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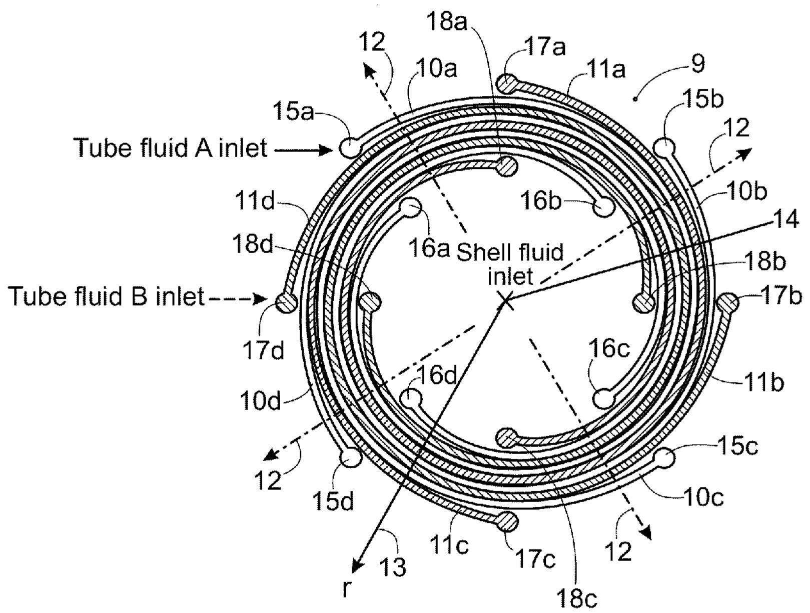

Fig. 7B

(57) **Abstract:** A heat exchanger (9) comprises a first conduit module (10a) for the flow of a first fluid, and a second conduit module (11a) for the flow of a second fluid. The second conduit module (11a) is fluidly isolated from the first conduit module (10a). The heat exchanger further comprises a first fluid flow path (12) for the flow of a third fluid in heat exchange with the first and second fluids. The first fluid flow path (12) extends in a substantially radial direction (13) of the heat exchanger (9). At least a portion of the first conduit module (10a) and at least a portion of the second conduit module (11a) are each arranged in a respective path that gradually widens or tightens about a longitudinal axis (14) of the heat exchanger (9). The first conduit module (10a) and the second conduit module (11a) are nested with one another.

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HEAT EXCHANGER

FIELD

The present disclosure relates to heat exchangers such as of the type which may be used in aerospace applications, automotive applications, industrial applications or other applications. The disclosure also relates to vehicles comprising such heat exchangers and to a method of operating such a heat exchanger.

BACKGROUND

GB2519147 describes a heat exchanger which comprises at least one first conduit section suitable for the flow of a first fluid in heat exchange with a second fluid in a flow path which passes the at least one first conduit section. At a first location, the at least one first conduit section is mounted on a support, and the at least one conduit section at a second location is moveable relative to the support in response to thermal change. The first conduit section may comprise a plurality of tubes extending between an inlet header to an outlet header, and an intermediate header is provided in the flow path therebetween. The inlet header may be fixed to the support and the outlet header may be moveable in response to thermal change. The support is capable of accepting high radially inward load and includes at least one circular ring in a cylindrical perforated drum structure, longeron members and X-shaped bracing. The first conduit section may comprise spiral sections that spiral inside one another. The heat exchanger may be used in a vehicle engine for an aircraft or orbital launch vehicle.

CN205679090 describes a multi-stream heat exchanger having different pipe diameters, comprising a casing, a plurality of heat exchange tubes, and a first tube plate and a second tube plate, wherein the ends of each heat exchange tube are limited to the first and second tubes. The heat exchange tubes between the plates and between the first and second tube sheets are helically coiled along the axial direction of the housing to form a multi-layer spiral tube which is interposed between the inner and outer portions, and is characterized in that the heat exchange tubes have at least two different outer diameters, the tubes being arranged adjacently. When used, the fluid with low pressure and small pressure drop can flow in the larger diameter heat exchange tube, and the fluid with higher pressure and larger pressure drop can be exchanged in the smaller diameter tube, so that the shell can be better distributed. The flow rate of the process is to meet the heat transfer requirements of each tube, and the heat exchange caused by the uneven distribution of the number of tubes in the heat transfer tube is not sufficient, so that the fluid in each heat exchange tube and the fluid in the shell side are sufficiently heat exchanged.

GB2241319 describes a heat exchanger comprising concentric annular arrays of parallel feeder tubes and receiver tubes which are interconnected by generally circumferentially extending heat exchanger tubes. Each heat exchanger tube interconnects one feeder tube with a corresponding receiver tube which is angularly spaced apart therefrom. In operation, a first fluid flows over the heat exchanger tubes while a second fluid flows through the heat exchanger tubes. The heat exchanger tubes are so arranged that the fluid flowing through them has a component which is opposite to that of the fluid flowing over them. In one aerospace application, the first fluid flow is of air and the second of liquid hydrogen, the heat exchanger being situated within the air intake and the air subsequently being diverted into the engine compressor.

GB2230594 describes a heat exchanger suitable for placing air and cold hydrogen in heat exchanger relationship with each other. The heat exchanger comprises two concentric annular arrays of header tubes, all the header tubes in the radially outer array being in flow communication with a first manifold while half of the header tubes in the radially inner array are in flow communication with a second manifold and the remainder are in flow communication with a third manifold. Heat exchange pipes interconnect the various header tubes and air flows over those pipes. Various valves and pipes are provided and are operable to ensure that the heat exchanger functions in two modes of operation; a first in which cold hydrogen flows through all the heat exchange pipes in a single direction and a second in which the cold hydrogen flows through alternate heat exchange pipes in the opposite direction.

The present disclosure seeks to alleviate, at least to a certain degree, the problems and/or address at least to a certain extent, the difficulties associated with the prior art.

SUMMARY

According to a first aspect of the disclosure, there is provided a heat exchanger comprising:

a first conduit module for the flow of a first fluid;

a second conduit module for the flow of a second fluid, wherein the second conduit module is fluidly isolated from the first conduit module; and

a first fluid flow path for the flow of a third fluid in heat exchange with the first and second fluids, wherein the first fluid flow path extends in a substantially radial direction of the heat exchanger;

wherein at least a portion of the first conduit module and at least a portion of the second conduit module are each arranged in a respective path that gradually widens or tightens about a longitudinal axis of the heat exchanger; and

wherein the first conduit module and the second conduit module are nested with one another.

The first conduit module and the second conduit module may be configured such that fluid is not able to flow from the first conduit module into the second conduit module and fluid is not able to flow from the second conduit module into the first conduit module, such that the second conduit module is fluidly isolated from the first conduit module. The first conduit module and the second conduit module may be configured such that the first fluid is not able to flow into the second conduit module, and such that the second fluid is not able to flow into the first conduit module, such that the second conduit module is fluidly isolated from the first conduit module. This fluid isolation allows different fluids to be provided in each conduit.

The heat exchanger may have a radial direction that extends from the centre of the heat exchanger to its outer perimeter, or that extends from the outer perimeter of the heat exchanger to its centre. The radial direction of the heat exchanger may lie in a plane which is perpendicular to the longitudinal direction of the heat exchanger.

The heat exchanger may have a radial direction that is perpendicular to the longitudinal direction of the heat exchanger.

The first fluid flow path may extend in a direction that is substantially coincident or parallel with the radial direction of the heat exchanger. The first fluid flow path may extend radially outwards or radially inwards with respect to the radial direction of the heat exchanger. Optionally, during operation of the heat exchanger, when the first fluid flow path contains the third fluid, there may be flow paths within the first fluid flow path that extend in other directions.

The heat exchanger may be substantially circular or square in shape in a plane which is perpendicular to the longitudinal direction of the heat exchanger.

Such a heat exchanger may advantageously provide the ability to cool and/or heat multiple fluids in a single heat exchanger installation. A single heat exchanger installation may advantageously be easier to install and has a lower overall volume than multiple individual units, which would otherwise be needed to cool and/or heat multiple fluids. A heat exchanger according to the first aspect of the disclosure can provide a heat exchanger with reduced size and mass, yielding space and weight saving benefits. Furthermore, such a heat exchanger may provide a high degree of flexibility for tailoring the effectiveness and temperatures of each fluid in the heat exchanger. Additionally, in such a heat exchanger, the pressure drop in the third fluid may be lower than if the flow of the third fluid had to be directed through multiple individual heat exchangers. In addition, such a heat exchanger may provide for a reduction or complete avoidance of congealing and/or freezing of fluids within the conduit modules. Even further, in such a heat exchanger the geometries and positions of each conduit module can be configured to offer a very high degree of optimisation (during the process of designing the heat exchanger) whilst maintaining high effectiveness of the heat exchanger. The heat exchanger thus provides a high degree of flexibility to optimise the heat exchanger across a wide range of applications.

The heat exchanger may be provided with additional conduit modules, each fluidly isolated from at least one of the other conduit modules.

Optionally, at least a portion of the first conduit module follows a first spiral path and at least a portion of the second conduit module follows a second spiral path.

Optionally, the first spiral path and/or the second spiral path comprises a plurality of straight sections and/or one or more curved sections.

Optionally, the first spiral path and/or the second spiral path is circular or elliptical or a polygon.

Optionally, the first spiral path and the second spiral path each comprises a circular spiral or a square spiral.

Optionally, the first spiral path and/or the second spiral path may be circular, elliptical, square, triangular, pentagonal, hexagonal, or any other polygon or suitable 2D shape.

Optionally, the first conduit module has a length and the second conduit module has a length. The first conduit module and the second conduit module may each be arranged such that they spiral or wind about the longitudinal axis of the heat exchanger in their respective path.

Optionally, the length of the first conduit module and the length of the second conduit module may each be arranged to gradually get closer to or further away from the longitudinal axis of the heat exchanger or a radial centre of the heat exchanger.

Optionally, the first spiral path and/or the second spiral path may be sized and/or shaped such that one of the first spiral path and the second spiral path may fit inside the other of the first spiral path and the second spiral path, such that the first conduit module and the second conduit module are nested with one another.

Optionally, at least a portion of one of the first spiral path and the second spiral path may be arranged to fit inside at least a portion of the other of the first spiral path and the second spiral path, such that the first conduit module and the second conduit module are nested with one another.

Optionally, the first spiral path and the second spiral path may be arranged to lie in the same plane, said plane being perpendicular to the longitudinal axis of the heat exchanger, such that the first conduit module and the second conduit module are nested with one another.

