A heat exchanger includes an outer tube and an inner tube coaxially arranged within the outer tube. Both of the outer tube and the inner tube include a fluid channel formed therein. A first fluid flows through the fluid channel of the outer tube, and a second fluid, in heat exchange relationship with the first fluid, flows through the fluid channel of the inner tube. At least one heat conductive feature is formed between the outer tube and the inner tube, and on an inner surface of the inner tube to maximize a heat exchange between the fluids.
INTERNAL HEAT EXCHANGER

FIELD OF THE INVENTION

[0001] The present invention relates to a heat exchanger. More particularly, the invention is directed to an internal heat exchanger.

BACKGROUND OF THE INVENTION

[0002] A typical air conditioning system of a vehicle includes a compressor, a condenser, an expansion device, and an evaporator, all fluidly connected by refrigerant conduits. The refrigerant conduits are capable of conveying a flow of high and low pressure refrigerant. Common refrigerants used in the air conditioning systems are environmentally friendly refrigerants such as R-134a, for refrigerant to low Global Warming Potential (GWP) refrigerants such as HFO-1234yf, for example. The compressor compresses and facilitates a transfer of the refrigerant throughout the system. The compressor includes a suction side and a discharge side. The suction side is referred to as the low pressure side and the discharge side is referred to as the high pressure side.

[0003] Typically, the evaporator is disposed in a passenger compartment of the vehicle and the condenser is disposed in an engine compartment, or more precisely, in front of a radiator of the vehicle. Within the evaporator, cold low pressure liquid refrigerant boils by absorbing heat from the passenger compartment. The low pressure vapor refrigerant exiting from the evaporator is received in the compressor and compressed thereby into a high temperature vapor refrigerant. The compressed high temperature vapor refrigerant is then discharged by the compressor to the condenser. As the high pressure vapor refrigerant passes through the condenser, the refrigerant is condensed to a high pressure, low temperature liquid refrigerant as it transfers the heat absorbed from the passenger compartment and from the compression process to the ambient air outside of the passenger compartment. Exiting the condenser, the high pressure liquid refrigerant passes through an expansion device that regulates the flow of the high pressure liquid refrigerant to the evaporator. A temperature of the low pressure vapor refrigerant returning to the compressor from the evaporator is typically about 40° F. to about 100° F. lower than a temperature of the high pressure liquid refrigerant exiting the condenser.

[0004] An internal heat exchanger such as a double pipe counter flow heat exchanger, for example, is known to be used to take advantage of the temperature differential between the low pressure, low temperature vapor refrigerant and the high pressure, high temperature liquid refrigerant to improve the overall cooling capacity of the air conditioning system. The double pipe heat exchanger includes an inner pipe and an inner pipe co-axially located within the outer pipe. The diameter of the inner pipe is smaller than the diameter of the outer pipe, thereby defining an annular gap between the inner pipe and the outer pipe for refrigerant flow. The relatively cooler low pressure vapor refrigerant exiting the evaporator is passed through the annular gap and the relatively hotter liquid refrigerant exiting the condenser is passed through the inner pipe. Heat is transferred from the high pressure liquid refrigerant exiting the condenser to the cooler low pressure vapor refrigerant returning to the compressor in the internal heat exchanger. By decreasing the temperature of the high pressure liquid refrigerant prior to its flowing through the expansion device, the expansion device may be set at a lower temperature. Accordingly, the temperature of the refrigerant entering the evaporator is at a lower temperature, thereby improving the cooling performance of the air conditioning system.

[0005] Current internal heat exchangers used in the air conditioning systems are bulky, heavy, and/or expensive. Further, the current internal heat exchangers are inefficient and require significant length to reach a desired cooling power.

[0006] It would be desirable to produce an internal heat exchanger that is suitable for use in an air conditioning system of a vehicle, which is easily manufactured, easily conformed to installation requirements, while minimizing a size, a weight, and a suction line pressure drop and maximizing a performance and an efficiency of the heat exchanger.

SUMMARY OF THE INVENTION

[0007] In concordance and agreement with the present invention, an internal heat exchanger that is suitable for use in an air conditioning system of a motor vehicle, which is easily manufactured, easily conformed to installation requirements, while minimizing a size, a weight, and a suction line pressure drop and maximizing a performance and an efficiency of the heat exchanger, has surprisingly been discovered.

[0008] In one embodiment, the heat exchanger comprises: an outer tube including at least one fluid channel formed therein, wherein the at least one fluid channel receives a first fluid therein; and a first inner tube arranged within the outer tube, the first inner tube including at least one fluid channel formed therein, wherein the at least one fluid channel receives a second fluid therein, and wherein a cross-sectional flow area of the at least one fluid channel of the first inner tube is greater than a cross-sectional flow area of the at least one fluid channel of the outer tube.

[0009] In another embodiment, the heat exchanger comprises: an outer tube including at least one fluid channel formed therein, wherein the at least one fluid channel receives a first fluid therein; a first inner tube arranged within the outer tube, the first inner tube including at least one fluid channel formed therein, wherein the at least one fluid channel receives a second fluid therein, and wherein a cross-sectional flow area of the at least one fluid channel of the first inner tube is greater than a cross-sectional flow area of the at least one fluid channel of the outer tube; and a first plurality of heat conductive features formed on an inner surface of the first inner tube.

[0010] In another embodiment, the heat exchanger comprises: an outer tube including at least one fluid channel formed therein, wherein the at least one fluid channel receives a first fluid therein; a first inner tube arranged within the outer tube, the first inner tube including at least one fluid channel formed therein, wherein the at least one fluid channel receives a second fluid therein; a second inner tube arranged within the first inner tube, the second inner tube including at least one fluid channel formed therein, wherein the at least one fluid channel receives the second fluid therein, and wherein a cumulative cross-sectional flow area of the fluid channels of the inner tubes is greater than a cumulative cross-sectional flow area of the at least one fluid channel of the outer tube; and a plurality of heat conductive features formed between the first inner tube and the second inner tube.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] The above, as well as other advantages of the present invention, will become readily apparent to those skilled in the
art from the following detailed description of the preferred embodiment when considered in the light of the accompanying drawings in which:

[0012] FIG. 1 is a schematic diagram of an internal heat exchanger shown within a representative air conditioning system of a motor vehicle;

[0013] FIG. 2 is a perspective view an internal heat exchanger, with directly connected fluid lines extending from the heat exchanger, in accordance with an embodiment of the present invention;

[0014] FIG. 3 is a fragmentary side perspective view, partially in section, of the heat exchanger illustrated in FIG. 2;

[0015] FIG. 4 is a cross-sectional view of the heat exchanger illustrated in FIG. 2;

[0016] FIG. 5 is a cross-sectional view of the heat exchanger illustrated in FIG. 2 according to another embodiment of the invention showing fewer ribs formed on an inner surface of the inner tube, wherein the ribs formed on an outer surface and the inner surface of the inner tube of the heat exchanger have a varied thickness, a varied height, and radiused nose portions;

[0017] FIG. 6 is a fragmentary sectional view of the heat exchanger illustrated in FIG. 5 taken along a central axis of the heat exchanger;

[0018] FIG. 7 is a cross-sectional view of an internal heat exchanger according to another embodiment of the present invention;

[0019] FIG. 8 is a cross-sectional view of an internal heat exchanger according to another embodiment of the present invention;

[0020] FIG. 9 is a cross-sectional view of an internal heat exchanger according to another embodiment of the present invention;

[0021] FIG. 10 is a cross-sectional view of an internal heat exchanger according to another embodiment of the present invention; and

[0022] FIG. 11 is a cross-sectional view of an internal heat exchanger according to another embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0023] The following detailed description and appended drawings describe and illustrate an exemplary embodiment of the invention. The description and drawings serve to enable one skilled in the art to make and use the invention, and are not intended to limit the scope of the invention in any manner.

