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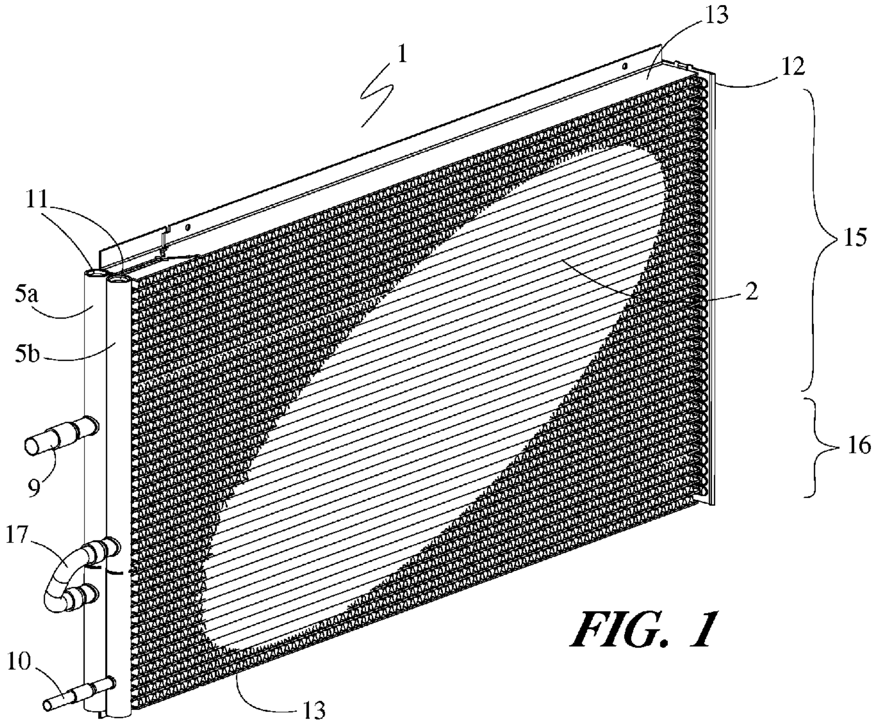

FIG. 1

(57) **Abstract:** A refrigerant condenser provides improved subcooling performance for zeotropic refrigerants. The condenser has flat tube sections arranged into a first row and a second row, with each one of the flat tube sections of the second row hydraulically connected to a corresponding flat tube section of the first row. Ends of the flat tube sections of the first row are received into one cylindrical header pipe, and ends of the flat tube sections of the second row are received into another cylindrical header pipe. Four fluid manifolds are arranged within the two header pipes, with ends of the flat tube sections extending into the fluid manifolds. A connecting tube extends between a fluid manifold in one cylindrical header pipe and a fluid manifold in the other cylindrical header pipe.

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REFRIGERANT CONDENSER

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to United States provisional patent application no. 62/779,598, filed on December 14, 2018, the entire contents of which are hereby incorporated by reference in their entirety.

TECHNICAL FIELD

[0002] The present application relates to heat exchangers for use in refrigerant systems, including refrigerant evaporators and condensers, and relates particularly to such heat exchangers as used in vapor compression systems.

BACKGROUND

[0003] Vapor compression systems are commonly used for refrigeration and/or air conditioning, among other uses. In a typical vapor compression system, a refrigerant, is circulated through a continuous thermodynamic cycle in order to transfer heat energy to or from a temperature and/or humidity controlled environment and from or to an uncontrolled ambient environment. While such vapor compression systems can vary in their implementation, they most often include at least one heat exchanger operating as an evaporator, and at least one other heat exchanger operating as a condenser.

[0004] In systems of the aforementioned kind, a refrigerant typically enters the evaporator at a thermodynamic state (i.e., a pressure and enthalpy condition) in which it is a subcooled liquid or a partially vaporized two-phase fluid of relatively low vapor quality. Thermal energy is directed into the refrigerant as it travels through the evaporator, so that the refrigerant exits the evaporator as a superheated vapor.

[0005] The superheated vapor refrigerant is compressed to a high pressure and, at another point in the system, enters the condenser. Thermal energy is rejected from the refrigerant as it travels through the condenser, so that the refrigerant exits the condenser in an at least partially condensed condition. Most preferably the refrigerant exits the condenser as a fully condensed, subcooled liquid. The liquid refrigerant is subsequently expanded to the lower pressure thermodynamic state at which it enters the evaporator.

[0006] A variety of refrigerants can be used within such a vapor compression system, including chlorofluorocarbons, hydrochlorofluorocarbons, hydrofluorocarbons, hydrocarbons, organic refrigerants, and others. While chlorofluorocarbons such as R12 and hydrochlorofluorocarbons such as R22 were once popular refrigerants, their use has been restricted due to their ozone depletion effects on the earth's atmosphere. In their stead, hydrofluorocarbons (which are not ozone-depleting) became more prevalent. In recent years, however, the use of such refrigerants has also been restricted by legislation and regulation due to their high global warming potential. Improvements in vapor compression systems and components that were previously optimized for such refrigerants have become necessary in order to achieve optimum performance with the use of newer low global warming potential refrigerants.

[0007] Low global warming potential refrigerants are often formulated as a zeotropic mixture of several refrigerant components that are themselves azeotropic. During evaporation and condensation of such a refrigerant, the various constituent refrigerants will vaporize or condense at different rates, resulting in a non-constant evaporation or condensation temperature at a constant pressure. The temperature glide is referred to as the change in saturation temperature, at constant pressure, as the refrigerant varies between fully vapor and fully liquid. A typical temperature glide within a condenser for a low global warming potential refrigerant can be more than ten degrees Fahrenheit, with the liquid saturation temperature at the condensing pressure being that amount lower than the vapor saturation temperature at that pressure. This temperature glide tends to make the condenser less efficient, as the reduced temperature of the liquid condensate makes the further removal of heat from the refrigerant more challenging.

