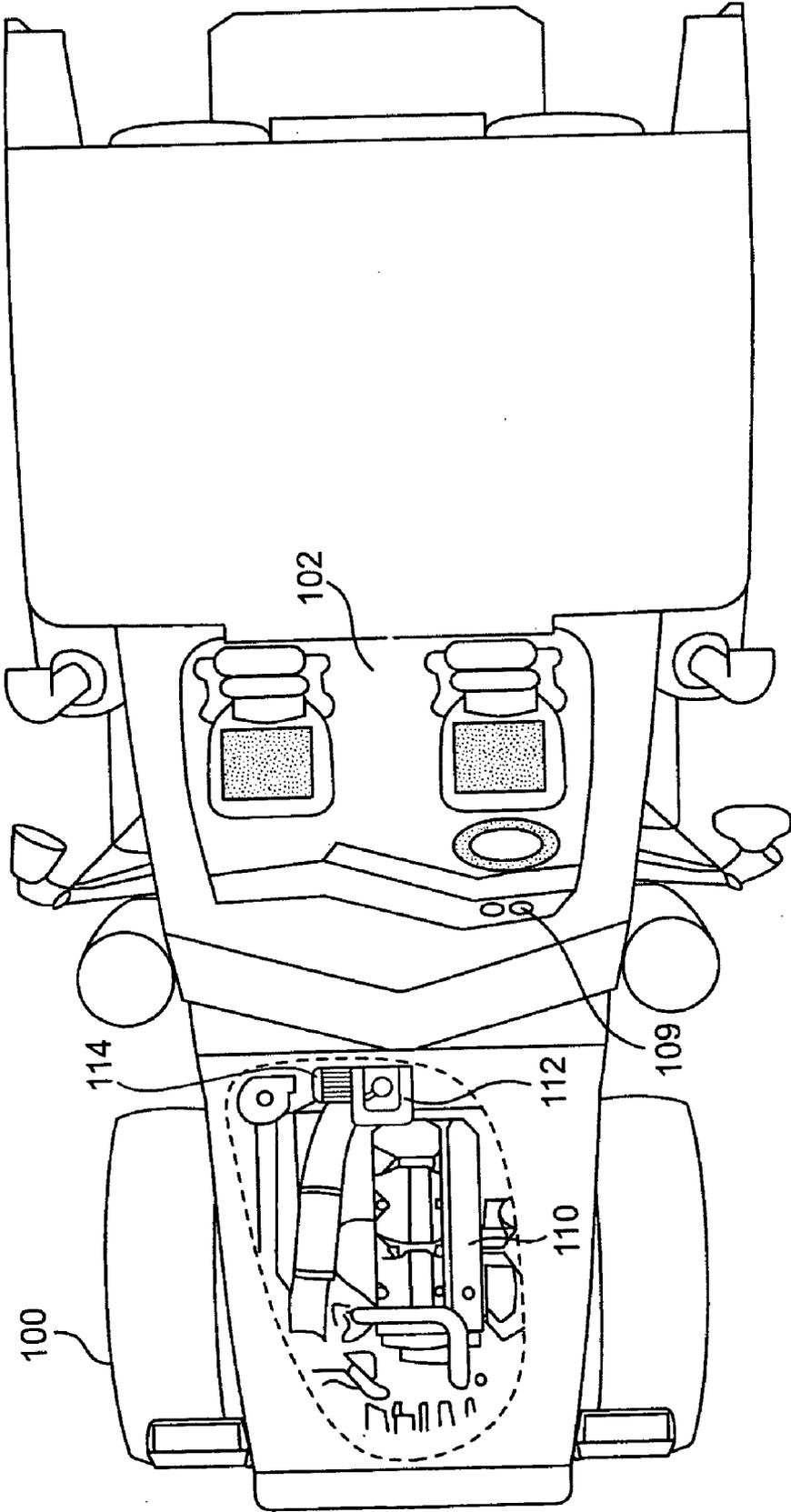


FIG. 1

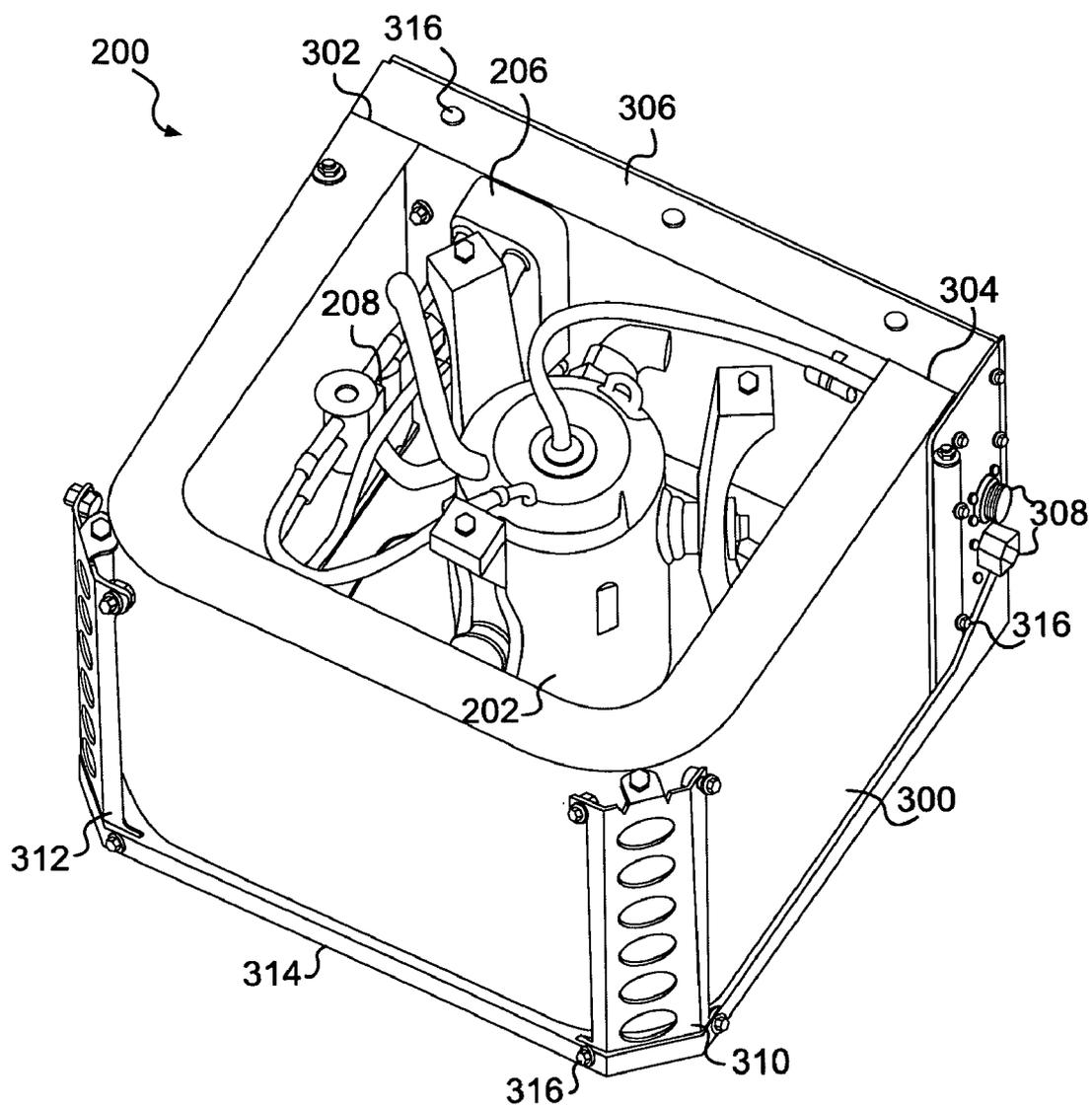


FIG. 3

METHOD AND SYSTEM FOR PACKAGING HVAC COMPONENTS

TECHNICAL FIELD

[0001] This disclosure relates generally to heating, ventilation, air conditioning (HVAC) systems, and more particularly to an assembly design for an HVAC system on a vehicle.

BACKGROUND

[0002] Modern vehicles may be equipped with heating, ventilation, and conditioning (HVAC) systems to control conditioned air supplied, for example, to the cabin of the vehicle. On some vehicle platforms, a component of the HVAC system may be disposed at one location while on other vehicle platforms, the same component of the HVAC system may be disposed at a different location. Additionally, some vehicle platforms may require one kind of HVAC system component while another kind or model of the same component may be required on another vehicle platform. Utilizing another kind or model of the same component may often require alternative connections, fittings, additional vehicle modifications, etc., in order to configure, for example, additional devices to the component. This may provide difficulties in trying to accommodate the component on various vehicle platforms. As a result, inefficiencies may exist in incorporating the component into various platform designs as well as extra expenditures which may be associated with additional efforts to retrofit different component designs.