[0024] FIG. 1 is a schematic view of an air conditioning system 10 of a motor vehicle (not shown). The air conditioning system 10 includes a compressor 12, a condenser 14, an expansion device 16, and an evaporator 18 fluidly connected by conduits 20. The air conditioning system 10 further includes a counter flow or internal heat exchanger (IHX) 100 to increase a heat transfer capacity of the air conditioning system 10. It is understood that the IHX 100 is not limited to use in vehicle air conditioning systems 10, and can be employed in other non-automotive applications requiring a heat exchanger. It is further understood that the air conditioning system 10 can include other components necessary for operation such as an electronic control unit, an accumulator, sensors, and the like, for example.

[0025] Typically, a low pressure vapor refrigerant flowing from the evaporator 18 is received into the compressor 12 and is compressed into a high pressure vapor refrigerant. The high pressure vapor refrigerant is then discharged from the compressor 12 and is received into the condenser 14. Within condenser 14, the high pressure vapor refrigerant is caused to condense into a high pressure liquid refrigerant by transferring heat to the ambient air. The high pressure liquid refrigerant then flows through the expansion device 16 and is caused to expand into a low pressure liquid refrigerant. The expansion device 16 regulates the flow of the low pressure liquid refrigerant to the evaporator 18. In the air conditioning system 10, the evaporator 18 is located in a passenger compartment of the motor vehicle. Within the evaporator 18, the low pressure liquid refrigerant absorbs heat from the passenger compartment of the vehicle and is caused to evaporate into the low pressure vapor refrigerant received by the compressor 12.

[0026] As shown, the internal heat exchanger 100 is disposed in the air conditioning system 10 between a discharge side of the evaporator 18 and a suction side of the compressor 12 and between a discharge side of the condenser 14 and an inlet side of the expansion device 16. The flow of the low pressure vapor refrigerant from the evaporator 18 through the IHX 100 is counter to the flow of the high pressure liquid refrigerant from the condenser 14 through the IHX 100. The relatively low temperature, low pressure vapor refrigerant flowing from the evaporator 18 is used to pre-cool the relatively high temperature, high pressure liquid refrigerant and the second fluid is the relatively low temperature, low pressure vapor refrigerant. It is understood, however, the first and second fluids can be any fluids as desired. Connectors 106, 108 are disposed at a first end 110 of the IHX 100 and a second end 112 of the IHX 100, respectively. An inlet end 114 of the inner tube 104 is in fluid communication with the discharge side of the evaporator 18 and an outlet end 116 of the inner tube 104 is in fluid communication with the suction side of the compressor 12 through the conduits 20. A first fluid supply conduit 118 extends laterally outwardly from the connector 106 and a first fluid return conduit 120 extends laterally outwardly from the connector 108. The first fluid supply conduit 118 is in fluid communication with the discharge side of the condenser 14 and the first fluid return conduit 120 is in fluid communication with the inlet side of the expansion device 16 through the conduits 20. A fluid-tight seal is formed between the first fluid supply conduit 118 and the connector 106 and between the first fluid return conduit 120 and the connector 108. It is understood that the fluid-tight seals between the conduits 118, 120 and the respective connectors 106, 108 can be formed by any means as desired such as by solder, braze, or weld connections, adhesive connections, or interference fit connections, supported by sealing means such as O-rings, for example.

[0028] As shown, the connectors 106, 108 have a generally circular cross-sectional shape. It is understood that the connectors 106, 108 can have any shape and size as desired. Each of the connectors 106, 108 includes a central aperture 122, shown in FIGS. 3 and 6, formed therein for receiving the inner tube 104 therein. A first portion 124 of a wall of the connectors 106, 108 circumscribes the inner tube 104 to form a fluid-tight seal therebetween. A second portion 126 of the wall of the connectors 106, 108 circumscribes the outer tube
to form a fluid-tight seal therebetween. It is understood that solder, braze, or weld connections, adhesive connections, or interference fit connections, supported by sealing means such as O-rings, for example, can be used to form the fluid-tight seals between the tubes 102, 104 and the respective connectors 106, 108. The connector 106, the tubes 102, 104, and the first fluid supply conduit 118 cooperate to form a cylindrical chamber 128 to facilitate a substantially uniform flow of the first fluid from the first fluid supply conduit 118 into the outer tube 102. The connector 108, the tubes 102, 104, and the first fluid return conduit 120 cooperate to form a cylindrical chamber 129, shown in FIG. 6, to facilitate a substantially uniform flow of the first fluid from the outer tube 102 into the first fluid return conduit 120.

[0029] FIGS. 3-4, and 6 show the IIHX 100 including the outer tube 102 and the inner tube 104 according to an embodiment of the invention. The inner tube 104 is coaxially arranged within the outer tube 102 in respect of a central axis A of the IIHX 100. As illustrated, the central axis A of the IIHX is substantially the same as a central axis of the outer tube 102 and a central axis of the inner tube 104. Each of the tubes 102, 104 shown is a separate component formed from a single piece of material. It is understood that the tubes 102, 104 can be integrally formed and formed by any process as desired such as an extrusion process, for example. It is further understood that the tubes 102, 104 can be formed from any suitable material to facilitate heat transfer such as a steel material, a stainless steel material, a copper material, or a plastic material, for example. In a non-limiting example, the tubes 102, 104 are formed from an aluminum material to minimize cost and a weight of the IIHX 100 and to maximize a heat conductivity and a formability thereof. The outer tube 102 shown has an outer diameter D1 of about 27 mm and an inner diameter D2 of about 23 mm. It is understood, however, that the outer tube 102 can have any size and shape as desired. The outer tube 102 has a generally smooth outer surface 140 and a generally smooth inner surface 142.