SUMMARY

[0008] A refrigerant condenser includes flat tube sections arranged into a first row and a parallel second row, with a one-to-one correspondence between the flat tube sections of the first row and the flat tube sections of the second row. Each one of the flat tube sections of the second row is hydraulically connected to the corresponding flat tube section of the first row at one end of the refrigerant condenser. At the opposing end of the refrigerant condenser are two cylindrical header pipes. Ends of the flat tube sections of the first row are received into one cylindrical header pipe, and ends of the flat tube sections of the second row are received into the other cylindrical header pipe. Four fluid manifolds are arranged within the two header pipes, with ends of the flat tube sections extending into the fluid manifolds. A connecting tube extends between a fluid manifold in one cylindrical header pipe and a fluid manifold in the other cylindrical header pipe.

[0009] In at least some embodiments, each cylindrical header pipe contains two fluid manifolds. A first subset of the flat tube sections of the first row extend into the first fluid manifold and a second subset of the flat tube sections of the first row extend into the second fluid manifold. A first subset of the flat tube sections of the second row extend into the third fluid manifold and a second subset of the flat tube sections of the second row extend into the fourth fluid manifold. The first subset of the second row corresponds to the first subset of the first row, and the second subset of the second row corresponds to the seconds subset of the first row. In some such embodiments the connecting tube extends between the second fluid manifold and the third fluid manifold.

[0010] In some embodiments the first subset of the flat tube sections of the first row defines a first refrigerant pass through the refrigerant condenser, the first subset of the flat tube sections of the second row defines a second refrigerant pass, the second subset of the flat tube sections of the first row defines a third refrigerant pass, and the second subset of the flat tube sections of the second row defines a fourth refrigerant pass through the condenser. Refrigerant flows sequentially through the first, second, third, and fourth passes.

[0011] In at least some embodiments, the refrigerant condenser includes a condenser section and a subcooler section. In some such embodiments the third and fourth refrigerant passes define the subcooler section.

[0012] Some embodiments include a refrigerant inlet that is connected to the first fluid manifold, and a refrigerant outlet that is connected to the fourth fluid manifold.

[0013] In some embodiments, a return header is arranged the end of the refrigerant condenser opposite the cylindrical header pipes. The return header fluidly connects corresponding ones of the first and second rows of flat tube sections. In other embodiments each of the corresponding flat tube sections is part of a single flat tube that has been bent and/or twisted to define the two parallel flat sections.

[0014] In at least some embodiments each flat tube section of the first row is hydraulically connected to exactly one flat tube section of the second row at the end opposite the cylindrical header pipes.

[0015] In some embodiments, the first and the second fluid manifolds are separated from each other by a baffle that is arranged within one cylindrical header pipe, and the third and the fourth fluid manifolds are separated from each other by a baffle that is arranged within the other cylindrical header pipe.

[0016] In some embodiments, the connecting tube has a first end that extends through the cylindrical wall of one header pipe and a second end that extends through the cylindrical wall of the other header pipe. In some other embodiments at least one of the ends extends through an end cap of one of the cylindrical header pipes.

[0017] In at least some embodiments one or both ends of the connecting tube are defined by a fitting that is part of the connecting tube.

[0018] A refrigerant condenser according to another aspect of the invention includes a first and a second cylindrical header pipe. The first and second cylindrical header pipes are arranged at a common end of the condenser. A first flow baffle is arranged within the first cylindrical header pipe to separate an internal volume of the first cylindrical header pipe into a first fluid manifold and a second fluid manifold. A second flow baffle is arranged within the second cylindrical header pipe to separate an internal volume of the second cylindrical header pipe into a third fluid manifold and a fourth fluid manifold. The third fluid manifold is arranged adjacent to the first fluid manifold, and the fourth fluid manifold is arranged adjacent to the second fluid manifold.

[0019] The refrigerant condenser can include a first set of refrigerant conduits that provide a refrigerant flow path between the first fluid manifold and the third fluid manifold, and a second set of refrigerant conduits that provide a refrigerant flow path between the second fluid manifold and the fourth fluid manifold. In some embodiments, each one of the first and second sets of refrigerant conduits includes a first flat tube section with an end that is sealingly received into the first cylindrical header pipe, and a second flat tube section with an end that is sealingly received into the second cylindrical header pipe.

[0020] The refrigerant condenser can also include a refrigerant inlet port connected to the first cylindrical header pipe and in direct fluid communication with the first fluid manifold, and a refrigerant outlet port connected to the second cylindrical header pipe and in direct fluid communication with the fourth fluid manifold. Refrigerant can enter the condenser through the refrigerant inlet port, and can exit the condenser through the refrigerant outlet port. Between the refrigerant inlet port and the refrigerant outlet port, the refrigerant can be directed to flow through the first and second sets of refrigerant conduits.

[0021] The refrigerant condenser can also include a connecting tube that connects the first and second cylindrical headers and that forms part of the refrigerant flow path between the inlet port and the outlet port. A first end of the connecting tube can be joined to the first cylindrical header pipe and can be in direct fluid communication with the second fluid manifold. A second end of the connecting tube can be joined to the second cylindrical header piper and can be in direct fluid communication with the third fluid manifold.

[0022] In some embodiments, the first end of the connecting tube is arranged adjacent to the first baffle. In some embodiments, the second end of the connecting tube is arranged adjacent to the second baffle. In some embodiments, the first end of the connecting tube is arranged adjacent to the first baffle and the second end of the connecting tube is arranged adjacent to the second baffle.

[0023] Each of the first and second sets of refrigerant conduits can include a first flat tube section with an end that is sealingly received into the first cylindrical header pipe and a second flat tube section with an end that is sealingly received into the second cylindrical header pipe. The refrigerant condenser can have a return header arranged at an end of the refrigerant condenser opposite the first and second cylindrical header pipes. Ends of the first and second flat tube sections of each of the refrigerant conduits can be sealingly received into the return header. The return header can provide a fluid connection between the first and second flat tube sections of each refrigerant conduit.

[0024] The first and second cylindrical header pipes can be arranged vertically when the refrigerant condenser is in an operating condition. The arrangement can be such that the second and the fourth fluid manifolds are arranged below the first and the third fluid manifolds.

BRIEF DESCRIPTION OF THE DRAWINGS

[0025] FIG. 1 is a perspective view of a refrigerant condenser according to some embodiments of the invention.

