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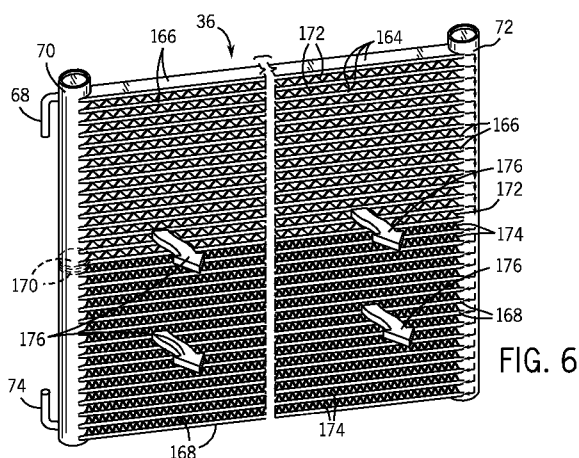
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(54) Title: MULTICHANNEL HEAT EXCHANGER WITH DIFFERING FIN SPACING



(57) Abstract: Heating, ventilation, air conditioning, and refrigeration (HVAC&R) systems and heat exchangers are provided that include fins of differing fin spacing. The heat exchangers include multiple sets of multichannel tubes in fluid communication with each other and fins of different spacing may be disposed between each set of multichannel tubes. In one embodiment, a first set of tubes may direct refrigerant from a first manifold to a second manifold and a second set of tubes may direct refrigerant back to the first manifold from the second manifold. The fins between the first tubes may have a relatively smaller density (e.g., fewer fins per inch) than the fins between the second tubes.

MULTICHANNEL HEAT EXCHANGER WITH DIFFERING FIN SPACING

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority from and the benefit of U.S. Provisional Application Serial No. 61/224,722, entitled “MULTICHANNEL HEAT EXCHANGER WITH DIFFERENT FIN SPACING”, filed July 10, 2009, which is hereby incorporated by reference.

BACKGROUND

[0002] The invention relates generally to multichannel heat exchangers with differing fin densities.

[0003] Heat exchangers are used in heating, ventilation, air conditioning, and refrigeration (HVAC&R) systems. Multichannel heat exchangers generally include multichannel tubes for flowing refrigerant through the heat exchanger. Each multichannel tube may contain several individual flow channels. Fins are positioned between the tubes to facilitate heat transfer between refrigerant contained within the tube flow channels and external air passing over the tubes. Multichannel heat exchangers may be used in small tonnage systems, such as residential systems, or in large tonnage systems, such as industrial chiller systems.

[0004] In general, heat exchangers transfer heat by circulating a refrigerant through a cycle of evaporation and condensation. In many systems, the refrigerant changes phases while flowing through heat exchangers in which evaporation and condensation occur. For example, the refrigerant may enter an evaporator heat exchanger as a liquid and exit as a vapor. In another example, the refrigerant may enter a condenser heat exchanger as a vapor and exit as a liquid. These phase changes result in both liquid and vapor refrigerant flowing through the heat exchanger flow channels. In particular, one portion of the heat exchanger may contain vapor refrigerant undergoing de-superheating while another portion of the heat exchanger contains a liquid undergoing subcooling.

[0005] The phase of the refrigerant flowing within the heat exchanger may affect the heat transfer rate. For example, different phases of refrigerant may possess different temperatures, flow rates, and heat transfer properties. Further, the phase of refrigerant undergoing a phase change (i.e., the vapor refrigerant in a condenser and the liquid refrigerant in an evaporator) may need to absorb or give off both latent and sensible heat. For example, in a condenser, the vapor refrigerant may need to give off both latent and sensible heat to become a liquid refrigerant while the liquid refrigerant may need to give off only sensible heat to undergo subcooling. In an evaporator, the liquid refrigerant may need to absorb both latent and sensible heat to become a vapor phase refrigerant.

SUMMARY

[0006] The present invention relates to a heat exchanger that includes a first manifold, a second manifold, a first plurality of multichannel tubes configured to direct a fluid from the first manifold to the second manifold, a second plurality of multichannel tubes configured to direct the fluid from the second manifold to the first manifold, a first set of fins coupled to the first plurality of multichannel tubes, the first set of fins having a first fin density, and a second set of fins coupled to the second plurality of multichannel tubes, the second set of fins having a second fin density different from the first fin density.

[0007] The present invention also relates to a heat exchanger that includes a first manifold, a second manifold, a pair of baffles disposed in the first manifold to isolate a volume therebetween from inlet and outlet sections of the first manifold, a first plurality of multichannel tubes configured to direct a fluid from the inlet section to the second manifold, a second plurality of multichannel tubes configured to direct the fluid from the second manifold to the outlet section, an isolated multichannel tube extending between the isolated volume of the first manifold and the second manifold, a first set of fins coupled to the first plurality of multichannel tubes, the first set of fins having a first fin density, and a second set of fins coupled to the second plurality of multichannel tubes, the second set of fins having a second fin density different from the first fin density.

[0008] The present invention further relates to a heating, ventilating, air conditioning, or refrigeration system that includes a compressor configured to compress a gaseous refrigerant, a condenser configured to receive and to condense the compressed refrigerant, an expansion device configured to reduce pressure of the condensed refrigerant, and an evaporator configured to evaporate the refrigerant prior to returning the refrigerant to the compressor. At least one of the condenser or the evaporator includes a multiple pass heat exchanger. The multiple pass heat exchanger includes a first manifold, a second manifold, a first plurality of multichannel tubes configured to direct a fluid between the first manifold and the second manifold in a first pass, a second plurality of multichannel tubes configured to direct the fluid between the second manifold and the first manifold in a second pass, a first set of fins coupled to the first plurality of multichannel tubes, the first set of fins having a first fin density, and a second set of fins coupled to the second plurality of multichannel tubes, the second set of fins having a second fin density different from the first fin density.

DRAWINGS

[0009] FIGURE 1 is an illustration of an exemplary embodiment of a commercial or industrial HVAC&R system that may employ heat exchangers with fins separated by dissimilar spacing.

[0010] FIGURE 2 is an illustration of an exemplary embodiment of a residential HVAC&R system that may employ heat exchangers with fins separated by dissimilar spacing.

[0011] FIGURE 3 is an exploded view of the outdoor unit shown in FIGURE 2.

[0012] FIGURE 4 is a diagrammatical overview of an exemplary air conditioning system that may employ one or more heat exchangers with fins separated by dissimilar spacing.

[0013] FIGURE 5 is a diagrammatical over of an exemplary heat pump system that may employ one or more heat exchangers with fins separated by dissimilar spacing.

[0014] FIGURE 6 is a perspective view of an exemplary embodiment of a heat exchanger containing multichannel tubes and fins separated by dissimilar spacing.

[0015] FIGURE 7 is a partially exploded view of a portion of the heat exchanger of FIGURE 6.

[0016] FIGURE 8 is a detail perspective view of a portion of the first fins of the heat exchanger of FIGURE 6.

[0017] FIGURE 9 is a detail perspective view of a portion of the second fins of the heat exchanger of FIGURE 6.

[0018] FIGURE 10 is a perspective cut away view of another heat exchanger that may employ fins separated by dissimilar spacing.

DETAILED DESCRIPTION

[0019] FIGURES 1 and 2 depict exemplary applications for heat exchangers with differing fin spacing. Fins may generally include a series of individual fins (i.e. fin walls) joined by curvatures or corrugations. The fins may be spaced apart to place a desired number of fins within a unit of length, which may be referred to as fin density or fin spacing. As used herein, the terms “fin spacing” and “fin density” shall mean the number of individual fins and/or corrugations within a unit of length. For example, fin spacing/fin density may be measured in fins per inch (fpi). When assembled into a heat exchanger, the fins may generally be disposed along the length of the heat exchanger tubes. Accordingly, fin density may be determined with respect to tube length in a heat exchanger.