Optionally, the first spiral path and the second spiral path may be arranged adjacent one another, such that the first conduit module and the second conduit module are nested with one another.

Optionally, the first conduit module and the second conduit module may be arranged adjacent one another, such that the first conduit module and the second conduit module are nested with one another.

Optionally, at least a portion of the first conduit module may be arranged adjacent at least a portion of the second conduit module, such that the first conduit module and the second conduit module are nested with one another.

Optionally, the first conduit module has an inner diameter and an outer diameter, and the second conduit module has an inner diameter and an outer diameter, wherein the inner diameter of the first conduit module is different to the inner diameter of the second conduit module and/or the outer diameter of the first conduit module is different to the outer diameter of the second conduit module. The inner and outer diameter of each of the first and second conduit modules may relate to a tubular portion thereof. The inner and outer diameters may be substantially constant along a tubular portion thereof, or may vary, for example a tapered form.

Optionally, the first conduit module has a wall thickness which is different to a wall thickness of the second conduit module.

Advantageously, such a heat exchanger may provide for the optimisation of energy transfer in each of the conduit modules, based on the fluid that each conduit module is for. In particular, by tailoring the tube diameter and/or wall thickness of each of the conduit modules (during the process of designing the heat exchanger), the heat transfer area and therefore the energy transferred can be tailored for each of the conduit modules. Tailoring the tube diameter of each of the conduit modules may include tailoring one or more of the inner diameter, the outer diameter, or the wall thickness, of each of the conduit modules, the wall thickness being defined as the difference between the outer diameter and the inner diameter of each of the conduit modules. Advantageously, tailoring the wall thickness of each of the conduit modules may provide for the optimisation (during the process of designing the heat exchanger) of safety considerations relating to the heat exchanger. For example, if the first fluid is water and the second fluid is fuel, the wall thickness of the first conduit module could be thinner than the wall thickness of the second conduit module, since a water leak would not be as serious as a fuel leak. Furthermore, another factor to consider could be foreign object damage FOD. A conduit module more susceptible to any impacts of FOD could be configured to have a greater wall thickness than another conduit module.

Optionally, the first conduit module comprises a first material and the second conduit module comprises a second material that is different to the first material.

Advantageously, such a heat exchanger may provide for the optimisation of energy transfer in each of the conduit modules, based on the fluid that each conduit module is for. In particular, by tailoring the material of each of the conduit modules, the heat transfer properties and therefore the energy transferred can be tailored for each of the conduit modules.

Optionally, the first material and/or the second material may comprise steel and/or an alloy material, such as a nickel alloy or an aluminium alloy.

Optionally, the first conduit module comprises an inlet and an outlet, and the second conduit module comprises an inlet and an outlet, wherein the inlet of the first conduit module is spaced apart from the outlet of the first conduit module in the radial direction of the heat exchanger, and the inlet of the second conduit module is spaced apart from the outlet of the second conduit module in the radial direction of the heat exchanger.

Optionally, the inlet of the first conduit module is spaced closer to a radial centre of the heat exchanger than the outlet of the first conduit module, and the inlet of the second conduit module is spaced closer to the radial centre of the heat exchanger than the outlet of the second conduit module.

Optionally, the outlet of the first conduit module is spaced closer to a radial centre of the heat exchanger than the inlet of the first conduit module, and the outlet of the second conduit module is spaced closer to the radial centre of the heat exchanger than the inlet of the second conduit module.

Optionally, the outlet of one of the first conduit module and the second conduit module is spaced closer to a radial centre of the heat exchanger than the inlet of the same one of the first conduit module and the second conduit module, and the inlet of the other one of the first conduit module and the second conduit module is spaced closer to the radial centre of the heat exchanger than the outlet of the same one of the first conduit module and the second conduit module.

Optionally, the first conduit module comprises an inlet and an outlet, and the second conduit module comprises an inlet and an outlet, wherein the inlet of the first conduit module is spaced apart from the inlet of the second conduit module in the radial direction of the heat exchanger and/or the outlet of the first conduit module is spaced apart from the outlet of the second conduit module in the radial direction of the heat exchanger.

Optionally, the inlet of the first conduit module is arranged at the same radial distance along the radial direction of the heat exchanger as the inlet of the second conduit module, and the outlet of the first conduit module is spaced apart from the outlet of the second conduit module in the radial direction of the heat exchanger.

Optionally, the outlet of the first conduit module is arranged at the same radial distance along the radial direction of the heat exchanger as the outlet of the second conduit module, and the inlet of the first conduit module is spaced apart from the inlet of the second conduit module in the radial direction of the heat exchanger.

Optionally, the inlet of the first conduit module is spaced apart from the inlet of the second conduit module in the radial direction of the heat exchanger, and the outlet of the first conduit module is spaced apart from the outlet of the second conduit module in the radial direction of the heat exchanger.

Optionally, the first conduit module may have a longer length than the second conduit module.

Optionally, the second conduit module may have a longer length than the first conduit module.

Advantageously, such a heat exchanger may provide for the optimisation (during the process of designing the heat exchanger) of the inlet and outlet temperatures of the first fluid and the second fluid. In particular, positioning the respective inlets and/or outlets of each of the first conduit module and the second conduit module at different positions along the radial direction of the heat exchanger allows the inlet and outlet temperatures of the first fluid and the second fluid, when contained within the first conduit module and the second conduit module respectively, to be tailored, to optimise the effectiveness of the heat exchanger. Additionally, positioning the respective inlets and/or outlets of each of the first conduit module and the second conduit module at different positions along the radial direction of the heat exchanger allows the lengths of the first conduit module and the second conduit module to be tailored, to optimise the effectiveness of the heat exchanger.

Optionally, the second conduit module is arranged to be substantially thermally isolated from the first conduit module.

Optionally, the second conduit module is arranged to be spaced apart from the first conduit module, such that the second conduit module does not touch the first conduit module. In other words, the second conduit module and the first conduit module may be arranged such that they do not directly contact one another. This can allow the third fluid to flow between and/or around the first conduit module and the second conduit module.

Optionally, the first conduit module and the second conduit module are arranged to allow the third fluid to flow between and/or around the first conduit module and the second conduit module.

Optionally, at least a portion of the first fluid flow path extends between the first conduit module and the second conduit module, such that the third fluid can flow between the first conduit module and the second conduit module.

Advantageously, the second conduit module being spaced apart from the first conduit module can provide that the first fluid and the second fluid can undergo heat transfer with the third fluid independently of one another. That is, the first fluid and the second fluid can be cooled independently by the third fluid. Furthermore, the spatial separation of the second conduit module from the first conduit module can allow for a low pressure drop for the third fluid combined with a high cooling efficacy.

Optionally, the heat exchanger further comprises a third conduit module for the flow of a fourth fluid in heat exchange with the third fluid, wherein the third conduit module is fluidly isolated from the first conduit module and the second conduit module, and wherein at least a portion of the third conduit module is arranged in a path that gradually widens or tightens about the longitudinal axis of the heat exchanger and is nested with the first and second conduit modules.

Optionally, the fourth fluid is one of water, oil or refrigerant.

Optionally, the third conduit module may be configured such that fluid is not able to flow from the third conduit module into the first conduit module or the second conduit module, and fluid is not able to flow from the first conduit module or the second conduit module into the third conduit module, such that the third conduit module is fluidly isolated from the first conduit module and the second conduit module.

Optionally, the third conduit module may be configured such that the fourth fluid is not able to flow into the first conduit module or the second conduit module, such that the third conduit module is fluidly isolated from the first conduit module and the second conduit module.

The fourth fluid may be different to the first fluid and/or the second fluid.

Optionally, at least a portion of the third conduit module may follow a third spiral path. The third spiral path may comprise a plurality of straight sections and/or one or more curved sections. The third spiral path may be circular or elliptical or a polygon.

Optionally, the third spiral path comprises a circular spiral or a square spiral.

Optionally, the third spiral path may be circular, elliptical, square, triangular, pentagonal, hexagonal, or any other polygon or suitable 2D shape.

Optionally, the third conduit module has a length. The length of the third conduit module may be arranged such that it spirals or winds about the longitudinal axis of the heat exchanger in a path that gradually widens or tightens.

Optionally, the length of the third conduit module may be arranged to gradually get closer to or further away from the longitudinal axis of the heat exchanger or a radial centre of the heat exchanger.

Optionally, the third spiral path may be sized and/or shaped such that the third spiral path may fit inside one of the first spiral path and the second spiral path or such that one of the first spiral path and the second spiral path may fit inside the third spiral path, such that the third conduit module is nested with the first and second conduit modules.

Optionally, at least a portion of the third spiral path may be arranged to fit inside at least a portion of one of the first spiral path and the second spiral path, or at least a portion of one of the first spiral path and the second spiral path may be arranged to fit inside at least a portion of the third spiral path, such that the third conduit module is nested with the first and second conduit modules.

Optionally, the third spiral path may be arranged to lie in the same plane as the first spiral path and the second spiral path, said plane being perpendicular to the longitudinal axis of the heat exchanger, such that the third conduit module is nested with the first and second conduit modules.

Optionally, the third spiral path may be arranged adjacent the first spiral path and/or the second spiral path, such that the third conduit module is nested with the first and second conduit modules.

Optionally, the third conduit module may be arranged adjacent the first conduit module and/or the second conduit module, such that the third conduit module is nested with the first and second conduit modules.

Optionally, at least a portion of the third conduit module may be arranged adjacent at least a portion of the first conduit module or at least a portion of the second conduit module, such that the third conduit module is nested with the first and second conduit modules.

Optionally, the third conduit module has an inner diameter and an outer diameter, wherein the inner diameter of the third conduit module is different to the inner diameter of the first conduit module and/or the inner diameter of the third conduit module is different to the inner diameter of the second conduit module and/or the outer diameter of the third conduit module is different to the outer diameter of the first conduit module and/or the outer diameter of the third conduit module is different to the outer diameter of the second conduit module.

The inner and outer diameters of the third conduit module may relate to a tubular portion thereof.

The inner and outer diameters of the third conduit module may be substantially constant along a tubular portion thereof, or may vary, for example a tapered form.

The third conduit module may comprise a third material that is different to one or more of the first and second materials.

The third conduit module may comprise an inlet and an outlet, wherein the inlet of the third conduit module is spaced apart from the outlet of the third conduit module in the radial direction of the heat exchanger.

