(54) Title: HEAT EXCHANGERS

(57) Abstract: Disclosed are exemplary embodiments of heat exchangers that may be capable of cooling multiple process loops with a single primary or shell-side fluid and/or have combined liquid-to-liquid and liquid-to-air heat exchange capability.
HEAT EXCHANGERS

CROSS-REFERENCE TO RELATED APPLICATION


FIELD

[0002] The present disclosure relates to heat exchangers.

BACKGROUND

[0003] This section provides background information related to the present disclosure which is not necessarily prior art.

[0004] Heat exchangers operate by facilitating the transfer of heat from one fluid to a second fluid by various means. One type of heat exchanger design is a shell and tube heat exchanger which includes a shell (a large pressure vessel) and multiple tubes. The tubes extend through an interior of the shell. The set of tubes may also be referred to as a tube bundle, and may be composed of several types of tubes, e.g., straight, bent, U-shaped, plain, longitudinally finned, etc. The tubes may be held in place within the shell by tube sheets.

[0005] During operation of the heat exchanger, one fluid (the tube-side fluid) runs through the tubes. Another separate fluid (the shell-side fluid) flows over the tubes but inside the shell. Heat is transferred from one fluid to the other through the tube walls, either from the tube-side fluid to the shell-side fluid or vice versa. For example, liquid-to-liquid heat exchange would occur when both the tube-side fluid and the shell-side fluid are liquids such that heat is transferred from one liquid to the other liquid via the tube walls. Or, for example, liquid-to-air (or liquid-to-gas) heat exchange would occur when one of the tube-side and shell-side fluid is a liquid and the other one is a gas (e.g., air, etc.) such that heat may be transferred between the liquid and the gas.
DRAWINGS

[0006] The drawings described herein are for illustrative purposes only of selected embodiments and not all possible implementations, and are not intended to limit the scope of the present disclosure.

[0007] FIG. 1 illustrates a heat exchanger according to an exemplary embodiment in which the heat exchanger is being used to cool three different process loops (e.g., OCU, GCU, and CCU of a medical imaging system, etc.) with a single primary side cooling fluid (e.g., facility water flow, etc.); and

[0008] FIG. 2 illustrates a heat exchanger according to another exemplary embodiment in which the heat exchanger is configured to be operable with liquid-to-liquid and liquid-to-air heat exchange capability.

DETAILED DESCRIPTION

[0009] Example embodiments will now be described more fully with reference to the accompanying drawings.

[0010] The inventor hereof has recognized a need for a heat exchanger that is capable of cooling multiple process loops (e.g., multiple tube-side fluids from different sources, etc.) with a single primary side cooling fluid or single shell-side fluid. The inventor hereof has also recognized a need for a heat exchanger having versatility such that either or both liquid-to-liquid heat exchange and/or liquid-to-air heat exchange may be used. After recognizing the above, the inventor hereof developed and discloses herein exemplary embodiments of heat exchangers capable of cooling multiple process loops with a single primary or shell-side fluid and/or having combined liquid-to-liquid and liquid-to-air heat exchange capability.

[0011] In exemplary embodiments, a heat exchanger includes a multi-core design having a liquid-to-air heat exchange section and a liquid-to-liquid heat exchange section. The liquid-to-air and liquid-to-liquid heat exchange sections are incorporated in the construction of the heat exchanger by the addition of one or more divider plates. The combined liquid-to-air and liquid-to-liquid heat exchanger may comprise a tube and fin heat exchanger, a shell and tube heat exchanger, or other suitable types of heat exchangers, etc.
The combined liquid-to-air and liquid-to-liquid heat exchanger may be useful when it is uncertain as to whether facility water will be available to cool the process fluid. If facility water is not available, the cooling system including the combined liquid-to-air and liquid-to-liquid heat exchanger may still operate completely under air cooled conditions. The combined liquid-to-air and liquid-to-liquid heat exchanger may thus allow for a versatile common platform that reduces the number of cooling system types that might otherwise be needed, such as air cooled or liquid cooled. The combined liquid-to-air and liquid-to-liquid heat exchanger may be useful in emergency cooling situations (e.g., power outages which could trigger city water or facility water valves to open and maintain the necessary cooling of the process fluid, etc.). The combined liquid-to-air and liquid-to-liquid heat exchanger may also be used in multi-loop applications in which process water may heat and/or cool a secondary cooling loop inside or within the end user's system.

In exemplary embodiments, a multi-core heat exchanger may be based on or have a shell and tube heat exchanger design. The heat exchanger includes one or more divider plates that allow for cooling different process loops with a single primary side or shell-side cooling fluid (e.g., facility water or refrigerant, etc.). For example, the heat exchanger may be used to cool three different process loops of a medical imaging system (e.g., OCU (Optional Cooling Unit), GCU (Gradient Coil Unit), and CCU (Cabinet Cooling Unit), etc.) with facility water flow as the single primary side or shell-side cooling fluid.