[0020] The heat exchangers may include multiple pass heat exchangers that employ fins with different fin spacing for each pass. For example, in a two-pass heat exchanger, fins of one spacing may be disposed between tubes that direct refrigerant or other fluid from a first manifold to a second manifold. Fins of another spacing may be disposed between tubes that return the refrigerant from the second manifold to the first manifold. Such heat exchangers and systems, in general, may be applied in a range of settings, both within the HVAC&R field and outside of that field. In presently contemplated applications, however, heat exchangers may be used in

residential, commercial, light industrial, industrial, and in any other application for heating or cooling a volume or enclosure, such as a residence, building, structure, and so forth. Moreover, the heat exchangers may be used in industrial applications, where appropriate, for basic refrigeration and heating of various fluids.

[0021] FIGURE 1 illustrates an exemplary application, in this case an HVAC&R system for building environmental management that may employ heat exchangers. A building 10 is cooled by a system that includes a chiller 12 and a boiler 14. As shown, chiller 12 is disposed on the roof of building 10 and boiler 14 is located in the basement; however, the chiller and boiler may be located in other equipment rooms or areas next to the building. Chiller 12 is an air cooled or water cooled device that implements a refrigeration cycle to cool water. Chiller 12 may be a stand-alone unit or may be part of a single package unit containing other equipment, such as a blower and/or integrated air handler. Boiler 14 is a closed vessel that includes a furnace to heat water. The water from chiller 12 and boiler 14 is circulated through building 10 by water conduits 16. Water conduits 16 are routed to air handlers 18, located on individual floors and within sections of building 10.

[0022] Air handlers 18 are coupled to ductwork 20 that is adapted to distribute air between the air handlers. In certain embodiments, the ductwork may receive air from an outside intake (not shown). Air handlers 18 include heat exchangers that circulate cold water from chiller 12 and hot water from boiler 14 to provide heated or cooled air. Fans, within air handlers 18, draw air through the heat exchangers and direct the conditioned air to environments within building 10, such as rooms, apartments, or offices, to maintain the environments at a designated temperature. A control device, shown here as including a thermostat 22, may be used to designate the temperature of the conditioned air. Control device 22 also may be used to control the flow of air through and from air handlers 18. Other devices may, of course, be included in the system, such as control valves that regulate the flow of water and pressure and/or temperature transducers or switches that sense the temperatures and pressures of the water, the air, and so forth. Moreover, control devices may include computer systems that are integrated with or separate from other building control or monitoring systems, and even systems that are remote from the building.

[0023] FIGURE 2 illustrates a residential heating and cooling system. In general, a residence 24 will include refrigerant conduits 26 that operatively couple an indoor unit 28 to an outdoor unit 30. Indoor unit 28 may be positioned in a utility room, an attic, a basement, and so forth. Outdoor unit 30 is typically situated adjacent to a side of residence 24 and is covered by a shroud to protect the system components and to prevent leaves and other contaminants from entering the unit. Refrigerant conduits 26 transfer refrigerant between indoor unit 28 and outdoor unit 30, typically transferring primarily liquid refrigerant in one direction and primarily vaporized refrigerant in an opposite direction.

[0024] When the system shown in FIGURE 2 is operating as an air conditioner, a coil in outdoor unit 30 serves as a condenser for recondensing vaporized refrigerant flowing from indoor unit 28 to outdoor unit 30 via one of the refrigerant conduits 26. In these applications, a coil of the indoor unit, designated by the reference numeral 32, serves as an evaporator coil. Evaporator coil 32 receives liquid refrigerant (which may be expanded by an expansion device, not shown) and evaporates the refrigerant before returning it to outdoor unit 30.

[0025] Outdoor unit 30 draws in environmental air through its sides as indicated by the arrows directed to the sides of the unit, forces the air through the outer unit coil by a means of a fan (not shown), and expels the air as indicated by the arrows above the outdoor unit. When operating as an air conditioner, the air is heated by the condenser coil within the outdoor unit and exits the top of the unit at a temperature higher than it entered the sides. Air is blown over indoor coil 32 and is then circulated through residence 24 by means of ductwork 20, as indicated by the arrows entering and exiting ductwork 20. The overall system operates to maintain a desired temperature as set by thermostat 22. When the temperature sensed inside the residence is higher than the set point on the thermostat (plus a small amount), the air conditioner will become operative to refrigerate additional air for circulation through the residence. When the temperature reaches the set point (minus a small amount), the unit will stop the refrigeration cycle temporarily.

[0026] When the unit in FIGURE 2 operates as a heat pump, the roles of the coils are simply reversed. That is, the coil of outdoor unit 30 will serve as an evaporator to evaporate refrigerant and thereby cool air entering outdoor unit 30 as the air passes

over the outdoor unit coil. Indoor coil 32 will receive a stream of air blown over it and will heat the air by condensing a refrigerant.

[0027] FIGURE 3 illustrates a partially exploded view of one of the units shown in FIGURE 2, in this case outdoor unit 30. Unit 30 includes a shroud 34 that surrounds the sides of unit 30 to protect the system components. Adjacent to shroud 34 is a heat exchanger 36. A cover 38 encloses a top portion of heat exchanger 36. Foam 40 is disposed between cover 38 and heat exchanger 36. A fan 42 is located within an opening of cover 38 and is powered by a motor 44. A wire way 46 may be used to connect motor 44 to a power source. A fan guard 48 fits within cover 38 and is disposed above the fan to prevent objects from entering the fan.

[0028] Heat exchanger 36 is mounted on a base pan 50. Base pan 50 provides a mounting surface and structure for the internal components of unit 30. A compressor 52 is disposed within the center of unit 30 and is connected to another unit within the HVAC&R system, for example an indoor unit, by connections 54 and 56 that connect to conduits circulating refrigerant within the HVAC&R system. A control box 58 houses the control circuitry for outdoor unit 30 and is protected by a cover 60. A panel 62 may be used to mount control box 58 to unit 30.

[0029] Refrigerant enters unit 30 through vapor connection 54 and flows through a conduit 64 into compressor 52. The vapor may be received from the indoor unit (not shown). After undergoing compression in compressor 52, the refrigerant exits compressor 52 through a conduit 66 and enters heat exchanger 36 through inlet 68. Inlet 68 directs the refrigerant into header 70. From header 70, the refrigerant flows through heat exchanger 36 to header 72. From header 72 the refrigerant flows back through heat exchanger 36 and exits through an outlet 74 disposed on header 70. After exiting heat exchanger 36, the refrigerant flows through conduit 76 to liquid connection 56 to return to the indoor unit where the process may begin again.

[0030] FIGURE 4 illustrates an air conditioning system 78, which may employ multichannel tube heat exchangers with differing fin densities. Refrigerant flows through system 78 within closed refrigeration loop 80. The refrigerant may be any fluid that absorbs and extracts heat. For example, the refrigerant may be hydrofluorocarbon (HFC) based R-410A, R-407, or R-134a, or it may be carbon

dioxide (R-744A) or ammonia (R-717). Air conditioning system 78 includes control devices 82 that enable the system to cool an environment to a prescribed temperature.

[0031] System 78 cools an environment by cycling refrigerant within closed refrigeration loop 80 through a condenser 84, a compressor 86, an expansion device 88, and an evaporator 90. The refrigerant enters condenser 84 as a high pressure and temperature vapor and flows through the multichannel tubes of the condenser. A fan 92, which is driven by a motor 94, draws air across the multichannel tubes. The fan may push or pull air across the tubes. As the air flows across the tubes, heat transfers from the refrigerant vapor to the air, producing heated air 96 and causing the refrigerant vapor to condense into a liquid. The liquid refrigerant then flows into an expansion device 88 where the refrigerant expands to become a low pressure and temperature liquid. Typically, expansion device 88 will be a thermal expansion valve (TXV); however, according to other exemplary embodiments, the expansion device may be an orifice or a capillary tube. After the refrigerant exits the expansion device, some vapor refrigerant may be present in addition to the liquid refrigerant.