[0030] Conversely, an outer surface 144 of the inner tube 104 includes at least one heat conductive feature such as an annular array of elongate ribs 146 formed thereon and extending substantially parallel to the central axis A of the IIHX 100. In a non-limiting example, the outer surface 144 includes twenty (20) ribs 146 formed thereon. Additional or fewer ribs 146 than shown can be employed if desired. Each of the ribs 146 can have any cross-sectional shape as desired such as a square cross-sectional shape as shown in FIGS. 3-4, a triangular cross-sectional shape as shown in FIG. 5, or a trapezoidal cross-sectional shape, for example. An outer diameter of the inner tube 104 defined by a nose portion 148 of the ribs 146 is slightly smaller than the inner diameter D2 of the outer tube 102 to permit the inner tube 104 to be easily disposed within the outer tube 102 during an assembly of the tubes 102, 104. It is understood that the tubes 102, 104 can be assembled by any process as desired such as by a manual assembly process, for example. As illustrated in FIG. 5, the nose portion 148 of the ribs 146 may be radiused if desired. In a non-limiting example, an outer diameter D3 of the inner tube 104 defined by the outer surface 144 thereof is about 21 mm. It is understood that the inner tube 104 can have any shape and size as desired.

[0031] The ribs 146 shown are circumferentially spaced apart at a substantially uniform predetermined interval forming a plurality of fluid channels 150 between the inner tube 104 and the outer tube 102. It is understood, however, that the ribs 146 can be circumferentially spaced apart at any uniform or non-uniform interval as desired. In a non-limiting example, twenty (20) fluid channels 150 are formed between the tubes 102, 104 for receiving the first fluid therein. Additional or fewer fluid channels 150 than shown can be employed if desired. Each of the fluid channels 150 shown has a substantially rectangular cross-sectional shape. It is understood that the fluid channels 150 can have any cross-sectional shape as desired. Corners 152 of the fluid channels 150 formed by the ribs 146 and the outer surface 144 of the inner tube 104 may be radiused if desired.

[0032] An inner surface 154 of the inner tube 104 includes at least one heat conductive feature such as an annular array of elongate ribs 156 formed thereon and extending substantially parallel to the central axis A of the IIHX 100. In a non-limiting example shown in FIGS. 3-4, the inner surface 154 includes ten (10) ribs 156 formed thereon. In another non-limiting example shown in FIG. 5, the inner surface 154 includes six (6) ribs 156 formed thereon. Additional or fewer ribs 156 than shown in FIGS. 3-5 can be employed if desired. It is understood that a ratio of a number of ribs 146 formed on the outer surface 144 of the inner tube 104 to a number of ribs 156 formed on the inner surface 154 of the inner tube 104 can be any ratio as desired to maximize a heat exchange between the fluids and minimize a pressure drop of the fluids such as a 2:1 ratio as shown in FIGS. 3-4 or a 10:3 ratio as shown in FIG. 5, for example. Sides 158 of each of the ribs 156 are angulated in respect of one another such that the ribs 156 have a generally triangular or trapezoidal cross-sectional shape. It is understood, however, that the ribs 156 can have any cross-sectional shape as desired.

[0033] As illustrated in FIG. 5, corners 160, formed where the ribs 156 transition to the inner surface 154 of the inner tube 104, can be radiused if desired. As shown, an inner diameter D2 of the inner tube 104 defined by a nose portion 162 of each of the ribs 156 is about 6 mm and an inner diameter D3 of the inner tube 104 defined by the inner surface 154 thereof is about 18 mm. It is understood that the inner tube 104 can have any inner diameters D2, D3 as desired. The nose portion 162 of each of the ribs 156 may be radiused as shown in FIG. 5, if desired.

[0034] The ribs 156 shown are circumferentially spaced apart at a substantially uniform predetermined interval forming a plurality of fluid channels 164. It is understood that the ribs 156 can be circumferentially spaced apart at any uniform or non-uniform interval as desired. In a non-limiting example, the fluid channels 164 receive the second fluid therein. Additional or fewer fluid channels 164 than shown can be employed if desired. A cumulative cross-sectional flow area of the fluid channels 164 is greater than a cumulative cross-sectional flow area of the fluid channels 150.

[0035] In a non-limiting example, a thickness of the ribs 146, 156 is about 1.0 mm or less to maximize the cross-sectional flow areas of the fluid channels 150, 164 and minimize the pressure drop of the fluids. As shown in FIGS. 5-6, the thickness of the ribs 146, 156 at a first end 170 of the ribs 146, 156 adjacent the first end 110 of the IIHX 100 and a thickness of the ribs 146, 156 at a second end 172 of the ribs 146, 156 adjacent the second end 112 of the IIHX 100 may be gradually decreased to further minimize the pressure drop of the fluids, wherein the thickness of the ribs 146, 156 at each of the ends 170, 172 is narrower than the thickness of the ribs 146, 156 between the ends 170, 172. Further, a height of the ribs 146, 156 at each of the ends 170, 172 may be gradually
decreased to further yet minimize the pressure drop of the fluids, wherein the height of the ribs 146, 156 at each of the ends 170, 172 is less than the height of the ribs 146, 156 between the ends 170, 172.

[0036] FIG. 7 shows an internal heat exchanger according to another embodiment of the invention. Reference numerals for similar structure in respect of the discussion of FIGS. 1-6 above are repeated with a prime (') symbol. The IIHX 100' shown includes an outer tube 102' and an inner tube 104'. The inner tube 104' is coaxially arranged within the outer tube 102' in respect of a central axis of the IIHX 100'. The central axis of the IIHX 100' is substantially the same as a central axis of the outer tube 102' and a central axis of the inner tube 104'. Each of the tubes 102', 104' shown is a separate component formed from a single piece of material. It is understood that the tubes 102', 104' can be integrally formed and formed by any process as desired such as an extrusion process, for example. It is further understood that the tubes 102', 104' can be formed from any suitable material to facilitate heat transfer such as a metal material, a stainless steel material, a copper material, or a plastic material, for example. In a non-limiting example, the tubes 102', 104' are formed from an aluminum material to minimize cost and a weight of the IIHX 100' and to maximize a heat conductivity and a formability thereof. The outer tube 102' shown has an outer diameter $D_o$ of about 27 mm and an inner diameter $D_i$ of about 23 mm. It is understood, however, that the outer tube 102' can have any size and shape as desired. The outer tube 102' has a generally smooth outer surface 140' and a generally smooth inner surface 141'.

[0037] Conversely, an outer surface 144' of the inner tube 104' includes at least one heat conductive feature such as an annular array of elongate ribs 146' formed thereon and extending substantially parallel to the central axis of the IIHX 100'. In a non-limiting example, the outer surface 144' includes twenty (20) ribs 146' formed thereon. Additional or fewer ribs 146' than shown can be employed if desired. Each of the ribs 146' can have any cross-sectional shape as desired such as a square cross-sectional shape, a triangular cross-sectional shape, or a trapezoidal cross-sectional shape, for example. An outer diameter of the inner tube 104' defined by a nose portion 148' of the ribs 146' is slightly smaller than the inner diameter $D_i$ of the outer tube 102' to permit the inner tube 104' to be easily disposed within the outer tube 102' during an assembly of the tubes 102', 104'. It is understood that the tubes 102', 104' can be assembled by any process as desired such as by a manual assembly process, for example. The nose portion 148' of the ribs 146' may be radiused if desired. In a non-limiting example, an outer diameter $D_o$ of the inner tube 104' defined by the outer surface 144' thereof is about 21 mm. It is understood that the inner tube 104' can have any shape and size as desired.