[0026] FIG. 2 is a planar section view through the refrigerant condenser of FIG. 1, depicting the flow of fluids through the refrigerant condenser.

[0027] FIG. 3 is a portion of FIG. 1 shown in greater detail.

[0028] FIG. 4 is a partial exploded view of select components of the refrigerant condenser of FIG. 1.

[0029] FIG. 5 is another planar section view through the refrigerant condenser of FIG. 1.

DETAILED DESCRIPTION

[0030] Before any embodiments of the invention are explained in detail, it is to be understood that the invention is not limited in its application to the details of construction and the arrangement of components set forth in the following description or illustrated in the accompanying drawings. The invention is capable of other embodiments and of being practiced or of being carried out in various ways. Also, it is to be understood that the phraseology and terminology used herein is for the purpose of description and should not be regarded as limiting. The use of “including,” “comprising,” or “having” and variations thereof herein is meant to encompass the items listed thereafter and equivalents thereof as well as additional items. Unless specified or limited otherwise, the terms “mounted,” “connected,” “supported,” and “coupled” and variations thereof are used broadly and encompass both direct and indirect mountings, connections, supports, and couplings. Further, “connected” and “coupled” are not restricted to physical or mechanical connections or couplings.

[0031] A refrigerant condenser 1 for use in a vapor-compression refrigeration system is depicted in FIG. 1. Such a vapor-compression refrigeration system can be used for comfort cooling applications, as one non-limiting example. The refrigerant condenser 1 can be particularly well-suited for such an application, wherein the refrigerant is compressed from a low-pressure vapor to a high-pressure vapor and is subsequently cooled and condensed to a sub-cooled liquid state within the refrigerant condenser 1. In other applications wherein such a condenser may be equally useful, such as for example freezing, refrigeration, process cooling, etc., the same principle can be used.

[0032] Various types of refrigerants can be suitable for use in a refrigeration system employing the refrigerant condenser 1, including but not limited to chlorofluorocarbons, hydrofluorocarbons, hydrocarbons, organic refrigerants, etc. As will be described hereafter, the refrigerant condenser 1 is especially suitable for use with refrigerants that exhibit a high glide behavior. Unlike azeotropic refrigerants, which have a single saturation temperature for any given pressure value, a high glide refrigerant will have a saturation temperature that varies as the refrigerant transitions from fully vapor to fully liquid, or vice-versa, even when the pressure value is held constant. That variance in saturation temperature is commonly referred to as the “temperature glide” of the refrigerant. Refrigerants with a high glide behavior (i.e. with a large variance in saturation temperature from being fully liquid to being fully vapor) are becoming increasingly more prevalent due to their decreased global warming potential in comparison to the more traditional azeotropic refrigerants.

[0033] The refrigerant condenser 1 is constructed using a core 2 of alternating tube sections 3 and serpentine air fins 4. The tube sections 3 are provided by flat tubes with internal flow passages by way of which the refrigerant is conveyed through the condenser 1. The air fins 4 are constructed from corrugated sheet material and are arranged between adjacent ones of the flat tube sections 3. Crests of the fins 4 are bonded to the flat surfaces of the tube sections 3 in order to efficiently transfer heat from the refrigerant passing through the tube sections 3 to a flow of cooling air that is directed through the air fins 4 in a direction generally perpendicular to the flow of refrigerant through the tube sections 3. The tube sections 3 and air fins 4 are preferably constructed from aluminum alloys, and are joined together by a brazing operation.

[0034] The tube sections 3 are arranged to form two parallel rows 20, 21 of tube sections. Each of the two rows 20, 21 are defined by a like number of tube sections, so that tube sections 3 of the first row 20 are in one-to-one correspondence with tube sections 3 of the second row 21. The flat tube sections 3 all extend from a first end 25 of the condenser 1 to a second opposing end 26. At the second end 26, each flat tube section of the row 20 is hydraulically connected to the corresponding flat tube section of the row 21. In this manner, each of the flat tube sections 3 of the second row 21 is serially connected with exactly one of the flat tube sections 3 of the first row 20, so that the refrigerant flowing through a given one of the flat tube sections of the first row 20 subsequently flow through the corresponding flat tube section of the second row 21.

[0035] In the exemplary embodiment, the hydraulic connections between the flat tube sections 3 of the first row 20 and the flat tube sections 3 of the second row 21 are accomplished through the use of a flat return header 12. Such a flat header 12 has been previously described in United States Patent No. 8,776,873, which is herein incorporated by reference, in its entirety. In an alternative embodiment that is not depicted, both members of a pair of corresponding flat tube sections 3 can be provided by a single flat tube which is bent and/or twisted to define the two parallel arranged flat tube sections 3.

[0036] The flat surfaces of corresponding ones of the flat tube sections 3 are preferably arranged to be co-planar with one another, so that a single corrugated fin 4 can extend across, and be joined to, the flat tube sections of both rows 20, 21. Alternatively, individual corrugated fin sections can be provided for each of the rows 20 and 21.

[0037] Two cylindrical header pipes 5 are arranged at the first end 25 of the condenser 1. Each of the cylindrical header pipes 5 is provided with a series of tube slots 6 that are formed into the cylindrical wall surface of the header pipe 5. Ends of those ones of the flat tube sections 3 that make up the first row 20 are received into the tube slots 6 of a first one of the cylindrical header pipes 5a, while ends of those ones of the flat tube sections 3 that make up the second row 21 are received into the tube slots 6 of a second one of the cylindrical header pipes 5b. The tube sections 3 are thereby placed in fluid communication with fluid manifolds 14 that are arranged within the cylindrical header pipes 5.

[0038] Each of the cylindrical header pipes 5 is further provided with a baffle 8 that is received into a baffle slot 7 formed into the cylindrical wall of the header pipe 5. The baffle slot 7 is preferably arranged between two adjacent ones of the tube slots 6. During the brazing of the condenser 1, the baffle 8 is sealingly joined to the cylindrical header pipe 5 to divide the internal volume of the cylindrical header pipe 5 into two hydraulically separated fluid manifolds 14. Preferably, the baffles 8 of both of the cylindrical header pipes 5a, 5b are arranged at an equivalent location along the axial lengths of the header pipes 5.