[0032] From expansion device 88, the refrigerant enters evaporator 90 and flows through the evaporator multichannel tubes. A fan 98, which is driven by a motor 100, draws air across the multichannel tubes. As the air flows across the tubes, heat transfers from the air to the refrigerant liquid, producing cooled air 102 and causing the refrigerant liquid to boil into a vapor. According to certain embodiments, the fan may be replaced by a pump that draws fluid across the multichannel tubes.

[0033] The refrigerant then flows to compressor 86 as a low pressure and temperature vapor. Compressor 86 reduces the volume available for the refrigerant vapor, consequently, increasing the pressure and temperature of the vapor refrigerant. The compressor may be any suitable compressor such as a screw compressor, reciprocating compressor, rotary compressor, swing link compressor, scroll compressor, or turbine compressor. Compressor 86 is driven by a motor 104 that receives power from a variable speed drive (VSD) or a direct AC or DC power source. According to an exemplary embodiment, motor 104 receives fixed line voltage and frequency from an AC power source although in certain applications the motor may be driven by a variable voltage or frequency drive. The motor may be a switched reluctance (SR) motor, an induction motor, an electronically commutated

permanent magnet motor (ECM), or any other suitable motor type. The refrigerant exits compressor 86 as a high temperature and pressure vapor that is ready to enter the condenser and begin the refrigeration cycle again.

[0034] The control devices 82, which include control circuitry 106, an input device 108, and a temperature sensor 110, govern the operation of the refrigeration cycle. Control circuitry 106 is coupled to the motors 94, 100, and 104 that drive condenser fan 92, evaporator fan 98, and compressor 86, respectively. Control circuitry 106 uses information received from input device 108 and sensor 110 to determine when to operate the motors 94, 100, and 104 that drive the air conditioning system. In certain applications, the input device may be a conventional thermostat. However, the input device is not limited to thermostats, and more generally, any source of a fixed or changing set point may be employed. These may include local or remote command devices, computer systems and processors, and mechanical, electrical and electromechanical devices that manually or automatically set a temperature-related signal that the system receives. For example, in a residential air conditioning system, the input device may be a programmable 24-volt thermostat that provides a temperature set point to the control circuitry. Sensor 110 determines the ambient air temperature and provides the temperature to control circuitry 106. Control circuitry 106 then compares the temperature received from the sensor to the temperature set point received from the input device. If the temperature is higher than the set point, control circuitry 106 may turn on motors 94, 100, and 104 to run air conditioning system 78. The control circuitry may execute hardware or software control algorithms to regulate the air conditioning system. According to exemplary embodiments, the control circuitry may include an analog to digital (A/D) converter, a microprocessor, a non-volatile memory, and an interface board. Other devices may, of course, be included in the system, such as additional pressure and/or temperature transducers or switches that sense temperatures and pressures of the refrigerant, the heat exchangers, the inlet and outlet air, and so forth.

[0035] FIGURE 5 illustrates a heat pump system 112 that may employ multichannel tube heat exchangers with different fin densities. Because the heat pump may be used for both heating and cooling, refrigerant flows through a reversible refrigeration/heating loop 114. The refrigerant may be any fluid that absorbs and

extracts heat. The heating and cooling operations are regulated by control devices 116.

[0036] Heat pump system 112 includes an outside coil 118 and an inside coil 120 that both operate as heat exchangers. Each coil may function as an evaporator or a condenser depending on the heat pump operation mode. For example, when heat pump system 112 is operating in cooling (or “AC”) mode, outside coil 118 functions as a condenser, releasing heat to the outside air, while inside coil 120 functions as an evaporator, absorbing heat from the inside air. When heat pump system 112 is operating in heating mode, outside coil 118 functions as an evaporator, absorbing heat from the outside air, while inside coil 120 functions as a condenser, releasing heat to the inside air. A reversing valve 122 is positioned on reversible loop 114 between the coils to control the direction of refrigerant flow and thereby to switch the heat pump between heating mode and cooling mode.

[0037] Heat pump system 112 also includes two metering devices 124 and 126 for decreasing the pressure and temperature of the refrigerant before it enters the evaporator. The metering devices also regulate the refrigerant flow entering the evaporator so that the amount of refrigerant entering the evaporator equals, or approximately equals, the amount of refrigerant exiting the evaporator. The metering device used depends on the heat pump operation mode. For example, when heat pump system 112 is operating in cooling mode, refrigerant bypasses metering device 124 and flows through metering device 126 before entering inside coil 120, which acts as an evaporator. In another example, when heat pump system 112 is operating in heating mode, refrigerant bypasses metering device 126 and flows through metering device 124 before entering outside coil 118, which acts as an evaporator. According to other exemplary embodiments, a single metering device may be used for both heating mode and cooling mode. The metering devices typically are thermal expansion valves (TXV), but also may be orifices or capillary tubes.

[0038] The refrigerant enters the evaporator, which is outside coil 118 in heating mode and inside coil 120 in cooling mode, as a low temperature and pressure liquid. Some vapor refrigerant also may be present as a result of the expansion process that occurs in metering device 124 or 126. The refrigerant flows through multichannel tubes in the evaporator and absorbs heat from the air changing the refrigerant into a

vapor. In cooling mode, the indoor air flowing across the multichannel tubes also may be dehumidified. The moisture from the air may condense on the outer surface of the multichannel tubes and consequently be removed from the air.

[0039] After exiting the evaporator, the refrigerant passes through reversing valve 122 and into a compressor 128. Compressor 128 decreases the volume of the refrigerant vapor, thereby, increasing the temperature and pressure of the vapor. The compressor may be any suitable compressor such as a screw compressor, reciprocating compressor, rotary compressor, swing link compressor, scroll compressor, or turbine compressor.

[0040] From compressor 128, the increased temperature and pressure vapor refrigerant flows into a condenser, the location of which is determined by the heat pump mode. In cooling mode, the refrigerant flows into outside coil 118 (acting as a condenser). A fan 130, which is powered by a motor 132, draws air across the multichannel tubes containing refrigerant vapor. According to certain exemplary embodiments, the fan may be replaced by a pump that draws fluid across the multichannel tubes. The heat from the refrigerant is transferred to the outside air causing the refrigerant to condense into a liquid. In heating mode, the refrigerant flows into inside coil 120 (acting as a condenser). A fan 134, which is powered by a motor 136, draws air across the multichannel tubes containing refrigerant vapor. The heat from the refrigerant is transferred to the inside air causing the refrigerant to condense into a liquid.

[0041] After exiting the condenser, the refrigerant flows through the metering device (124 in heating mode and 126 in cooling mode) and returns to the evaporator (outside coil 118 in heating mode and inside coil 120 in cooling mode) where the process begins again.

[0042] In both heating and cooling modes, a motor 138 drives compressor 128 and circulates refrigerant through reversible refrigeration/heating loop 114. The motor may receive power either directly from an AC or DC power source or from a variable speed drive (VSD). The motor may be a switched reluctance (SR) motor, an induction motor, an electronically commutated permanent magnet motor (ECM), or any other suitable motor type.

