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(54) Title: COOLING SYSTEM

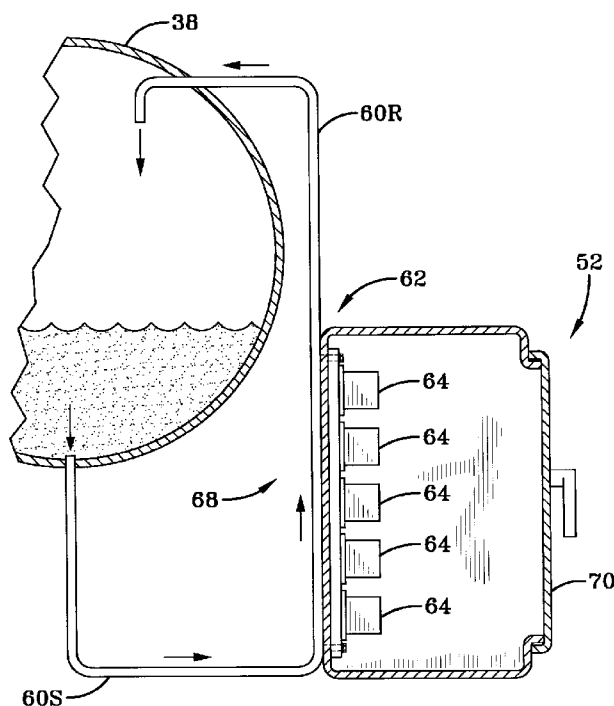


FIG-4

(57) Abstract: A cooling system to cool an electronic component is disclosed. The cooling system includes a first connection to receive refrigerant, a region to transfer heat from an electronic component to the refrigerant from the first connection, at least one of a cooling coil, a cooling tube, or a cooling block positioned in the region and in fluid communication with the first connection, and a second connection to return refrigerant from the region to an evaporator.



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COOLING SYSTEM

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority from and the benefit of U.S. Provisional Application No. 61/080,658, entitled "MOTOR APPLICATIONS," filed July 14, 2008, which is hereby incorporated by reference.

BACKGROUND

[0002] The application relates generally to cooling systems. The application relates more specifically to cooling of at least one component in a variable speed drive.

[0003] A Variable Speed Drive (VSD) is a system that can control the speed of an alternating current (AC) electric motor by controlling the frequency and voltage of the electrical power supplied to the motor. For example, VSDs may be used in various applications, such as with motors for fans in ventilation systems with motors for compressors or pumps, and in machine tool drives. Operation of VSDs can generate heat. Heat can be generated by electronic components of VSDs. During operation, the heat can continue to build up within the VSDs. Ultimately, a build up of too much heat can result in substantial operational issues.

[0004] Conventional chilled liquid systems used in heating, ventilation, air conditioning, and refrigeration systems include an evaporator to effect or implement a transfer of thermal energy between the refrigerant of the system and another fluid, generally a liquid to be cooled. One type of evaporator includes a shell with a plurality of tubes forming a tube bundle(s) inside the shell. The fluid to be cooled is circulated inside the tubes and the refrigerant is brought into contact with the outer or exterior surfaces of the tubes, resulting in a transfer of thermal energy between the fluid to be cooled and the refrigerant. The heat transferred to the refrigerant from the fluid to be cooled causes the refrigerant to undergo a phase change to a vapor, that is, the refrigerant is boiled on the outside of the tubes. For example, refrigerant can be deposited onto the exterior surfaces of the tubes by spraying or other similar techniques in what is commonly referred to as a "falling film" evaporator. In a further example, the exterior surfaces of the tubes can be fully or

partially immersed in liquid refrigerant in what is commonly referred to as a "flooded" evaporator. In yet another example, a portion of the tubes can have refrigerant deposited on the exterior surfaces and another portion of the tube bundle can be immersed in liquid refrigerant in what is commonly referred to as a "hybrid falling film" evaporator.

[0005] As a result of the transfer of thermal energy from the fluid being cooled, the refrigerant is heated and converted to a vapor state, which is then returned to a compressor where the vapor is compressed, to begin another refrigerant cycle. The cooled fluid can be circulated to a plurality of heat exchangers located throughout a building. Warmer air from the building is passed over the heat exchangers where the cooled fluid is warmed while cooling the air for the building. The fluid warmed by the building air is returned to the evaporator to repeat the process.

SUMMARY

[0006] The present invention relates to a cooling system to cool an electronic component. The cooling system includes a first connection to receive refrigerant, a region to transfer heat from an electronic component to the refrigerant from the first connection, at least one of a cooling coil, a cooling tube, or a cooling block positioned in the region and in fluid communication with the first connection, and a second connection to return refrigerant from the region to an evaporator.

[0007] The present invention also relates to a cooling system to cool an electronic component. The cooling system includes a first connection to receive a liquid refrigerant via a supply line, a region to transfer heat from the electronic component to the refrigerant from the first connection, a cooling coil positioned in the region and in fluid communication with the first connection, a second connection to return vapor refrigerant from the region to an evaporator via a return line, the cooling coil being positioned to transfer heat from the electronic component to the liquid refrigerant, the liquid refrigerant being supplied from within the evaporator by the supply line, the cooling coil further being positioned to phase change the liquid refrigerant into the vapor refrigerant, and the cooling coil further being positioned to supply the vapor refrigerant to the return line. In the exemplary embodiment, the heat transferred from the electronic component cools the electronic component.

[0008] The present invention also relates to a cooling system to cool an electronic component. The cooling system includes a first connection to receive a liquid refrigerant via a supply line, a region to transfer heat from the electronic component to the refrigerant from the first connection, at least one cooling tube or at least one cooling block positioned in the region and in fluid communication with the first connection, a second connection to return vapor refrigerant from the region to an evaporator via a return line, the at least one cooling tube or the at least one cooling block being positioned to transfer heat from the electronic component to the liquid refrigerant, the liquid refrigerant being supplied from within the evaporator by the supply line, the at least one cooling tube or the at least one cooling block further being positioned to phase change the liquid refrigerant into the vapor refrigerant, and the at least one cooling tube or the at least one cooling block further being positioned to supply the vapor refrigerant to the return line. In the exemplary embodiment, the heat transferred from the electronic component cools the electronic component.