In operations in which multiple process fluids will be cooled (e.g., at different flow rates, at different temperatures, and/or for different consumers, etc.), exemplary embodiments of the heat exchangers disclosed herein may not require the use of additional manifolds when cooling multiple process fluids. Thus, exemplary embodiments may eliminate the need to use additional manifolds and reduce the total number of heat exchangers that would otherwise be used. Hence, these exemplary embodiments may allow for reduced package size and reduced number of fittings and joints, which, in turn, may increase reliability, reduce part count, and reduce complexity. By using a single high performance heat exchanger on the primary side (in contrast to splitting the flow into three different heat exchangers), the pressure drop on the primary side may be greatly reduced. This, in return, reduces the amount of energy consumption on the system level within the installation (e.g., less hydraulic pressure required from the HVAC system or cooling tower, etc.). Some exemplary embodiments have a shell and tube multi-loop heat exchanger design that allows the performance element (e.g., tube bundle removable
from the housing, etc.) to be removed from the assembly and cleaned for reuse. In contrast, conventional braze plate type heat exchangers cannot be opened and/or cleaned easily.

[0015] In exemplary embodiments, a heat exchanger is based in part on a shell and tube heat exchanger design. In such exemplary embodiments, the heat exchanger generally includes tubes extending within and through a shell. First and second headers may be positioned at opposite ends of the shell. The first and second headers may respectively include first and second tube sheets. The first and second headers may respectively include or define inlet and outlet plenums that are fluidically connected to or in fluid communication with the respective inlet and outlet ends of the tubes through holes in first and second tube sheets. One or more divider plates may be oriented generally parallel to the first and second tube sheets and extend generally between the first and second headers in order to divide the heat exchanger and shell into multiple sections. The shell may include one or more inlets (e.g., openings, holes, etc.) for allowing the shell-side fluid (e.g., liquid, air, etc.) to flow into the shell between the first and second headers to thereby allow exchange between the tube-side fluid and the shell-side fluid.

[0016] In some exemplary embodiments where there are inlets for allowing air to flow into the shell between the first and second headers, the heat exchanger may be configured to be operable with a shell-side liquid so as to allow both liquid-to-liquid heat exchange and liquid-to-air heat exchange. Alternatively, the heat exchanger may be configured to be operable without a shell-side liquid such that the heat exchanger relies only on liquid-to-air heat exchange.

[0017] With reference to the drawings, FIG. 1 illustrates an exemplary embodiment of a heat exchanger 100 embodying one or more aspects of the present disclosure. As shown, the heat exchanger 100 includes divider plates 104 that separate the shell 106 into separate sections. This allows the heat exchanger 100 to be used for cooling three different process loops with a single primary side or shell-side cooling fluid (e.g., facility water flow, etc.) as represented by arrow 108. In this example, the heat exchanger 100 is shown in use with an OCU (Optional Cooling Unit) cooling loop, a GCU (Gradient Coil Unit) cooling loop, and a CCU (Cabinet Cooling Unit) of a medical imaging system. The heat exchanger 100 may also be used in other applications for cooling more or less than three process loops, different process loops, and/or in different systems besides medical imaging systems.

[0018] With continued reference to FIG. 1, arrows 112 and 116 represent a secondary or tube-side fluid of the OCU cooling loop respectively flowing into and out of the heat exchanger 100. Arrows 120 and 124 represent a secondary or tube-side fluid of the GCU cooling loop respectively flowing into and out of the heat exchanger system 100. Arrows 128 and 132 represent a secondary or
tube-side fluid of the CCU cooling loop respectively flowing into and out of the heat exchanger 100. Arrow 108 represents the single primary side or shell-side fluid entering the heat exchanger 100 generally perpendicularly to the flow of the secondary or tube-side fluids represented by arrows 112, 116, 120, 124, 128, 132. In the heat exchanger 100, the primary side or shell-side fluid exchanges heat with secondary or tube-side fluids of the OCU, GCU, and CCU cooling loops. The primary side fluid then egresses or exits the heat exchanger 100 as represented by arrow 136. The result is the cooling of all three loops (OCU, GCU, and CCU) with a single primary side fluid with a single heat exchanger 100. In this exemplary embodiment, the heat exchanger 100 may be configured such that the single primary side fluid is one continuous, straight flow through a continuous, seamless tube.