[0043] The operation of motor 138 is controlled by control circuitry 140. Control circuitry 140 receives information from an input device 142 and sensors 144, 146, and 148 and uses the information to control the operation of heat pump system 112 in both cooling mode and heating mode. For example, in cooling mode, input device 142 provides a temperature set point to control circuitry 140. Sensor 148 measures the ambient indoor air temperature and provides it to control circuitry 140. Control circuitry 140 then compares the air temperature to the temperature set point and engages compressor motor 138 and fan motors 132 and 136 to run the cooling system if the air temperature is above the temperature set point. In heating mode, control circuitry 140 compares the air temperature from sensor 148 to the temperature set point from input device 142 and engages motors 132, 136, and 138 to run the heating system if the air temperature is below the temperature set point.

[0044] Control circuitry 140 also uses information received from input device 142 to switch heat pump system 112 between heating mode and cooling mode. For example, if input device 142 is set to cooling mode, control circuitry 140 will send a signal to a solenoid 150 to place reversing valve 122 in an air conditioning position 152. Consequently, the refrigerant will flow through reversible loop 114 as follows: the refrigerant exits compressor 128, is condensed in outside coil 118, is expanded by metering device 126, and is evaporated by inside coil 120. If the input device is set to heating mode, control circuitry 140 will send a signal to solenoid 150 to place reversing valve 122 in a heat pump position 154. Consequently, the refrigerant will flow through the reversible loop 114 as follows: the refrigerant exits compressor 128, is condensed in inside coil 120, is expanded by metering device 124, and is evaporated by outside coil 118.

[0045] The control circuitry may execute hardware or software control algorithms to regulate heat pump system 112. According to exemplary embodiments, the control circuitry may include an analog to digital (A/D) converter, a microprocessor, a non-volatile memory, and an interface board.

[0046] The control circuitry also may initiate a defrost cycle when the system is operating in heating mode. When the outdoor temperature approaches freezing, moisture in the outside air that is directed over outside coil 118 may condense and freeze on the coil. Sensor 144 measures the outside air temperature, and sensor 146

measures the temperature of outside coil 118. These sensors provide the temperature information to the control circuitry which determines when to initiate a defrost cycle. For example, if either sensor 144 or 146 provides a temperature below freezing to the control circuitry, system 112 may be placed in defrost mode. In defrost mode, solenoid 150 is actuated to place reversing valve 122 in air conditioning position 152, and motor 132 is shut off to discontinue airflow over the multichannel tubes. System 112 then operates in cooling mode until the increased temperature and pressure refrigerant flowing through outside coil 80 defrosts the coil. Once sensor 146 detects that coil 118 is defrosted, control circuitry 140 returns the reversing valve 122 to heat pump position 154. As will be appreciated by those skilled in the art, the defrost cycle can be set to occur at many different time and temperature combinations.

[0047] FIGURE 6 is a perspective view of an exemplary heat exchanger that may be used in air conditioning system 78, shown in FIGURE 4, or heat pump system 112, shown in FIGURE 5. The exemplary heat exchanger may be a condenser 84, an evaporator 90, an outside coil 118, or an inside coil 120, as shown in FIGURES 4 and 5. It should be noted that in similar or other systems, the heat exchanger might be used as part of a chiller or in any other heat exchanging application. The heat exchanger includes manifolds 70 and 72 that are connected by multichannel tubes 164. Although 30 tubes are shown in FIGURE 6, the number of tubes may vary. The manifolds and tubes may be constructed of aluminum or any other material that promotes good heat transfer. Refrigerant flows from manifold 70 through a set of first tubes 166 to manifold 72. The refrigerant then returns to manifold 70 in an opposite direction through a set of second tubes 168. The first tubes may be of identical construction to the second tubes, or the first tubes may vary from the second tubes by properties such as construction material, shape, internal flow paths, size, and the like. According to certain exemplary embodiments, the heat exchanger may be rotated approximately 90 degrees so that the multichannel tubes run vertically between a top manifold and a bottom manifold. Furthermore, the heat exchanger may be inclined at an angle relative to the vertical. Although the multichannel tubes are depicted as having an oblong shape, the tubes may be any shape, such as tubes with a cross-section in the form of a rectangle, square, circle, oval, ellipse, triangle, trapezoid, or parallelogram. According to exemplary embodiments, the tubes may have a diameter ranging from 0.5 mm to 3 mm. It should also be noted that the heat

exchanger may be provided in a single plane or slab, or may include bends, corners, contours, and so forth.

[0048] Refrigerant enters heat exchanger 36 through inlet 68 and exits the heat exchanger through outlet 74. Although FIGURE 6 depicts the inlet at the top of the manifold and the outlet at the bottom of the manifold, the inlet and outlet positions may be interchanged so that the fluid enters at the bottom and exits at the top. The fluid also may enter and exit the manifold from multiple inlets and outlets positioned on bottom, side, or top surfaces of the manifold. Baffles 170 separate the inlet and outlet portions of manifold 70. As shown in FIGURE 6, baffle 170 is a double baffle that is disposed on opposite sides of a multichannel tube 164 within manifold 70. As described further below with respect to FIGURE 10, double baffle 70 may be employed to produce an isolated tube 196 within manifold 70. However, in other embodiments, the baffle may be a single baffle, and the isolated tube may be omitted. Further, although one double baffle 170 is shown in FIGURE 6, in other embodiments, any number of single or double baffles may be employed to create separation of the inlet and outlet portions. It should also be noted that according to other exemplary embodiments, the inlet and outlet might be contained on separate manifolds, eliminating the need for a baffle.

[0049] Fins 172 and 174 are located between multichannel tubes 164 to promote the transfer of heat between the tubes and the environment. Fins 172 are disposed generally between first tubes 166 and fins 174 are disposed generally between second tubes 168. Fins 172 may have a different density or spacing than fins 174 to maximize heat transfer. Specifically, more individual fins (i.e. fin walls) may be disposed per unit of length in one of the sets of fins than in the other set of fins. According to an exemplary embodiment, the fins are constructed of aluminum, brazed or otherwise joined to the tubes, and disposed generally parallel to the flow of refrigerant. However, according to other exemplary embodiments, the fins may be made of other materials that facilitate heat transfer and may extend perpendicular or at varying angles with respect to the flow of the refrigerant. The fins may be louvered fins, corrugated fins, plate fins, or any other suitable type of fin. Further, the construction materials, orientations, and features, such as louvers, ribs, and the like,

may vary between the fins 172 disposed between the first tubes 166 and the fins 176 disposed between the second tubes 168.

[0050] In a typical heat exchanger application, refrigerant may enter manifold 88 in one phase and exit manifold 88 in another phase. In certain embodiments, a majority of the phase change may occur as the refrigerant travels through first tubes 166. For example, if the heat exchanger operates as a condenser, refrigerant may enter the inlet 98 as a vapor (or a mixture of vapor and liquid). As the vapor travels through first multichannel tubes 94, the vapor releases heat to the air (arrow 176) causing the vapor to be de-superheated and condensed into a liquid. Then, as the liquid refrigerant travels through second multichannel tubes 96, the liquid releases heat to the air 176, causing subcooling. If the heat exchanger operates as an evaporator, refrigerant may enter the inlet 98 as a liquid (or a mixture of vapor and liquid). As the liquid travels through first multichannel tubes 94, the liquid may absorb heat from the air 176, causing the liquid to evaporate into a vapor. For both the liquid and vapor phases of the refrigerant, air flowing through the fins and around the tubes facilitates the heat transfer.