BRIEF DESCRIPTION OF THE FIGURES

[0009] FIG. 1 shows an exemplary embodiment for a heating, ventilation and air conditioning system in a commercial setting.

[0010] FIG. 2 shows an isometric view of an exemplary vapor compression system.

[0011] FIG. 3 schematically illustrates an exemplary embodiment of a HVAC system.

[0012] FIG. 4 shows an exemplary embodiment of a cooling system at least one component of a variable speed drive.

[0013] FIG. 5 shows an exemplary cooling coil for the exemplary embodiment of FIG. 4.

[0014] FIG. 6 shows another exemplary embodiment of cooling system at least one component of a variable speed drive.

[0015] FIG. 7 shows a partial isometric view of a shield and variable speed drive components from the exemplary embodiment of FIG. 6.

[0016] FIG. 8 shows a partial view of another exemplary embodiment of a cooling system for at least one component of a variable speed drive.

[0017] FIG. 9 shows a partial view of another exemplary embodiment of cooling system for at least one component of a variable speed drive.

[0018] FIG. 10 shows an exemplary cooling coil for the exemplary embodiment of FIG. 8 or FIG. 9.

DETAILED DESCRIPTION OF THE EXEMPLARY EMBODIMENTS

[0019] FIG. 1 shows an exemplary environment for a heating, ventilation and air conditioning (HVAC) system 10 incorporating a chilled liquid system in a building 12 for a typical commercial setting. System 10 can include a vapor compression system 14 that can supply a chilled liquid which may be used to cool building 12. System 10 can include a boiler 16 to supply a heated liquid that may be used to heat building 12, and an air distribution system which circulates air through building 12. The air distribution system can also include an air return duct 18, an air supply duct 20 and an air handler 22. Air handler 22 can include a heat exchanger that is connected to boiler 16 and vapor compression system 14 by conduits 24. The heat exchanger in air handler 22 may receive either heated liquid from boiler 16 or chilled liquid from vapor compression system 14, depending on the mode of operation of system 10. System 10 is shown with a separate air handler on each floor of building 12, but it is appreciated that the components may be shared between or among floors.

[0020] FIGS. 2 and 3 show an exemplary vapor compression system 14 that can be used in an HVAC system, such as HVAC system 10. Vapor compression system 14 can circulate a refrigerant through a compressor 32 driven by a motor 50, a condenser 34, expansion device(s) 36, and a liquid chiller or evaporator 38. Vapor compression system 14 can also include a control panel 40 that can include an analog to digital (A/D) converter 42, a microprocessor 44, a non-volatile memory 46, and an interface board 48. Some examples of fluids that may be used as refrigerants in vapor compression system 14 are: hydrofluorocarbon (HFC) based refrigerants, for example, R-410A, R-407C, R-134a; hydrofluoro olefin (HFO); “natural” refrigerants like

ammonia (NH₃), R-717, carbon dioxide (CO₂), R-744, or hydrocarbon based refrigerants; water vapor or any other suitable type of refrigerant. In an exemplary embodiment, vapor compression system 14 may use one or more of each of variable speed drives (VSDs) 52, motors 50, compressors 32, condensers 34 and/or evaporators 38.

[0021] Motor 50 used with compressor 32 can be powered by VSD 52. VSD 52 receives AC power having a particular fixed line voltage and fixed line frequency from the AC power source and provides power having a variable voltage and frequency to motor 50. Motor 50 can include any type of electric motor that can be powered by VSD 52. For example, motor 50 can be a switched reluctance motor, an induction motor, an electronically commutated permanent magnet motor or any other suitable motor type. VSD 52 incorporates several stages to provide speed control to motor 50. VSD 52 may include a rectifier or converter stage, a DC link stage, and an inverter stage. The rectifier or converter stage, also known as the converter, converts the fixed line frequency, fixed line voltage AC power from an AC power source into DC power. The DC link stage, also known as the DC link, filters the DC power from the converter. Finally, the inverter stage, also known as the inverter, is connected in parallel with the DC link and converts the DC power from the DC link into a variable frequency, variable voltage AC power.

[0022] Compressor 32 compresses a refrigerant vapor and delivers the vapor to condenser 34 through a discharge line. Compressor 32 can be a centrifugal compressor, screw compressor, reciprocating compressor, rotary compressor, swing link compressor, scroll compressor, turbine compressor, or any other suitable compressor. The refrigerant vapor delivered by compressor 32 to condenser 34 transfers heat to a fluid, for example, water or air. The refrigerant vapor condenses to a refrigerant liquid in condenser 34 as a result of the heat transfer with the fluid. The liquid refrigerant from condenser 34 flows through expansion device 36 to evaporator 38. In the exemplary embodiment shown in FIG. 3, condenser 34 is water cooled and includes a tube bundle 54 connected to a cooling tower 56.

[0023] The liquid refrigerant delivered to evaporator 38 absorbs heat from another fluid, which may or may not be the same type of fluid used for condenser 34, and undergoes a phase change to a refrigerant vapor. In the exemplary embodiment shown in FIG. 3, evaporator 38

includes a tube bundle having a supply line 60S and a return line 60R connected to a cooling load 62. A process fluid, for example, water, ethylene glycol, calcium chloride brine, sodium chloride brine, or any other suitable fluid, enters evaporator 38 via return line 60R and exits evaporator 38 via supply line 60S. Evaporator 38 lowers the temperature of the process fluid in the tubes. The tube bundle in evaporator 38 can include a plurality of tubes and/or a plurality of tube bundles. The vapor refrigerant exits evaporator 38 and returns to compressor 32 by a suction line to complete the cycle or loop.