[0038] The ribs 146' shown are circumferentially spaced apart at a substantially uniform predetermined interval forming a plurality of fluid channels 150'. The ribs 146' and the outer tube 102'. It is understood, however, that the ribs 146' can be circumferentially spaced apart at any uniform or non-uniform interval as desired. In a non-limiting example, twenty (20) fluid channels 150' are formed between the tubes 102', 104' for receiving the first fluid therein. Additional or fewer fluid channels 150' than shown can be employed if desired. Each of the fluid channels 150' shown has a substantially rectangular cross-sectional shape. It is understood that the fluid channels 150' can have any cross-sectional shape as desired. Corners 152' of the fluid channels 150' formed by the ribs 146' and the outer surface 144' of the inner tube 104' may be radiussed if desired.

[0039] An inner surface 154' of the inner tube 104' includes at least one heat conductive feature such as an annular array of elongate first or short ribs 200, an annular array of elongate second or medium ribs 202, and an annular of elongate third or long ribs 204 formed thereon and extending substantially parallel to the central axis of the IIHX 100'. In a non-limiting example, the inner surface 154' includes twelve (12) first ribs 200, six (6) second ribs 202, and six (6) third ribs 204. Additional or fewer ribs 200, 202, 204 than shown can be employed if desired. In a non-limiting example, the ribs 200, 202, 204 are formed in a repeating pattern including a third rib 204, a first rib 200, a second rib 202, and another first rib 200. It is understood that the ribs 200, 202, 204 can be formed in any pattern or in other configurations as desired. A ratio of a number of ribs 146' formed on the outer surface 144' of the inner tube 104' to a number of ribs 200, 202, 204 formed on the inner surface 154' of the inner tube 104' can be any ratio as desired to maximize a heat exchange between the fluids and minimize a pressure drop of the fluids such as a 5:6 ratio, for example.

[0040] Sides 205 of each of the ribs 200, 202, 204 are substantially parallel in respect of one another such that the ribs 200, 202, 204 have a generally obround cross-sectional shape. It is understood, however, that the ribs 200, 202, 204 can have any cross-sectional shape as desired. Corners 207, formed where the ribs 200, 202, 204 transition to the inner surface 154' of the inner tube 104', can be radiussed if desired. As shown, an inner diameter $D_i$ of the inner tube 104' defined by the inner surface 154' thereof is about 18 mm. An inner diameter $D_o$ of the inner tube 104' defined by a nose portion 206 of each of the first ribs 200 is about 16 mm. An inner diameter $D_o$ of the inner tube 104' defined by a nose portion 208 of each of the second ribs 202 is about 12 mm. An inner diameter $D_o$ of the inner tube 104' defined by a nose portion 210 of each of the third ribs 204 is about 6 mm. It is understood that the inner tube 104' can have any size and shape as desired.

[0041] The ribs 200, 202, 204 shown are circumferentially spaced apart at a substantially uniform predetermined interval forming a plurality of fluid channels 164'. It is understood that the ribs 200, 202, 204 can be circumferentially spaced apart at any uniform or non-uniform interval as desired. In a non-limiting example, the fluid channels 164' receive the second fluid therein. Additional or fewer fluid channels 164' than shown can be employed if desired. A cumulative cross-sectional flow area of the fluid channels 164' is greater than a cumulative cross-sectional flow area of the fluid channels 150'.

[0042] In a non-limiting example, a thickness of the ribs 146', 200, 202, 204 is about 1.0 mm or less to maximize the cross-sectional flow areas of the fluid channels 150', 164' and minimize the pressure drop of the fluids. The thickness of the ribs 146' and the thickness of the ribs 200, 202, 204 may be gradually decreased at ends thereof adjacent ends of the IIHX 100' to further minimize the pressure drop of the fluids, wherein the thickness of the ribs 146', 200, 202, 204 at each of the ends is narrower than the thickness of the ribs 146', 200, 202, 204 between the ends. Further, a height of the ribs 146', 200, 202, 204 may be gradually decreased at the ends thereof to further yet minimize the pressure drop of the fluids,
wherein the height of the ribs 146', 200, 202, 204 at each of the ends is less than the height of the ribs 146', 200, 202, 204 between the ends.

[0043] FIG. 8 shows an internal heat exchanger according to another embodiment of the invention. Reference numerals for similar structure in respect of the discussion of FIGS. 1-7 above are repeated with a prime (') symbol. The IHX 100" shown includes an outer tube 102" and an inner tube 104". The inner tube 104" is coaxially arranged within the outer tube 102" in respect of a central axis of the IHX 100". The central axis of the IHX 100" is substantially the same as a central axis of the outer tube 102" and a central axis of the inner tube 104". Each of the tubes 102", 104" shown is a separate component formed from a single piece of material. It is understood that the tubes 102", 104" can be integrally formed and formed by any process as desired such as an extrusion process, for example. It is further understood that the tubes 102", 104" can be formed from any suitable material to facilitate heat transfer such as a steel material, a stainless steel material, a copper material, or a plastic material, for example. In a non-limiting example, the tubes 102", 104" are formed from an aluminum material to minimize cost and for a weight of the IHX 100" and to maximize a heat conductivity and a formability thereof. The outer tube 102" shown has an outer diameter D₁₁ of about 27 mm. The outer tube 102" has a generally smooth outer surface 140". An inner surface 142" of the outer tube 102" includes at least one heat conductive feature such as an annular array of elongate ribs 300 formed thereon and extending substantially parallel to the central axis of the IHX 100". In a non-limiting example, the inner surface 142" includes twenty (20) ribs 300 formed thereon. Additional or fewer ribs 300 than shown can be employed if desired.

[0044] Each of the ribs 300 can have any cross-sectional shape as desired such as a square cross-sectional shape, a triangular cross-sectional shape, or a trapezoidal cross-sectional shape, for example. An inner diameter D₁₁ of the outer tube 102" defined by a nose portion 302 of the ribs 300 is slightly larger than an outer diameter of the inner tube 104" to permit the inner tube 104" to be easily disposed within the outer tube 102" during an assembly of the tubes 102", 104". It is understood that the tubes 102", 104" can be assembled by any process as desired such as by a manual assembly process, for example. The nose portion 302 of the ribs 300 may be radiussed if desired. In a non-limiting example, the inner diameter D₁₁ of the outer tube 102" defined by the inner surface 142" thereof is about 23 mm. It is understood that the inner tube 102" can have any shape and size as desired.