[0039] Side plates 13 are joined to the core 2 at opposing ends of the condenser 1 in the axial direction of the cylindrical header pipes 5. End caps 11 are received into the open ends of the cylindrical header pipes 5 in order to close off the manifolds 14.

[0040] A refrigerant inlet 9 is connected to cylindrical header pipe 5a, i.e. the cylindrical header pipe 5 that receives the ends of the flat tube sections 3 of the first row 20. The refrigerant inlet 9 is arranged along the axial length of the cylindrical header pipe 5a at a location that is partway between the baffle 8 of the cylindrical header pipe 5a and a first one of the side plates 13. During operation of the vapor compression system into which the refrigerant condenser 1 is integrated, a flow of compressed and superheated refrigerant is directed through the refrigerant inlet port 9 into a fluid manifold 14a within that cylindrical header pipe 5a, the fluid manifold 14a being that portion of the internal volume of the cylindrical header pipe 5a between the baffle 8 and the end cap 11 adjacent that first one of the side plates 13.

[0041] A refrigerant outlet 10 is similarly connected to cylindrical header pipe 5b, i.e. the cylindrical header pipe 5 that receives the ends of the flat tube sections 3 of the second row 21. The refrigerant outlet 10 is arranged along the axial length of the cylindrical header pipe 5b at a location that is partway between the baffle 8 of the cylindrical header pipe 5b and a second one of the side plates 13, that second one of the side plates 13 being the side plate 13 arranged at the opposite end, in the axial direction of the cylindrical header pipes 5, from the first one of the side plates 13. During operation of the vapor compression system into which the refrigerant condenser 1 is integrated, the flow of refrigerant, having been condensed and subcooled to a liquid phase, is removed from a fluid manifold 14d by way of the refrigerant outlet 10, the fluid manifold 14d being that portion of the internal volume of the cylindrical header pipe 5b between the baffle 8 and the end cap 11 adjacent that second one of the side plates 13.

[0042] As can be seen in FIG. 5, the remainder of the internal volume of the cylindrical header pipe 5a defines a fluid manifold 14c. Similarly, the remainder of the internal volume of the cylindrical header pipe 5b defines a fluid manifold 14b. A connecting tube 17 is joined to both of the cylindrical header pipes 5 to provide a fluid connection between the fluid manifold 14b and the fluid manifold 14c. The connecting tube includes an end fitting 18 arranged at one end of the connecting tube 17, and an end fitting 19 arranged at the opposite end of the connecting tube 17. These end fittings 18, 19 can be considered as part of the connecting tube 17.

[0043] The connecting tube 17 is joined to the cylindrical header pipe 5b by way of the first end fitting 18, and is joined to the cylindrical header pipe 5a by way of the second end fitting 19. In some embodiments it may be especially preferable for both end fittings 18 and 19 to be arranged in close proximity to their respective cylindrical header pipe’s baffle 8, as depicted in FIGs. 1 and 3. In other embodiments it may be preferable for at least one of the end fittings 18, 19 to be arranged closer to an end cap 11 of the respective header pipe 5, or even to extend through one of the end caps 11.

[0044] The refrigerant condenser 1 includes a condenser section 15 and a subcooler section 16. During operation of the refrigerant condenser 1, the flow of refrigerant entering through the refrigerant inlet port 9 is first cooled and condensed to an at least partially liquid state within the condenser section 15. The liquid refrigerant is subsequently directed through the subcooler section 16 in order to be subcooled to a temperature that is below the saturation temperature of the refrigerant, and is removed as a subcooled liquid refrigerant through the refrigerant outlet port 10.

[0045] Each of the two sections 15, 16 include a pass 22 for the refrigerant and a pass 23 for the refrigerant, with the pass 23 being arranged downstream of the pass 22 with respect to the direction of refrigerant flow. As can be best seen in FIG. 2, the pass 22 is defined by a portion of the flat tube sections 3 of the first row 20, while the pass 23 is defined by a portion of the flat tube sections 3 of the second row 21. In especially preferable embodiments, the direction of the cooling air flow through the refrigerant condenser is such that the air passes first over the tube sections of the second row 21 and subsequently over the tube sections of the first row 20, as indicated by the arrows 24. In this way, the flow of refrigerant is in a cross-counter flow arrangement to the flow of air, leading to increased heat exchanger effectiveness. This is especially preferable when the refrigerant is a high glide refrigerant, since the temperature of the refrigerant in the pass 23 will in such cases be lower than the temperature of the refrigerant in the pass 22. Since the flow of air will tend to increase in temperature as it passes through the refrigerant condenser 1, the heat exchanger effectiveness will be higher when the air that is to receive heat from the lower temperature refrigerant (i.e. the refrigerant in the pass 23) has not yet been heated by receiving thermal energy from the higher temperature refrigerant in the pass 22.

[0046] The refrigerant passing through the refrigerant condenser 1 thus makes four total passes between the inlet 9 and the outlet 10. A first pass of the refrigerant is defined by a first subset of the flat tube sections 3 of the first row 20, that subset being those flat tube sections of the first row 20 that communicate directly with the fluid manifold 14a. A second pass of the refrigerant is defined by a first subset of the flat tube sections 3 of the second row 21, that subset being those flat tube sections of the second row 21 that communicate directly with the fluid manifold 14b. In other words, the first subset of the tube sections of the second row 21 are those tube sections that correspond with the first subset of the tube sections of the first row 20. In a similar fashion, the third pass of the refrigerant is defined by a second subset of the tube sections 3 of the first row 20 and the fourth pass of the refrigerant is defined by a second subset of the tube sections 3 of the second row 21. The second subset of the first row 20 includes those tube sections that communicate directly with the fluid manifold 14c, and the second of the second row 20 includes those tube sections that communicate directly with the fluid manifold 14d.

[0047] The condensing section 15 is defined by the first subsets of the tube sections 3, and the subcooler section 16 is defined by the second subsets of the tube sections 3. Accordingly, the first pass of refrigerant is a pass 22, the second pass of refrigerant is a pass 23, the third pass of refrigerant is again a pass 22, and the fourth pass of refrigerant is again a pass 23. In this manner, the arrangement of refrigerant flow to air flow can be a cross-counter flow arrangement in both the condensing section 15 and the subcooler section 16.