[0024] FIG. 4 shows an exemplary embodiment of a cooling system for cooling at least one electronic component 64 of VSD 52 by transferring heat from VSD 52 to evaporator 38. In an exemplary embodiment, electronic components 64 can be high frequency electrical switching components (for example, insulated gate bipolar transistors), which generate heat within VSD 52. In another exemplary embodiment, the cooling system may be used to cool other systems, subsystems, or components of the HVAC system, such as the motor and/or control panel and associated electronic components. In one embodiment, components 64 may be cooled by a thermosiphon. In the thermosiphon, convective movement of a liquid can begin when liquid in a loop is heated. The heating of the liquid causes the liquid to expand and become less dense. This results in heated liquid being at the top of the loop and cooler liquid being at the bottom of the loop. Convection can move the heated liquid upwards as it is replaced by cooler liquid returning by gravity. Increased flow of the liquid in such a thermosiphon can decrease hydraulic resistance.

[0025] Referring back to FIG. 4, refrigerant from evaporator 38 is directed by gravity toward VSD 52 via supply line 60S with the heated refrigerant expanding upon heat being transferred from components 64 to the refrigerant. In an exemplary embodiment, the refrigerant phase changes to gas. Heated refrigerant can be returned to evaporator 38 via return line 60R. FIG. 5 shows an exemplary cooling coil 60 for VSD 52 cooling. In an exemplary embodiment, cooling coils 60 may be at or near a thermal interface region 68. Thermal interface region 68 is where most, if not all, of the heat transfer from electrical components 64 occurs. Cooling coils 60 increase heat transfer by increasing surface area of coils in contact with or proximal to thermal interface region 68. In one embodiment, cooling coils 60 are external to an enclosure 70 (for example, a box) to avoid moisture condensation within the enclosure. In a further embodiment,

enclosure 70 includes gaps, spacings, other breathable features, or a desiccant to prevent moisture condensation. Additionally or alternatively, refrigerant from condenser 34 may be used to cool components 64 of VSD 52. In a further embodiment, refrigerant at condenser pressure may be pumped by making use of thermosiphon systems.

[0026] FIG. 6 and 7 illustrate an exemplary embodiment of a cooling system for cooling at least one electronic component 64 of VSD 52 by transferring heat from the component to evaporator 38. Evaporator 38 includes a shield 72 provided to separate liquid refrigerant entrained in vapor. For example, when refrigerant vapor with entrained liquid, such as from a splash from a pool of boiling refrigerant comes into contact with shield 72, the entrained liquid can separate from the vapor thereby allowing the vapor to continue around the shield 72. Components 64 of VSD 52 are enclosed within enclosure 70. Components 64 include cooling tubes 74, which extend through enclosure 70 into shell 76 of evaporator 38. Cooling tubes 74 act as thermal interface region 68 facilitating heat transfer from components 64 of VSD 52 to refrigerant fluid in evaporator 38. In one embodiment, shield 72 includes openings 78 that operate as a demister to aggregate liquid droplets into larger particles that can return by gravity to a sump of evaporator 38, improving the distribution of the flow of refrigerant fluid inside evaporator 38. In addition, shield 72 can restrict flow of refrigerant liquid into the compressor suction line (not shown) at the top of shell 76. In one embodiment, enclosure 70, tubes 74, and/or tube bundles may be attached to shell 76 by insulation 80. Positioning of insulation 80 may permit prevention, reduction, and/or elimination of thermal conduction between enclosure 70 and evaporator 38. As will be appreciated, other heat transfer surfaces suitable for transferring heat from components 64 of VSD 52 may be used.

[0027] FIG. 8 shows a partial view of an embodiment for cooling VSD 52 by transferring heat to evaporator 38. VSD 52 can include a thermal interface region 68 having a cooling block 82 for transferring heat from components 64 of VSD 52 to evaporator 38. In an exemplary embodiment, refrigerant may be provided as in the other embodiments disclosed herein or any other suitable source. In an exemplary embodiment, cooling block 82 may surround a coil. Cooling block 82 may be made of a material and have a design configured to increase the conduction of heat from the dissipation in components 64 to the refrigerant. In one embodiment,

cooling block 82 is positioned within the interior of enclosure 70. Condensation, which occurs predominantly on shell 76 of evaporator 38, can be drained away from the electrical components of VSD 52 via a moisture drain 84 positioned between enclosure 70 and evaporator 38. Referring to FIG. 9, alternatively, cooling block 82 is positioned adjacent to enclosure 70. Cooling block 82 being located adjacent to enclosure 70 may permit prevention, reduction, and/or elimination of leaks in non-pressure vessel enclosures because the location of cooling block 82 outside of enclosure 70 can limit any leaking refrigerant from cooling block 82 from entering enclosure. FIG. 10 shows an exemplary cooling coil 60 and cooling block 82 for VSD 52 cooling. Cooling coil 60 and cooling block 82 shown in FIG. 10 can be included in the embodiment shown in FIG. 8 or FIG. 9. Cooling coil 60 and cooling block 82 can form a portion or all of thermal interface region 68.

[0028] While only certain features and embodiments of the invention have been shown and described, many modifications and changes may occur to those skilled in the art (for example, variations in sizes, dimensions, structures, shapes and proportions of the various elements, values of parameters (for example, temperatures, pressures, etc.), mounting arrangements, use of materials, colors, orientations, etc.) without materially departing from the novel teachings and advantages of the subject matter recited in the claims. The order or sequence of any process or method steps may be varied or re-sequenced according to alternative embodiments. It is, therefore, to be understood that the appended claims are intended to cover all such modifications and changes as fall within the true spirit of the invention. Furthermore, in an effort to provide a concise description of the exemplary embodiments, all features of an actual implementation may not have been described (that is, those unrelated to the presently contemplated best mode of carrying out the invention, or those unrelated to enabling the claimed invention). It should be appreciated that in the development of any such actual implementation, as in any engineering or design project, numerous implementation specific decisions may be made. Such a development effort might be complex and time consuming, but would nevertheless be a routine undertaking of design, fabrication, and manufacture for those of ordinary skill having the benefit of this disclosure, without undue experimentation.