[0045] The ribs 300 shown are circumferentially spaced apart at a substantially uniform predetermined interval forming a plurality of fluid channels 306 between the outer tube 102" and the inner tube 104". It is understood, however, that the ribs 300 can be circumferentially spaced apart at any uniform or non-uniform interval as desired. In a non-limiting example, twenty (20) fluid channels 306 are formed between the tubes 102", 104" for receiving the first fluid therein. Additional or fewer fluid channels 306 than shown can be employed if desired. Each of the fluid channels 306 shown has a substantially rectangular cross-sectional shape. It is understood that the fluid channels 306 can have any cross-sectional shape as desired. Corners 308 of the fluid channels 306 formed by the ribs 300 and the inner surface 142" of the outer tube 102" may be radiussed if desired.

[0046] As illustrated, the inner tube 104" has a substantially smooth outer surface 144". An inner surface 154" of the inner tube 104" includes at least one heat conductive feature such as an annular array of elongate first or short ribs 200", an annular array of elongate second or medium ribs 202", and an annular array of elongate third or long ribs 204" formed thereon and extending substantially parallel to the central axis of the IHX 100". In a non-limiting example, the inner surface 154" includes twelve (12) first ribs 200", six (6) second ribs 202", and six (6) third ribs 204". Additional or fewer ribs 200", 202", 204" than shown can be employed if desired. In a non-limiting example, the ribs 200", 202", 204" are formed in a repeating pattern including a third rib 204", a first rib 200", a second rib 202", and another first rib 200". It is understood that the ribs 200", 202", 204" can be formed in any pattern or in other configurations as desired. A ratio of a number of ribs 300 formed on the inner surface 142" of the outer tube 102" to a number of ribs 200", 202", 204" formed on the inner surface 154" of the inner tube 104" can be any ratio as desired to maximize a heat exchange between the fluids and minimize a pressure drop of the fluids such as a 5:6 ratio, for example.

[0047] Sides 205" of each of the ribs 200", 202", 204" are substantially parallel in respect of one another such that the ribs 200", 202", 204" have a generally ovoid cross-sectional shape. It is understood, however, that the ribs 200", 202", 204" can have any cross-sectional shape as desired. Corners 207", formed where the ribs 200", 202", 204" transition to the inner surface 154" of the inner tube 104", can be radiussed if desired. An inner diameter D₁₄ of the inner tube 104" defined by the inner surface 154" thereof is about 18 mm. An inner diameter D₁₄ of the inner tube 104" defined by a nose portion 206" of each of the first ribs 200" is about 16 mm. An inner diameter D₁₄ of the inner tube 104" defined by a nose portion 208" of each of the second ribs 202" is about 12 mm. An inner diameter D₁₄ of the inner tube 104" defined by a nose portion 210" of each of the third ribs 204" is about 6 mm. It is understood that the inner tube 104" can have any size and shape as desired.

[0048] The ribs 200", 202", 204" shown are circumferentially spaced apart at a substantially uniform predetermined interval forming a plurality of fluid channels 164". It is understood that the ribs 200", 202", 204" can be circumferentially spaced apart at any uniform or non-uniform interval as desired. In a non-limiting example, the fluid channels 164" receive the second fluid therein. Additional or fewer fluid channels 164" than shown can be employed if desired. A cumulative cross-sectional flow area of the fluid channels 164" is greater than a cumulative cross-sectional flow area of the fluid channels 306."
FIG. 9 shows an internal heat exchanger according to another embodiment of the invention. Reference numerals for similar structure in respect of the discussion of FIGS. 1-8 above are repeated with a prime (’) symbol. The IHX 100" shown includes an outer tube 102", and an inner tube 104". The tubes 102", 104" shown are integrally formed from a single piece of material. The tubes 102", 104" can be integrally formed by any process as desired such as an extrusion process, for example. It is further understood that the tubes 102", 104" can be formed from any suitable material to facilitate heat transfer such as a steel material, a stainless steel material, a copper material, or a plastic material, for example. In a non-limiting example, the tubes 102", 104" are formed from an aluminum material to minimize cost and a weight of the IHX 100" and to maximize a heat conductivity and a formability thereof.

The inner tube 104" is coaxially formed within the outer tube 102" in respect of a central axis of the IHX 100". The central axis of the IHX 100" is substantially the same as a central axis of the outer tube 102" and a central axis of the inner tube 104". The inner tube 104" extends an entire length of the IHX 100". The outer tube 102" terminates at positions where connectors (not shown) for a first fluid supply conduit (not shown) and a first fluid return conduit (not shown) are attached. The outer tube 102" shown has an outer diameter D1, of about 27 mm and an inner diameter D2, of about 23 mm. It is understood that the outer tube 102" can have any shape and size as desired. The outer tube 102" has a generally smooth outer surface 140" and inner surface 142". At least one heat conductive feature such as an annular array of elongate ribs 400 is formed between the inner surface 142" of the outer tube 102" and an outer surface 144" of the inner tube 104". The ribs 400 are formed to extend substantially parallel to the central axis of the IHX 100". In a non-limiting example, the IHX 100" includes twenty (20) ribs 400 formed between the tubes 102", 104". Additional or fewer ribs 400 than shown can be employed if desired. Each of the ribs 400 can have any cross-sectional shape as desired such as a square cross-sectional shape, for example.

The ribs 400 shown are circumferentially spaced apart at a substantially uniform predetermined interval forming a plurality of fluid channels 406 between the outer tube 102" and the inner tube 104". It is understood, however, that the ribs 400 can be circumferentially spaced apart at any uniform or non-uniform interval as desired. In a non-limiting example, twenty (20) fluid channels 406 are formed between the tubes 102", 104" for receiving the first fluid therein. Additional or fewer fluid channels 406 than shown can be employed if desired. Each of the fluid channels 406 shown has a substantially rectangular cross-sectional shape. It is understood that the fluid channels 406 can have any cross-sectional shape as desired. Corners 408 of the fluid channels 406 formed by the ribs 400 and the inner surface 142" of the outer tube 102" may be radiused if desired.

The inner tube 104" shown has an outer diameter D1,1 of about 21 mm and an inner diameter D1,4 of about 18 mm. It is understood that the inner tube 104" can have any shape and size as desired. The inner tube 104" has a generally smooth outer surface 144" and inner surface 154". At least one heat conductive feature such as an annular array of elongate ribs 410, for example, is formed between the inner surface 154" of the inner tube 104" and an outer surface 412 of a second inner tube 414 coaxially arranged within the inner tube 104" in respect of the central center axis of the IHX 100". The central axis of the IHX 100" is substantially the same as a central axis of the second inner tube 414.