[0019] In exemplary embodiments, the shell 106 includes one or more inlets (e.g., openings, holes, gaps, etc.) in the shell's outer portion between a first header and a second header. The one or more inlets are configured to allow gas (e.g., ambient air, heated air, cooled air, other gas, etc.) to flow (pressurized or unpressurized) into the shell's interior region between the first and second headers. For example, the one or more inlets may be configured (e.g., positioned, etc.) such that they do not allow air into the first and second headers. The air that flows into the shell via the one or more inlets may function or act as a shell-side fluid for liquid-to-air heat exchange. More specifically, heat may be transferred from the liquid within the tubes (tube-side fluid) to the air (shell-side fluid) within the shell that flows over the tubes, or vice versa. In some exemplary embodiments, the one or more inlets of the shell may be expansive, effectively acting as a single gap allowing air to flow unimpeded through the shell. The shell-side gas may be ambient temperature or heated or cooled to a desired temperature.

[0020] In exemplary embodiments, the heat exchanger includes divider plates separating the shell into separate sections. This allows the heat exchanger to be used for cooling multiple different process loops with a single primary side or shell-side cooling fluid (e.g., facility water, refrigerant flow, etc.). For example, the heat exchanger may be used with an OCU (Optional Cooling Unit) cooling loop, a GCU (Gradient Coil Unit) cooling loop, and a CCU (Cabinet Cooling Unit) of a medical imaging system. But the heat exchanger may also be used in other applications for cooling more or less than three process loops, different process loops, and/or in different systems besides medical imaging systems. For example, the heat exchanger may be used with industrial drives and frequency converters that use several cooling loops for different heat sources or a common cooling system cooling two or more drives. Or, for example, the heat exchanger may be used with semiconductor fabrication tools that use several cooling loops for temperature controlling different heat sources or using a common cooling
system to cool multiple tools. As yet another example, the heat exchanger may be used with data infrastructure for cooling several heat sources in serves and or cooling several server racks with a common cooling system.

[0021] First and second headers are at opposite ends of the shell. The first header may include or be fluidically connected to or in fluid communication with one or more first tube sheets. In this example, the heat exchanger may include four divider plates having end portions respectively disposed between corresponding pairs of the five first tube sheets. The first header may also include or define an inlet plenum that is fluidically connected to or in fluid communication with the inlet ends of the tubes through openings (e.g., holes, perforations, etc.) in the first tube sheets. Similarly, the second header may include or be fluidically connected to or in fluid communication with one or more second tube sheets. The divider plates may have end portions also respectively disposed between corresponding pairs of the second tube sheets. The second header may also include or define an outlet plenum that is fluidically connected to or in fluid communication with the outlet ends of the tubes through openings (e.g., holes, perforations, etc.) in the second tube sheets. The divider plates may be oriented generally parallel to the first tube sheets and the second tube sheets. The divider plates may extend generally between the first and second headers in order to divide the heat exchanger and shell into five sections in this example. The divider plates may be used to separate and completely seal the five sections, and the fluid may turn several times within one body. Alternatively, the heat exchanger may be configured differently in other embodiments, such as with more or less than four divider plates, more or less than five first and second tube sheets, and/or more or less than five sections.

[0022] In addition to the first tube sheets and the second tube sheets at the opposite end portions of the shell, the heat exchanger may include additional tube sheets. The tube sheets may be spaced apart the opposite end portions of the shell to help hold the tubes in place within the shell. If the tubes are microtubes, stiffener plates may also be used to increase stability.

[0023] The heat exchanger may include one or more baffles positioned between (e.g., about midway, etc.) between the first and second headers. A baffle may be configured to direct the flow of the primary side or shell-side fluid through the shell so that the primary side or shell-side fluid does not take a short cut through the shell leaving ineffective low flow volumes. The baffle may be configured to increase turbulence of the shell-side fluid in order to achieve more effective heat transfer. The baffle may be attached to the tube bundle so that the tube bundle is more readily removable for cleaning and/or maintenance. Alternatively, the heat exchanger may be configured differently in other embodiments,
such as with more or less than one baffle and/or a baffle configured differently (e.g., positioned elsewhere, attached to the shell instead of the tube bundle, etc.).

[0024] The heat exchanger may be configured such that the primary side or shell-side fluid passes through the shell in a single pass. For example, the heat exchanger may include a seamless single tube through which the fluid flows from one end to the other end. Or, for example, two loops may be created such as by completely welding the body to a baffle so that there is no fluid bypass between the chambers.

[0025] The first and second headers are configured to allow tube-side fluid to respectively flow into and out of the tubes without contacting the shell-side fluid. The heat exchanger may be configured such that a different tube-side fluid enters the tubes of each of the corresponding sections or process loops of the heat exchanger. Thus, the set of tubes of one section or process loop may contain a tube-side fluid different than the tube-side fluids within the sets of tubes of the other sections or process loops.

[0026] FIG. 2 illustrates another exemplary embodiment of a heat exchanger 300 embodying one or more aspects of the present disclosure. The heat exchanger 300 is configured to be selectively operable with either or both liquid-to-liquid heat exchange and liquid-to-air heat exchange.