WHAT IS CLAIMED IS:

1. A cooling system to cool electronic components, the cooling system comprising:
a first connection to receive refrigerant;
a region to transfer heat from an electronic component to the refrigerant from the first connection;
at least one of a cooling coil, a cooling tube, or a cooling block positioned in the region and in fluid communication with the first connection; and
a second connection to return refrigerant from the region to an evaporator.
2. The cooling system of claim 1, wherein the region comprises the cooling coil.
3. The cooling system of claim 1, wherein the region comprises the cooling tube.
4. The cooling system of claim 1, wherein the region comprises the cooling block, the region being positioned within an enclosure of a variable speed drive.
5. The cooling system of claim 1, wherein the region comprises the cooling block, the region being positioned adjacent to an enclosure of a variable speed drive.
6. The cooling system of claim 1, wherein the electronic component is an electrical switching component of a variable speed drive.
7. The cooling system of claim 1, further comprising a variable speed drive, the variable speed drive comprising the electronic component and an enclosure.
8. The cooling system of claim 7, further comprising insulation positioned between the enclosure and the evaporator, the insulation being configured to prevent, reduce, or eliminate conduction between the enclosure and the evaporator.
9. The cooling system of claim 7, further comprising a moisture drain positioned between the enclosure and the evaporator, the moisture drain being configured to drain condensed moisture from the enclosure.
10. The cooling system of claim 7, further comprising at least one gap in the enclosure.

11. A cooling system to cool an electronic component, the cooling system comprising:
 - a first connection to receive a liquid refrigerant via a supply line;
 - a region to transfer heat from the electronic component to the refrigerant from the first connection;
 - a cooling coil positioned in the region and in fluid communication with the first connection;
 - a second connection to return vapor refrigerant from the region to an evaporator via a return line;
 - the cooling coil being positioned to transfer heat from the electronic component to the liquid refrigerant, the liquid refrigerant being supplied from within the evaporator by the supply line;
 - the cooling coil further being positioned to phase change the liquid refrigerant into the vapor refrigerant; and
 - the cooling coil further being positioned to supply the vapor refrigerant to the return line; and,
 - wherein the heat transferred from the electronic component cools the electronic component.
12. The cooling system of claim 11, wherein the electronic component is an electrical switching component.
13. The cooling system of claim 11, further comprising a variable speed drive, the variable speed drive comprising the electronic component and the enclosure.
14. The cooling system of claim 13, further comprising at least one gap in the enclosure configured to prevent, reduce, or eliminate moisture condensation.
15. A cooling system to cool an electronic component, the cooling system comprising:
 - a first connection to receive a liquid refrigerant via a supply line;
 - a region to transfer heat from the electronic component to the refrigerant from the first connection;

at least one cooling tube or at least one cooling block positioned in the region and in fluid communication with the first connection;

a second connection to return vapor refrigerant from the region to an evaporator via a return line;

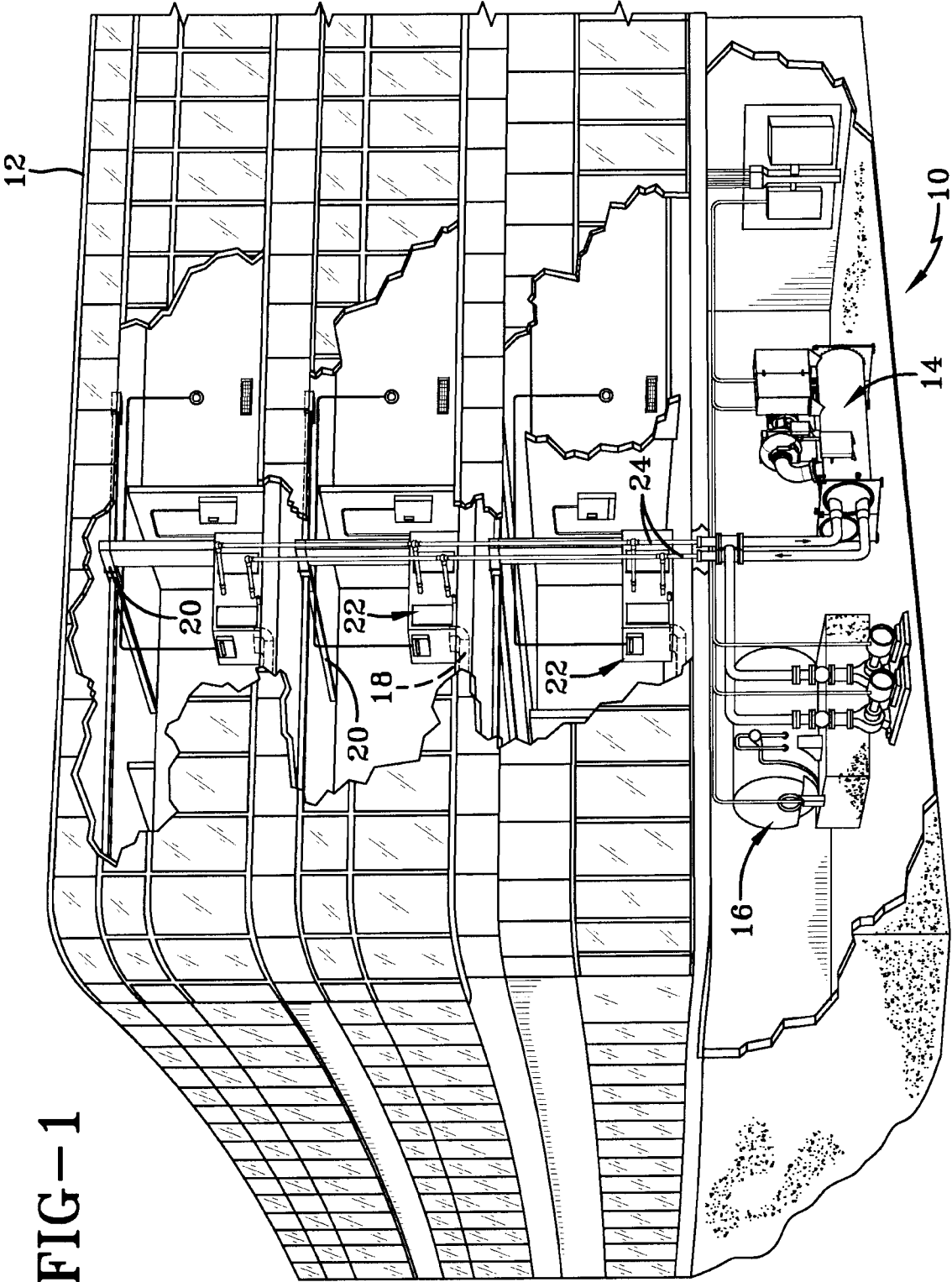
the at least one cooling tube or the at least one cooling block being positioned to transfer heat from the electronic component to the liquid refrigerant, the liquid refrigerant being supplied from within the evaporator by the supply line;

