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(54) COOLING SYSTEM

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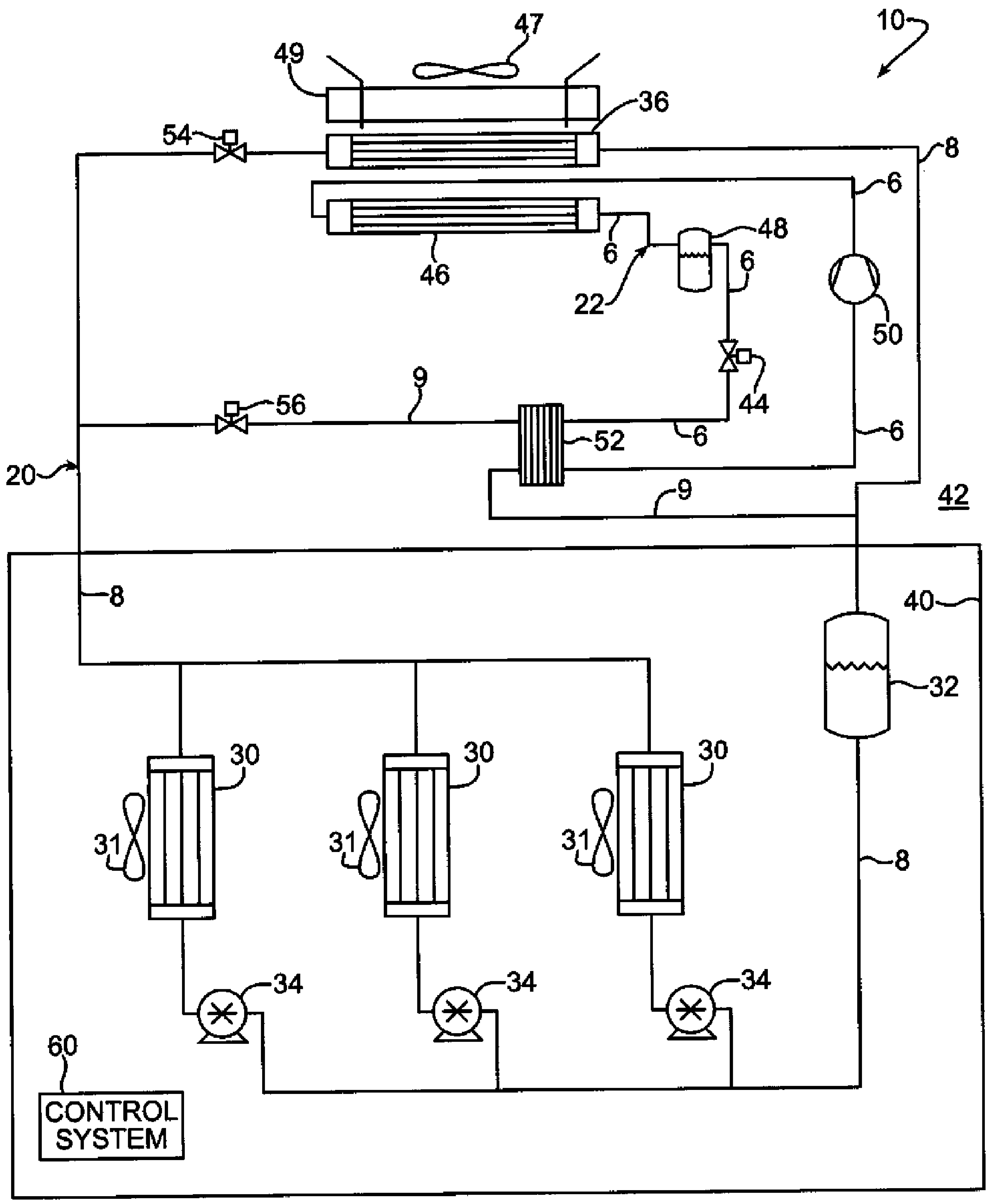
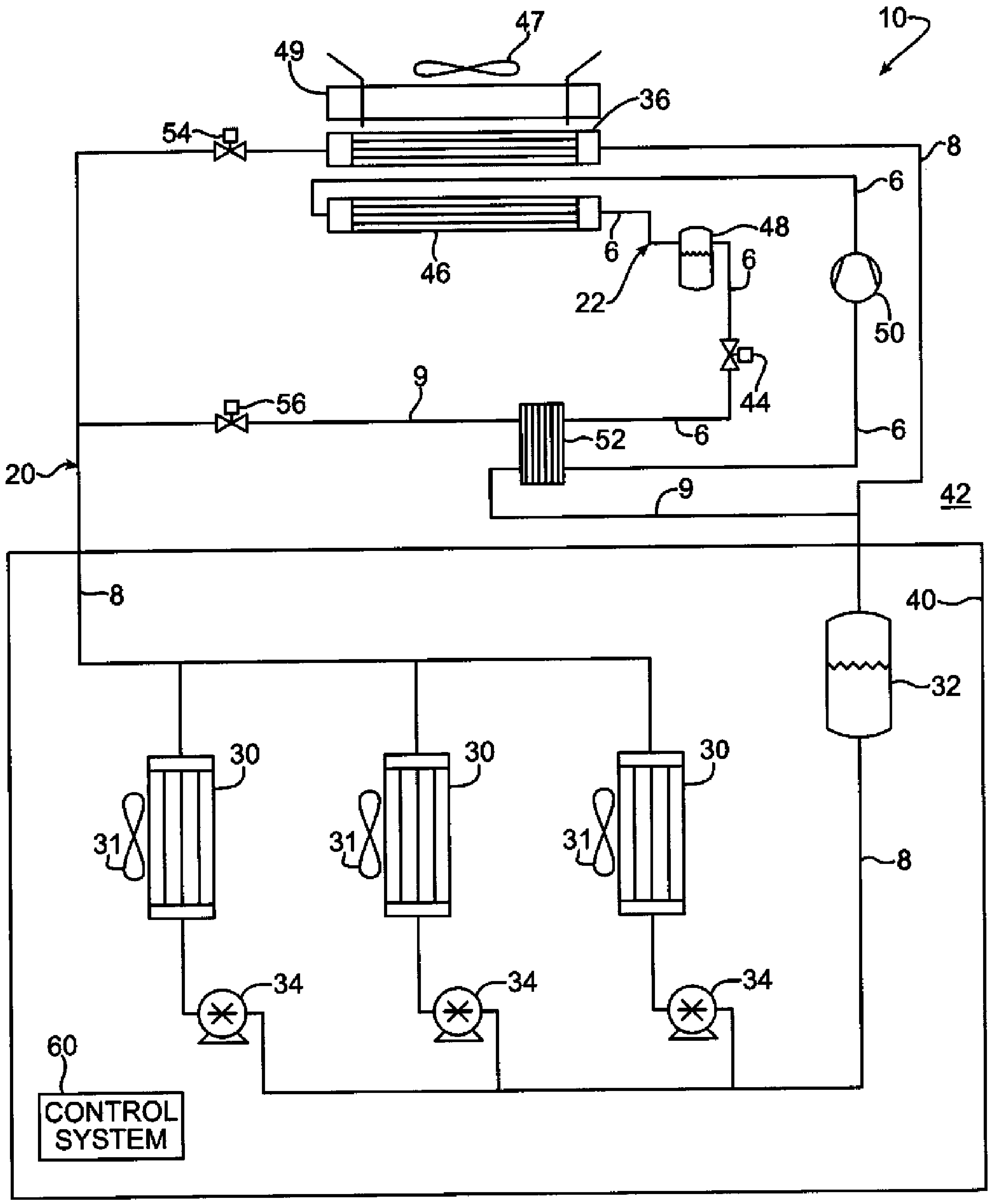
(57) ABSTRACT