[0048] By virtue of the refrigerant being at least partially condensed within the condensing section 15, the refrigerant enters the fluid manifold 14b in an at least partially liquid state. It is most preferable during operation for the refrigerant condenser 1 to be arranged such that the axial direction of the cylindrical header pipes 5 is generally aligned with the force of gravity (i.e. a vertical arrangement), with the fluid manifolds 14a, 14b arranged above the fluid manifolds 14c, 14d. In this way, when the refrigerant exiting the second pass has a vapor quality of between 0 and 1 (i.e. is in a two-phase liquid-vapor state), the differing densities of the liquid and vapor phases will cause them to be separated from one another within the fluid manifold 14b, with the liquid portion occupying the bottom portion of the fluid manifold 14b and the vapor portion occupying the top portion of the fluid manifold 14b.

[0049] By arranging the fitting 18 close to the baffle 8 of the cylindrical header pipe 5b, the saturated liquid refrigerant collecting at the bottom of the fluid manifold 14b is directed through the connecting tube 17 to the fluid manifold 14c. From there, the saturated liquid refrigerant flows through the passes 22 and 23 and is thereby cooled from a saturated liquid state to a subcooled liquid state by the flow of air passing through the subcooler section 16. While the exemplary embodiment depicts both the fittings 18 and 19 as extending through a cylindrical wall of a header pipe 5, it may be preferable, in some alternative embodiments, to arrange the fitting 19 so that it extends through the bottom end cap 11 of the cylindrical header pipe 5a, in order to provide more optimal flow distribution of the refrigerant in the third and fourth flow passes.

[0050] The refrigerant condenser 1 can be installed so that the cylindrical heaper pipes 5 are arranged vertically, as is shown in FIG. 5. With such an arrangement, the fluid manifold 14a is arranged above the fluid manifold 14c, and the fluid manifold 14b is arranged above the fluid manifold 14d. During operation of the condenser, the refrigerant passes firs through the condenser section 15 (located in the upper portion) and subsequently though the subcooler section 16 (located in the lower portion). As the refrigerant is transferred through the connecting tube 17, the direction of refrigerant travel is aligned with the gravitational direction. The first end fitting 18 can be conveniently located adjacent to, and just above, the baffle 8 of the header pipe 5b. During operation, the liquid portion of the refrigerant exiting the first subsets of the tube sections 3 will collect by gravity in that region of the fluid manifold 14b that is immediately above the baffle 8. By locating the first end fitting 18 in that region, the refrigerant that is delivered to the subcooler section 16 by the connecting tube 17 will be mostly or completely liquid.

[0051] Various alternatives to the certain features and elements of the present invention are described with reference to specific embodiments of the present invention. With the exception of features, elements, and manners of operation that are mutually exclusive of or are inconsistent with each embodiment described above, it should be noted that the alternative features, elements, and manners of operation described with reference to one particular embodiment are applicable to the other embodiments.

[0052] The embodiments described above and illustrated in the figures are presented by way of example only and are not intended as a limitation upon the concepts and principles of the present invention. As such, it will be appreciated by one having ordinary skill in the art that various changes in the elements and their configuration and arrangement are possible without departing from the spirit and scope of the present invention.

What is claimed is:

1. A refrigerant condenser comprising:

a first plurality of flat tube sections arranged in a first row and extending from a first end of the refrigerant condenser to a second end of the refrigerant condenser;

a second plurality of flat tube sections arranged in a second row parallel to the first row and extending from the first end to the second end, the flat tube sections of the second plurality being in one-to-one correspondence with the flat tube sections of the first plurality, each one of the second plurality of flat tube sections being hydraulically connected to a corresponding one of the first plurality of flat tube sections at the second end of the refrigerant condenser;

a first and a second cylindrical header pipe arranged at the first end of the refrigerant condenser, ends of the first plurality of flat tube sections being sealingly received into the first cylindrical header pipe and ends of the second plurality of flat tube sections being sealingly received into the second cylindrical header pipe;

a first and a second fluid manifold arranged within the first cylindrical header pipe, a first subset of the first plurality of flat tube sections extending into the first fluid manifold and a second subset of the first plurality of flat tube sections extending into the second fluid manifold;

a third and a fourth fluid manifold arranged within the second cylindrical header pipe, a first subset of the second plurality of flat tube sections extending into the third fluid manifold and a second subset of the second plurality of flat tube sections extending into the fourth fluid manifold, the first subset of the second plurality of flat tube sections consisting of those ones of the second plurality of flat tube sections that correspond to the first subset of the first plurality of flat tube sections and the second subset of the second plurality of flat tube sections consisting of those ones of the second plurality of flat tube sections that correspond to the second subset of the first plurality of flat tube sections; and

a connecting tube extending between the second fluid manifold and the third fluid manifold to transport refrigerant between the first subset of the second plurality of flat tube sections and the second subset of the first plurality of tube sections.

2. The refrigerant condenser of claim 1, wherein the first subset of the first plurality of flat tube sections defines a first refrigerant pass through the condenser, the first subset of the second plurality of flat tube sections defines a second refrigerant pass through the condenser, the second subset of the first plurality of flat tube sections defines a third refrigerant pass through the condenser, and the second subset of the second plurality of flat tube sections defines a fourth refrigerant pass through the condenser, refrigerant flowing sequentially through the first, second, third, and fourth passes.

3. The refrigerant condenser of claim 2, wherein the third and fourth passes define a subcooler section of the refrigerant condenser.

4. The refrigerant condenser of claim 1, further comprising a refrigerant inlet connected to the first fluid manifold and a refrigerant outlet connected to the fourth fluid manifold.

5. The refrigerant condenser of claim 1, further comprising a return header arranged at the second end to fluidly connect corresponding ones of the first and the second pluralities of flat tube sections.

6. The refrigerant condenser of claim 1, wherein the first and second fluid manifolds are separated by a baffle arranged within the first cylindrical header pipe and wherein the third and fourth fluid manifolds are separated by a baffle arranged within the second cylindrical header pipe.