[0003] Another trend in modern vehicle manufacturing may include a rapid increase in the number of components or accessories in the engine compartment of a vehicle. Thus, a resultant decrease in available space within the engine compartment may increase a desirability of combining related components into a compact assembly. Such a combination assembly is compact and often more economical than separate components. In addition, connections between the formerly separate components can often be simplified or eliminated.

[0004] Combining related components into a compact assembly has been proposed in an effort to accommodate the needs of a particular type of vehicle. U.S. Pat. No. 3,754,410 issued to Jacobs describes a combination compressor and condenser assembly for a vehicle air conditioning system. While the system of the '410 patent may provide a combined compressor and condenser assembly, the compressor is driven by a pulley-fan member connected to an internal combustion engine via drive belt. Thus, a power outlet of the compressor is tied directly with a drive speed of the engine. The compressor can therefore provide over-cooling or under-cooling to the compartment of the automobile based upon the engine speed of the vehicle. This can result in an inefficient use of vehicle power. Accordingly, additional means may be employed to compensate for the over-cooling or under-cooling effect. However, such means may add undesirable costs.

[0005] Methods and systems consistent with certain features of the disclosure are directed to solving one or more of the problems set forth above.

SUMMARY OF THE INVENTION

[0006] In one embodiment, a heating, ventilation, and air conditioning (HVAC) module for an HVAC system is pro-

vided. The HVAC module may include an input port, a compressor connected to the input port, a condenser connected to the compressor, a heat exchanger connected to the compressor, an output port connected to the heat exchanger, and a thermostatic expansion valve connected to the condenser, the compressor, and the heat exchanger.

[0007] Another aspect of the present disclosure includes a work machine having a heating and cooling system. The work machine may include an operator cabin and a heating, ventilation, and air conditioning (HVAC) system configured to provide conditioned air to the cabin. The HVAC system may have an HVAC module coupled to an evaporator assembly. The HVAC module may further include an input port, a compressor connected to the input port, a condenser connected to the compressor, a heat exchanger connected to the compressor, an output port connected to the heat exchanger, and a thermostatic expansion valve connected to the condenser, the compressor, and the heat exchanger.

[0008] Yet another aspect of the present disclosure includes a method of controlling a heating and cooling system. The method may include circulating a refrigerant, in order, to and through a compressor, to and through a condenser, to and through a heat exchanger, to and through an evaporator assembly and back to the compressor. The method may further include circulating a portion of the refrigerant, in order, from the condenser to and through a first thermostatic expansion valve, to and through the heat exchanger, to and back through the first thermostatic expansion valve, and to the compressor.

[0009] Yet another aspect of the present disclosure includes a work machine having an operator cabin, a heating, ventilation, and air conditioning (HVAC) system configured to provide conditioned air to the cabin. The work machine may further include an HVAC system having a containment assembly having an HVAC module including an input port, a compressor connected to the input port, a condenser connected to the compressor, a heat exchanger connected to the compressor, an output port connected to the heat exchanger, and a thermostatic expansion valve connected to the condenser, the compressor, and the heat exchanger.

[0010] Yet another aspect of the present disclosure includes a method of controlling a heating and cooling system. The method may include circulating a refrigerant through an input of a compressor, to a condenser, and directly to and out of a heat exchanger. The method may further include diverting a portion of the refrigerant exiting the condenser and indirectly providing the portion through the heat exchanger and back to the compressor for subsequent transfer of the portion to the heat exchanger.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] FIG. 1 is an illustration of an exemplary work machine with a HVAC module according to the present disclosure;

[0012] FIG. 2 is a schematic illustration of the HVAC module of FIG. 1; and

[0013] FIG. 3 is a perspective view of the HVAC module of FIG. 1 and FIG. 2.