[0027] The heat exchanger 300 includes a first or top header 340 and a second or bottom header 344. The first and second headers 340, 344 are along or at opposite top and bottom (or upper and lower) portions of a shell 306 of the heat exchanger 300.

[0028] The first header 340 may include or be fluidically connected to or in fluid communication with a first tube sheet 348. The first tube sheet 348 may include openings (e.g., holes, perforations, etc.) defining or fluidically connected to or in fluid communication with inlet ends of the process fluid tubes 354. In an example embodiment, end portions of the tubes 354 may be coupled (e.g., welded, brazed, epoxied, other suitable "leak free" connection, etc.) to the first tube sheet 348. The first header 340 includes a tube-side fluid inlet 356 (e.g., process fluid fitting, etc.) by which a tube-side fluid may enter the heat exchanger 300. The tube-side fluid inlet 356 may allow the tube-side fluid to enter the tubes 354 without contacting the shell-side fluid.

[0029] The second header 344 may include or be fluidically connected to or in fluid communication with a second tube sheet 350. The second tube sheet 350 may include openings (e.g., holes, perforations, etc.) defining or fluidically connected to or in fluid communication with outlet ends of the tubes 354. In an example embodiment, end portions of the tubes 354 may be coupled (e.g.,
welded, brazed, epoxied, other suitable "leak free" connection, etc.) to the second tube sheet 350. The
second header 344 includes a tube-side fluid outlet 360 (e.g., process fluid fitting, etc.) through which
the tube-side fluid may exit or be discharged from the heat exchanger 300 without contacting the shell-
side fluid.

[0030] The tubes 354 generally extend downwardly from the top header 340 through the first
tube sheet 348, additional tube sheet 352, shell 306, and the second tube sheet 350 to the bottom header
344. In this example, the tubes 354 are generally parallel to each other and held in position by the tube
sheets 348, 352, and 350. Each tube sheet 348, 352, 350 may include openings in which are positioned
(e.g., friction or interference fit, etc.) portions of the tubes 354. Alternatively, the tubes 354 may be
configured differently, such as nonlinearly, curved, U-shaped, etc.

[0031] The heat exchanger 300 also includes an area 372, which may also be referred to as a
liquid-to-liquid heat exchange area 372. More specifically, the heat exchanger 300 includes a shell-side
fluid inlet 364 (e.g., facility fluid fitting, etc.) and a shell-side fluid outlet 368 (e.g., facility fluid fitting,
etc.) by which a shell-side fluid may respectively enter and exit the area 372. The area 372 may be
defined generally below and sealed off from the portion of the first header 340 that receives the tube-
side fluid via the tube-side fluid inlet 356. Accordingly, a shell-side fluid (e.g., facility water, etc.) may
enter the heat exchanger 300 via the inlet 364, flow through the area 372 and around portions of the
tubes 354 within the area 372, and exit the heat exchanger 300 via outlet 368. As the shell-side fluid
flows through and around portions of the tubes 354, heat may be transferred between the tube-side fluid
and the shell-side fluid via the tube walls. When the shell-side fluid and tube-side fluid are both liquids,
the area 372 may also be referred to as a liquid-to-liquid heat exchange area. The shell-side fluid may be
generally contained within the area 372. The tubes 354 are "leak free" coupled to the tube sheet 352
such that liquid within area 372 cannot leak into area 376.

[0032] The heat exchanger 300 may also be configured to allow air (or other suitable gas) to
flow around portions of the tubes 354 within the area 376 between and sealed off from the area 372, tube
sheets 350, 352, and first and second headers 340, 344. This may allow heat exchange between the tube-
side fluid and the air within area 376 via the tube walls. The area 376 may also be referred to as a liquid-
to-air heat exchange area when the tube-side fluid is a liquid and the fluid within area 376 is air. The
area 376 may also be referred to as a liquid-to-gas heat exchange area when the tube-side fluid is a
liquid and the fluid within area 376 is a gas.
In exemplary embodiments, one or more tube-side fluid inlets may allow flow of multiple different tube-side fluids (also known as "process fluids" or "secondary side fluids") into the tubes. A tube-side fluid inlet may be constructed so as to allow a tube-side fluid to enter the tubes and flow through the shell without contacting the shell-side fluid. Further, each tube-side fluid inlet may be constructed so as to allow a different tube-side fluid to flow into a distinct set of tubes among the plurality of tubes. For example, each tube-side fluid inlet may permit flow of one tube-side fluid into only one set of tubes from among the plurality of sets of tubes. Each tube-side inlet may thus allow for fluid flow for a different cooling loop through the heat exchanger.