7. The refrigerant condenser of claim 1, wherein the connecting tube includes a first end extending through a cylindrical wall of the second cylindrical header pipe and a second end extending through a cylindrical wall of the first cylindrical header pipe.

8. The refrigerant condenser of claim 1, wherein the connecting tube includes a first

end extending through a cylindrical wall of the second cylindrical header pipe and a second end extending through an end cap of the first cylindrical header pipe.

9. A refrigerant condenser comprising:

a first and a second cylindrical header pipe arranged at a common end of the refrigerant condenser;

a first flow baffle arranged within the first cylindrical header pipe to separate an internal volume of the first cylindrical header pipe into a first fluid manifold and a second fluid manifold;

a second flow baffle arranged within the second cylindrical header pipe to separate an internal volume of the second cylindrical header pipe into a third fluid manifold and a fourth fluid manifold, the third fluid manifold being arranged adjacent to the first fluid manifold and the fourth fluid manifold being arranged adjacent to the second fluid manifold;

a first plurality of refrigerant conduits providing a refrigerant flow path between the first fluid manifold and the third fluid manifold, the first plurality of refrigerant conduits being at least partially defined by flat tube sections;

a second plurality of refrigerant conduits providing a refrigerant flow path between the second fluid manifold and the fourth fluid manifold, the second plurality of refrigerant conduits being at least partially defined by flat tube sections;

a refrigerant inlet port connected to the first cylindrical header pipe and in direct fluid communication with the first fluid manifold;

a refrigerant outlet port connected to the second cylindrical header pipe and in direct fluid communication with the fourth fluid manifold; and

a connecting tube having a first end joined to the first cylindrical header pipe and in direct fluid communication with the second fluid manifold, and a second end joined to the second cylindrical header pipe and in direct fluid communication with the third fluid manifold.

10. The refrigerant condenser of claim 9, wherein the first end of the connecting tube is arranged adjacent to the first baffle.

11. The refrigerant condenser of claim 9, wherein the second end of the connecting tube is arranged adjacent to the second baffle.

12. The refrigerant condenser of claim 9, wherein each of the first and second pluralities of refrigerant conduits includes a first flat tube section with an end that is sealingly received into the first cylindrical header pipe and a second flat tube section with an end that is sealingly received into the second cylindrical header pipe.

13. The refrigerant condenser of claim 12, further comprising a return header arranged at an end of the refrigerant condenser opposite the first and second cylindrical header pipes, ends of the first and second flat tube sections of each of the first and second pluralities of refrigerant conduits being sealingly received into the return header, the return header providing a fluid connection between the first and second flat tube sections of each refrigerant conduit.

14. The refrigerant condenser of claim 9, wherein the first plurality of refrigerant conduits defines a condensing section of the refrigerant condenser and wherein the second plurality of refrigerant conduits defines a subcooler section of the refrigerant condenser.

15. The refrigerant condenser of claim 9, wherein the first and second cylindrical header pipes are arranged vertically and wherein the second and the fourth fluid manifolds are arranged below the first and the third fluid manifolds.