A cooling system having a pumped loop cooling system and an embedded vapor compression loop system for cooling air inside an enclosed space such as a container both when the required air temperature inside container is warmer or cooler than the outside ambient air temperature. The pumped loop cooling system is positioned within the container except for a condenser positioned outside the container. The vapor compression loop system is positioned outside the container and includes a liquid to liquid heat exchanger which cools the fluid in the pumped loop system when the condenser is selectively bypassed when the temperature inside the container is higher than the temperature outside the container.

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CONTROL SYSTEM

FIG. 1

COOLING SYSTEM

TECHNICAL FIELD

[0001] The present invention relates generally to cooling air inside an enclosed space that is used to cool components within that space such as power electronics, batteries, etc., and more particularly to a method and apparatus for cooling the air inside the container both when the required air temperature inside container is warmer or cooler than the outside ambient air temperature.

BACKGROUND

[0002] Power electronic devices, such as IGBTs, SCRs, etc., continue to achieve higher power switching capacity in a smaller envelope. The amount of heat created by these devices continues to climb as well. Conventional cooling methods include using blowing air, or circulating a water-based fluid through cold plates in thermal contact with the electronic device heat sink. A more recent cooling method utilizes a phase change fluid, or refrigerant, that will evaporate to remove heat from an electronic device heat sink, and condense back to liquid state through heat exchange process with a cold medium (air or water).

[0003] In a typical prior art two-phase pumped loop cooling system. Liquid refrigerant enters the pump, where static pressure is raised and flow is induced. Sub-cooled liquid flows into an evaporator. The evaporator may be in the form of a cold plate mounted in contact with the heat sink of an electronic device. Refrigerant fluid absorbs heat from the electronic device and partially evaporates as it flows through the cold plate. Partially evaporated refrigerant fluid is collected in a manifold, and then flows in the condenser heat exchanger. The condenser heat exchanger may be air cooled or water cooled and it may be located indoors or outdoors. For the condenser to reject heat to a cold medium, the refrigerant fluid temperature must be above that of the cold medium, or the ambient air. Since the refrigerant is undergoing a condensing process, the refrigerant pressure will follow the refrigerant temperature based on the fluid's saturation pressure-temperature relationship. The refrigerant fluid will leave the condenser as a subcooled liquid, the temperature will be above ambient, and the pressure will correspond to an even higher saturation temperature. The sub-cooled liquid flows into a receiver tank which acts a storage tank to compensate for varying volumes of the fluid in the system. The refrigerant fluid volume of liquid and vapor will vary throughout the system based on operating temperatures and heat load, due to varying densities through the operating temperature range.

[0004] A problem exists in these prior art systems when the power electronics are located indoors or in a container and the condenser heat exchanger is located outdoors and exposed to extreme cold temperatures. Since the refrigerant fluid temperature will closely follow the condenser ambient air, there will be conditions where the refrigerant fluid entering back indoors will be cold enough to cool the refrigerant fluid conduit surface temperature to a level below the indoor air dew point thereby causing condensation on the fluid conduits and other system components from the moisture of the indoor air. This moisture can drip onto the electronic devices and cause damage from short circuiting.

SUMMARY

[0005] At least one embodiment of the invention provides a cooling system comprising: a pumped loop cooling system comprising an evaporator, and a pump located in a first environment having a first ambient temperature and a first compressor located in a second environment having a second ambient temperature; a vapor compression system comprising an expansion valve, a second condenser, a compressor, and a liquid to liquid heat exchanger, the vapor compression system located in the second environment; a primary fluid conduit through which a first refrigerant fluid is circulated by the pump through the evaporator, to the first condenser, and back to the pump; a secondary fluid conduit selectively diverting the first refrigerant fluid from the evaporator to the liquid to liquid heat exchanger of the vapor compression system and back to the pump; and a third fluid conduit through with a second refrigerant fluid is circulated from the compressor to the liquid to liquid heat exchanger, to the expansion valve, to the second condenser, and back to the compressor.