DETAILED DESCRIPTION

[0014] FIG. 1 illustrates a heating, ventilation, and air conditioning (HVAC) system 112 incorporated into a work

machine **100**. Work machine **100** may refer to any type of fixed or mobile machine that performs some type of operation associated with a particular industry, such as mining, construction, farming, transportation, etc., and operates between or within work environments (e.g., construction site, mine site, power plants, on-highway applications, etc.). Non-limiting examples of work machines **100** may include commercial machines, such as cranes, earth moving work machines, other material handling equipment, farming equipment, marine vessels, aircraft, and any type of machine that operates in a work environment. Work machine **100** may also refer to any type of automobile or other type of commercial vehicle. FIG. 1 illustrates the work machine **100** as an on-highway truck type work machine.

[0015] HVAC system **112** may be powered by any appropriate power source. For example, HVAC system may be driven by a generator **114** coupled to an internal combustion engine **110** of the work machine **100**. Alternatively, HVAC system **112** may be driven by an alternative power unit, such as a fuel cell or direct electrical connection (not shown), or may be driven directly by the internal combustion engine **110** of the work machine **100**. The HVAC system **112** may be configured to supply conditioned air to a desired compartment **102** of the work machine **100**. Compartment **102** may include, for example, an operator's cab of the work machine **100**, with the conditioned air being delivered to the operator's cab through one or more vents **109**.

[0016] Referring to FIG. 2, the HVAC system **112** may include numerous components coupled together to form a single unit or structure. This single unit or structure will hereinafter be referred to as HVAC module **200**. HVAC module **200** may include an electric motor driven compressor **202**, a condenser **204**, a vapor injection heat exchanger **206**, and a vapor injection heat exchanger thermostatic expansion valve **208**. As will be described in more detail below, a plurality of connection lines may be used to connect these components of the HVAC module **200**.

[0017] HVAC module **200** may be connected to an evaporator **210** of the work machine **100** to form a closed loop refrigeration circuit **212** for circulating an appropriate conditioning fluid, for example, a refrigerant fluid. Thus, the refrigerant fluid may be subjected to a partial thermodynamic process within the HVAC module **200** and further processing through the evaporator **210** as the refrigerant fluid is converted into a gaseous phase. The evaporator **210** may be configured to be swept by an airflow in order to produce a refrigerated or cooled air supply that may be delivered through one or more vents **109** to compartment **102** of work machine **100** in any conventional manner.

[0018] HVAC module **200** may include any variety of plumbing for connecting the components of the HVAC module **200**. Such plumbing may include non-limiting items such as connection hoses, piping, and conduits, with appropriate fittings, such as, for example, threaded and/or slip-on type fittings. With respect to the particular plumbing of HVAC module **200**, a connection line **214** may be utilized to connect a refrigerant input port **216** of the HVAC module **200** to a first input **270** compressor **202**. Condenser **204** may be connected via connection line **218** to the compressor **202**. Connection line **220** may be utilized to connect the condenser **206** to a first input **222** of the vapor injection heat exchanger **206**. Connection line **224** connects a first output

226 of the vapor injection heat exchanger **206** to a refrigerant output port **228** of the HVAC module **200**.

[0019] A portion of refrigerant from the condenser **204** may also be supplied to the vapor injection heat exchanger thermostatic expansion valve **208**. Connection line **230** may be utilized to couple connection line **220** to a first input **232** of the vapor injection heat exchanger thermostatic expansion valve **208**. A connection line **234** may be utilized to couple the vapor injection heat exchanger thermostatic expansion valve **208** back to the vapor injection heat exchanger **206**. Thus, connection line **234** may connect a first output **236** of the vapor injection heat exchanger thermostatic expansion valve **208** to a second input **238** of the vapor injection heat exchanger **206**. The vapor injection heat exchanger **206** may be connected back to the vapor injection heat exchanger thermostatic expansion valve **208**. Connection line **240** may connect a second output **242** of the vapor injection heat exchanger **206** to a second input **244** of the vapor injection heat exchanger thermostatic expansion valve **208**. An output of the vapor injection heat exchanger thermostatic expansion valve **208** may be linked to the compressor **202** through connection line **248** extending between a second output **246** of the vapor injection heat exchanger thermostatic expansion valve **208** and a second input **250** of compressor **202**.