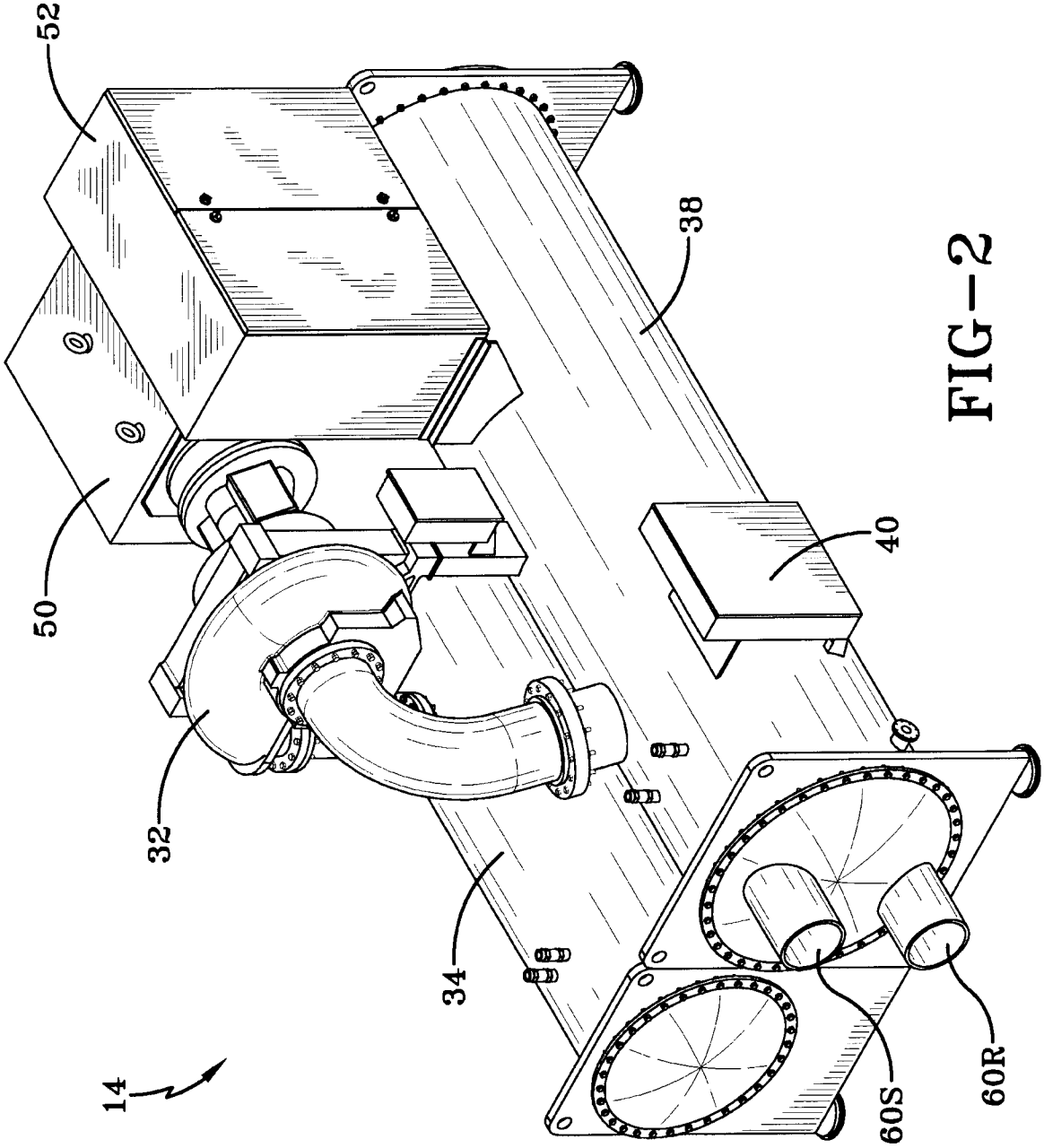
the at least one cooling tube or the at least one cooling block further being positioned to phase change the liquid refrigerant into the vapor refrigerant; and

the at least one cooling tube or the at least one cooling block further being positioned to supply the vapor refrigerant to the return line; and,

wherein the heat transferred from the electronic component cools the electronic component.

16. The cooling system of claim 15, comprising the at least one cooling block, the at least one cooling block being disposed within the enclosure.
17. The cooling system of claim 15, comprising the at least one cooling block, the at least one cooling block being disposed adjacent to the enclosure.
18. The cooling system of claim 15, wherein the electronic component is an electrical switching component.
19. The cooling system of claim 15, further comprising insulation positioned between the enclosure and the evaporator, the insulation being configured to prevent, reduce, or eliminate conduction between the enclosure and the evaporator.
20. The cooling system of claim 15, further comprising a moisture drain positioned between the enclosure and the evaporator, the moisture drain being configured to drain condensed moisture from the enclosure.