The inlet of the third conduit module may be spaced apart from the inlet of the first conduit module and/or the inlet of the second conduit module in the radial direction of the heat exchanger and/or the outlet of the third conduit module may be spaced apart from the outlet of the first conduit module and/or the outlet of the second conduit module in the radial direction of the heat exchanger.

Advantageously, such a heat exchanger may provide the ability to cool and/or heat multiple fluids in a single heat exchanger installation. There may be two, three or more fluids provided in separate conduit modules. A single heat exchanger installation may advantageously be easier to install and has a lower overall volume than multiple individual units, which would otherwise be needed to cool and/or heat multiple fluids. Accordingly, such a heat exchanger has reduced size and mass, yielding space and weight saving benefits.

Optionally, the third conduit module is thermally isolated from the first conduit module and the second conduit module.

Optionally, the third conduit module is arranged to be spaced apart from the first conduit module and the second conduit module, such that the third conduit module does not touch the first conduit module or the second conduit module. In other words, the third conduit module, the second conduit module and the first conduit module may be arranged such that they do not directly contact one another. This can allow the third fluid to flow between and/or around the first conduit module, the second conduit module and the third conduit module.

Optionally, the first conduit module, the second conduit module and the third conduit module are arranged to allow the third fluid to flow between and/or around the first conduit module, the second conduit module and the third conduit module.

Advantageously, the third conduit module being spaced apart from the second conduit module and the first conduit module can provide that the fourth fluid, the first fluid and the second fluid can undergo heat transfer with the third fluid independently of one another. That is, the fourth fluid, the first fluid and the second fluid can be cooled independently by the third fluid. Furthermore, the spatial separation of the third conduit module from the second conduit module and the first conduit module can allow for a low pressure drop for the third fluid combined with a high cooling efficacy.

Optionally, the heat exchanger may further comprise one or more additional conduit modules for the flow of one or more additional fluids in heat exchange with the third fluid, wherein one or more of the additional conduit modules are fluidly isolated from the first conduit module, the second conduit module, and the third conduit module, and wherein at least a portion of each of the additional conduit modules is arranged in a respective path that gradually widens or tightens about the longitudinal axis of the heat exchanger. For example, in addition to the first conduit module, the second conduit module, and the third conduit module, the heat exchanger may further comprise *n* additional conduit modules, such that the heat exchanger is configured to provide for the heat exchange of *n+3* fluids with the third fluid, where *n* is an integer greater than or equal to 1.

Optionally, the one or more additional conduit modules are thermally isolated from the first conduit module, the second conduit module and the third conduit module.

Optionally, the one or more additional conduit modules are arranged to be spaced apart from the first conduit module, the second conduit module and the third conduit module, such that the one or more additional conduit modules do not touch the first conduit module, the second conduit module or the third conduit module. In other words, the one or more additional conduit modules, the third conduit module, the second conduit module and the first conduit module may be arranged such that they do not directly contact one another. This can allow the third fluid to flow between and/or around the first conduit module, the second conduit module, the third conduit module, and the one or more additional conduit modules.

Optionally, the first conduit module, the second conduit module, the third conduit module and the one or more additional conduit modules are arranged to allow the third fluid to flow between and/or around the first conduit module, the second conduit module, the third conduit module and the one or more additional conduit modules.

Advantageously, the one or more additional conduit modules being spaced apart from the third conduit module, the second conduit module and the first conduit module can provide that the one or more additional fluids, the fourth fluid, the first fluid and the second fluid can undergo heat transfer with the third fluid independently of one another. That is, the one or more additional fluids, the fourth fluid, the first fluid and the second fluid can be cooled independently by the third fluid. Furthermore, the spatial separation of the one or more additional conduit modules from the third conduit module, the second conduit module and the first conduit module can allow for a low pressure drop for the third fluid combined with a high cooling efficacy.

The gradual widening or tightening is typically along the length of the respective path of each conduit module. In this way, the path of a respective conduit module is spaced closer or further away from the longitudinal axis of the heat exchanger at a starting portion than at an end portion the part of the respective conduit module.

Optionally, the first conduit module comprises a plurality of first tubes each wound in a respective path that gradually widens or tightens about the longitudinal axis of the heat exchanger and each spaced from one another in rows along the longitudinal direction of the heat exchanger, and wherein the second conduit module comprises a plurality of second tubes each wound in a respective path that gradually widens or tightens about the longitudinal axis of the heat exchanger and each spaced from one another in rows along the longitudinal direction of the heat exchanger.

Optionally, the plurality of first tubes are connected at a first end thereof to an inlet header of the first conduit module, and the plurality of first tubes are connected at a second end thereof to an outlet header of the first conduit module.

Optionally, the plurality of second tubes are connected at a first end thereof to an inlet header of the second conduit module, and the plurality of second tubes are connected at a second end thereof to an outlet header of the second conduit module.

Optionally, the inlet header of the first conduit module, the outlet header of the first conduit module, the inlet header of the second conduit module, and the outlet header of the second conduit module, each extends substantially in the longitudinal direction of the heat exchanger.

Optionally, the plurality of first tubes are connected to the inlet header of the first conduit module and the outlet header of the first conduit module by one or more of vacuum brazing, dip brazing and an adhesive, or any other suitable joining method.

Optionally, the plurality of second tubes are connected to the inlet header of the second conduit module and the outlet header of the second conduit module by one or more of vacuum brazing, dip brazing and an adhesive, or any other suitable joining method.

Optionally, the inlet header of the first conduit module may be in fluid communication with an inlet end of each of the plurality of first tubes.

Optionally, the outlet header of the first conduit module may be in fluid communication with an outlet end of each of the plurality of first tubes.

Optionally, the inlet header of the second conduit module may be in fluid communication with an inlet end of each of the plurality of second tubes.

Optionally, the outlet header of the second conduit module may be in fluid communication with an outlet end of each of the plurality of second tubes.

Optionally, the plurality of first tubes and the plurality of second tubes are each arranged in between about 10 to 1000 rows spaced along the longitudinal direction of the heat exchanger, for example about 70 to 100 such rows. Optionally, the plurality of the first tubes and the plurality of second tubes are arranged in rows of between about 1 and 40, i.e. with between about 1 and 40 tubes in each row, for example with 4 tubes in each row.

Optionally, the third conduit module may comprise a plurality of third tubes each wound in a respective path that gradually widens or tightens about the longitudinal axis of the heat exchanger and each spaced from one another in rows along the longitudinal direction of the heat exchanger.

Optionally, the plurality of third tubes are connected at a first end thereof to an inlet header of the third conduit module, and the plurality of third tubes are connected at a second end thereof to an outlet header of the third conduit module.

Optionally, the inlet header of the third conduit module and the outlet header of the third conduit module each extends substantially in the longitudinal direction of the heat exchanger.

Optionally, the plurality of third tubes are connected to the inlet header of the third conduit module and the outlet header of the third conduit module by one or more of vacuum brazing, dip brazing and an adhesive, or any other suitable joining method.

Optionally, the inlet header of the third conduit module may be in fluid communication with an inlet end of each of the plurality of third tubes.

Optionally, the outlet header of the third conduit module may be in fluid communication with an outlet end of each of the plurality of third tubes.

Optionally, the plurality of third tubes are each arranged in between about 10 to 1000 rows spaced along the longitudinal direction of the heat exchanger, for example about 70 to 100 such rows. Optionally, the plurality of third tubes are arranged in rows of between about 1 and 40, i.e. with between about 1 and 40 tubes in each row, for example with 4 tubes in each row.

Optionally, the heat exchanger comprises a plurality of the first conduit modules and a plurality of the second conduit modules, wherein at least a portion of each of the plurality of the first conduit modules and at least a portion of each of the plurality of the second conduit modules are nested with one another in an alternating manner.

Such a heat exchanger may advantageously provide the ability to cool and/or heat multiple fluids in a single heat exchanger installation. A single heat exchanger installation may advantageously be easier to install and has a lower overall volume than multiple individual units, which would otherwise be needed to cool and/or heat multiple fluids. Accordingly, a heat exchanger according to the first aspect of the disclosure provides a heat exchanger with reduced size and mass, yielding space and weight saving benefits.

Optionally, the plurality of the second conduit modules are arranged to be substantially thermally isolated from the plurality of the first conduit modules.

Optionally, each of the plurality of the first conduit modules are arranged to be spaced apart from one another, and each of the plurality of the second conduit modules are arranged to be spaced apart from one another. That is, each of the plurality of the first conduit modules may be arranged such that they do not touch one another, and each of the plurality of the second conduit modules may be arranged such that they do not touch one another. In other words, each of the plurality of the first conduit modules may be arranged such that they do not directly contact one another, and each of the plurality of the second conduit modules are arranged such that they do not directly contact one another. This can allow the third fluid to flow between and/or around the plurality of the first conduit modules and the plurality of the second conduit modules.

Optionally, the plurality of the first conduit modules and the plurality of the second conduit modules are arranged to allow the third fluid to flow between and/or around the plurality of the first conduit modules and the plurality of the second conduit modules.

Optionally, the plurality of the first conduit modules and the plurality of the second conduit modules are orientated such that their respective inlets and outlets are angularly spaced relative to one another.

Optionally, as an example, there may be 6 first conduit modules and 3 or 4 second conduit modules. The first fluid may be water and the second fluid may be oil.

Advantageously, such a heat exchanger may provide improved flow uniformity in the first fluid flow path for the third fluid. In particular, more conduit modules may be arranged at an angular/circumferential position relative to their respective inlets and outlets where a higher amount of driving pressure difference is available in the first fluid flow path for the third fluid. Advantageously, this may provide for a heat exchanger with reduced complexity and mass, as consequently no flow guides are required.

Optionally, the heat exchanger may further comprise a plurality of the third conduit modules, wherein at least a portion of each of the plurality of the third conduit modules are nested with at least a portion of each of the plurality of the first conduit modules and at least a portion of each of the plurality of second conduit modules.

Optionally, the plurality of the first conduit modules and the plurality of the second conduit modules and the plurality of the third conduit modules are orientated such that their respective inlets and outlets are angularly spaced relative to one another.

Optionally, when viewed in the radial direction of the heat exchanger, at least a portion of one of the plurality of first conduit modules is arranged adjacent at least a portion of one of the plurality of second conduit modules, which is arranged adjacent at least a portion of another one of the plurality of first conduit modules.