In some embodiments, each separate cooling loop may include a different tube-side fluid into a different tube-side inlet to form a system involving a single heat exchanger and multiple different cooling loops. In some exemplary embodiments, there are two or more cooling loops and two or more corresponding tube-side inlets. This functionally allows for cooling multiple cooling loops (e.g., cooling tube-side fluids from different sources, etc.) in a single system. By way of example only, a system of three different cooling loops (e.g., for use in a medical imaging device, etc.) may be cooled using a heat exchanger of the present disclosure. Each cooling loop may have its own tube-side fluid and distinct tube-side inlet. In which case, each cooling loop may include fluid flow through its own distinct set of tubes. Accordingly, the tube-side fluid within each of the multiple loops may be cooled as each passes through the heat exchanger by a single shell-side (or "primary side") fluid without the tube-side fluids contacting each other or contacting the shell-side fluid. Thus, this example allows cooling of multiple separate cooling loops with a single heat exchanger using a single shell-side (or "primary side") fluid.

In exemplary embodiments that include one or more divider plates, the divider plates may be operable to separate or segregate different sets of tubes carrying different tube-side fluids, e.g., OCU, GCU, and CCU tube side-side fluids, etc. The divider plates may be made of various materials, such as metals, metal alloys, plastics, etc.

As disclosed herein, exemplary embodiments may include a shell and one or more divider plates. The divider plates may extend through the shell parallel to the tubes and perpendicular the first and second headers. In this exemplary manner, the divider plates may divide the shell into two or more separate sections, wherein each section has a tube-side fluid inlet separate from the other. In exemplary embodiments, the shell-side fluid may be free to flow through the first header and second header unimpeded.
In some exemplary embodiments, the tubes may include one or more surfaces (e.g., fins, etc.) extending outwardly from the exterior surface of the tube walls to thereby increase the heat transfer surface area. In other exemplary embodiments, the tubes may not include any such outwardly extending fins or other surfaces. In some exemplary embodiments, the tubes may have enhanced surfaces (e.g., metal coatings on the inside and/or outside of the tube walls, etc.) to facilitate heat transfer and/or prevent corrosion.

The tube wall thickness may vary depending, for example, on the fluid pressures used in the heat exchanger system, materials used, and/or other factors. The length of the tubes and overall size of the shell and heat exchanger may depend, for example, on the space available for the heat exchanger, the level of cooling needed, and/or other factors.

In exemplary embodiments, the tubes may be made of various materials including metal, metal alloys, and other non-metal materials. For example, the tubes may be made of carbon steel, low carbon steel, stainless steel, copper, copper-nickel stainless steel, nickel-chromium iron alloys, titanium, and other alloys thereof. The tube may be made of an alloy including, for example, cobalt, chromium, iron, nickel, tungsten, manganese, molybdenum, copper, titanium, zirconium, aluminum, carbon, silicon, sulfur, phosphorus, boron, etc. In some exemplary embodiments, the tubes may be conventionally-sized tubes with diameters of, for example, greater than 1 millimeter. In other exemplary embodiments, the tubes may be microtubes having a diameter smaller than conventional tubes, e.g., a diameter less than 1 millimeter, etc. Such microtubes may be made of metals, metal alloys, plastic, ceramic materials, etc., depending on the intended application or end use, fluid properties, operation temperature of the heat exchanger system, potential for fouling, and other factors.

The tubes may be attached (e.g., welded, mechanically fastened, brazed, glued, etc.) to the shell and/or the first or second headers. In exemplary embodiments, machined grooves in tube sheets and corresponding nodules at the appropriate location on the tubes may allow for increased anchoring strength between the tube sheet and tubes. In other exemplary embodiments, the tubes may be secured to the tube sheets by welding, gaskets, or other forms of hermetic sealing commonly known in the art.

Various fluids may be used for the shell-side and tube-side fluids in exemplary embodiments. For example, exemplary embodiments may include on or more of ethylene glycol water (EGW), water, water-glycol mixtures, electronics cooling fluid (e.g., Fluorinert, etc.), oil, inert
fluorinated fluid (e.g., perfluoropolyether (PFPE) fluorinated fluids, galden PFPE fluid, etc.), deionized water, demineralized water, ultrapure water, fuel, etc.

[0042] The shell may be made from various materials, such as metals, metal alloys (e.g., low carbon steel, etc.), and other materials. For example, the shell may be made of a metal alloy including one or more of cobalt, chromium, iron, nickel, tungsten, manganese, molybdenum, copper, titanium, zirconium, aluminum, carbon, silicon, sulfur, phosphorus, boron, etc.