[0006] At least one embodiment of the present invention provides a cooling system comprising: a pumped loop cooling system comprising an evaporator, a first liquid receiver, and a pump located in a first environment having a first ambient temperature and a first compressor located in a second environment having a second ambient temperature; a vapor compression system comprising an expansion valve, a second condenser, a second liquid receiver, a compressor, and a liquid to liquid heat exchanger, the vapor compression system located in the second environment; a primary fluid conduit through which a first refrigerant fluid is circulated by the pump through the evaporator, to the first condenser, to the first liquid receiver, and back to the pump; a secondary fluid conduit selectively diverting the first refrigerant fluid from the evaporator to the liquid to liquid heat exchanger of the vapor compression system, to the liquid receiver, and back to the pump; and a third fluid conduit through with a second refrigerant fluid is circulated from the compressor to the liquid to liquid heat exchanger, to the expansion valve, to the second liquid receiver, to the second condenser, and back to the compressor.

[0007] At least one embodiment of the invention provides a cooling system comprising: a pumped loop cooling system comprising an evaporator, a first liquid receiver, and a pump located in a first environment having a first ambient temperature and a first compressor located in a second environment having a second ambient temperature; a vapor compression system comprising an expansion valve, a second condenser, a second liquid receiver, a compressor, and a liquid to liquid heat exchanger, the vapor compression system located in the second environment; a primary fluid conduit through which a first refrigerant fluid is circulated by the pump through the evaporator, to the first condenser, to the first liquid receiver, and back to the pump; a secondary fluid conduit selectively diverting the first refrigerant fluid from the evaporator to the liquid to liquid heat exchanger of the vapor compression system, to the liquid receiver, and back to the pump; and a third fluid conduit through with a second refrigerant fluid is circulated from the compressor to the liquid to liquid heat exchanger, to the expansion valve, to the second liquid receiver, to the second condenser, and back to the compressor; a control system adapted to direct the first refrigerant through the first conduit to the first condenser and to bypass the second conduit when the temperature in the first environment is higher than the temperature in the second environment; the control system adapted to direct the first refrigerant through the second conduit and bypass a portion of first conduit including the first condenser and operating the compressor of the vapor compression system when the temperature in the first environment is higher than the temperature in the second environment.

BRIEF DESCRIPTION OF THE DRAWING

[0008] Embodiments of this invention will now be described in further detail with reference to the accompanying drawings, in which:

[0009] FIG. **1** is a schematic view of an embodiment of the cooling system of the present invention.

DETAILED DESCRIPTION OF THE DRAWING

[0010] Referring to the drawing in detail, the cooling system **10** comprises a pumped loop cooling system **20** and an imbedded vapor compression system **22**. The pumped loop cooling system **20** comprising at least one evaporator **30**, a first liquid receiver **32**, and at least one pump **34** located in a first environment **40** (represented as a box) having a first ambient temperature and a first condenser **36** located in a second environment **42** (outside the box) having a second ambient temperature—all connected by a first fluid conduit **8**. The vapor compression system **22** is located in the second environment **42** and comprises an expansion valve **44**, a second condenser **46**, a second liquid receiver **48**, a compressor **50**, and a liquid to liquid heat exchanger **52**—all connected by a third fluid conduit **6**.

[0011] In operation, the one or more liquid pumps **34** circulate refrigerant fluid through the pumped loop cooling system **20** portion of the cooling system **10**. The fluid flows through one or more evaporators **30**, each shown with an associated fan **31** to assist the evaporator in the absorption of heat from the air inside the enclosed space designated and referred to as the first environment **40**. The absorption of the heat partially boils the refrigerant fluid. The two-phase fluid is then routed outside the first environment **40** to second environment **42**. If the outside ambient temperature is much colder than the required air temperature within the enclosed space **40**, the fluid is routed through condenser **36** where the fluid is cooled back to a liquid by means of blowing cooler ambient air across the condenser coil. If the outside ambient air temperature is nearly the same or warmer than the required enclosed space temperature, fluid is diverted through a secondary conduit or bypass conduit **9** by one or more valves **56**, **54** to a liquid to liquid heat exchanger **52**. The heat is transferred to the secondary refrigerant loop comprising vapor compression system **22**. The vapor compression system **22** includes compressor **50** and expansion valve **44** which allow for that fluid circuit to remain below outside ambient temperature. The vapor compression loop **22** only turns on when sub-ambient cooling is needed. The heat from the vapor compression loop **22** is rejected to the outdoor ambient air by means of a condenser coil **46** and a fan **47**. Because heat is only being rejected from one of the two condensing coils **36**, **46** at a given time, the condensing coils **36**, **46** may be interlaced together, although the fluids would remain separate and not mix. This also means the two condensing coils **36** may share the same fan **47** and fan enclosure **49**.