Optionally, when viewed in the radial direction of the heat exchanger, at least a portion of one of the plurality of second conduit modules is arranged adjacent at least a portion of one of the plurality of first conduit modules, which is arranged adjacent at least a portion of another one of the plurality of second conduit modules.

Optionally, when viewed in the radial direction of the heat exchanger, at least a portion of one of the plurality of third conduit modules is arranged adjacent at least a portion of one of the plurality of first conduit modules or one of the plurality of second conduit modules, which is arranged adjacent at least a portion of another one of the plurality of first conduit modules or one of the plurality of second conduit modules or one of the plurality of third conduit modules.

Optionally, when designing the heat exchanger, the number of the plurality of first conduit modules, and/or the number of the plurality of second conduit modules, and/or the number of the plurality of third conduit modules, may be chosen depending on the fluids that the first conduit module, the second conduit module, the third conduit module, and/or the first fluid flow path are for.

Optionally, the heat exchanger further comprises a first inlet manifold in fluid communication with the inlets of each of the first conduit modules, a first outlet manifold in fluid communication with the outlets of each of the plurality of first conduit modules, a second inlet manifold in fluid communication with the inlets of each of the plurality of second conduit modules, and a second outlet manifold in fluid communication with the outlets of each of the plurality of second conduit modules.

Such a heat exchanger provides that each of the first conduit modules is fluidly isolated from each of the second conduit modules.

Optionally, each of the first inlet manifold, the first outlet manifold, the second inlet manifold and the second outlet manifold is annular in shape.

Optionally, each of the first inlet manifold, the first outlet manifold, the second inlet manifold and the second outlet manifold may be a ring manifold.

Optionally, the heat exchanger further comprises a third inlet manifold in fluid communication with the inlets of each of the third conduit modules, and a third outlet manifold in fluid communication with the outlets of each of the plurality of third conduit modules.

Optionally, each of the third inlet manifold and the third outlet manifold is annular in shape.

Optionally, each of the third inlet manifold and the third outlet manifold may be a ring manifold.

Optionally, the heat exchanger further comprises one or more valves arranged within the first conduit module and/or the second conduit module, the one or more valves being configured to selectively reverse, stop or alter a flow of the first fluid in the first conduit module and/or a flow of the second fluid in the second conduit module.

Optionally, the heat exchanger further comprises one or more valves arranged within the third conduit module, the one or more valves being configured to selectively reverse, stop or alter a flow of the first fluid in the third conduit module.

Advantageously, such a heat exchanger may be configured to operate in a number of distinct modes, wherein in each mode, the flows of one or more of the first fluid, the second fluid and the third fluid may be reversed and/or altered, and/or the flow of one of the first fluid and the second fluid may even be stopped. This may alter or even reverse the heat transfer in the first conduit module, the second conduit module and/or the first fluid flow path. Advantageously, using such modes, such a heat exchanger may provide for both the cooling and/or heating of certain desired fluids, within the same mode or different modes, depending on the temperatures and properties of the first fluid, the second fluid and the third fluid. For example, such a heat exchanger may provide for independently heating and cooling separate fluids within the same compact heat exchanger. Furthermore, using such modes, such a heat exchanger may advantageously provide for the control and/or reduction and/or elimination of frost formation on and/or within the conduit modules. Advantageously, such a heat exchanger may also provide for a reduction or complete avoidance of congealing and/or freezing of fluids within the conduit modules.

Optionally, the first fluid is one of water, oil or refrigerant, and the second fluid is a different one of water, oil or refrigerant, and the third fluid is air.

Advantageously, such a heat exchanger may for example be employed in a heating, ventilation and air conditioning system such that water is used to heat the incoming air, and refrigerant is used to cool the air.

Optionally, the first conduit module contains the first fluid, the second conduit module contains the third fluid, and the first fluid flow path contains the third fluid.

Optionally, during and/or after operation/use of the heat exchanger, one or more of the plurality of first conduit modules may contain the first fluid, one or more of the plurality of second conduit modules may contain the second fluid, the first fluid flow path may contain the third fluid, and/or one or more of the plurality of third conduit modules may contain the fourth fluid.

According to a second aspect of the disclosure, there is provided a vehicle, such as an aircraft, flying machine or automobile, comprising a heat exchanger according to the first aspect of the disclosure with or without any optional feature thereof.

According to a third aspect of the disclosure, there is provided a method of operating the heat exchanger according to the first aspect of the disclosure with or without any optional feature thereof, comprising:

heating or cooling the first fluid and heating or cooling the second fluid by causing the first fluid to flow through the first conduit module, the second fluid to flow through the second conduit module, and the third fluid to flow through the first fluid flow path.

Such a method may advantageously provide the ability to cool and/or heat multiple fluids in a single heat exchanger installation. A single heat exchanger installation may advantageously be easier to install and has a lower overall volume than multiple individual units, which would otherwise be needed to cool and/or heat multiple fluids. Accordingly, a method according to the third aspect of the disclosure provides a heat exchanger with reduced size and mass, yielding space and weight saving benefits.

Furthermore, such a method may provide a high degree of flexibility for tailoring the effectiveness and temperatures of each fluid in the heat exchanger.

Additionally, in such a method, the pressure drop in the third fluid may be lower than if the flow of the third fluid had to be directed through multiple individual heat exchangers.

In addition, such a method may provide for a reduction or complete avoidance of congealing and/or freezing of fluids within the conduit modules.

Even further, such a method may provide for the ability to tune the geometries and positions of each conduit module, advantageously offering a very high degree of optimisation (during the process of designing the heat exchanger) whilst maintaining high effectiveness of the heat exchanger. The heat exchanger thus provides a high degree of flexibility to optimise the heat exchanger across a wide range of applications.

Optionally, the method comprises providing a means for forcing the third fluid to flow through the first fluid flow path.

Optionally, the means for forcing the third fluid to flow through the first fluid flow path comprises a fan, a pump, or other suitable means.

Optionally, the method further comprises reversing or altering the direction of flow in one or more of the first conduit module, the second conduit module and the first fluid flow path.

Optionally, the method further comprises stopping the flow in one of the first conduit module and the second conduit module while maintaining flow in the other of the first conduit module and the second conduit module and then subsequently starting the flow in said one of the first conduit module and the second conduit module.

Optionally, the method further comprises operating the heat exchanger in one or more modes of operation, wherein in at least one of the modes of operation the flow in one or more of the first conduit module, the second conduit module and the first fluid flow path may be reversed or altered and/or the flow in one of the first conduit module and the second conduit module may be stopped.

Advantageously, such a method may provide for a heat exchanger to be configured to operate in a number of distinct modes, wherein in each mode, the flows of one or more of the first fluid, the second fluid and the third fluid may be reversed and/or altered, and/or the flow of one of the first fluid and the second fluid may even be stopped. This may alter or even reverse the heat transfer in the first conduit module, the second conduit module and/or the first fluid flow path. Advantageously, using such heat exchanger modes, such a method may provide for both the cooling and/or heating of certain desired fluids, within the same mode or different modes, depending on the temperatures and properties of the first fluid, the second fluid and the third fluid. For example, such a method may provide for independently heating and cooling separate fluids within the same compact heat exchanger. Furthermore, using such a method, a heat exchanger may advantageously provide for the control and/or reduction and/or elimination of frost formation on and/or within the conduit modules. Advantageously, such a method may also provide for a reduction or complete avoidance of congealing and/or freezing of fluids within the conduit modules.

BRIEF DESCRIPTION OF THE DRAWINGS

The present disclosure may be carried out in various ways and embodiments of the disclosure will now be described by way of example with reference to the accompanying drawings, in which:

Figure 1A prior art shows a graph of fluid temperature plotted against distance through a heat exchanger, for the heat exchangers of Figure 1B;

Figure 1B prior art shows heat exchangers arranged in series;

Figure 2A prior art shows a graph of fluid temperature plotted against distance through a heat exchanger, for the heat exchangers of Figure 2B;

Figure 2B prior art shows heat exchangers arranged in parallel;

Figure 3 prior art shows a heat exchanger arrangement;

Figure 4 prior art shows a simplified plan view of a spiral conduit of the heat exchanger arrangement of Figure 3;

Figure 5 prior art shows a detailed isometric view of a part of the heat exchanger arrangement of Figure 3;

Figure 6 prior art shows an isometric view of the spiral conduit of Figure 4;

Figure 7A shows a graph of fluid temperature plotted against distance through a heat exchanger, for the heat exchanger of Figure 7B;

Figure 7B shows a schematic plan view of a heat exchanger;

Figure 8 shows a schematic plan view of a plurality of first conduits and a plurality of second conduits;

Figure 9A shows a schematic plan view of a spiral path that is square;

Figure 9B shows a schematic plan view of a spiral path that is circular;

Figure 9C shows a schematic plan view of a spiral path that is a polygon;

Figure 10A shows a graph of fluid temperature plotted against distance through a heat exchanger, for the heat exchanger of Figure 10B;

Figure 10B shows a schematic plan view of a heat exchanger;

Figure 11A shows a graph of fluid temperature plotted against distance through a heat exchanger, for the heat exchanger of Figure 11B;

Figure 11B shows a schematic plan view of a heat exchanger;

Figure 12A shows a graph of fluid temperature plotted against distance through a heat exchanger, for the heat exchanger of Figure 12B;

Figure 12B shows a schematic plan view of a heat exchanger;

Figure 13A shows a graph of fluid temperature plotted against distance through a heat exchanger, for the heat exchanger of Figure 13B; and

Figure 13B shows a schematic plan view of a heat exchanger.

DETAILED DESCRIPTION

In automotive applications, as an example, it is necessary to cool multiple fluids in a common air duct. Conventionally this is done using heat exchangers in series or parallel arrangements, as shown in Figures 1B and 2B respectively. The example arrangement shown in Figure 1B is used to cool water in a first heat exchanger module 1, and oil in a second heat exchanger module 2, using a flow of air 3 over the first heat exchanger module 1 and the second heat exchanger module 2. The first and second heat exchanger modules 1, 2 are arranged in series such that the flow of air 3 flows firstly through the second heat exchanger module 2 and then through the first heat exchanger module 1. The example arrangement shown in Figure 1B fails to achieve close approach temperatures with the cooling air, as shown in Figure 1A, and provides limited performance.