[0020] As noted above, the HVAC module **200** may connect to an evaporator **210** of the work machine **100**. In particular, a connection line **252** may connect a first input **254** of an evaporator thermostatic expansion valve **256** to a refrigerant output port **228** of the HVAC module **200**. A first output **258** of the evaporator thermostatic expansion valve **256** may be connected to evaporator **210** via connection line **260**. The evaporator **210** may be further connected to a second input **262** of the evaporator thermostatic expansion valve **256** via connection line **264**. Connection line **266** may connect a second output **268** of the evaporator thermostatic expansion valve **256** to the refrigerant input port **216** of the HVAC module **200**. By way of the above described fluid connections, the closed loop refrigeration circuit **212** is formed connecting the compressor **202**, condenser **204**, vapor injection heat exchanger **206**, and vapor injection heat exchanger thermostatic expansion valve **208** of HVAC module **200** with the evaporator thermostatic expansion valve **256** and evaporator **210**.

[0021] It is understood that an electronic control system (not shown) may be included to facilitate operation of the refrigeration circuit **212**. For example, the electronic control system could include a plurality of various sensors for measuring various operational aspects of the refrigeration circuit **212**. The sensed information could be provided to a controller for analyzing the received information and generating operation commands for the refrigeration circuit **212**.

[0022] FIG. 3 illustrates a perspective view of an arrangement of the HVAC module **200** according to an exemplary embodiment of the present disclosure. An arrangement of the HVAC module **200** may be disposed within a containment assembly **318** to create a self-contained assembly of components of the HVAC module **200**. In some embodiments of the disclosure, the compressor **202** may be disposed generally central to the HVAC module **200**. The condenser **204** may include condenser coil **300** for radiating heat. In one embodiment, the condenser coil **300** may contain a U-shaped configuration to generally contain addi-

tional components of the HVAC module **200**. The compressor **202** may be disposed within ends **302**, **304** of the condenser coil **300**. A rear attachment end **306** may be disposed on ends **302**, **304** to close the U-shaped configuration of condenser coil **300**. The HVAC module **200** may incorporate one or more features into the design of the rear attachment end **306**. In one example, the refrigerant input port **216** and the refrigerant output port **228** may be configured through a surface of the rear attachment end **306**. One of a plurality of non-limiting connection means may be utilized to attach the rear attachment end **306** to ends **302**, **304** the condenser coil **300**. Such connection means may include an appropriate amount of welding, seals, and/or sealing material(s), and/or fasteners for example. Other connection means to rigidly secure the rear attachment end **306** to ends **302**, **304** of condenser coil **300** known by those skilled in the art may also be utilized.

[0023] One or more wiring connection ports **308** may be provided to the HVAC module **200**. These wiring connection ports **308** may be utilized to provide power to the HVAC module **200** and/or provide electrical connectors to input and/or output information to the HVAC module **200**. The information may be utilized to facilitate operation of the refrigeration circuit **212** in HVAC module **200**.

[0024] One or more support brackets **310**, **312** may be utilized, for example, to provide an amount of protection to a surface of the condenser coil **300**. Additionally, the support brackets **310**, **312** may be connected to additional components of the HVAC module **200** to provide additional rigid support to the overall structure. In one embodiment, an end of support brackets **310**, **312** may be connected to a bottom plate **314** of HVAC module **200**. The bottom plate **314** may be designed to accommodate components of the HVAC module **200**, for example, as part of the containment assembly **318**. For example, the bottom plate **314** may include a generally flat surface having flanged edges around a front and side surfaces. An end of the support brackets **310**, **312** may be attached to the bottom plate **314** using fasteners **316** such as a screw and nut assembly. Additional non-limiting fastening means may be employed to attach the support brackets **310**, **312** to the bottom plate **314** such as weldments, glues, and other kinds of fasteners. A portion of the side surface of the bottom plate **314** is shown in attachment with rear attachment end **306**. Again, appropriate fasteners such as a screw and nut assembly or other attachment means such as weldments may be utilized to secure the bottom plate **314** to the rear attachment end **306**. Thus, the condenser coil **300** may be seated within a space defined by an assembly of the bottom plate **314** attached to the rear attachment end **306** and further attached to support brackets **310**, **312** as described herein. A surface of the bottom plate **314** may also serve as mounting points for additional equipment to be secured thereto.