[0012] The system **10** includes a control system **60** based on the temperature within the enclosed space and optionally the outdoor ambient temperature to determine when to switch to the vapor compression system. The control system **60** may be adapted to direct the first refrigerant through the first conduit **8** to the first condenser **36** and to bypass the second conduit **9** (utilizing valves **54**, **56**) when the temperature in the first environment **40** is higher than the temperature in the second environment **42**. The control system **60** may be adapted to direct the first refrigerant through the second conduit **6** and bypass a portion of first conduit **8** including the first condenser **36** and selectively operating the compressor **50** of the vapor compression system when the temperature in the first environment **40** is higher than the temperature in the second environment **42**. The control system **60** may be adapted to selectively activate the compressor **50** when the temperature of the second environment **42** is higher than the temperature of the first environment **40** and to deactivate the compressor **50** when temperature of the second environment **42** is lower than the temperature of the first environment **40**.

[0013] The system **10** also allows for complete bypass of all condensing by allowing all of the pumped system flow to go through the liquid to liquid heat exchanger **52** without the vapor compression system **22** running. In this mode, there would be no cooling of the fluid. This is necessary when there is only a light heat load on the cooling system and a cold outside ambient temperature.

[0014] Furthermore, in some applications it may be required to initially heat the enclosed space ambient air on initial start-up in cold ambient environments. This is usually just temporary until the devices needing cooled can create enough heat on their own to maintain a warmer enclosed space temperature. The vapor compression loop **22** can be designed as a heat pump loop, where it can run in reverse when needed to put heat into the system and thus reject hot air into the enclosed space.

[0015] Although the invention has been shown and described with respect to a certain preferred embodiment or embodiments, it is obvious that equivalent alterations and modifications will occur to others skilled in the art upon the reading and understanding of this specification and the annexed drawings. In particular regard to the various functions performed by the above described elements (components, assemblies, devices, compositions, etc.), the terms (including a reference to a "means") used to describe such elements are intended to correspond, unless otherwise indicated, to any element which performs the specified function of the described element (i.e., that is functionally equivalent), even though not structurally equivalent to the disclosed structure which performs the function in the herein illustrated exemplary embodiment or embodiments of the invention. In addition, while a particular feature of the invention may have been described above with respect to only one or more of several illustrated embodiments, such feature may be combined with one or more other features of the other embodiments, as may be desired and advantageous for any given or particular application.

What is claimed is:

1. A cooling system comprising:

a pumped loop cooling system comprising an evaporator, and a pump located in a first environment having a first ambient temperature and a first compressor located in a second environment having a second ambient temperature;

a vapor compression system comprising an expansion valve, a second condenser, a compressor, and a liquid to liquid heat exchanger, the vapor compression system located in the second environment;

a primary fluid conduit through which a first refrigerant fluid is circulated by the pump through the evaporator, to the first condenser, and back to the pump;

a secondary fluid conduit selectively diverting the first refrigerant fluid from the evaporator to the liquid to liquid heat exchanger of the vapor compression system and back to the pump; and

a third fluid conduit through with a second refrigerant fluid is circulated from the compressor to the liquid to liquid heat exchanger, to the expansion valve, to the second condenser, and back to the compressor.

2. The cooling system of claim **1**, wherein the first refrigerant fluid is selectively diverted to the secondary fluid conduit by at least one valve.

3. The cooling system of claim **2**, wherein the at least one valve diverts the first refrigerant fluid to the secondary fluid conduit when the first ambient temperature is greater than the second ambient temperature

4. The cooling system of claim **2**, wherein the at least one valve is a first and a second two-way valve positioned in parallel with each other.

5. The cooling system of claim **4**, wherein the first two way valve is located in the primary fluid conduit upstream of the first condenser and downstream of the evaporator.