The example arrangement shown in Figure 2B is also used to cool water in a first heat exchanger module 1, and oil in a second heat exchanger module 2, using a flow of air 3 over the first heat exchanger module 1 and the second heat exchanger module 2. The first and second heat exchanger modules 1, 2 are arranged in parallel such that the flow of air 3 encounters both of the first and second heat exchanger modules 1, 2 at the same time. The example arrangement shown in Figure 2B requires the frontal area of the heat exchanger arrangement to be doubled and provides limited performance. Figure 2A shows the cooling effect of the flow of air 3 on the water in the first heat exchanger module 1 and the oil in the second heat exchanger module 2 in the heat exchanger arrangement of Figure 3B.

Figure 3 shows a plan view of a heat exchanger arrangement 4 as described in GB2519147. The heat exchanger arrangement 4 comprises a plurality of spiral conduit modules 5a, 5b, 5c, etc. each having an inlet 6a, 6b, 6c, etc. and an outlet 7a, 7b, 7c, etc.. A simplified plan view of one of the spiral conduit modules 5a, which has an inlet 6a and an outlet 7a, is shown in Figure 4. The spiral conduit modules 5a, 5b, 5c, etc. are nested with one another and are orientated such that their respective inlets 6a, 6b, 6c, etc. and their respective outlets 7a, 7b, 7c, etc. are angularly spaced relative to one another. Each of the inlets 6a, 6b, 6c, etc. are in fluid communication with one another, and each of the outlets 7a, 7b, 7c, etc. are in fluid communication with one another, such that each of the spiral conduit modules 5a, 5b, 5c, etc. is in fluid communication with one another. In other words, all of the spiral conduit modules 5a, 5b, 5c, etc. are configured to contain the same fluid.

Figure 6 shows an isometric view of the spiral conduit module 5a shown in Figure 4. The spiral conduit module 5a includes a plurality of tubes 8. The plurality of tubes 8 are spaced from one another in rows along the longitudinal direction of the heat exchanger, as shown in Figure 5.

Figure 7B shows a schematic plan view of a heat exchanger 9 in accordance with the present disclosure. The heat exchanger 9 comprises a first conduit module 10a for the flow of a first fluid and a second conduit module 11a for the flow of a second fluid. The second conduit module 11a is fluidly isolated from the first conduit module 10a. Depending upon application, the first fluid can be different to the second fluid. The first fluid, the second fluid and the third fluid can be chosen, during the design process of the heat exchanger, depending on the application.

A first fluid flow path 12 for the flow of a third fluid in heat exchange with the first and second fluids extends in a substantially radial direction, r 13 of the heat exchanger 9. In the example shown in Figure 7B, the first fluid flow path 12 is illustrated as flowing radially outwards. Though, it is also envisaged that the first fluid flow path 12 may be configured to flow radially inwards, i.e. in the opposite direction to that depicted in Figure 7B. In the example shown in Figure 7B, in a plane perpendicular to the longitudinal direction 14 of the heat exchanger 9, the heat exchanger 9 is substantially circular in shape. However, it is envisaged that the heat exchanger 9 may be any other shape, such as a square, for example. The heat exchanger 9 has a longitudinal axis 14, which in Figure 7B is shown going into the page. The longitudinal axis 14 is substantially perpendicular to the radial direction, r 13.

At least a portion of the first conduit module 10a and at least a portion of the second conduit module 11a are each arranged in a respective path that gradually widens or tightens about the longitudinal axis 14 of the heat exchanger 9. In other words, each of the first conduit module 10a and the second conduit module 11a has a length. The lengths of each of the first conduit module 10a and the second conduit module 11a are arranged such that they spiral/wind about the longitudinal axis 14 in a gradually widening or tightening path. In other words, they are each arranged to gradually get closer or further away from the longitudinal axis 14 or radial centre (marked at the location of the “X” indicating the position of the longitudinal axis 14 in Figure 7B) of the heat exchanger 9. In the example shown in Figure 7B, at least a portion of the first conduit module 10a follows a first spiral path along the length of the first conduit module 10a, and at least a portion of the second conduit module 11a follows a second spiral path along the length of the second conduit module 11a. The first spiral path comprises one curved section and is a circular spiral path, and the second spiral path also comprises one curved section and is a circular spiral path. Although, it is envisaged that the first spiral path and the second spiral path may also comprise any other shape. For example, the first spiral path and the second spiral path may each comprise a plurality of straight sections and/or one or more curved sections. Figure 8 shows an exemplary such arrangement comprising a first conduit module 19a and a second conduit module 19b, wherein at least a portion of the first conduit module 19a and at least a portion of the second conduit module 20a follows a first spiral path and a second spiral path respectively. The first and second spiral paths each comprise a plurality of straight sections.

As further examples, the first spiral path and/or the second spiral path may be circular, elliptical, square, triangular, pentagonal, hexagonal, or any other polygon or suitable 2D shape. Figure 9A shows an exemplary square spiral path. Figure 9B shows an exemplary circular spiral path. Figure 9C shows an exemplary hexagonal spiral path.

Referring back to Figure 7B, the first conduit module 10a and the second conduit module 11a are nested with one another. The first conduit module 10a and the second conduit module 11a and accordingly also the first spiral path and the second spiral path lie in the same plane, said plane being perpendicular to the longitudinal axis 14 of the heat exchanger 9. The first and second spiral paths that the first conduit module 10a and the second conduit module 11a respectively follow are arranged adjacent one another. Accordingly, when viewed in the radial direction, r 13 of the heat exchanger 9, at least a portion of the first conduit module 10a is arranged adjacent at least a portion of the second conduit module 10b. Figure 8 shows another example in which the first and second spiral paths comprise a plurality of straight sections and the first conduit section 19a and the second conduit section 20a are nested with one another.

Such a heat exchanger advantageously provides the ability to cool and/or heat multiple fluids in a single heat exchanger installation. A single heat exchanger installation is advantageously easier to install and has a lower overall volume than multiple individual units, which would otherwise be needed to cool and/or heat multiple fluids. Accordingly, such a heat exchanger provides for reduced size and mass, yielding space and weight saving benefits. Furthermore, such a heat exchanger provides a high degree of flexibility for tailoring the effectiveness and temperatures of each fluid in the heat exchanger. Additionally, in such a heat exchanger, the pressure drop in the third fluid can be lower than if the flow of the third fluid had to be directed through multiple individual heat exchangers. In addition, such a heat exchanger may provide for a reduction or complete avoidance of congealing and/or freezing of fluids within the conduit modules. Even further, such a heat exchanger may provide for the ability to tune the geometries and positions of each conduit module during the process of designing the heat exchanger, advantageously offering a very high degree of optimisation during the process of designing the heat exchanger, whilst maintaining high effectiveness of the heat exchanger. The heat exchanger thus provides a high degree of flexibility to optimise the design of the heat exchanger for a wide range of applications.

Referring again to Figure 7B, the first conduit module 10a comprises an inlet 15a and an outlet 16a, and the second conduit module 11a comprises an inlet 17a and an outlet 18a. The inlet 15a is spaced apart from the outlet 16a in the radial direction, r 13 of the heat exchanger 9. The inlet 15a is arranged closer to the radial centre of the heat exchanger 9 than the outlet 16a. Though, it is envisaged that the radial positions of the inlet 15a and the outlet 16a may be reversed such that the outlet 16a is arranged closer to the radial centre of the heat exchanger 9 than the inlet 15a. Similarly, the inlet 17a is spaced apart from the outlet 18a in the radial direction, r 13 of the heat exchanger 9. The inlet 17a is arranged closer to the radial centre of the heat exchanger 9 than the outlet 18a. Though, it is envisaged that the radial positions of the inlet 17a and the outlet 18a may be reversed such that the outlet 18a is arranged closer to the radial centre of the heat exchanger 9 than the inlet 17a.

Figure 7A shows a graph of fluid temperature plotted against distance through the heat exchanger of Figure 7B. The arrows on each of the three curves represent the directions of flow of the first, second and third fluids through the distance of the heat exchanger. The curves show the temperature profiles of the first, second and third fluids that can be achieved using the heat exchanger of Figure 7B, in particular, the respective inlet and outlet temperatures of the first, second and third fluids (for each curve, the inlet temperature is shown at one of end of the curve behind the direction of the arrow, and the outlet temperature is shown at the other end of the curve ahead of the direction the arrow is pointing in).

In the example shown in Figure 8, wherein the first and second spiral paths each comprise a plurality of straight sections, the first conduit module 19a has an inlet 21a and an outlet 22a, and the second conduit module 20a has an inlet 23a and an outlet 24a. The inlet 21a is arranged farther from the radial centre (marked at the location of the “X” indicating the position of the longitudinal axis 14 in Figure 8) of the heat exchanger than the outlet 22a. Similarly, the inlet 23a is arranged farther from the radial centre of the heat exchanger than the outlet 24a. Though, it is envisaged that the radial positions of the inlet 21a and the outlet 22a may be reversed. It is also envisaged that the radial positions of the inlet 23a and the outlet 24a may be reversed.

Referring back to Figure 7B, in one example, the inlet 15a of the first conduit module 10a and the inlet 17a of the second conduit module 11a are arranged at the same radial distance along the radial direction, r 13 of the heat exchanger 9, and the outlet 16a of the first conduit module 10a and the outlet 18a of the second conduit module 11a are arranged at the same radial distance along the radial direction r 13 of the heat exchanger 9. However, other positions of the inlets and outlets of the respective conduit modules can also be envisaged. In particular, the inlet 15a of the first conduit module 10a may be spaced apart from the inlet 17a of the second conduit module 11a in the radial direction, r 13 of the heat exchanger 9, and/or the outlet 16a of the first conduit module 10a may be spaced apart from the outlet 18a of the second conduit module 11a in the radial direction, r 13 of the heat exchanger 9.

For example, as shown in Figure 10B, which is a schematic plan view of another exemplary heat exchanger, the inlet 15a of the first conduit module 10a is spaced apart from the inlet 17a of the second conduit module 11a in the radial direction, r 13 of the heat exchanger 9. The inlet 15a of the first conduit module 10a is arranged closer to the radial centre of the heat exchanger (marked at the location of the “X” indicating the position of the longitudinal axis 14 in Figure 10B) than the inlet 17a of the second conduit module 11a. The outlet 16a of the first conduit module 10a and the outlet 18a of the second conduit module 11a are arranged at the same radial distance along the radial direction, r 13 of the heat exchanger 9. In such an arrangement, the second conduit module 11a has a longer length than the first conduit module 10a. In other words, the second spiral is longer than the first spiral path, such that only a portion of the length of the second conduit module 11a is nested with the first conduit module 10a. In the example shown in Figure 10B, the first fluid flow path 12 is illustrated as flowing radially outwards. Though, it is also envisaged that the first fluid flow path 12 may be configured to flow radially inwards, i.e. in the opposite direction to that depicted in Figure 10B.