[0025] Additionally, in some embodiments, a top plate may also be provided as part of the containment assembly **318**. The top plate in connection with additional components of the containment assembly **318** may effectively seal and/or provide additional protection to components of the HVAC module **200**. The top plate may be connected to another end of the plurality of support brackets **310**, **312**, and the rear attachment end **306**. Additional embodiments of the top plate may include a surface for mounting additional equipment thereto. Additional non-limiting fastening means may

be employed to attach the support brackets **310**, **312** to the top plate such as weldments, glues, and other kinds of fasteners. Thus, the condenser coil **300** may be seated within a space defined by a containment assembly **318** of the top plate in connection with the rear attachment end **306**, support brackets **310**, **312** and the bottom plate **314**. The bottom plate **314**, support brackets **310**, **312**, rear attachment end **306**, and the top plate may include steel sheet metal or other materials known by those skilled in the art to be appropriate.

INDUSTRIAL APPLICABILITY

[0026] In some embodiments of the disclosure, the HVAC module **200** includes an electric motor driven compressor **202** and a condenser **204** that are attached together and approximately co-located. The mating portion or connection ports **216**, **228** of the HVAC module **200** for engaging an evaporator assembly are configured so that the size of the conduit, the thickness of the wall of the conduit, the number of conduits, and the spacing between the conduits may accommodate a variety of HVAC applications including a demanding environment. Furthermore, a mating portion that is configured to fit the mating portion of connection ports **216**, **228** of the HVAC module **200** may be provided to more than one type of evaporator assembly. This standardization of the connection between the HVAC module **200** and the evaporator assembly may be advantageous in certain embodiments, because the mating portions are not required to be reconfigured depending on the type of evaporator assembly or evaporator assembly configuration being utilized. This may further improve a manufacturing efficiency of HVAC systems.

[0027] A function of the compressor **202** may include receiving refrigerant fluid, in a gaseous phase, (e.g., first input **270** of compressor **202**) and compressing the gas as a cool, low-pressure vapor refrigerant. This, in effect, may cause the refrigerant to become a hot, high-pressure vapor refrigerant. In some embodiments, the compressor **202** may be driven by an electrical power source including, for example, generator **114** and/or an alternate power unit. In some embodiments, a controller may be employed to regulate a desired operational speed of the compressor **202**, for instance, in order to achieve a desired temperature within the compartment **102** of the work machine **100**. Regulation of the controller may be based upon inputted information to the controller.

[0028] A function of the condenser **204** may include transferring heat out of the refrigerant. This may cause the hot, high-pressure vapor entering into the condenser **204** to condense into warm, high-pressure liquid at an exit point of the condenser **204**. In an exemplary embodiment, a condenser fan may be provided to blow air over the condenser **204** in order to facilitate heat transfer.

[0029] The vapor injection heat exchanger **206** may use a small portion of refrigerant exiting out of the condenser **204** to further sub-cool a majority of refrigerant exiting the condenser and ultimately out of the refrigerant output port **228**. To facilitate additional sub-cooling, a re-circulated refrigerant line may be established, for example, to provide additional cooling to the refrigerant as it circulates to and through the refrigerant output port **228**. In one embodiment, the re-circulated refrigerant line may include passing a small

portion of refrigerant through connection line 230, through the vapor injection heat exchanger thermostatic expansion valve 208, through connection line 234, through vapor injection heat exchanger 206, and into connection line 240. Thus, as refrigerant is circulated from connection line 234 through the vapor injection heat exchanger 206, an additional cooling effect may be incurred upon refrigerant passing through connection line 220, through the vapor injection heat exchanger 206, through connection line 224. Thus, the vapor injection heat exchanger thermostatic expansion valve 208 may be utilized as an expansion device for causing hot liquid exiting the condenser 204 to become a cool two-phase fluid available to enter into the vapor injection heat exchanger 206. The vapor injection heat exchanger thermostatic expansion valve 208 may also be used to meter an amount of flow in a portion of the connection line circuit by sensing a temperature and pressure of the refrigerant as it returns back to the vapor injection heat exchanger thermostatic expansion valve 208 from the vapor injection heat exchanger 206. Thus, an amount of refrigerant may be regulated back to the compressor 202 and, hence, to the condenser 204 to ultimately provide for additional cooling as needed. This design may allow for additional control to increase an efficiency of heat exchange and/or a capacity of heat exchanged by the vapor injection heat exchanger 206 of HVAC module 200.

[0030] Those skilled in the art will recognize that the processes described above are exemplary only and not intended to be limiting. Other processes may be created, steps in the described processes may be removed or modified, the order of these steps may be changed, and/or other operation steps may be added without departing from the principle and scope of the disclosed invention.