The ribs 410 are formed to extend substantially parallel to and radially outwardly from the central axis of the IHX 100". Corners 416, formed where the ribs 410 transition to the inner surface 154" of the inner tube 104", and corners 418, formed where the ribs 410 transition to the outer surface 412 of the inner tube 414, can be radiused if desired. In a non-limiting example, the IHX 100" includes ten (10) ribs 410 formed between the tubes 104", 414. Additional or fewer ribs 410 than shown can be employed if desired. A ratio of a number of ribs 410 formed between the inner tubes 104", 414 to a number of ribs 400 formed between the tubes 102", 104" can be any ratio as desired to maximize a heat exchange between the fluids and minimize a pressure drop of the fluids such as a 1:2 ratio, for example.

In a non-limiting example, a thickness of the ribs 400, 410 is about 1.0 mm or less to maximize a cross-sectional flow area of the fluid channels 406, 420 and minimize the pressure drop of the fluids. The thickness of the ribs 400, 410 may be gradually decreased at ends of the respective tubes 102", 104" adjacent ends of the IHX 100", wherein the thickness of the ribs 400, 410 at each of the ends is narrower than the thickness of the ribs 400, 410 between the ends.

The inner tube 414 shown has an outer diameter D1,3 of about 6 mm and an inner diameter D1,4 of about 4 mm. It is understood that the inner tube 414 can have any shape and size as desired. The inner tube 414 increases a surface area exposed to the fluid flowing therethrough, thereby further facilitating the heat transfer between the fluids. The inner tube 414 has a generally smooth outer surface 412 and inner surface 422. The inner surface 422 of the inner tube 414 defines a fluid channel 424. In a non-limiting example, the fluid channel 424 has a generally circular cross-sectional shape and receives the second fluid therein. It is understood that the fluid channel 424 can have any shape and receive other fluids if desired. A cumulative cross-sectional flow area of the fluid channels 402, 424 is greater than a cumulative cross-sectional flow area of the fluid channels 406.

FIG. 10 shows an internal heat exchanger according to another embodiment of the invention. Reference numerals for similar structure in respect of the discussion of FIGS. 1-9 above are repeated with a prime (") symbol. The IHX 100" shown includes an outer tube 102" and an inner tube 104". The inner tube 104" is coaxially arranged within the outer tube 102" in respect of a central axis of the IHX 100". The central axis of the IHX 100" is substantially the same as a central axis of the outer tube 102" and a central axis of the inner tube 104". Each of the tubes 102", 104" shown is a
separate component. It is understood that the tubes 102", 104" can be formed by any process as desired such as an extrusion process, for example. It is further understood that the tubes 102", 104" can be formed from any suitable material to facilitate heat transfer such as a steel material, a stainless steel material, a copper material, or a plastic material, for example. In a non-limiting example, the tubes 102", 104" are formed from an aluminum material to minimize cost and a weight of the IIX 100", and to maximize a heat conductivity and a formability thereof. The outer tube 102" shown has an outer diameter D₁", of about 27 mm and an inner diameter D₂", of about 23 mm. It is understood, however, that the outer tube 102" can have any size and shape as desired. The outer tube 102" has a generally smooth outer surface 140" and a generally smooth inner surface 142".

Conversely, an outer surface 144" of the inner tube 104" includes at least one heat conductive feature such as an annular array of elongate ribs 146" formed thereon and extending substantially parallel to the central axis of the IIX 100". In a non-limiting example, the outer surface 144" includes twenty (20) ribs 146" formed thereon. Additional or fewer ribs 146" than shown can be employed if desired. Each of the ribs 146" can have any cross-sectional shape as desired such as a square cross-sectional shape, a triangular cross-sectional shape, or a trapezoidal cross-sectional shape, for example. An outer diameter of the inner tube 104" defined by a nose portion 148" of the ribs 146" is slightly smaller than the inner diameter D₂", of the outer tube 102" to permit the inner tube 104" to be easily disposed within the outer tube 102", during an assembly of the tubes 102", 104". It is understood that the tubes 102", 104" can be assembled by any process as desired such as by a manual assembly process, for example. The nose portion 148" of the ribs 146" may be radiaised if desired. The ribs 146" shown are circumferentially spaced apart at a substantially uniform predetermined interval forming a plurality of fluid channels 150", 240", and minimize the pressure drop of the fluids. The thickness of the ribs 146", 140" may be gradually decreased at ends of the respective tubes 102", 104" adjacent ends of the IIX 100", wherein the thickness of the ribs 146", 140" at each of the ends is narrower than the thickness of the ribs 146", 140" between the ends.

The inner tube 144", 140", is about 1.0 mm or less to maximize a cross-sectional flow area of the fluid channels 150", 240", and minimize the pressure drop of the fluids. The thickness of the ribs 146", 140" may be gradually decreased at ends of the respective tubes 102", 104" adjacent ends of the IIX 100", wherein the thickness of the ribs 146", 140" at each of the ends is narrower than the thickness of the ribs 146", 140" between the ends.

The inner tube 144", 140", shown has an outer diameter D₁", of about 6 mm and an inner diameter D₂", of about 4 mm. It is understood that the inner tube 144" can have any shape and size as desired. The inner tube 144" has a generally smooth outer surface 144" and an inner surface 142". At least one heat conductive feature such as an annular array of elongate ribs 410", for example, is formed between the inner surface 154" of the inner tube 144" and an outer surface 412" of a second inner tube 414". The second inner tube 414" is coaxially arranged within the inner tube 104" in respect of the central axis of the IIX 100". The central axis of the IIX 100" is substantially the same as a central axis of the second inner tube 414".

The ribs 410" are formed to extend substantially parallel to and radially outwardly from the central axis of the IIX 100". Corners 416", formed where the ribs 410" transition to the inner surface 154" of the inner tube 104" and corners 418", formed where the ribs 410" transition to the outer surface 412" of the inner tube 414", can be radiaised if desired. In a non-limiting example, the IIX 100" includes ten (10) ribs 410" formed between the tubes 104", 414". Additional or fewer ribs 410" than shown can be employed if desired. A ratio of a number of ribs 410" formed between the inner tubes 104", to a number of ribs 414" formed between the tubes 102", 104" can be any ratio as desired to maximize a heat exchange between the fluids and minimize a pressure drop of the fluids such as a 1:2 ratio, for example.

The ribs 410" shown are circumferentially spaced apart at a substantially uniform predetermined interval forming a plurality of fluid channels 420", therebetween. It is understood that the ribs 410" can be circumferentially spaced apart at any uniform or non-uniform interval as desired. In addition to facilitating heat transfer between the fluids, the ribs 410" provide support to the tubes 102", 104", 414" when the IIX 100" is bent and shaped during a manufacturing thereof. In a non-limiting example, ten (10) substantially wedge-shaped fluid channels 420" for receiving the second fluid therein are formed by the ribs 410". It is understood that additional or fewer fluid channels 420" than shown can be employed if desired. It is further understood that the fluid channels 420" can have any shape and size, and receive other fluids therein, if desired.