Figure 10A shows a graph of fluid temperature plotted against distance through the heat exchanger of Figure 10B. The arrows on each of the three curves represent the directions of flow of the first, second and third fluids through the distance of the heat exchanger. The curves show the temperature profiles of the first, second and third fluids that can be achieved using the heat exchanger of Figure 10B, in particular, the respective inlet and outlet temperatures of the first, second and third fluids (for each curve, the inlet temperature is shown at one of end of the curve behind the direction of the arrow, and the outlet temperature is shown at the other end of the curve ahead of the direction the arrow is pointing in).

Another example is shown in Figure 11B, wherein the inlet 15a of the first conduit module 10a and the inlet 17a of the second conduit module 11b are arranged at the same radial distance along the radial direction, r 13 of the heat exchanger 9. The outlet 16a of the first conduit module 10a is spaced apart from the outlet 18a of the second conduit module 11a in the radial direction, r 13 of the heat exchanger 9. The outlet 16a of the first conduit module 10a is arranged closer to the radial centre of the heat exchanger (marked at the location if the “X” indicating the position of the longitudinal axis 14 in Figure 11B) than the outlet 18a of the second conduit module 11a. In such an arrangement, the first conduit module 10a has a longer length than the second conduit module 11a. In other words, the first spiral path is longer than the second spiral path, such that only a portion of the length of the first conduit module 10a is nested with the second conduit module 11a. It is also envisaged that both the inlet 15a of the first conduit module 10a may be spaced apart from the inlet 17a of the second conduit module 11a in the radial direction, r 13 of the heat exchanger 9, and also the outlet 17a of the first conduit module 10a may be spaced apart from the outlet 19a of the second conduit module 11a in the radial direction, r 13 of the heat exchanger 9. In the example shown in Figure 11B, the first fluid flow path 12 is illustrated as flowing radially outwards. Though, it is also envisaged that the first fluid flow path 12 may be configured to flow radially inwards, i.e. in the opposite direction to that depicted in Figure 11B.

Advantageously, such a heat exchanger provides for the optimisation of the inlet and outlet temperatures of the first fluid and the second fluid. In particular, positioning the respective inlets and/or outlets of each of the first conduit module and the second conduit module at different positions along the radial direction of the heat exchanger allows the inlet and outlet temperatures of the first fluid and the second fluid, when contained within the first conduit module and the second conduit module respectively, to be tailored, during the process of designing the heat exchanger, to optimise the effectiveness of the heat exchanger. Additionally, positioning the respective inlets and/or outlets of each of the first conduit module and the second conduit module at different positions along the radial direction of the heat exchanger allows the lengths of the first conduit module and the second conduit module to be tailored, during the process of designing the heat exchanger, to optimise the effectiveness of the heat exchanger.

Figure 11A shows a graph of fluid temperature plotted against distance through the heat exchanger of Figure 11B. The arrows on each of the three curves represent the directions of flow of the first, second and third fluids through the distance of the heat exchanger. The curves show the temperature profiles of the first, second and third fluids that can be achieved using the heat exchanger of Figure 11B, in particular, the respective inlet and outlet temperatures of the first, second and third fluids (for each curve, the inlet temperature is shown at one of end of the curve behind the direction of the arrow, and the outlet temperature is shown at the other end of the curve ahead of the direction the arrow is pointing in).

In the example shown in Figure 13B, the heat exchanger 9 further comprises a third conduit module 25a for the flow of a fourth fluid in heat exchange with the third fluid. The third conduit module 25a is fluidly isolated from the first conduit module 10a and the second conduit module 11a. In the example shown in Figure 13B, the first fluid flow path 12 is illustrated as flowing radially outwards. Though, it is also envisaged that the first fluid flow path 12 may be configured to flow radially inwards, i.e. in the opposite direction to that depicted in Figure 13B.

Figure 13A shows a graph of fluid temperature plotted against distance through the heat exchanger of Figure 13B. The arrows on each of the four curves represent the directions of flow of the first, second, third and fourth fluids through the distance of the heat exchanger. The curves show the temperature profiles of the first, second, third and fourth fluids that can be achieved using the heat exchanger of Figure 13B, in particular, the respective inlet and outlet temperatures of the first, second, third and fourth fluids (for each curve, the inlet temperature is shown at one of end of the curve behind the direction of the arrow, and the outlet temperature is shown at the other end of the curve ahead of the direction the arrow is pointing in).

At least a portion of the third conduit module 25a is arranged in a path that gradually widens or tightens about the longitudinal axis 14 of the heat exchanger 9. In other words, the third conduit module 25a has a length. The length of the third conduit module 25a is arranged such that it spirals/winds about the longitudinal axis 14 in a gradually widening or tightening path. In other words, it is arranged to gradually get closer or further away from the longitudinal axis 14 or radial centre (marked at the location of the “X” indicating the position of the longitudinal axis 14 in Figure 13B) of the heat exchanger 9. As shown in Figure 13B, at least a portion of the third conduit module 25a follows a third spiral path along the length of the third conduit module 25a. The third conduit module 25a follows a third spiral path that comprises one curved section and is a circular spiral path. Though, it is envisaged that the third spiral path may comprise any suitable shape. At least a portion of the third conduit module 25a is nested with the first conduit module 10a and the second conduit module 11a.

Advantageously, such a heat exchanger provides the ability to cool and/or heat multiple, specifically, three or more, fluids in a single heat exchanger installation. A single heat exchanger installation is advantageously easier to install and has a lower overall volume than multiple individual units, which would otherwise be needed to cool and/or heat multiple fluids. Accordingly, such a heat exchanger has reduced size and mass, yielding space and weight saving benefits.

Referring now to Figure 5, the first conduit module 10a comprises a plurality of first tubes 8 each wound in a respective path that gradually widens or tightens along a length of said respective path about the longitudinal axis 14 of the heat exchanger 9. In other words, the plurality of first tubes 8 are each wound in a respective path about the longitudinal axis 14 of the heat exchanger 9 that is arranged to gradually get closer to or further away from the longitudinal axis 14 of the heat exchanger 9. The plurality of first tubes 8 are each spaced from one another in rows along the longitudinal direction i.e. along a direction which is substantially parallel to the longitudinal axis 14 of the heat exchanger 9.

In the example shown in Figure 5, the plurality of first tubes 8 are arranged in a plurality of rows along the longitudinal direction of the heat exchanger. For the sake of clarity, in Figure 5, only one row of the tubes 8 is shown installed, with 3 tubes 8 illustrated in the row. Though, it is envisaged that there may be any number of tubes 8 in each row. Each of the plurality of first tubes 8 are connected to the inlet header 100 by a brazing process. Though, it is envisaged that any suitable joining method may be used, for example, by use of one or more of vacuum brazing, dip brazing, and an adhesive. The inlet header 100 at one end of the plurality of first tubes 8 is in fluid communication with an inlet end of each of the plurality of first tubes, which is fluidly associated with the inlet 15a of the first conduit section 10a. The header (not shown) at the other end (not shown) of the plurality of first tubes 7 is in fluid communication with an outlet end of each of the plurality of first tubes 8, which is fluidly associated with the outlet 16a of the first conduit section 10a.

Similarly, the second conduit module 11a comprises a plurality of second tubes, which are each spaced from one another in rows along the longitudinal direction of the heat exchanger

9. The plurality of second tubes are also arranged in the layout described above in relation to the plurality of first tubes, and as illustrated in Figure 5. Similarly, the third conduit module 25a comprises a plurality of third tubes, which are each spaced from one another in rows along the longitudinal direction of the heat exchanger 9. The plurality of third tubes are also arranged in the layout described above in relation to the plurality of first tubes, and as illustrated in Figure 5.

As shown in Figures 7B, 10B, 11B, 12B and 13B, the heat exchanger 9 comprises a plurality of the first conduit modules 10a, 10b, 10c and 10d and a plurality of the second conduit modules 11a, 11b, 11c and 11d. At least a portion of each of the plurality of the first conduit modules 10a, 10b, 10c and 10d and at least a portion of each of the plurality of the second conduit modules 11a, 11b, 11c and 11d are nested with one another in an alternating matter. Exemplary alternating nesting arrangements are shown in Figures, 7B, 10B, 11B, 12B and 13B.

Such a heat exchanger advantageously provides the ability to cool and/or heat multiple fluids in a single heat exchanger installation. A single heat exchanger installation is advantageously easier to install and has a lower overall volume than multiple individual units, which would otherwise be needed to cool and/or heat multiple fluids. Accordingly, such a heat exchanger provides reduced size and mass, yielding space and weight saving benefits.

As an example, there may be 4 first conduit modules 10a, 10b, 10c and 10d, and 4 second conduit modules 11a, 11b, 11c and 11d, for example as shown in Figures 7B, 10B, 11B and 12B. For example, if the first fluid is water and the second fluid is oil, there may be 6 first conduit modules 10a, 10b, 10c and 10d and 3 or 4 second conduit modules 11a, 11b, 11c, and 11d. This is because the present inventors have noted that almost twice as much heat can be rejected from water than from oil, so the number of first and second conduit modules may be selected accordingly to optimise the effectiveness of the heat exchanger 9. Though, it is envisaged that the heat exchanger 9 may comprise any number greater than one of the first conduit modules and any number greater than one of the second conduit modules. As described in the aforementioned example, the number of first conduit modules and the number of second conduit modules may be selected depending on what the first, second and third fluids are, to optimise the effectiveness of the heat exchanger 9.

Advantageously, such a heat exchanger provides improved flow uniformity in the first fluid flow path for the third fluid. In particular, more conduit modules can be arranged at an angular/circumferential position relative to their respective inlets and outlets where a higher amount of driving pressure difference is available in the first fluid flow path for the third fluid. Advantageously, this provides for a heat exchanger with reduced complexity and mass, as consequently no flow guides are required.

First conduit modules 10a, 10b, 10c and 10d have inlets 15a, 15b, 15c and 15d and outlets 16a, 16b, 16c and 16d respectively. Second conduit modules 11a, 11b, 11c and 11d have inlets 17a, 17b, 17c and 17d and outlets 18a, 18b, 18c and 18d respectively.