[0051] To promote good heat transfer in both first tubes 166 and second tubes 168, fins 172 may have a different density than fins 174. In certain embodiments, fins 174 disposed between the second tubes 168 may have a relatively larger density to customize the heat transfer for these tubes containing a majority of refrigerant that has already exchanged heat with the environment to change phases. For example, when heat exchanger 36 is functioning as a condenser, the first tubes 166 may contain refrigerant largely in the vapor phase and the second tubes 168 may contain refrigerant primarily in the liquid phase. The temperature differential between the liquid refrigerant and the air 176 may be much smaller than the temperature differential between the vapor refrigerant and the air 176, which in certain embodiments may result in a smaller rate of heat transfer through the second tubes 168 than through the first tubes 166. Accordingly, fins 174 between the second tubes 178 may have a higher fin density (e.g., more fpi) than fins 172 between the first tubes 172. The increased fin density may provide an increased surface area for heat transfer through the second tubes 178, which in turn may increase the overall heat transfer efficiency of heat exchanger 36. The increased fin density also may slow the

flow of air 176 through the second tubes 168, allowing generally more time for heat transfer between air 176 and the second tubes 178. Further, the relatively small fin density of the fins 172 between the first tubes 172 may allow increased flow of air 176 through the first tubes 166 where the temperature differential between the refrigerant and the airflow 176 may be the greatest.

[0052] The differing fin spacing may be applied for various heat exchanger configurations. For example, in other embodiments, the fins between the first tubes may have a relatively small fin density (e.g., fewer fpi) when compared to the fins between the second tubes. Further, the different fin densities may be employed in heat exchangers with three, four, five, or more passes, with each pass, or some of the passes, having different fin spacing customized based on the properties of the refrigerant flowing through each pass. Differing fin spacing also may be employed within the same pass of a heat exchanger to control the airflow profile through the coil. For example, in certain embodiments, the tubes nearest to the bottom of the coil may have a smaller fin density than the adjacent tubes in order to provide more airflow through the bottom of the coil.

[0053] FIGURE 7 illustrates certain components of the heat exchanger of FIGURE 6 in a somewhat more detailed and exploded view. Each manifold (manifold 70 being shown in FIGURE 7) is a tubular structure with open ends that are closed by a cap 178. Openings, or apertures, 180 are formed in the manifolds, such as by conventional piercing operations. Multichannel tubes 166 and 168 may then be inserted into openings 180 in a generally parallel fashion. Ends 182 of the tubes are inserted into openings 180 so that fluid may flow from the manifold into flow paths within the tubes. Fins 172 and 174 may then be inserted between the tubes 166 and 168 to promote heat transfer between an external fluid, such as air or water, and the refrigerant flowing within the tubes. During insertion, length A of fins 172 and 174 may be generally aligned with the width of tubes 166 and 168. In certain embodiments, length A may be greater than the tube width so the fins extend slightly over the edges of the tubes. Fins 172 and 174 may generally include unitary pieces folded from thin metal sheet stock, or other suitable materials, to form corrugations, or crests 184 and 186. The crests may be curved in a semicircle or V-shaped configuration. In certain embodiments, flux may be disposed around the crests for

brazing the crests to the tubes during heating. Specifically, crests 184 may be brazed or otherwise joined to surfaces of the first tubes 166 and crests 186 may be brazed or otherwise joined to surfaces of the second tubes 168.

[0054] FIGURE 8 is a detailed view of a portion of one of the first fins 172. Fin 172 may be attached to the surface of a first tube 166. Refrigerant (arrows 190) may flow through a flow path 188 of first tube 166. The multichannel tubes may contain any number of flow paths in various sizes, shapes, and other configurations. Fin 172 includes a series of adjacent fin walls 192 joined together at adjacent and alternating top and bottom crests 184. The crests are generally perpendicular to the direction of refrigerant flow 190. Each wall 192 has a width F measured generally between adjacent crests 184. In certain embodiments, the walls may have louvers, ribs, or other features. Each crest 184 may generally have a curvature D. The radius and/or tightness of curvature D may determine an angle E between adjacent walls 192. The wall angle E may generally be an acute angle and may be varied to adjust the fin density. For example, a larger angle E may result in an increased distance B between crests 184 that creates a smaller fin density. A smaller angle E may result in a reduced distance B between crests 184 that creates a larger fin density.

[0055] Air may flow through fins 172 generally along crests 184 to exchange heat with refrigerant flowing through tubes 166. A reduced fin density may provide additional openings between crests 184 for airflow, which may in turn increase the air flowing through the fins 172. An increased fin density may provide more fin walls 192 for heat transfer and may reduce the openings between crests 184, which in turn may decrease the air flowing through the fins 172. The fin density may be altered using a variety of factors, such as the wall width F, the curvature D, and the angle E, or combinations thereof. For example, a tighter curvature D may provide an increased fin density. In another example, a greater wall width F may provide a smaller fin density.

[0056] FIGURE 9 depicts a portion of the second fins 174. Fins 174 have a width H. In certain embodiments, width H of second fins 174 may be approximately equal to width F of first fins 172 (FIGURE 8). However, in other embodiments the widths H and F may vary between the first and second sets of fins 172 and 174. Further, the amplitude of the fins 172 and 174 may be the same or may vary. Fins 174 include

walls 192 separated by a distance C, which may be smaller than distance B separating first fins 172 (FIGURE 8). The walls are generally parallel to each other due to a curvature G. In other embodiments, the walls may be disposed at acute angles from each other. However, this angle may be generally smaller than the acute angle E of first fins 172. In general, the second fins 174 may have a greater fin density than first fins 172 (FIGURE 8). As described above with respect to FIGURE 6, the increased fin density may provide additional surface areas for heat transfer and may reduce the airflow through fins 174.

[0057] The relative fin densities may best be illustrated by comparing FIGURES 8 and 9. Each figure shows fins within a unit of length J. In FIGURE 8, four sets of adjacent fin walls are disposed within length J. In contrast, eight pairs of adjacent fin walls are included within the same unit of length J in FIGURE 9. Therefore, the second fins 174 are approximately twice as dense as the first fins 172. The density differences are due to the change in curvatures D and G. Specifically, curvature D is configured to place adjacent fin walls together at acute angles E. Curvature G of second fins 174 is configured to place the fin walls in a generally parallel configuration. Although the second fins 174 are shown as twice as dense as fins 172 other relative fin densities may be used. For example, the second fins 174 may be approximately 1.5, 5, 10, or 20 times denser than the first fins 172. More specifically, the second fins 174 may be approximately 0 to 5 times as dense as first fins 172, as well as all subranges therebetween. Further, in other embodiments, the second fins may be approximately 1.5, 5, 10, or 20 times less dense than the first fins. Moreover, the first fins may have a density that is more than 20 times greater or less than the density of the second fins. The relative densities may depend on properties of the heat exchanger, such as the refrigerant used, the external air temperature, the capacity, and the material used for construction, among other things. Further, the fin densities may vary due to differences in the fin lengths F and H, the curvatures D and G, and the angles between fin walls (such as angle E), or combinations thereof. In general, the relative fin densities may be adapted for the particular thermal properties and transfers intended for the heat exchangers. Moreover, although the fins in FIGURES 6-10 are illustrated as corrugated fins, the varying fin densities described herein may be applied to a variety of fin types, such as plate fins where the density may be varied by increasing or decreasing the spacing between fins.

[0058] FIGURE 10 illustrates a perspective view of a exchanger that may employ fins of different densities. A portion of manifold 70 is cut away to show the manifold interior. The refrigerant exits manifold 70 through flow channels 188 contained within first tubes 166 and returns to the manifold 70 through flow channels 188 contained within second tubes 168. In some embodiments, the flow channels are disposed parallel to one another. Any number of flow channels may be contained within the tubes. For example, in one embodiment, the tubes may each contain 18 flow channels.