In a non-limiting example, a thickness of the ribs 146", 410" is about 1.0 mm or less to maximize a cross-sectional flow area of the fluid channels 150", 420", and minimize the pressure drop of the fluids. The thickness of the ribs 146", 410" may be gradually decreased at ends of the respective tubes 102", 104" adjacent ends of the IIX 100", wherein the thickness of the ribs 146", 410" at each of the ends is narrower than the thickness of the ribs 146", 410" between the ends
be formed by any process as desired such as an extrusion process, for example. It is further understood that the tubes 102””, 104”” can be formed from any suitable material to facilitate heat transfer such as a steel material, a stainless steel material, a copper material, or a plastic material, for example. In a non-limiting example, the tubes 102””, 104”” are formed from an aluminum material to minimize cost and a weight of the IHX 100”” and to maximize a heat conductivity and a formability thereof. The outer tube 102”” shown has an outer diameter D1”” of about 27 mm. The outer tube 102”” has a generally smooth outer surface 140””. An inner surface 142”” of the outer tube 102”” includes at least one heat conductive feature such as an annular array of elongate ribs 300”” formed thereon and extending substantially parallel to the central axis of the IHX 100””. In a non-limiting example, the inner surface 142”” includes twenty (20) ribs 300”” formed thereon. Additional or fewer ribs 300”” than shown can be employed if desired.

[0067] Each of the ribs 300”” can have any cross-sectional shape as desired such as a square cross-sectional shape, a triangular cross-sectional shape, or a trapezoidal cross-sectional shape, for example. An inner diameter D11”” of the outer tube 102”” defined by a nose portion 302”” of the ribs 300”” is slightly larger than an outer diameter of the inner tube 104”” to permit the inner tube 104”” to be easily disposed within the outer tube 102”” during an assembly of the tubes 102””, 104””. It is understood that the tubes 102””, 104”” can be assembled by any process as desired such as by a manual assembly process, for example. The nose portion 302”” of the ribs 300”” may be radiused if desired. In a non-limiting example, the inner diameter D11”” is about 21 mm and an inner diameter D2”” of the outer tube 102”” defined by the inner surface 142”” thereof is about 23 mm. It is understood that the inner tube 102”” can have any shape and size as desired.

[0068] The ribs 300”” shown are circumferentially spaced apart at a substantially uniform predetermined interval forming a plurality of fluid channels 306”” between the outer tube 102”” and the inner tube 104””. It is understood, however, that the ribs 300”” can be circumferentially spaced apart at any uniform or non-uniform interval as desired. In a non-limiting example, twenty (20) fluid channels 306”” are formed between the tubes 102””, 104”” for receiving the first fluid therein. Additional or fewer fluid channels 306”” than shown can be employed if desired. Each of the fluid channels 306”” shown has a substantially rectangular cross-sectional shape. It is understood that the fluid channels 306”” can have any cross-sectional shape as desired. Corners 308”” of the fluid channels 306”” formed by the ribs 300”” and the inner surface 142”” of the outer tube 102”” may be radiused if desired.

[0069] The inner tube 104”” shown has an outer diameter D12”” of about 21 mm and an inner diameter D2”” of about 18 mm. It is understood that the inner tube 104”” can have any shape and size as desired. The inner tube 104”” has a generally smooth outer surface 144”” and inner surface 154””. At least one heat conductive feature such as an annular array of elongate ribs 410””, for example, is formed between the inner surface 154”” of the inner tube 104”” and an outer surface 412”” of a second inner tube 414””. The second inner tube 414”” is coaxially arranged within the inner tube 104”” in respect of the central axis of the IHX 100””. The central axis of the IHX 100”” is substantially the same as a central axis of the second inner tube 414””.

[0070] The ribs 410”” are formed to extend substantially parallel to and radially outwardly from the central axis of the IHX 100””. Corners 416””, formed where the ribs 410”” transition to the inner surface 154”” of the inner tube 104””, and corners 418””, formed where the ribs 410”” transition to the outer surface 412”” of the inner tube 414””, can be radiused if desired. In a non-limiting example, the IHX 100”” includes ten (10) ribs 410”” formed between the tubes 104””, 414””. Additional or fewer ribs 410”” than shown can be employed if desired. A ratio of a number of ribs 410”” formed between the inner tubes 104””, 414”” to a number of ribs 146”” formed between the tubes 102””, 104”” can be any ratio as desired to maximize a heat exchange between the fluids and minimize a pressure drop of the fluids such as a 1:2 ratio, for example.

[0071] The ribs 410”” shown are circumferentially spaced apart at a substantially uniform predetermined interval forming a plurality of fluid channels 420”” therebetween. It is understood that the ribs 410”” can be circumferentially spaced apart at any uniform or non-uniform interval as desired. In addition to facilitating heat transfer between the fluids, the ribs 410”” provide support to the tubes 102””, 414”” when the IHX 100”” is bent and shaped during a manufacturing thereof. In a non-limiting example, ten (10) substantially wedge-shaped fluid channels 420”” for receiving the second fluid therein are formed by the ribs 410””. It is understood that additional or fewer fluid channels 420”” than shown can be employed if desired. It is further understood that the fluid channels 420”” can have any shape and size, and receive other fluids therein, if desired.

[0072] In a non-limiting example, a thickness of the ribs 300””, 410”” is about 1.0 mm or less to maximize a cross-sectional flow area of the fluid channels 306””, 420”” and minimize the pressure drop of the fluids. The thickness of the ribs 300””, 410”” may be gradually decreased at ends of the respective tubes 102””, 104”” adjacent ends of the IHX 100””, wherein the thickness of the ribs 146””, 410”” at each of the ends is narrower than the thickness of the ribs 146””, 410”” between the ends.

[0073] The inner tube 414”” shown has an outer diameter D12”” of about 6 mm and an inner diameter D2”” of about 4 mm. It is understood that the inner tube 414”” can have any shape and size as desired. The inner tube 414”” increases a surface area exposed to the fluid flowing therethrough, thereby further facilitating the heat transfer between the fluids. The inner tube 414”” has a generally smooth outer surface 412”” and inner surface 422””. The inner surface 422”” of the inner tube 414”” defines a fluid channel 424””. In a non-limiting example, the fluid channel 424”” has a generally circular cross-sectional shape and receives the second fluid therein. It is understood that the fluid channel 424”” can have any shape and receive other fluids if desired. A cumulative cross-sectional flow area of the fluid channels 420””, 424”” is greater than a cumulative cross-sectional flow area of the fluid channels 306””.

[0074] An operation of the air conditioning system 10 including the IHX 100”” is substantially similar to an operation of the air conditioning system 10 including at least one of the IHXs 100”, 100”, 100”, 100”, 100”. Therefore, for simplicity, only the operation of the air conditioning system 10 including the IHX 100”” is described hereinafter.