What is claimed is:

1. A heating, ventilation, and air conditioning (HVAC) module for an HVAC system, comprising:

- an input port;
- a compressor connected to the input port;
- a condenser connected to the compressor;
- a heat exchanger connected to the compressor;
- an output port connected to the heat exchanger; and
- a thermostatic expansion valve connected to the condenser, the compressor, and the heat exchanger.

2. The apparatus according to claim 1, wherein an evaporator assembly is coupled to the input port and the output port.

3. The apparatus according to claim 1, wherein the compressor includes an electric compressor actuated by an electric power source.

4. The apparatus according to claim 1, wherein the HVAC module includes a refrigeration circuit and is configured to receive operational information regarding the refrigeration to control operation of the refrigeration circuit.

5. A work machine having a heating and cooling system, comprising:

- an operator cabin;
- a heating, ventilation, and air conditioning (HVAC) system configured to provide conditioned air to the cabin,

the HVAC system having an HVAC module coupled to an evaporator assembly, wherein the HVAC module includes:

- an input port;
- a compressor connected to the input port;
- a condenser connected to the compressor;
- a heat exchanger connected to the compressor;
- an output port connected to the heat exchanger; and
- a thermostatic expansion valve connected to the condenser, the compressor, and the heat exchanger.

6. The work machine according to claim 5, wherein the evaporator assembly includes a thermostatic expansion valve connected to the output port and an evaporator coupled to the thermostatic expansion valve and the input port.

7. The apparatus according to claim 5, further including:

an electric power source, wherein the compressor is actuated by the electric power source.

8. The apparatus according to claim 5, wherein the HVAC module includes a refrigeration circuit and is configured to receive operational information regarding the refrigeration to control operation of the refrigeration circuit.

9. A method of controlling a heating and cooling system, comprising:

circulating a refrigerant, in order, to and through a compressor, to and through a condenser, to and through a heat exchanger, to and through an evaporator assembly and back to the compressor; and

circulating a portion of said refrigerant, in order, from the condenser to and through a first thermostatic expansion valve, to and through the heat exchanger, to and back through the first thermostatic expansion valve, and to the compressor.

10. The method according to claim 9, wherein the evaporator assembly includes an evaporator and a second thermostatic expansion valve.

11. The method according to claim 10, wherein the refrigerant is circulated to and through the second thermostatic expansion valve, to and through the evaporator, and to and back through the second thermostatic expansion valve when refrigerant is circulated to and through the evaporator assembly.

12. The method according to claim 9, further including:

metering an amount of flow of the refrigerant using the first thermostatic expansion valve.

13. The method according to claim 10, further including:

metering an amount of flow of the refrigerant using the second thermostatic expansion valve.

14. The method according to claim 9, further including:

monitoring a temperature of the refrigerant in the compressor and regulating a circulation of refrigerant based upon the temperature monitoring.

15. The method according to claim 9, further including:

monitoring a temperature of the refrigerant in the condenser and regulating a circulation of refrigerant based upon the temperature monitoring.

16. A work machine having a heating and cooling system comprising:

an operator cabin;
a heating, ventilation, and air conditioning (HVAC) system configured to provide conditioned air to the cabin, said HVAC system having a containment assembly having an HVAC module including:
an input port;
a compressor connected to the input port;
a condenser connected to the compressor;
a heat exchanger connected to the compressor;
an output port connected to the heat exchanger; and
a thermostatic expansion valve connected to the condenser, the compressor, and the heat exchanger.

17. The work machine according to claim 16, wherein the containment assembly is coupled to an evaporator assembly.

18. The work machine according to claim 16, wherein the HVAC module includes a refrigeration circuit and is con-

figured to receive operational information regarding the refrigeration to control operation of the refrigeration circuit.

19. A method of controlling a heating and cooling system comprising:

circulating a refrigerant through an input of a compressor, to a condenser, and directly to and out of a heat exchanger; and

diverting a portion the refrigerant exiting the condenser and indirectly providing said portion through the heat exchanger and back to the compressor for subsequent transfer of said portion to the heat exchanger.

20. The method according to claim 19, wherein the indirect providing of said portion to the heat exchanger includes circulating the refrigerant to and through a thermostatic expansion valve.

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