[0059] Baffles 170 divide the first tube section of the manifold from the second tube section. The refrigerant in the first tube section of the manifold may be a different phase than the refrigerant in the second tube section. Baffles 170 are spaced apart to create an isolated volume 194 within the manifold. In some embodiments, an isolated tube 196 may be placed in between baffles 170 to provide separation between first tubes 166 and second tubes 168. The isolated volume and the isolated tube may provide insulation between the tube sections and allow the heat transfer properties of the tube sections to be varied independently of each other. For example, in one embodiment where the heat exchanger functions as a condenser, the first tubes may contain a high temperature vapor while the second tubes contain a lower temperature liquid. The isolated volume and the isolated tube may provide insulation between the vapor and liquid sections and, therefore, inhibit heat transfer from the vapor refrigerant to the liquid refrigerant. Consequently, the liquid refrigerant may be able to reach a lower temperature because it absorbs less heat from the vapor refrigerant.

[0060] Baffles 170 may be generally disposed to separate the first fins 172 from second fins 198. Second fins 198 may include walls disposed at an angle M. Angle M may be an acute angle that is smaller than angle E (FIGURE 8) of the first fins 172 to provide an increased density for the second fins 198. In certain embodiments, fins may be omitted from the openings adjacent to the isolated tube 196. However, in other embodiments fins 172 or 198 may be included and coupled to the isolated tube 196. For example, fins may be coupled to both sides of the isolated tube, as shown in FIGURE 6. In other embodiments, fins may be coupled to only one side of the isolated tube. The first tubes 166 are separated by a height K, and second tubes 168 are separated by a height L. Even though the first tubes and second tubes are

separated by different heights K and L, differing fin densities still may be employed between the tubes. In certain embodiments, the different fin densities may be achieved by varying the fin widths (such as widths F and H shown in FIGURES 8 and 9).

[0061] The tube configurations described herein may find application in a variety of heat exchangers and HVAC&R systems containing heat exchangers. However, the configurations are particularly well-suited to evaporators used in residential air conditioning and heat pump systems where there is a need to vary the heat transfer properties for different passes within multi-pass heat exchangers. The configurations and are intended to improve heat exchanger efficiency by tailoring sets of fins within a heat exchanger for the refrigerant phase flowing through the tubes.

[0062] It should be noted that the present discussion makes use of the term “multichannel” tubes or “multichannel heat exchanger” to refer to arrangements in which heat transfer tubes include a plurality of flow paths between manifolds that distribute flow to and collect flow from the tubes. A number of other terms may be used in the art for similar arrangements. Such alternative terms might include “microchannel” and “microport.” The term “microchannel” sometimes carries the connotation of tubes having fluid passages on the order of a micrometer and less. However, in the present context such terms are not intended to have any particular higher or lower dimensional threshold. Rather, the term “multichannel” used to describe and claim embodiments herein is intended to cover all such sizes. Other terms sometimes used in the art include “parallel flow” and “brazed aluminum.” However, all such arrangements and structures are intended to be included within the scope of the term “multichannel.” In general, such “multichannel” tubes will include flow paths disposed along the width or in a plane of a generally flat, planar tube, although, again, the invention is not intended to be limited to any particular geometry unless otherwise specified in the appended claims.

[0063] While only certain features and embodiments of the invention have been illustrated and described, many modifications and changes may occur to those skilled in the art (e.g., variations in sizes, dimensions, structures, shapes and proportions of the various elements, values of parameters (e.g., temperatures, pressures, etc.), mounting arrangements, use of materials, orientations, etc.) without materially

departing from the novel teachings and advantages of the subject matter recited in the claims. 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 (i.e., 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.

CLAIMS:

1. A heat exchanger comprising:
 - a first manifold;
 - a second manifold;
 - a first plurality of multichannel tubes configured to direct a fluid from the first manifold to the second manifold;
 - a second plurality of multichannel tubes configured to direct the fluid from the second manifold to the first manifold;
 - a first set of fins coupled to the first plurality of multichannel tubes, the first set of fins having a first fin spacing; and
 - a second set of fins coupled to the second plurality of multichannel tubes, the second set of fins having a second fin spacing different from the first fin spacing.
2. The heat exchanger of claim 1, wherein the first fin spacing is greater than the second fin spacing.
3. The heat exchanger of claim 1, wherein at least one of the first set of fins or the second set of fins comprises corrugated fins with alternating crests brazed to the first plurality of multichannel tubes or the second plurality of multichannel tubes.
4. The heat exchanger of claim 1, wherein the first set of fins comprises first fin walls disposed at a first acute angle and the second set of fins comprises second fin walls disposed at a second acute angle smaller than the first acute angle.
5. The heat exchanger of claim 1, wherein the first set of fins and the second set of fins each comprise fin walls adjoined by alternating crests.
6. The heat exchanger of claim 5, wherein the walls of the first set of fins are spaced from one another by a first distance and the walls of the second set of fins are spaced from one another by a second distance larger than the first distance.

7. The heat exchanger of claim 5, wherein a first amplitude extending between alternating crests of the first set of fins is greater than a second amplitude extending between alternating crests of the second set of fins.

8. The heat exchanger of claim 1, wherein each tube of the first and second plurality of multichannel tubes is generally flat in cross-section and includes a plurality of generally parallel flow paths disposed along the width thereof.

9. The heat exchanger of claim 1, comprising a pair of baffles in the first manifold to isolate at least one multichannel tube between the plurality of first plurality of multichannel tubes and the second plurality of multichannel tubes.

10. A heat exchanger comprising:
a first manifold;
a second manifold;
a pair of baffles disposed in the first manifold to isolate a volume therebetween from inlet and outlet sections of the first manifold;
a first plurality of multichannel tubes configured to direct a fluid from the inlet section to the second manifold;
a second plurality of multichannel tubes configured to direct the fluid from the second manifold to the outlet section;
an isolated multichannel tube extending between the isolated volume of the first manifold and the second manifold;
a first set of fins coupled to the first plurality of multichannel tubes, the first set of fins having a first fin spacing; and
a second set of fins coupled to the second plurality of multichannel tubes, the second set of fins having a second fin spacing different from the first fin spacing.

11. The heat exchanger of claim 10, wherein the first set of fins comprises corrugated fins extending between each of the first plurality of multichannel tubes and wherein the second set of fins comprises corrugated fins extending between each of the second plurality of multichannel tubes.

12. The heat exchanger of claim 10, wherein the first plurality of multichannel tubes are spaced from one another by a first height and the second plurality of multichannel tubes are spaced from one another by a second height different from the first height.

13. The heat exchanger of claim 10, wherein at least one of the first set of fins or the second set of fins are coupled to the isolated multichannel tube.

14. The heat exchanger of claim 10, wherein the first set of fins and the second set of fins are coupled to the isolated multichannel tube.

15. The heat exchanger of claim 10, wherein the first set of fins comprises first fin walls disposed at a first acute angle and the second set of fins comprises second fin walls disposed at a second acute angle different from the first acute angle.

16. The heat exchanger of claim 10, wherein the second manifold is configured to direct the fluid exiting the first plurality of multichannel tubes into both the isolated multichannel tube and the second plurality of multichannel tubes.

17. A heating, ventilating, air conditioning, or refrigeration system, comprising:

a compressor configured to compress a gaseous refrigerant;

a condenser configured to receive and to condense the compressed refrigerant;

an expansion device configured to reduce pressure of the condensed refrigerant; and

an evaporator configured to evaporate the refrigerant prior to returning the refrigerant to the compressor;

wherein at least one of the condenser or the evaporator includes a multiple pass heat exchanger comprising:

a first manifold;

a second manifold;

a first plurality of multichannel tubes configured to direct a fluid between the first manifold and the second manifold in a first pass;

a second plurality of multichannel tubes configured to direct the fluid between the second manifold and the first manifold in a second pass;

a first set of fins coupled to the first plurality of multichannel tubes, the first set of fins having a first fin spacing;

and a second set of fins coupled to the second plurality of multichannel tubes, the second set of fins having a second fin spacing different from the first fin spacing.