[0075] During the operation of the air conditioning system 10, a low pressure vapor refrigerant flowing from the evaporator 18 is received into the compressor 12 and compressed
into a high pressure, high temperature vapor refrigerant. The high pressure, high temperature vapor refrigerant is then discharged from the compressor 12 and is received into the condenser 14. Within condenser 14, the high pressure, high temperature vapor refrigerant is caused to condense into a relatively high temperature, high pressure liquid refrigerant by transferring heat to the ambient air. The relatively high temperature, high pressure liquid refrigerant then flows through the fluid channels 150 formed between the tubes 102, 104 of the IHX 100 and is cooled. Thereafter, the cooled high pressure liquid refrigerant flows through the expansion device 16 and is caused to expand into a low pressure liquid refrigerant. The expansion device 16 regulates the flow of the cool low pressure liquid refrigerant to the evaporator 18. In the air conditioning system 10, the evaporator 18 is located in a passenger compartment of the vehicle. Within the evaporator 18, the cool low pressure liquid refrigerant absorbs heat from the passenger compartment of the vehicle and is caused to evaporate into a relatively low temperature, low pressure vapor refrigerant. The relatively low temperature, low pressure vapor refrigerant then flows from the evaporator into the fluid channels 164 of the inner tube 104 of the IHX 100. A direction of flow of the relatively low temperature, low pressure vapor refrigerant is counter to a direction of flow of the relatively high temperature, high pressure liquid refrigerant flowing through the fluid channels 150.

Within the IHX 100, the relatively low temperature, low pressure vapor refrigerant absorbs heat from the relatively high temperature, high pressure liquid refrigerant. Accordingly, the low pressure vapor refrigerant is heated and the high pressure liquid refrigerant is cooled. Thereafter, the heated low pressure vapor refrigerant flows to the compressor 12 to be compressed, and the cooled high pressure liquid refrigerant flows to the expansion device 16 as described hereinabove. The heat conductive features such as the ribs 146, 156 of the IHX 100 increase a surface area of the tubes 102, 104 exposed to the fluids flowing through the IHX 100. As a result, a performance of the IHX 100 (e.g., an amount of heat exchanged between the fluids) and an efficiency of the IHX 100 (e.g., a rate at which the heat exchange occurs) are maximized. Because of the maximized efficiency and performance of the IHX 100, a size, particularly a length of the IHX 100, and a weight thereof can be minimized.

From the foregoing description, one ordinarily skilled in the art can easily ascertain the essential characteristics of this invention and, without departing from the spirit and scope thereof, make various changes and modifications to the invention to adapt it to various usages and conditions.

What is claimed is:

1. A heat exchanger comprising:
   an outer tube including at least one fluid channel formed therein, wherein the at least one fluid channel receives a first fluid therein; and
   a first inner tube arranged within the outer tube, the first inner tube including at least one fluid channel formed therein, wherein the at least one fluid channel receives a second fluid therein, and wherein a cross-sectional flow area of the at least one fluid channel of the first inner tube is greater than a cross-sectional flow area of the at least one fluid channel of the outer tube.

2. The heat exchanger according to claim 1, further comprising at least one heat conductive feature formed between the outer tube and the first inner tube.

3. The heat exchanger according to claim 1, wherein the first inner tube includes at least one heat conductive feature formed on an inner surface thereof.

4. The heat exchanger according to claim 1, further comprising a second inner tube arranged within the first inner tube, the second inner tube including at least one fluid channel formed therein.

5. The heat exchanger according to claim 4, further comprising at least one heat conductive feature formed between the first inner tube and the second inner tube.

6. The heat exchanger according to claim 1, wherein the first fluid is a liquid refrigerant and the second fluid is a vapor refrigerant.

7. A heat exchanger, comprising:
   an outer tube including at least one fluid channel formed therein, wherein the at least one fluid channel receives a first fluid therein;
   a first inner tube arranged within the outer tube, the first inner tube including at least one fluid channel formed therein, wherein the at least one fluid channel receives a second fluid therein, and wherein a cross-sectional flow area of the at least one fluid channel of the first inner tube is greater than a cross-sectional flow area of the at least one fluid channel of the outer tube; and
   a first plurality of heat conductive features formed on an inner surface of the first inner tube.

8. The heat exchanger according to claim 7, wherein the heat conductive features are circumferentially spaced apart at a predetermined interval.

9. The heat exchanger according to claim 7, wherein a thickness of the heat conductive features gradually decreases at ends of the heat exchanger.

10. The heat exchanger according to claim 7, wherein a height of the heat conductive features gradually decreases at ends of the heat exchanger.

11. The heat exchanger according to claim 7, further comprising a first plurality of heat conductive features formed between the outer tube and the first inner tube.

12. The heat exchanger according to claim 11, wherein a number of the heat conductive features formed between the outer tube and the first inner tube is greater than a number of the heat conductive features formed on the inner surface of the first inner tube.

13. The heat exchanger according to claim 7, further comprising a second plurality of heat conductive features formed on an inner surface of the first inner tube, wherein a height of the second plurality of heat conductive features formed on the inner surface of the first inner tube is less than a height of the first plurality of heat conductive features formed thereon.

14. The heat exchanger according to claim 13, further comprising a third plurality of heat conductive features formed on an inner surface of the first inner tube, wherein a height of the third plurality of heat conductive features formed on the inner surface of the first inner tube is less than a height of the second plurality of heat conductive features formed thereon.

15. The heat exchanger according to claim 14, wherein a number of the heat conductive features formed between the outer tube and the first inner tube is less than a number of the heat conductive features formed on the inner surface of the first inner tube.
16. A heat exchanger, comprising:
an outer tube including at least one fluid channel formed
therein, wherein the at least one fluid channel receives a
first fluid therein;
a first inner tube arranged within the outer tube, the first
inner tube including at least one fluid channel formed
therein, wherein the at least one fluid channel receives a
second fluid therein;
a second inner tube arranged within the first inner tube, the
second inner tube including at least one fluid channel
formed therein, wherein the at least one fluid channel
receives the second fluid therein; and
a plurality of heat conductive features formed between the
first inner tube and the second inner tube.
17. The heat exchanger according to claim 16, wherein a
cumulative cross-sectional flow area of the fluid channels of
the inner tubes is greater than a cumulative cross-sectional
flow area of the at least one fluid channel of the outer tube.
18. The heat exchanger according to claim 16, wherein the
heat conductive features formed between the first inner tube
and the second inner tube are circumferentially spaced apart
at a predetermined interval.
19. The heat exchanger according to claim 16, further
comprising a first plurality of heat conductive features formed
between the outer tube and the first inner tube.
20. The heat exchanger according to claim 19, wherein a
number of the heat conductive features formed between the
outer tube and the first inner tube is greater than a number of
the heat conductive features formed on the inner surface of the
first inner tube.

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