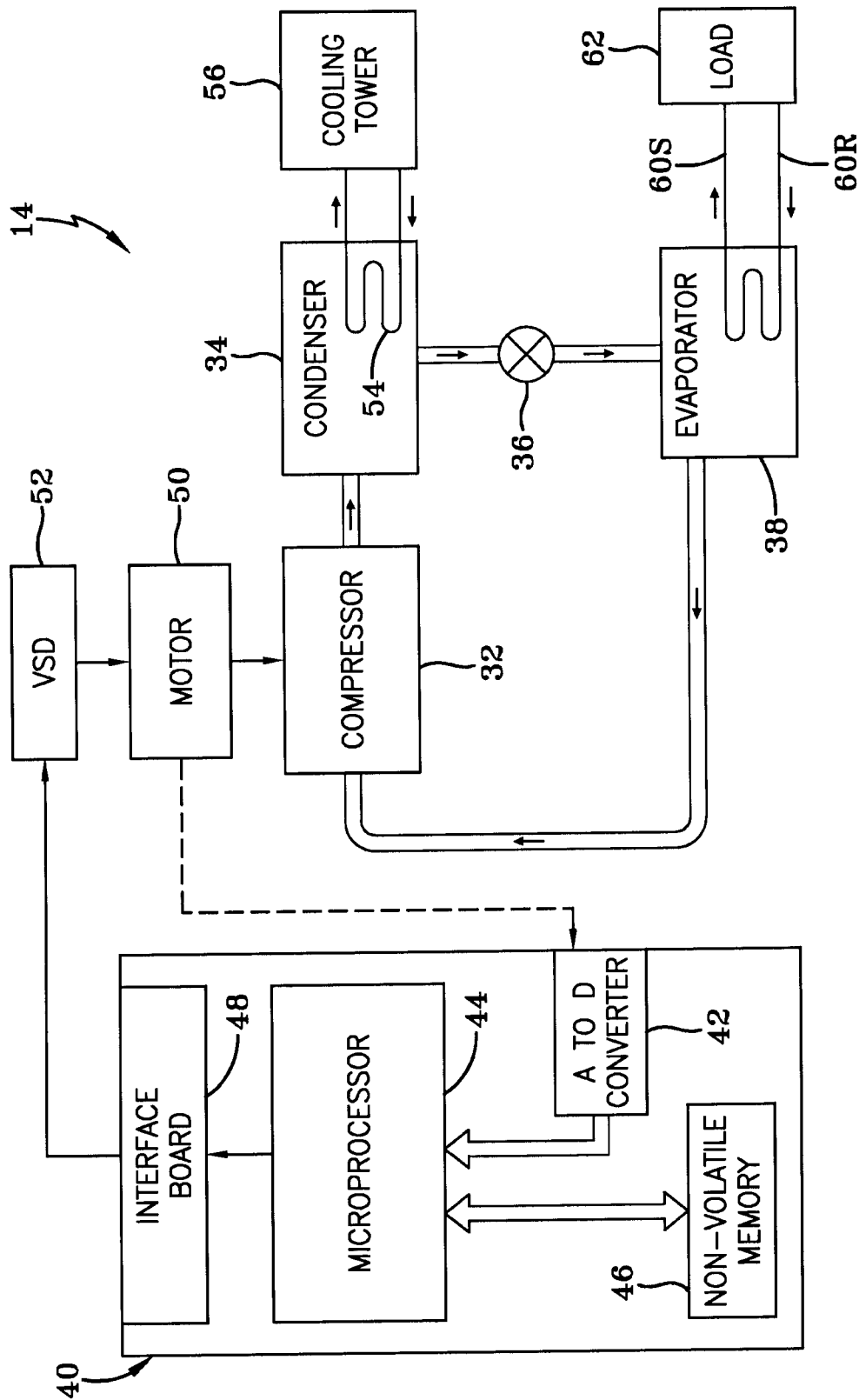


FIG-3

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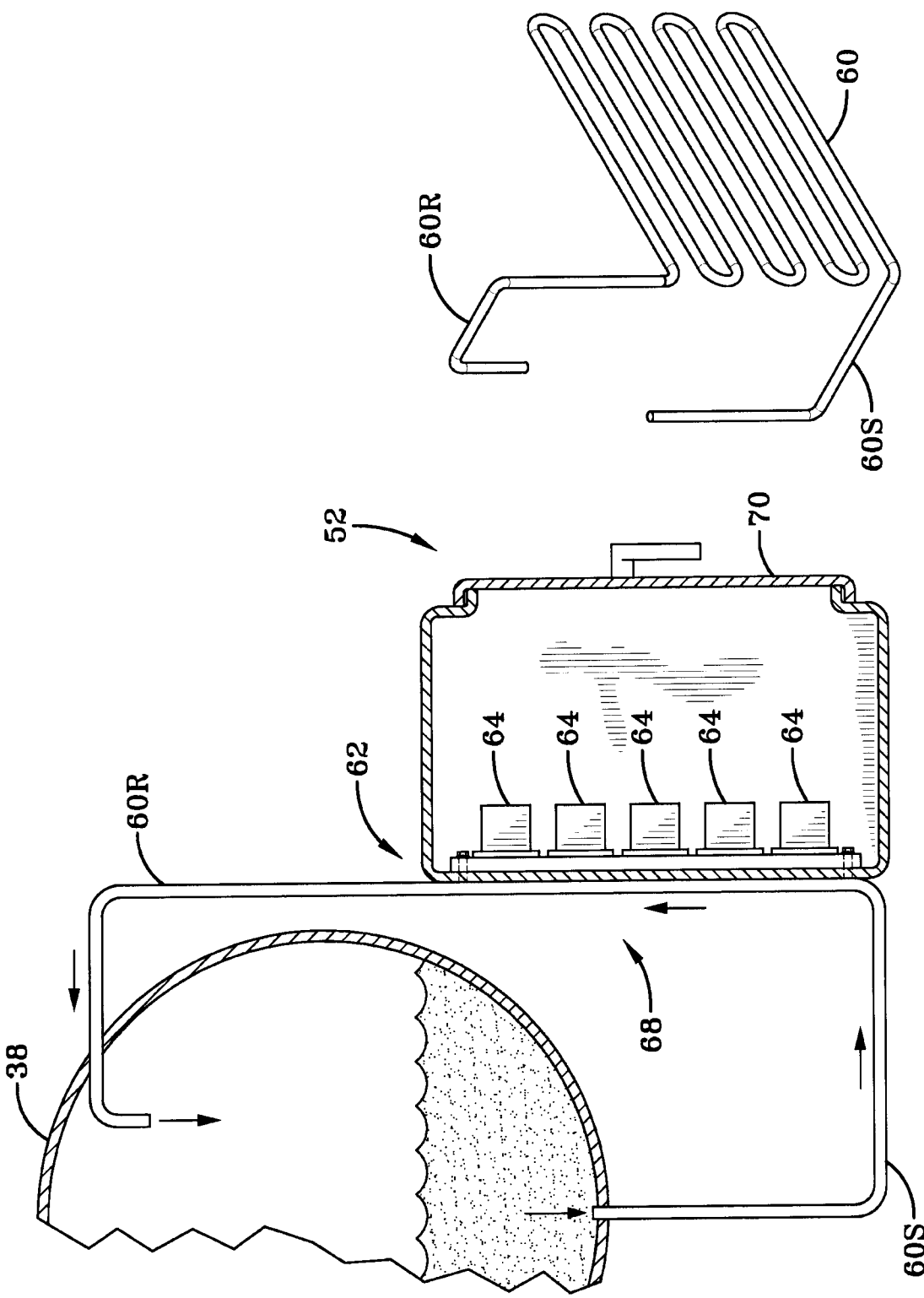