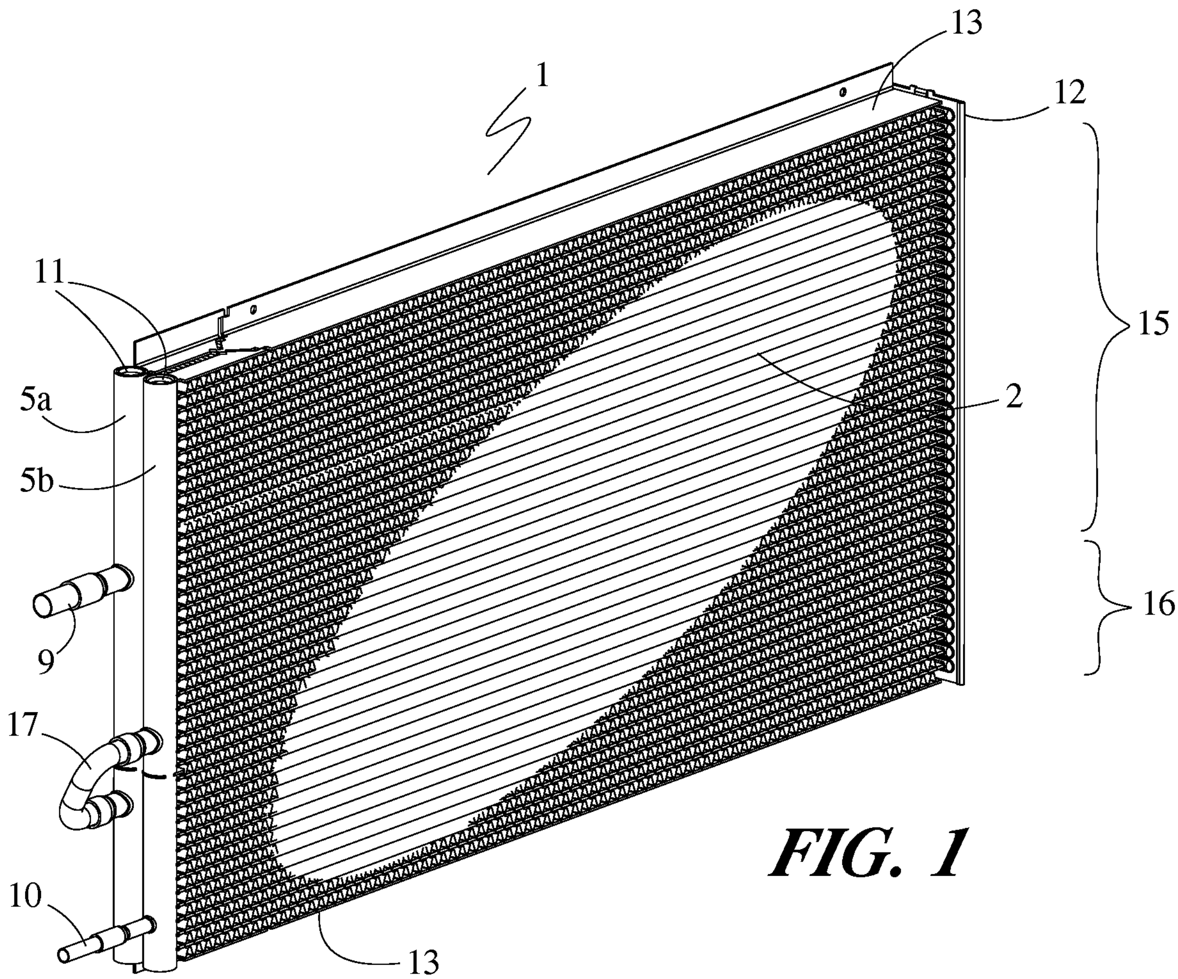
1
13
12
15
16
11
5a
5b
2
9
17
10
13

FIG. 1

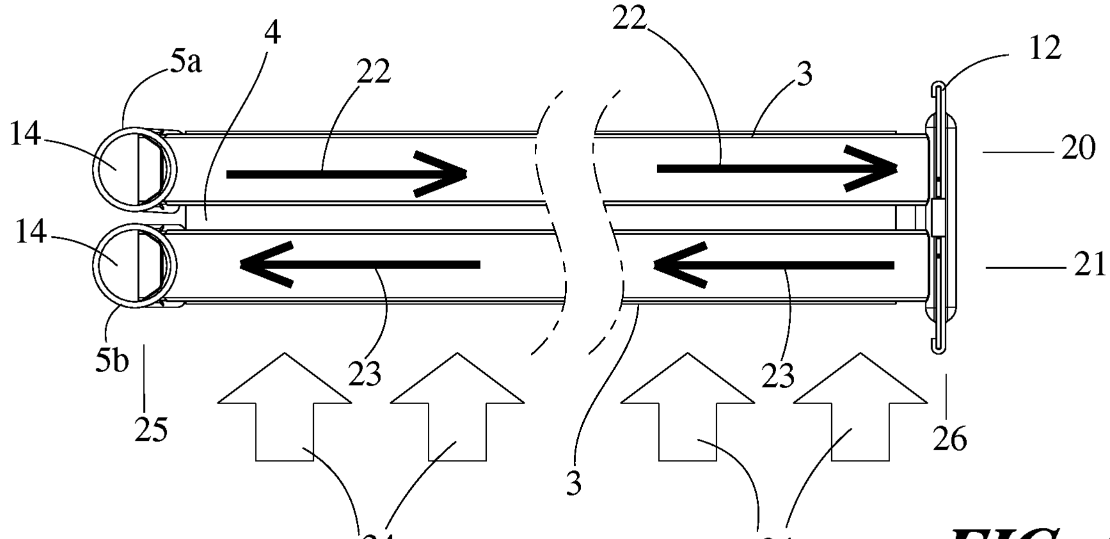
4
22
22
12
5a
3
14
20
14
21
5b
23
23
25
26
3
24
24