18. The system of claim 17, comprising a pair of baffles disposed in the first manifold to direct flow from an inlet section of the first manifold through the first plurality of multichannel tubes to the second manifold and therefrom through the second plurality of multichannel tubes to an outlet section of the first manifold.

19. The system of claim 18, comprising an isolated tube extending between the first and second manifolds, wherein the isolated tube is disposed between the pair of baffles within the first manifold to isolate the isolated tube from the inlet section and the outlet section within the first manifold.

20. The system of claim 17, wherein the first set of fins and the second set of fins each comprise fin walls adjoined by alternating crests.

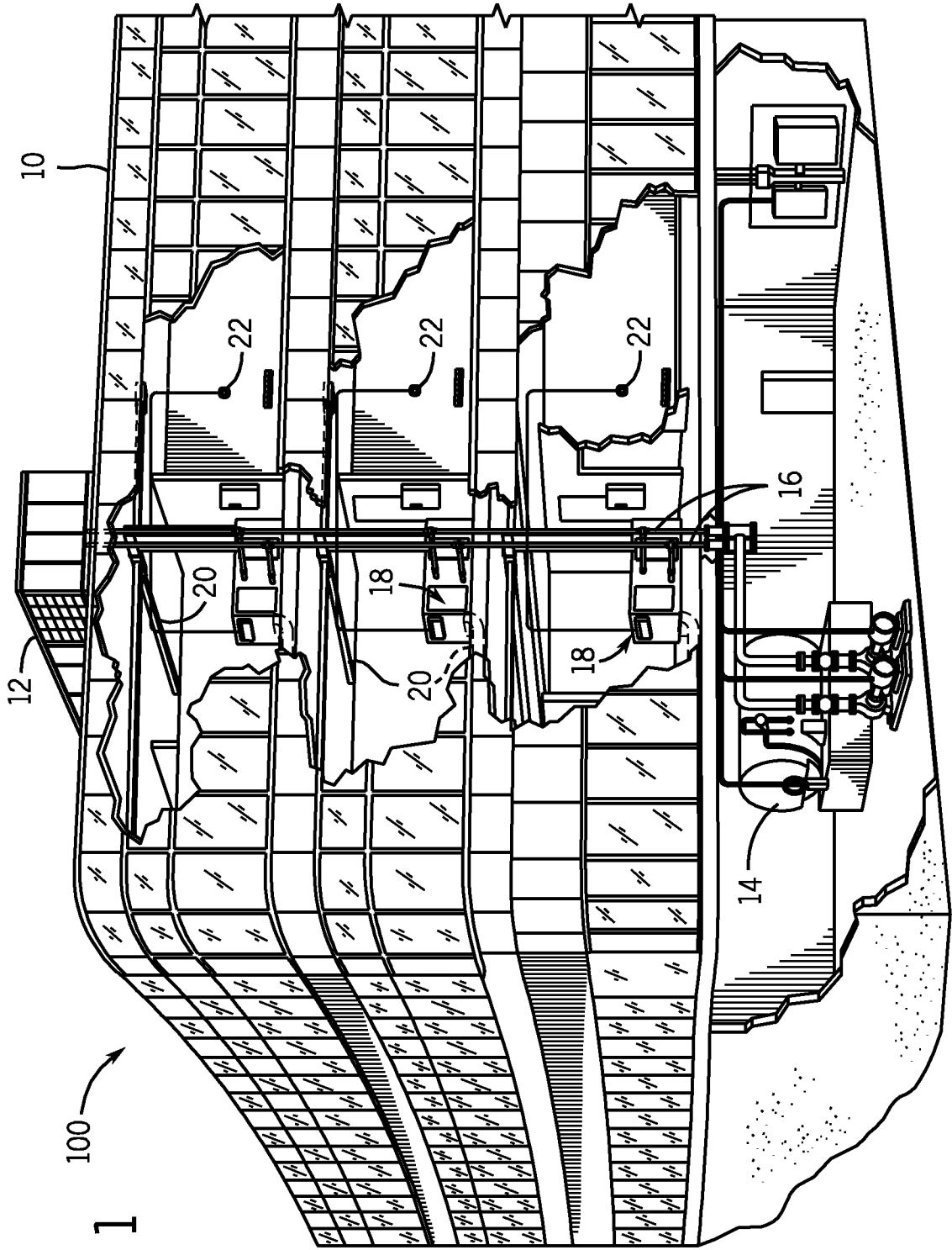


FIG. 1

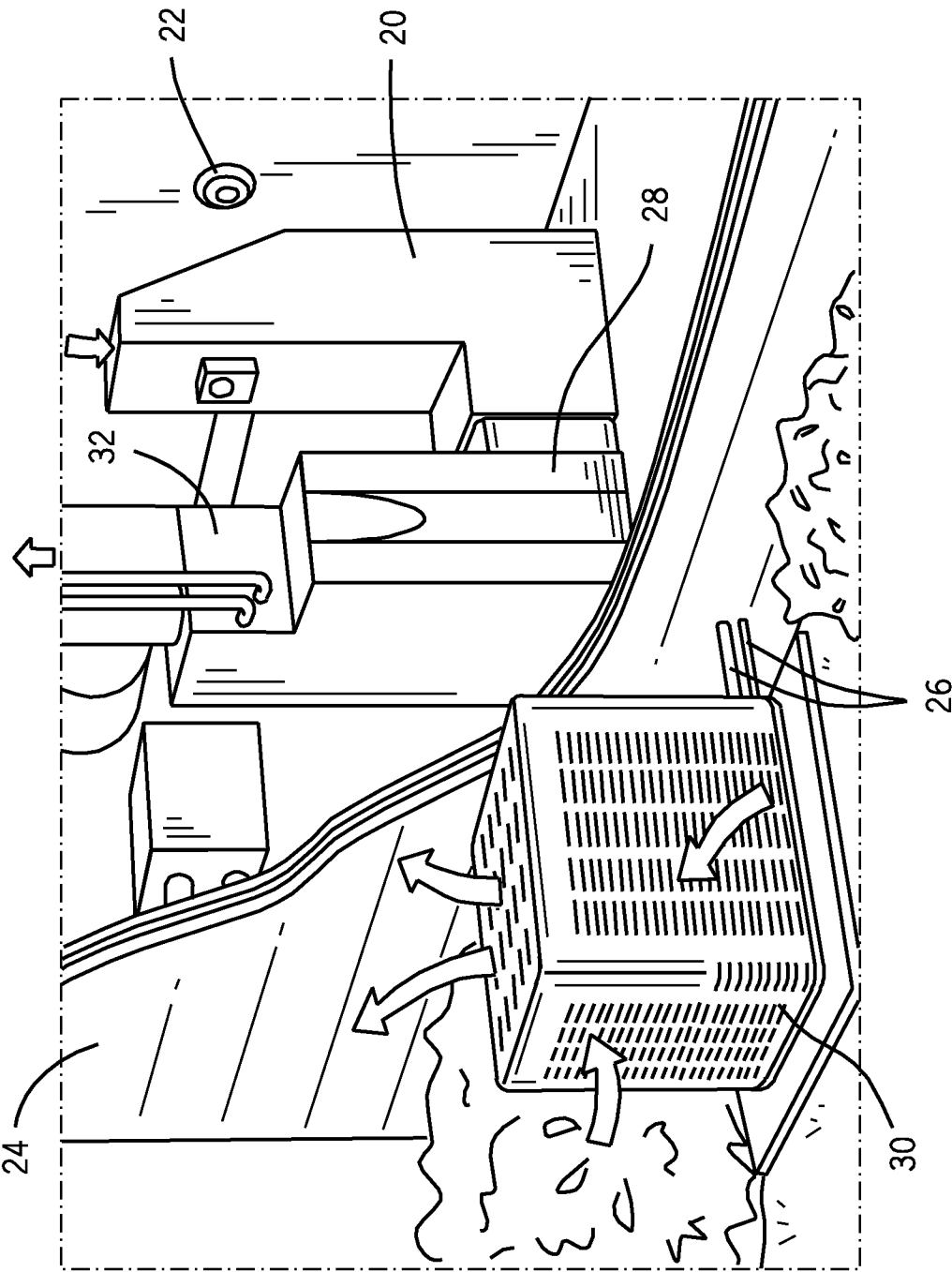
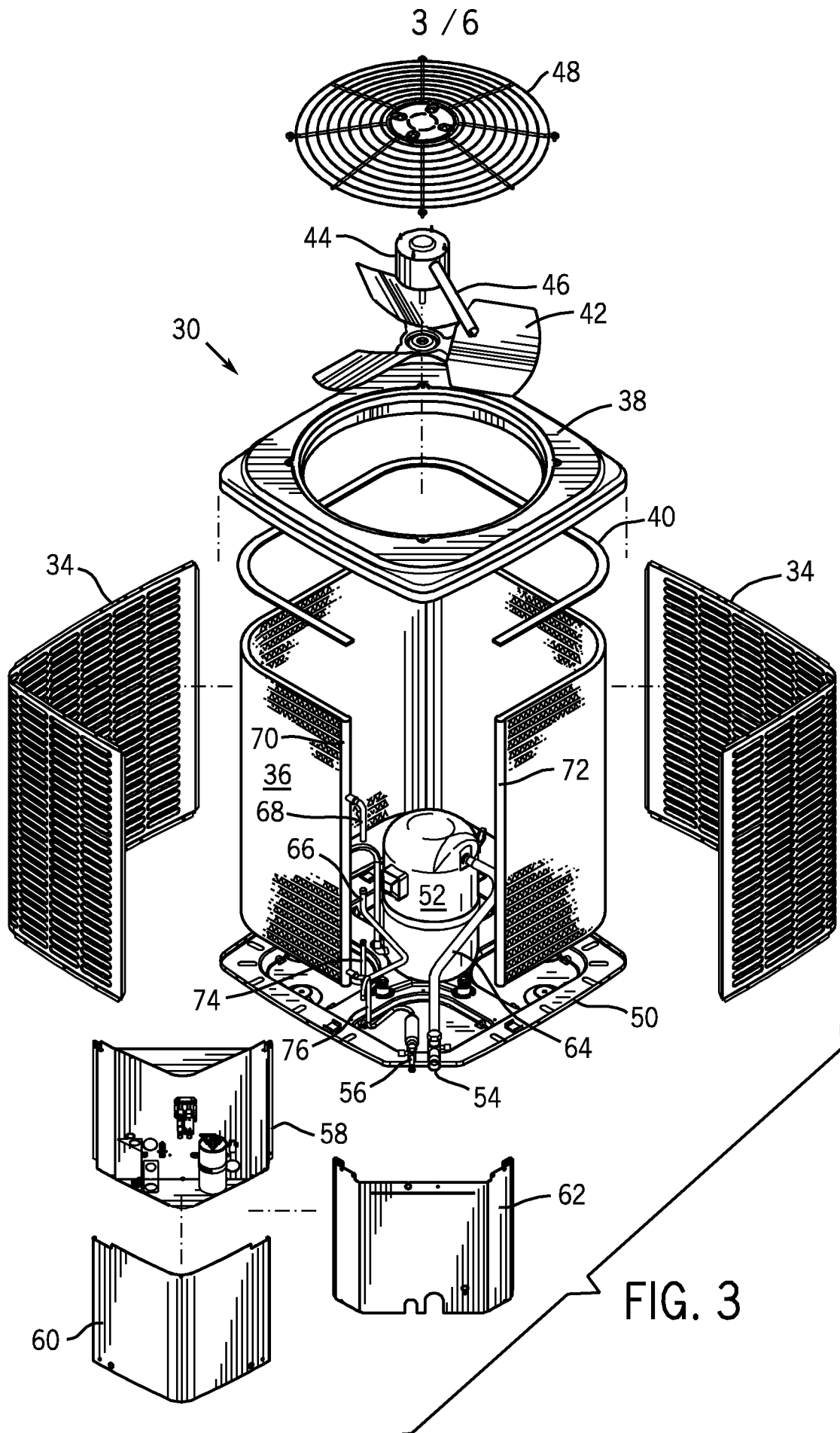


FIG. 2



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FIG. 4

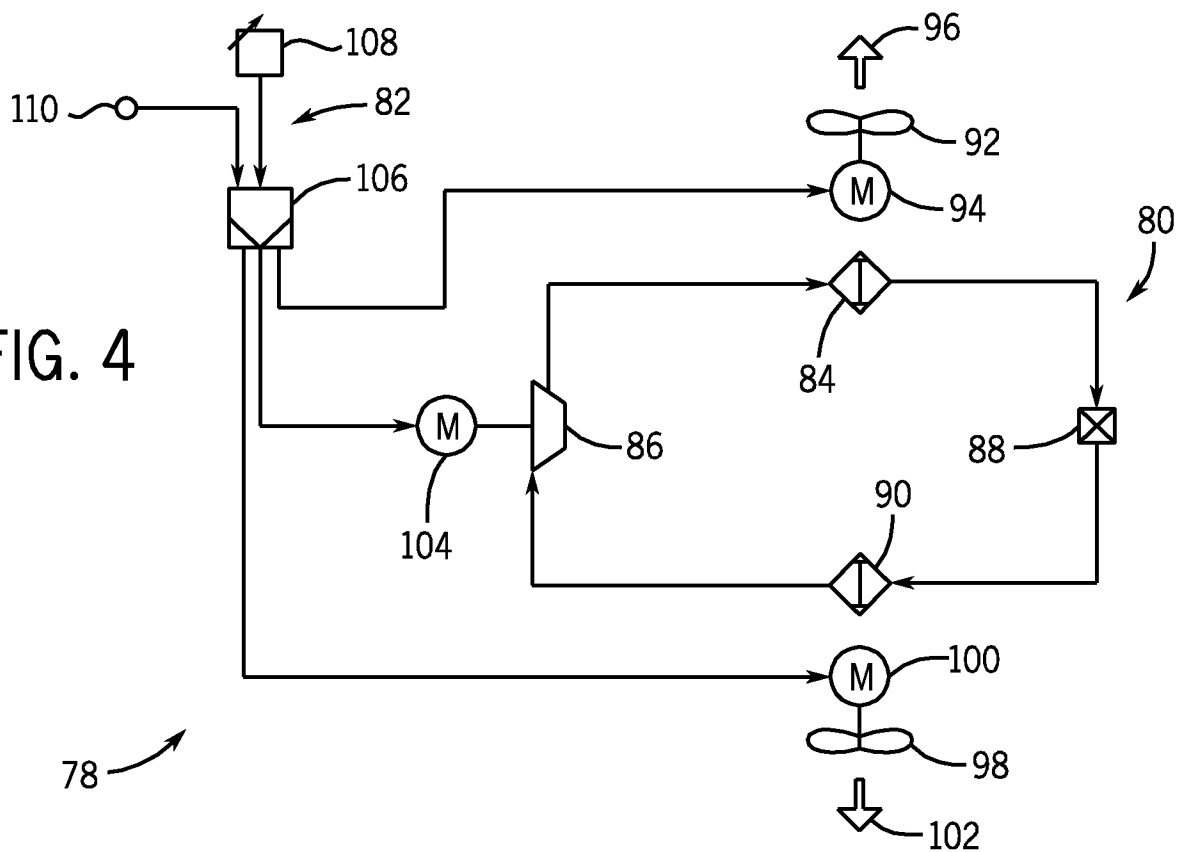


FIG. 5