FIG-5

FIG-4

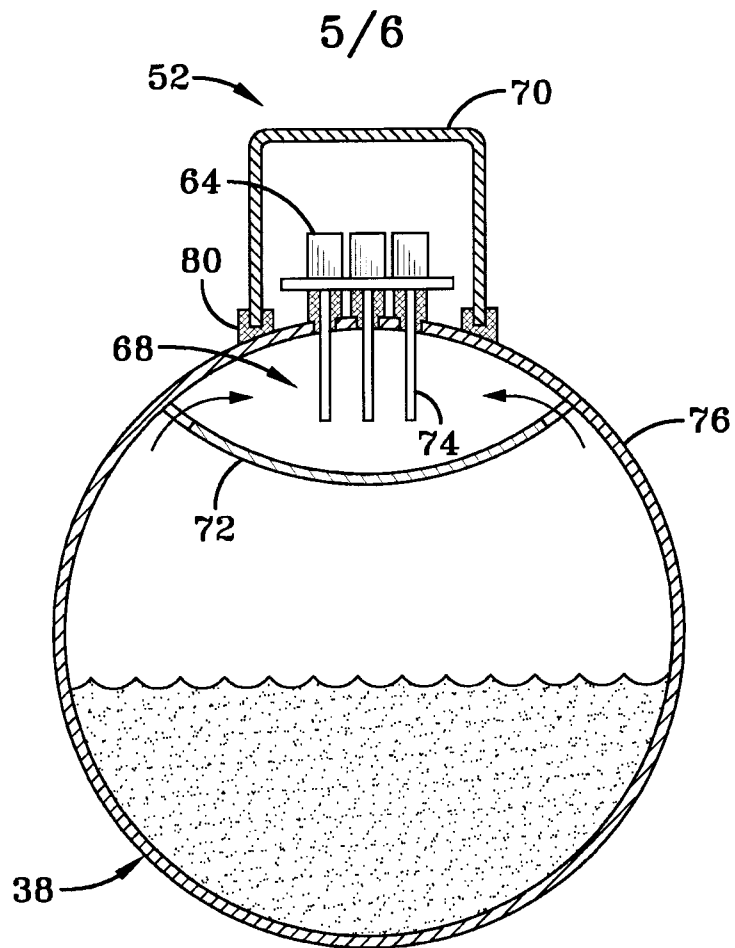


FIG-6

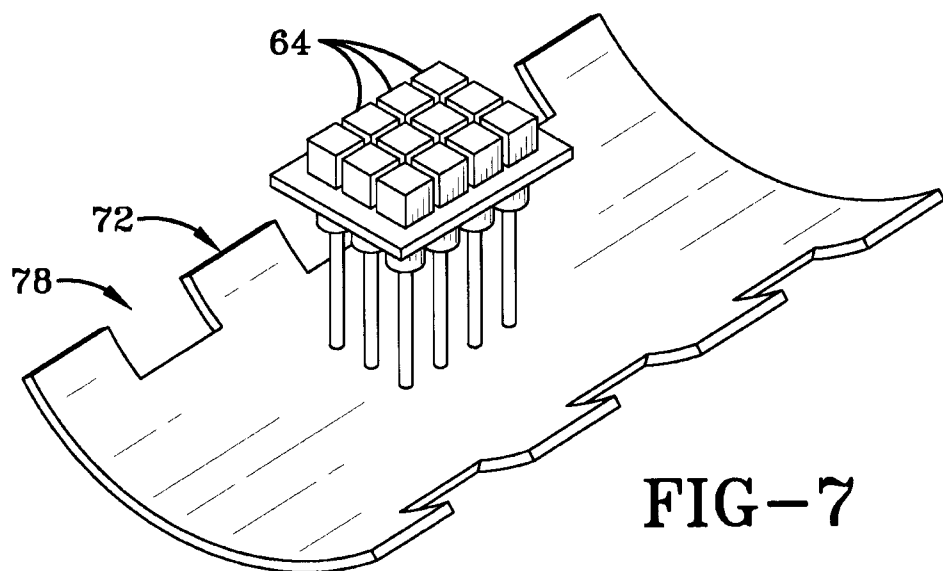
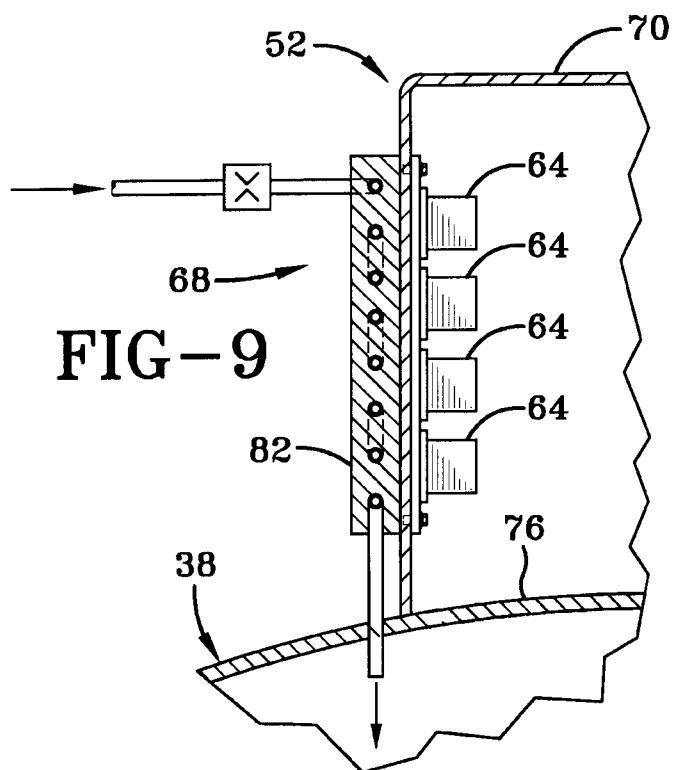
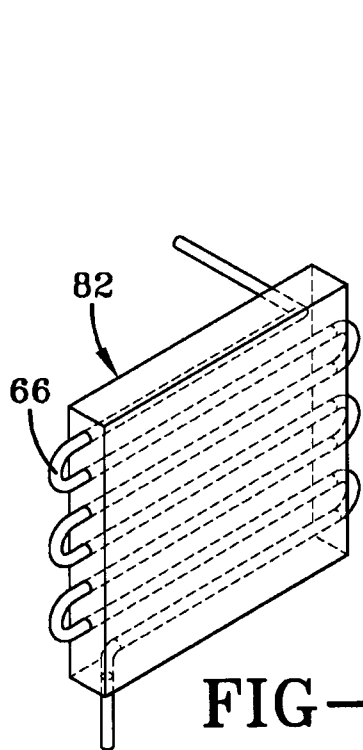
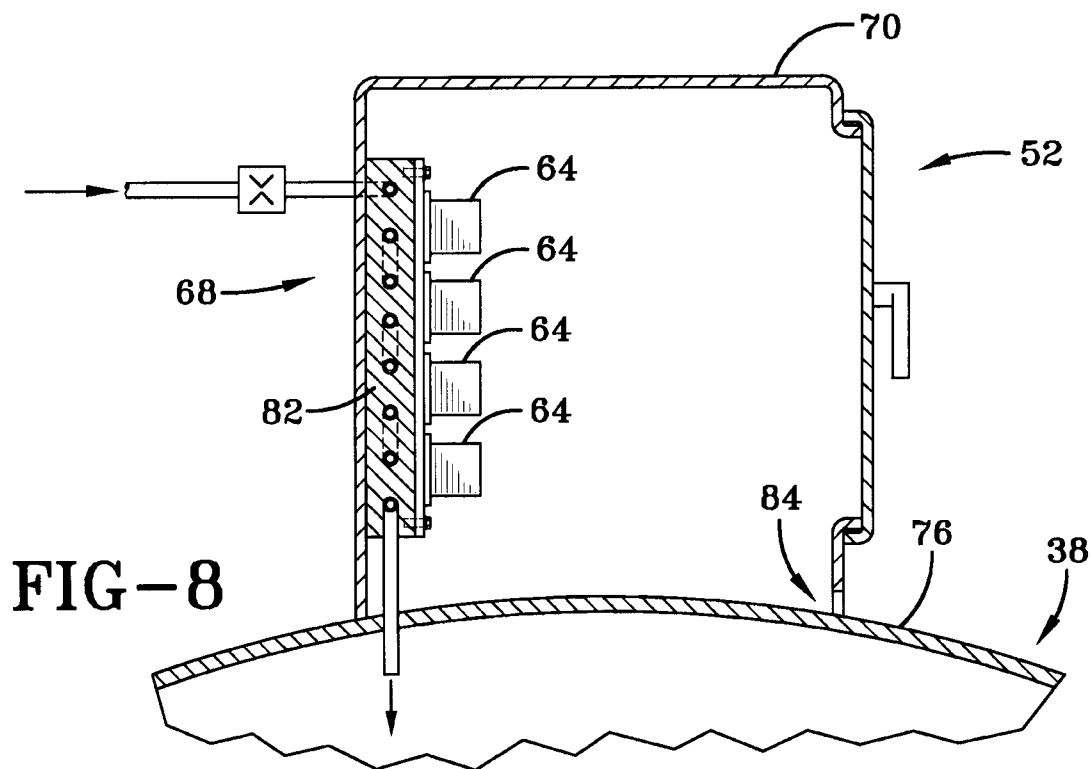


FIG-7

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INTERNATIONAL SEARCH REPORT

International application No

PCT/US2010/041675

A. CLASSIFICATION OF SUBJECT MATTER

INV. H05K7/20

ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H05K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 058 391 A (PERIOT ROBERT [FR]) 22 October 1991 (1991-10-22) * abstract figure 2 column 3, lines 25-45	1-20
X,P	DE 10 2008 058370 A1 (TALANIN YRU V [RU]) 27 May 2010 (2010-05-27) figure 13 paragraph [0034] * abstract paragraph [0030] paragraph [0042]	1-20
X	WO 2007/131355 A1 (1252110 ALBERTA LTD [CA]; MYLES JUSTIN E [CA]; REDDIN DANIEL EAMON [CA]) 22 November 2007 (2007-11-22) figure 3 page 18	1-20



Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

17 November 2010

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26/11/2010

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Galary, Grzegorz

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

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