FIG. 2

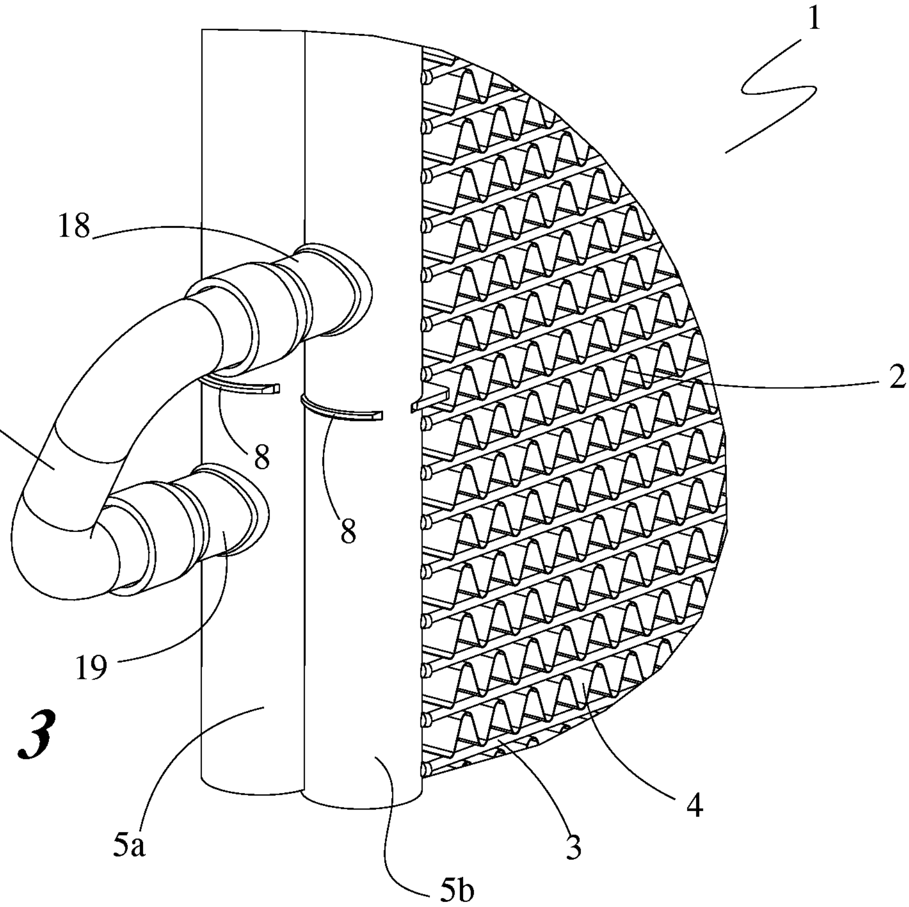

FIG. 3

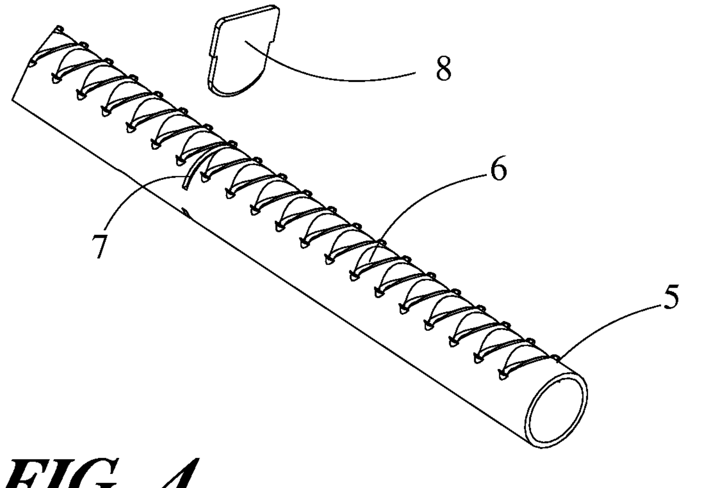

FIG. 4

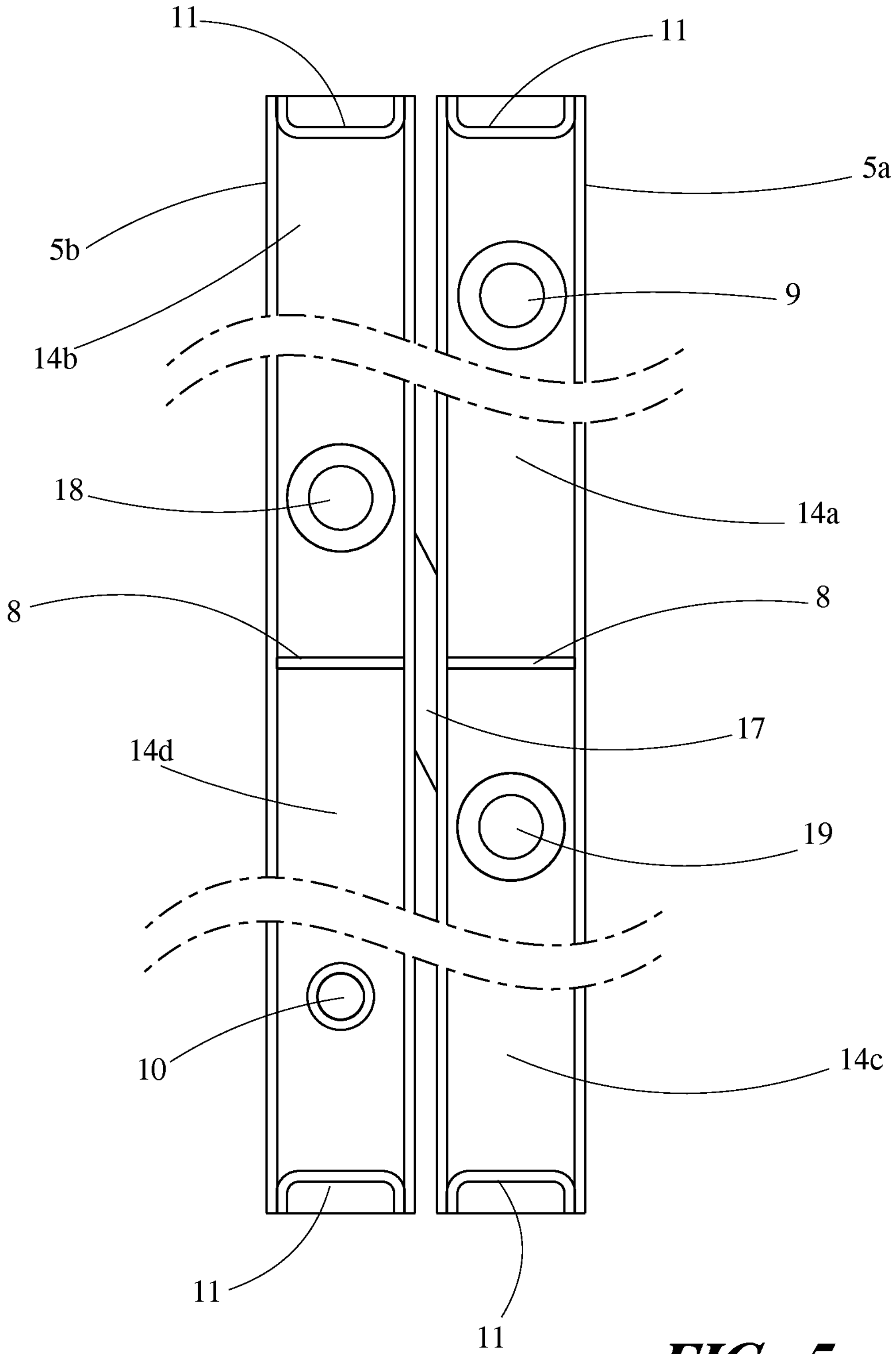

FIG. 5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 19/65729

A. CLASSIFICATION OF SUBJECT MATTER
IPC - F28D 1/04 (2020.01)

CPC - F28D 1/05391

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
See Search History document

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
See Search History document

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y	US 6,189,604 B1 (YAMAUCHI et al.) 20 February 2001 (20.02.2001), entire document, especially Fig 1-2; col 3, ln 48-57; col 4, ln 43-67; col 5, ln 1-12, 26-67; col 5, ln 1-13, 40-58	9-11, 14-15 ---------------- 1-8, 12-13
Y	EP 1 643 202 A1 (BEHR GMBH & CO. KG) 05 April 2006 (05.04.2006), entire document, especially Fig 1; para [0016]-[0017]	1-8, 12-13
Y	US 2008/0135222 A1 (BIVER et al.) 12 June 2008 (12.06.2008), entire document, especially Fig 1; para [0025], [0030]-[0031]	8
A	US 9,995,513 B2 (DENSO CORPORATION) 12 June 2018 (12.06.2018), entire document	1-15
A	US 2016/0138871 A1 (SANDEN HOLDINGS CORPORATION) 19 May 2016 (19.05.2016), entire document	1-15
A	US 2016/0033182 A1 (CARRIER CORPORATION) 04 February 2016 (04.02.2016), entire document	1-15
A	US 5,529,116 A (SASAKI et al.) 25 June 1996 (25.06.1996), entire document	1-15
A	US 5,348,081 A (HALSTEAD et al.) 20 September 1994 (20.09.1994), entire document	1-15

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
27 January 2020	02 MAR 2020
Name and mailing address of the ISA/US	**Authorized officer**
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