Similarly, in the example shown in Figure 8, first conduit modules 19a and 19b have inlets 21a and 21b, and outlets 22a and 22b respectively, and second conduit modules 20a and 20b have inlets 23a and 23b and outlets 24a and 24b respectively.

The exemplary heat exchanger shown in Figure 13B comprises a plurality of the third conduit modules 25a, 25b. At least a portion of each of the plurality of the third conduit modules 25a, 25b is nested with at least a portion of one or more of the plurality of first conduits 10a, 10b, 10c, 10d and/or one or more of the plurality of second conduits 11a ,11b, 11c, 11d in an alternating manner.

Third conduit modules 25a and 25b have inlets 26a and 26b and outlets 271 and 27b respectively.

As shown in Figures 7B, 10B, 11B, 12B and 13B, the plurality of the first conduit modules 10a, 10b, 10c, 10d and/or the plurality of the second conduit modules 11a, 11b, 11c, 11d and/or if present, the plurality of the third conduit modules 25a, 25b, are orientated such that their respective inlets and outlets are angularly spaced relative to one another.

The heat exchanger 9 comprises a first inlet manifold (not shown) in fluid communication with the inlets 15a, 15b, 15c and 15d of each of the first conduit modules 10a, 10b, 10c, 10d. The heat exchanger 9 comprises a second inlet manifold (not shown) in fluid communication with the inlets 17a, 17b, 17c and 17d of each of the second conduit modules 11a, 11b, 11c and 11d. The heat exchanger 9 comprises a third inlet manifold (not shown) in fluid communication with the inlets 26a and 26b of each of the third conduit modules 15a and 25b. The heat exchanger 9 comprises a first outlet manifold (not shown) in fluid communication with the outlets 16a, 15b, 16c and 16d of each of the first conduit modules 10a, 10b, 10c and 10d. The heat exchanger 9 comprises a second outlet manifold (not shown) in fluid communication with the outlets 18a, 18b, 18c and 18d of each of the second conduit modules 11a, 11b, 11c and 11d. The heat exchanger 9 comprises a third outlet manifold (not shown) in fluid communication with the outlets 27a and 27b of each of the third conduit modules 25a and 25b.

The first inlet manifold, the second inlet manifold, the third inlet manifold, the first outlet manifold, the second outlet manifold, and the third outlet manifold are ring manifolds. The first inlet manifold and the first outlet manifold are fluidly isolated from the second inlet manifold, the second outlet manifold, the third inlet manifold, and the third outlet manifold, and the second inlet manifold and the second outlet manifold are fluidly isolated from the third inlet manifold and the third outlet manifold, such that the plurality of first conduit modules 10a, 10b, 10c and 10d is fluidly isolated from the plurality of second conduit modules 11a, 11b, 11c and

11d and the plurality of third conduit modules 25a and 25b, and the plurality of second conduit modules 11a, 11b, 11c and 11d is fluidly isolated from the plurality of third conduit modules 25a and 25b.

Each of the plurality of first conduit modules 10a, 10b, 10c and 10d, each of the plurality of second conduit modules 11a, 11b, 11c and 11d, and each of the plurality of third conduit modules 25a and 25b comprises an inner diameter and an outer diameter. Specifically, each of the plurality of tubes 8 of each of the plurality of first conduit modules 10a, 10b, 10c and 10d, each of the plurality of second conduit modules 11a, 11b, 11c and 11d, and each of the plurality of third conduit modules 25a and 25b comprises an inner diameter and an outer diameter. The inner diameter and/or the outer diameter and/or the wall thickness of the plurality of tubes in each of the first conduit modules 10a, 10b, 10c and 1d, the second conduit modules 11a, 11b, 11c and 11d, and the third conduit modules 25a and 25b may be chosen, during the design of the heat exchanger, to optimise the heat transfer area in each of the conduit modules.

Advantageously, such a heat exchanger provides for the optimisation of energy transfer in each of the conduit modules, based on the fluid that each conduit module is for. In particular, by tailoring the tube diameter and/or wall thickness of each of the conduit modules, the heat transfer area and therefore the energy transferred can be tailored for each of the conduit modules. Advantageously, tailoring the wall thickness of each of the conduit modules may also provide for the optimisation (during the process of designing the heat exchanger) of safety considerations relating to the heat exchanger. For example, if the first fluid is water and the second fluid is fuel, the wall thickness of the first conduit module could be thinner than the wall thickness of the second conduit module, since a water leak would not be as serious as a fuel leak. Furthermore, another factor to consider could be foreign object damage FOD. A conduit module more susceptible to any impacts of FOD could be configured to have a greater wall thickness than another conduit module.

Additionally, during the design of the heat exchanger, the materials of the conduit modules may be chosen to optimise the effectiveness of the heat exchanger, by optimising the heat transfer properties and therefore the energy transferred for each of the conduit modules. As an example, one or more of the conduit modules can be manufactured from steel and/or an alloy material, such as a nickel alloy or an aluminium alloy. Though, it is envisaged that any suitable material(s) may be used.

The heat exchanger may comprise one or more valves (not shown). The one or more valves may be arranged within one or more of the plurality of first conduit modules 10a, 10b, 10c and 10d, and/or within one or more of the plurality of second conduit modules 11a, 11b, 11c and 11d, and/or within one or more of the plurality of third conduit modules 25a and 25b. The one or more valves can be configured to selectively reverse, stop or alter (e.g. alter the mass flow rate or another property of the flow) a flow of the first fluid in one or more of the plurality of first conduit modules 10a, 10b, 10c and 10d, and/or a flow of the second fluid in one or more of the plurality of second conduit modules 11a, 11b, 11c and 11d, and/or a flow of the fourth fluid in one or more of the third conduit modules 25a and 25b.

Advantageously, such a heat exchanger may be configured to operate in a number of distinct modes, wherein in each mode, the flows of one or more of the first fluid, the second fluid and the third fluid may be reversed and/or altered, and/or the flow of one of the first fluid and the second fluid may even be stopped. This may alter or even reverse the heat transfer in the first conduit module, the second conduit module and/or the first fluid flow path. Advantageously, using such modes, such a heat exchanger can provide for both the cooling and/or heating of certain desired fluids, within the same mode or different modes, depending on the temperatures and properties of the first fluid, the second fluid and the third fluid. For example, such a heat exchanger can provide for independently heating and cooling separate fluids within the same compact heat exchanger. Furthermore, using such modes, such a heat exchanger may advantageously provide for the control and/or reduction and/or elimination of frost formation on and/or within the conduit modules. Advantageously, such a heat exchanger may also provide for a reduction or complete avoidance of congealing and/or freezing of fluids within the conduit modules.

In the exemplary arrangements of Figures 7B, 10B and 11B, the first fluid is water, the second fluid is oil, and the third fluid is air.

In the example arrangement of Figure 12B, the first fluid is water, the second fluid is refrigerant, and the third fluid is air. Advantageously, such a heat exchanger can for example be employed in a heating, ventilation and air conditioning system such that water is used to heat the incoming air, and refrigerant is used to cool the air. In the example shown in Figure 12B, the first fluid flow path 12 is illustrated as flowing radially outwards. Though, it is also envisaged that the first fluid flow path 12 may be configured to flow radially inwards, i.e. in the opposite direction to that depicted in Figure 12B.

Figure 12A shows a graph of fluid temperature plotted against distance through the heat exchanger of Figure 12B. The arrows on each of the three curves represent the directions of flow of the first, second and third fluids through the distance of the heat exchanger. The curves show the temperature profiles of the first, second and third fluids that can be achieved using the heat exchanger of Figure 12B, in particular, the respective inlet and outlet temperatures of the first, second and third fluids (for each curve, the inlet temperature is shown at one of end of the curve behind the direction of the arrow, and the outlet temperature is shown at the other end of the curve ahead of the direction the arrow is pointing in).

As another example, in the arrangement of Figure 13B, the first fluid is water, the second fluid is oil, the third fluid is air, and the fourth fluid is another fluid.

The heat exchanger 9 can be employed in a vehicle, such as an aircraft, flying machine or automobile.

The operation of the heat exchanger 9 shall now be described with reference to the exemplary embodiment shown in Figure 7B. During a method of operating the heat exchanger 9, the first fluid and/or the second fluid can be heated and/or cooled by causing the first fluid to flow through the first conduit module 10a, the second fluid to flow through the second conduit module 11a, and the third fluid to flow through the first fluid flow path 12. The method comprises providing a means for forcing the third fluid to flow through the first fluid flow path 12. Such means may, for example, comprise a fan, a pump, or other suitable means. In the example shown in Figure 7B, the third fluid is configured to travel radially outwards. Though, it is envisaged that the direction of flow of the third fluid in the first fluid flow path 12 could be reversed such that the third fluid is configured to travel/flow radially inwards.

Such a method advantageously provides the ability to cool and/or heat multiple fluids in a single heat exchanger installation. A single heat exchanger installation is advantageously easier to install and has a lower overall volume than multiple individual units, which would otherwise be needed to cool and/or heat multiple fluids. Accordingly, such a method provides a heat exchanger with reduced size and mass, yielding space and weight saving benefits. Furthermore, such a method may provide a high degree of flexibility for tailoring the effectiveness and temperatures of each fluid in the heat exchanger. Additionally, in such a method, the pressure drop in the third fluid can be lower than if the flow of the third fluid had to be directed through multiple individual heat exchangers. In addition, such a method may provide for a reduction or complete avoidance of congealing and/or freezing of fluids within the conduit modules. Even further, such a method may provide for the ability to tune the geometries and positions of each conduit module, advantageously offering a very high degree of optimisation (during the process of designing the heat exchanger) whilst maintaining high effectiveness of the heat exchanger.

Referring again to the example shown in Figure 7B, the first fluid (which is water in the example) is caused to flow through the plurality of first conduit modules 10a, 10b, 10c and 10d, to flow from the outside of the heat exchanger 9 towards the inside (i.e. radial centre) of the heat exchanger 9. Though, it is envisaged that the direction of flow of the first fluid in the plurality of first conduit modules 10a, 10b, 10c and 10d could be reversed such that the first fluid is configured to flow from the inside (i.e. radial centre) of the heat exchanger 9 towards the outside of the heat exchanger 9. Similarly, also in the example shown in Figure 7B, the second fluid (which is oil in the example) is caused to flow through the plurality of second conduit modules 11a, 11b, 11c and 11d, to flow from the outside of the heat exchanger 9 towards the inside (i.e. radial centre) of the heat exchanger 9. Though, it is envisaged that the direction of flow of the second fluid in the plurality of second conduit modules 11a, 11b, 11c and 11d could be reversed such that the second fluid is configured to flow from the inside (i.e. radial centre) of the heat exchanger 9 towards the outside of the heat exchanger 9.