[0043] The size of the first and second headers may vary depending on the size of overall heat exchanger, ratio of liquid-to-liquid heat exchange to liquid-to-air heat exchange desired in the heat exchanger, and/or other factors. The first and second headers may be made from various materials, such as metals, metal alloys (e.g., low carbon steel, etc.), and other materials. For example, the headers may be made of a metal alloy including one or more of cobalt, chromium, iron, nickel, tungsten, manganese, molybdenum, copper, titanium, zirconium, aluminum, carbon, silicon, sulfur, phosphorus, boron, etc.

[0044] In exemplary embodiments, a tube-side fluid may have a higher temperature than the shell-side fluid such that heat is transferred from the tube-side fluid to the shell-side fluid. When configured in this exemplary manner, the heat exchanger may be used to cool the tube-side fluid. In other exemplary embodiments, a tube-side fluid may have a lower temperature than the shell-side fluid such that heat is transferred from the shell-side fluid to the tube-side fluid. When configured in this exemplary manner, the heat exchanger may be used to warm the tube-side fluid.

[0045] In exemplary embodiments, ambient air is allowed to flow into the shell between the first and second headers and around the tubes. When the ambient air has a lower temperature than the tube-side fluid, the tube-side fluid may be cooled by the ambient air. In other exemplary embodiments, the ambient air may have a higher temperature than the tube-side fluid, such that the tube-side fluid may be warmed by the ambient air.

[0046] In exemplary embodiments, an intermediate region of the shell between the first and second headers may include one or more inlets (e.g., holes, gaps, etc.) in the shell outer surface to allow a gas (e.g., pressurized, cooled, warmed, or ambient air, etc.) to flow through the intermediate region. This allows the ambient air or other gas to act as a second, additional, or alternative shell-side fluid that may flow over and around the portions of the tubes within the intermediate region. In which case, heat may be exchanged between the tube-side fluid and the ambient air or other gas within the intermediate region via the walls of the tubes. The ambient air or other gas may then exit or be discharged from the shell via one or more outlets (e.g., holes, gaps, etc.). In exemplary embodiments, the intermediate region
of the shell is between the first and second headers and optionally includes one or more divider plates separating groups of tubes carrying different tube-side fluids.

[0047]  Exemplary embodiments of the heat exchangers disclosed herein may be used in a wide array of applications, such as heating and air-conditioning (HVAC) systems, medical imaging systems, oil refining processes, heat pumps, engines, and other systems where cooling or heating of fluids is useful.

[0048]  Example embodiments are provided so that this disclosure will be thorough, and will fully convey the scope to those who are skilled in the art. Numerous specific details are set forth such as examples of specific components, devices, and methods, to provide a thorough understanding of embodiments of the present disclosure. It will be apparent to those skilled in the art that specific details need not be employed, that example embodiments may be embodied in many different forms, and that neither should be construed to limit the scope of the disclosure. In some example embodiments, well-known processes, well-known device structures, and well-known technologies are not described in detail. In addition, advantages and improvements that may be achieved with one or more exemplary embodiments of the present disclosure are provided for purpose of illustration only and do not limit the scope of the present disclosure, as exemplary embodiments disclosed herein may provide all or none of the above mentioned advantages and improvements and still fall within the scope of the present disclosure.

[0049]  Specific dimensions, specific materials, and/or specific shapes disclosed herein are example in nature and do not limit the scope of the present disclosure. The disclosure herein of particular values and particular ranges of values for given parameters are not exclusive of other values and ranges of values that may be useful in one or more of the examples disclosed herein. Moreover, it is envisioned that any two particular values for a specific parameter stated herein may define the endpoints of a range of values that may be suitable for the given parameter (i.e., the disclosure of a first value and a second value for a given parameter can be interpreted as disclosing that any value between the first and second values could also be employed for the given parameter). For example, if Parameter X is exemplified herein to have value A and also exemplified to have value Z, it is envisioned that parameter X may have a range of values from about A to about Z. Similarly, it is envisioned that disclosure of two or more ranges of values for a parameter (whether such ranges are nested, overlapping or distinct) subsume all possible combination of ranges for the value that might be claimed using endpoints of the disclosed ranges. For example, if parameter X is exemplified herein to have values in the range of 1 -
10, or 2 - 9, or 3 - 8, it is also envisioned that Parameter X may have other ranges of values including 1 - 9, 1 - 8, 1 - 3, 1 - 2, 2 - 10, 2 - 8, 2 - 3, 3 - 10, and 3 - 9.

[0050] The terminology used herein is for the purpose of describing particular example embodiments only and is not intended to be limiting. As used herein, the singular forms "a", "an" and "the" may be intended to include the plural forms as well, unless the context clearly indicates otherwise. The terms "comprises," "comprising," "including," and "having," are inclusive and therefore specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof. The method steps, processes, and operations described herein are not to be construed as necessarily requiring their performance in the particular order discussed or illustrated, unless specifically identified as an order of performance. It is also to be understood that additional or alternative steps may be employed.