6. The cooling system of claim **4**, wherein the first two way valve is located in the second environment.

7. The cooling system of claim **4**, wherein the second two way valve is located in the secondary fluid conduit upstream of the liquid to liquid heat exchanger and downstream of the evaporator.

8. The cooling system of claim **4**, wherein the second two way valve is located in the second environment.

9. The cooling system of claim **1** further comprising a liquid receiver located in the first environment upstream of the pump.

10. The cooling system of claim **1**, wherein the vapor compression system further comprises a liquid receiver located downstream from the expansion valve and upstream of the second condenser.

11. The cooling system of claim **1**, wherein the evaporator includes a fan.

12. The cooling system of claim **1**, wherein the first condenser includes a fan.

13. The cooling system of claim **12**, wherein the second condenser is positioned adjacent the first condenser and shares the fan of the first condenser.

14. The cooling system of claim **1** further comprising a control system operable to selectively divert the refrigerant fluid from the primary fluid conduit to the secondary fluid conduit when the first ambient temperature is greater than the second ambient temperature.

15. The cooling system of claim **1**, wherein the second refrigerant fluid is selectively flowed through the third conduit in reverse and the heat exchanger, the expansion valve, the second condenser, and the compressor of the secondary fluid conduit act as a heat pump rejecting heat from the second refrigerant to the first refrigerant at the liquid to liquid heat exchanger.

16. The cooling system of claim **1**, wherein the refrigerant is selectively diverted to the secondary fluid conduit without operation of the vapor compression system.

17. A cooling system comprising:

a pumped loop cooling system comprising an evaporator, a first liquid receiver, and a pump located in a first environment having a first ambient temperature and a first compressor located in a second environment having a second ambient temperature;

a vapor compression system comprising an expansion valve, a second condenser, a second liquid receiver, a compressor, and a liquid to liquid heat exchanger, the vapor compression system located in the second environment;

a primary fluid conduit through which a first refrigerant fluid is circulated by the pump through the evaporator, to the first condenser, to the first liquid receiver, and back to the pump;

a secondary fluid conduit selectively diverting the first refrigerant fluid from the evaporator to the liquid to liquid heat exchanger of the vapor compression system, to the liquid receiver, and back to the pump; and

a third fluid conduit through with a second refrigerant fluid is circulated from the compressor to the liquid to liquid heat exchanger, to the expansion valve, to the second liquid receiver, to the second condenser, and back to the compressor.

18. The cooling of claim **17** further comprising:

a control system adapted to direct the first refrigerant through the first conduit to the first condenser and to bypass the second conduit when the temperature in the first environment is higher than the temperature in the second environment;

the control system adapted to direct the first refrigerant through the second conduit and bypass a portion of first conduit including the first condenser and selectively operating the compressor of the vapor compression system when the temperature in the first environment is higher than the temperature in the second environment.

19. A cooling system comprising:

a pumped loop cooling system comprising an evaporator, a first liquid receiver, and a pump located in a first environment having a first ambient temperature and a first compressor located in a second environment having a second ambient temperature;

a vapor compression system comprising an expansion valve, a second condenser, a second liquid receiver, a compressor, and a liquid to liquid heat exchanger, the vapor compression system located in the second environment;

a primary fluid conduit through which a first refrigerant fluid is circulated by the pump through the evaporator, to the first condenser, to the first liquid receiver, and back to the pump;

a secondary fluid conduit selectively diverting the first refrigerant fluid from the evaporator to the liquid to liquid heat exchanger of the vapor compression system, to the liquid receiver, and back to the pump; and

a third fluid conduit through with a second refrigerant fluid is circulated from the compressor to the liquid to liquid heat exchanger, to the expansion valve, to the second liquid receiver, to the second condenser, and back to the compressor;

a control system adapted to direct the first refrigerant through the first conduit to the first condenser and to bypass the second conduit when the temperature in the first environment is higher than the temperature in the second environment;

the control system adapted to direct the first refrigerant through the second conduit and bypass a portion of first conduit including the first condenser and operating the compressor of the vapor compression system when the temperature in the first environment is higher than the temperature in the second environment.

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