[0051] When an element or layer is referred to as being "on", "engaged to", "connected to" or "coupled to" another element or layer, it may be directly on, engaged, connected or coupled to the other element or layer, or intervening elements or layers may be present. In contrast, when an element is referred to as being "directly on," "directly engaged to", "directly connected to" or "directly coupled to" another element or layer, there may be no intervening elements or layers present. Other words used to describe the relationship between elements should be interpreted in a like fashion (e.g., "between" versus "directly between," "adjacent" versus "directly adjacent," etc.). As used herein, the term "and/or" includes any and all combinations of one or more of the associated listed items.

[0052] The term "about" when applied to values indicates that the calculation or the measurement allows some slight imprecision in the value (with some approach to exactness in the value; approximately or reasonably close to the value; nearly). If, for some reason, the imprecision provided by "about" is not otherwise understood in the art with this ordinary meaning, then "about" as used herein indicates at least variations that may arise from ordinary methods of measuring or using such parameters. For example, the terms "generally", "about", and "substantially" may be used herein to mean within manufacturing tolerances. Whether or not modified by the term "about", the claims include equivalents to the quantities.

[0053] Although the terms first, second, third, etc. may be used herein to describe various elements, components, regions, layers and/or sections, these elements, components, regions, layers and/or sections should not be limited by these terms. These terms may be only used to distinguish one
element, component, region, layer or section from another region, layer or section. Terms such as "first," "second," and other numerical terms when used herein do not imply a sequence or order unless clearly indicated by the context. Thus, a first element, component, region, layer or section could be termed a second element, component, region, layer or section without departing from the teachings of the example embodiments.

[0054] Spatially relative terms, such as "inner," "outer," "beneath," "below", "lower", "above", "upper" and the like, may be used herein for ease of description to describe one element or feature's relationship to another element(s) or feature(s) as illustrated in the figures. Spatially relative terms may be intended to encompass different orientations of the device in use or operation in addition to the orientation depicted in the figures. For example, if the device in the figures is turned over, elements described as "below" or "beneath" other elements or features would then be oriented "above" the other elements or features. Thus, the example term "below" can encompass both an orientation of above and below. The device may be otherwise oriented (rotated 90 degrees or at other orientations) and the spatially relative descriptors used herein interpreted accordingly.

[0055] The foregoing description of the embodiments has been provided for purposes of illustration and description. It is not intended to be exhaustive or to limit the disclosure. Individual elements, intended or stated uses, or features of a particular embodiment are generally not limited to that particular embodiment, but, where applicable, are interchangeable and can be used in a selected embodiment, even if not specifically shown or described. The same may also be varied in many ways. Such variations are not to be regarded as a departure from the disclosure, and all such modifications are intended to be included within the scope of the disclosure.
CLAIMS

What is claimed is:

1. A heat exchanger comprising:
   a shell defining an interior;
   one or more tubes extending through the interior of the shell;
   at least one shell-side fluid inlet;
   at least one shell-side fluid outlet;
   at least one shell-side gas inlet; and
   at least one shell-side gas outlet;
   at least one tube-side fluid inlet for allowing at least one tube-side fluid to enter the heat exchanger and flow into the one or more tubes;
   at least one tube-side fluid outlet for allowing the at least one tube-side fluid to exit the heat exchanger after flowing through the one or more tubes;
   wherein:
      the at least one shell-side fluid inlet and the at least one shell-side fluid outlet are configured to allow a shell-side fluid to respectively enter and exit an area of the heat exchanger such that the shell-side fluid flows around portions of the tubes within the area thereby allowing heat transfer between the at least one tube-side fluid within the one or more tubes and the shell-side fluid within the area; and
      the at least one shell-side gas inlet and the at least one shell-side gas outlet are configured to allow a shell-side gas to respectively enter and exit the interior of the shell such that the shell-side gas flows around portions of the one or more tubes within the interior thereby allowing heat transfer between the shell-side gas and the at least one tube-side fluid within the one or more tubes within the interior of the shell.

2. The heat exchanger of claim 1, further comprising first and second headers at opposite end portions of the shell, and wherein:
   the one or more tubes extend between the first and second headers through the interior of the shell;
   the first header includes the at least one tube-side fluid inlet; and
the second header includes the at least one tube-side fluid outlet.

3. The heat exchanger of claim 2, wherein:
the first header includes one or more first tube sheets having one or more openings in which are positioned corresponding inlet end portions of the one or more tubes; and
the second header includes one or more second tube sheets having one or more openings in which are positioned corresponding outlet end portions of the one or more tubes;
whereby the first and second tube sheets are operable for helping retain the positioning of the one or more tubes.

4. The heat exchanger of claim 1, wherein:
the at least one tube-side fluid is at least one tube-side liquid;
the shell-side fluid is a shell-side liquid;
the shell-side gas is air; and
the heat exchanger is selectively operable for providing either or both of:
liquid-to-liquid heat exchange between the at least one tube-side liquid and the shell-side liquid within the area; and
liquid-to-air heat exchange between the air within the interior of the shell and the at least one tube-side liquid.

5. The heat exchanger of any one of claims 1 to 4, further comprising one or more divider plates that separate the shell into separate sections such that the heat exchanger is operable for cooling multiple process loops with a single shell-side fluid.

6. The heat exchanger of claim 5, wherein the heat exchanger is operable for cooling at least three process loops with a single shell-side fluid.

7. The heat exchanger of claim 5, wherein the heat exchanger is operable for cooling three process loops of a medical imaging system with facility water flow as the single shell-side fluid.
8. The heat exchanger of claim 5, wherein:
   the one or more tubes comprise at least two sets of tubes separated by the one or more divider plates; and
   each set of tubes is configured to receive a different tube-side fluid than the other sets of tubes.

9. The heat exchanger of any one of claims 1 to 4, wherein the heat exchanger is selectively operable for providing either or both of liquid-to-liquid heat exchange and/or liquid-to-air heat exchange.

10. A heat exchanger comprising:
    a shell defining an interior;
    one or more divider plates that separate the shell into separate sections;
    at least two sets of one or more tubes extending through the interior of the shell and separated by the one or more divider plates, each set of one or more tubes configured to receive a different tube-side fluid than each other set of tubes;
    whereby the heat exchanger is operable for cooling multiple process loops with a single shell-side fluid.

11. The heat exchanger of claim 10, wherein the heat exchanger is operable for cooling at least three process loops with a single shell-side fluid.

12. The heat exchanger of claim 10, wherein the heat exchanger is operable for cooling three process loops of a medical imaging system with facility water flow as the single shell-side fluid.

13. The heat exchanger of claim 10, wherein the heat exchanger includes at least one shell-side fluid inlet and at least one shell-side fluid outlet configured to allow a shell-side fluid to respectively enter and exit an area of the heat exchanger such that the shell-side fluid flows around portions of the at least two sets of one or more tubes within the area.
14. The heat exchanger of claim 13, wherein the heat exchanger includes at least one tube-
side fluid inlet and at least one tube-side fluid outlet configured to allow at least one tube-side fluid to re-
spectively enter and exit the heat exchanger.

15. The heat exchanger of any one of claims 10 to 14, wherein the heat exchanger includes at least one shell-side gas inlet and at least one shell-side gas outlet configured to allow a shell-side gas to re-
spectively enter and exit the interior of the shell such that the shell-side gas flows around portions of the at least two sets of one or more tubes within the interior of the shell.

16. The heat exchanger of any one of claims 10 to 14, further comprising first and second headers at opposite end portions of the shell, and wherein:

the at least two sets of one or more tubes extend between the first and second headers through the interior of the shell;

the first header includes at least one tube-side fluid inlet configured to allow at least one tube-
side fluid to enter the heat exchanger; and

the second header includes at least one tube-side fluid outlet configured to allow the at least one tube-side fluid to exit the heat exchanger.

17. The heat exchanger of claim 16, wherein:

the first header includes one or more first tube sheets having one or more openings in which are positioned corresponding inlet end portions of the at least two sets of one or more tubes; and

the second header includes one or more second tube sheets having one or more openings in which are positioned corresponding outlet end portions of the at least two sets of one or more tubes;

whereby the first and second tube sheets are operable for helping retain the positioning of the at least two sets of one or more tubes.

18. The heat exchanger of any one of claims 10 to 14, wherein the heat exchanger is selec-
tively operable for providing either or both of liquid-to-liquid heat exchange and/or liquid-to-air heat exchange.
### A. CLASSIFICATION OF SUBJECT MATTER

HOIL 23/473(2006.01)i, HOIL 23/467(2006.01)i, HOIL 23/367(2006.01)i, H05K 7/20(2006.01)i

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)
HOIL 23/473; F28D 7/00; F28D 7/10; F15D 1/00; F28F 3/08; F24F 3/00; F28F 1/00; F28F 1/14; F28F 9/22; H01L 23/467; H01L 23/367; H05K 7/20

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
kompas/KIPO internal) & keywords: heat exchange, tube, fluid, gas, inlet, outlet

### C. DOCUMENTS CONSIDERED TO BE RELEVANT

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Further documents are listed in the continuation of Box C.

See patent family annex.

* Special categories of cited documents:
  "A" document defining the general state of the art which is not considered to be of particular relevance
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Date of the actual completion of the international search
29 March 2017 (29.03.2017)

Date of mailing of the international search report
29 March 2017 (29.03.2017)

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