In the method of operating the heat exchanger, the first fluid flow path 12 and hence the third fluid are configured to flow over and around the plurality of first conduit modules 10a, 10b, 10c and 10d, the plurality of second conduit modules 11a, 11b, 11c and 11d, and if present, also the plurality of third conduit modules 25a and 25b.

The method can additionally include, as an example, reversing or altering the direction of flow in one or more of the plurality of first conduit modules 10a, 10b, 10c and 10d, and/or in one or more of the plurality of second conduit modules 11a, 11b, 11c and 11d. Such a method may include stopping the flow in one or more of the plurality of first conduit modules 10a, 10b, 10c and 10d, or stopping the flow in one or more of the plurality of second conduit modules 11a, 11b, 11c and 11d, and then subsequently starting the flow in said one or more of the plurality of first conduit modules 10a, 10b, 10c, 10d or the plurality of second conduit modules 11a, 11b, 11c and 11d.

Accordingly, the method of operating the heat exchanger may comprise operating the heat exchanger in one or more modes of operation. In at least one of the modes of operation, the flow in one or more of the plurality of first conduit modules 10a, 10b, 10c and 10d, and/or the flow in one or more of the plurality of second conduit modules 11a, 11b, 11c and 11d, and/or the flow in the first fluid flow path 12 may be reversed or altered, and/or the flow in one or more of the plurality of first conduit modules 10a, 10b, 10c and 10d, or the flow in one or more of the plurality of second conduit modules 11a, 11b, 11c and 11d, may be stopped.

Advantageously, such a method provides for a heat exchanger to be configured to operate in a number of distinct modes, wherein in each mode, the flows of one or more of the first fluid, the second fluid and the third fluid may be reversed and/or altered, and/or the flow of one of the first fluid and the second fluid may even be stopped. This may alter or even reverse the heat transfer in the first conduit module, the second conduit module and/or the first fluid flow path. Advantageously, using such heat exchanger modes, such a method can provide for both the cooling and/or heating of certain desired fluids, within the same mode or different modes, depending on the temperatures and properties of the first fluid, the second fluid and the third fluid. For example, such a method may provide for independently heating and cooling separate fluids within the same compact heat exchanger. Furthermore, using such a method, a heat exchanger may advantageously provide for the control and/or reduction and/or elimination of frost formation on and/or within the conduit modules. Advantageously, such a method may also provide for a reduction or complete avoidance of congealing and/or freezing of fluids within the conduit modules.

As an example, in a first mode the heat exchanger is configured to cool the third fluid using the first fluid, and in a second mode the heat exchanger is configured to heat the third fluid using the second fluid. This could be achieved by stopping the flow of the second fluid in the first mode, and stopping the flow of the first fluid in the second mode.

As another example, with reference to the heat exchanger shown in Figure 11B, if the second fluid (which in the example of Figure 11B, is oil) was not required to be cooled continuously, then in one exemplary mode, the flow of the second fluid in one or more of the plurality of second conduit modules 11a, 11b, 11c and 11d is reduced or stopped. The flow of the first fluid (which in the example of Figure 11B, is water) in one or more of the plurality of first conduit modules 10a, 10b, 10c and 10d is reduced or stopped to still give the same effective heat transfer between the active fluids.

As yet another example, with reference to the heat exchanger shown in Figure 12B, the method of operating the heat exchanger could be applied to a heating, ventilation and air conditioning system such that the first fluid (which in the example of Figure 12B, is water) is used to heat the incoming third fluid (which in the example of Figure 12B, is air), and the second fluid (which in the example of Figure 12B, is refrigerant), is used to cool the third fluid by means of controlling the flow of the fluids to the plurality of first conduit modules 10a, 10b, 10c and 10d, and to the plurality of second conduit modules 11a, 11b, 11c and 11d.

The control of the first, second and third fluids, and also the fourth fluid, if present, is achieved using one or more valves.

Various modifications may be made to the described embodiment(s) without departing from the scope of the invention as defined by the accompanying claims.

CLAIMS

1. A heat exchanger comprising:

a first conduit module for the flow of a first fluid;

a second conduit module for the flow of a second fluid, wherein the second conduit module is fluidly isolated from the first conduit module; and

a first fluid flow path for the flow of a third fluid in heat exchange with the first and second fluids, wherein the first fluid flow path extends in a substantially radial direction of the heat exchanger;

wherein at least a portion of the first conduit module and at least a portion of the second conduit module are each arranged in a respective path that gradually widens or tightens about a longitudinal axis of the heat exchanger; and

wherein the first conduit module and the second conduit module are nested with one another.

2. A heat exchanger as claimed in claim 1, wherein at least a portion of the first conduit module follows a first spiral path and at least a portion of the second conduit module follows a second spiral path.

3. A heat exchanger as claimed in claim 2, wherein the first spiral path and/or the second spiral path comprises a plurality of straight sections and/or one or more curved sections.

4. A heat exchanger as claimed in claim 3, wherein the first spiral path and/or the second spiral path is circular or elliptical or a polygon.

5. A heat exchanger as claimed in any one of the preceding claims, wherein the first conduit module has an inner diameter and an outer diameter, and the second conduit module has an inner diameter and an outer diameter, wherein the inner diameter of the first conduit

module is different to the inner diameter of the second conduit module and/or the outer diameter of the first conduit module is different to the outer diameter of the second conduit module.

6. A heat exchanger as claimed in any one of the preceding claims, wherein the first conduit module comprises a first material and the second conduit module comprises a second material that is different to the first material.

7. A heat exchanger as claimed in any one of the preceding claims, wherein the first conduit module comprises an inlet and an outlet, and the second conduit module comprises an inlet and an outlet, wherein the inlet of the first conduit module is spaced apart from the outlet of the first conduit module in the radial direction of the heat exchanger, and the inlet of the second conduit module is spaced apart from the outlet of the second conduit module in the radial direction of the heat exchanger.

8. A heat exchanger as claimed in any one of the preceding claims, wherein the first conduit module comprises an inlet and an outlet, and the second conduit module comprises an inlet and an outlet, wherein the inlet of the first conduit module is spaced apart from the inlet of the second conduit module in the radial direction of the heat exchanger and/or the outlet of the first conduit module is spaced apart from the outlet of the second conduit module in the radial direction of the heat exchanger.

9. A heat exchanger as claimed in any one of the preceding claims, wherein the heat exchanger further comprises a third conduit module for the flow of a fourth fluid in heat exchange with the third fluid, wherein the third conduit module is fluidly isolated from the first conduit module and the second conduit module, and wherein at least a portion of the third conduit module is arranged in a path that gradually widens or tightens about the longitudinal axis of the heat exchanger and is nested with the first and second conduit modules.

10. A heat exchanger as claimed in any one of the preceding claims, wherein the first conduit module comprises a plurality of first tubes each wound in a respective path that gradually widens or tightens about the longitudinal axis of the heat exchanger and each spaced from one another in rows along the longitudinal direction of the heat exchanger, and wherein the second conduit module comprises a plurality of second tubes each wound in a respective path that gradually widens or tightens about the longitudinal axis of the heat exchanger and each spaced from one another in rows along the longitudinal direction of the heat exchanger.

11. A heat exchanger as claimed in any one of the preceding claims, wherein the heat exchanger comprises a plurality of the first conduit modules and a plurality of the second conduit modules, wherein at least a portion of each of the plurality of the first conduit modules and at least a portion of each of the plurality of the second conduit modules are nested with one another in an alternating manner.

12. A heat exchanger as claimed in claim 11, wherein the plurality of the first conduit modules and the plurality of the second conduit modules are orientated such that their respective inlets and outlets are angularly spaced relative to one another.

13. A heat exchanger as claimed in claim 11 or claim 12, wherein the heat exchanger further comprises a first inlet manifold in fluid communication with the inlets of each of the first conduit modules, a first outlet manifold in fluid communication with the outlets of each of the plurality of first conduit modules, a second inlet manifold in fluid communication with the inlets of each of the plurality of second conduit modules, and a second outlet manifold in fluid communication with the outlets of each of the plurality of second conduit modules.

14. A heat exchanger as claimed in claim 13, wherein each of the first inlet manifold, the first outlet manifold, the second inlet manifold and the second outlet manifold is annular in shape.

15. A heat exchanger as claimed in any one of the preceding claims, wherein the heat exchanger further comprises one or more valves arranged within the first conduit module and/or the second conduit module, the one or more valves being configured to selectively reverse, stop or alter a flow of the first fluid in the first conduit module and/or a flow of the second fluid in the second conduit module.

16. A heat exchanger as claimed in any one of the preceding claims, wherein the first fluid is one of water, oil or refrigerant, wherein the second fluid is a different one of water, oil or refrigerant, and wherein the third fluid is air.

17. A heat exchanger as claimed in any one of the preceding claims, wherein the first conduit module contains the first fluid, the second conduit module contains the second fluid, and the first fluid flow path contains the third fluid.

18. A vehicle, such as an aircraft, flying machine or automobile, comprising a heat exchanger as claimed in any one of the preceding claims.

19. A method of operating the heat exchanger as claimed in claim 17, comprising:

heating or cooling the first fluid and heating or cooling the second fluid by causing the first fluid to flow through the first conduit module, the second fluid to flow through the second conduit module, and the third fluid to flow through the first fluid flow path.

20. A method as claimed in claim 19, comprising providing a means for forcing the third fluid to flow through the first fluid flow path.

21. A method as claimed in claim 19 or claim 20, when dependent on claim 16, wherein the method further comprises reversing or altering the direction of flow in one or more of the first conduit module, the second conduit module and the first fluid flow path.

22. A method as claimed in any one of claims 19 to 21, when dependent on claim 16, wherein the method further comprises stopping the flow in one of the first conduit module and the second conduit module while maintaining flow in the other of the first conduit module and the second conduit module and then subsequently starting the flow in said one of the first conduit module and the second conduit module.

23. A method as claimed in claim 21 or 22, wherein the method further comprises operating the heat exchanger in one or more modes of operation, wherein in at least one of the modes of operation the flow in one or more of the first conduit module, the second conduit module and the first fluid flow path may be reversed or altered and/or the flow in one of the first conduit module and the second conduit module may be stopped.

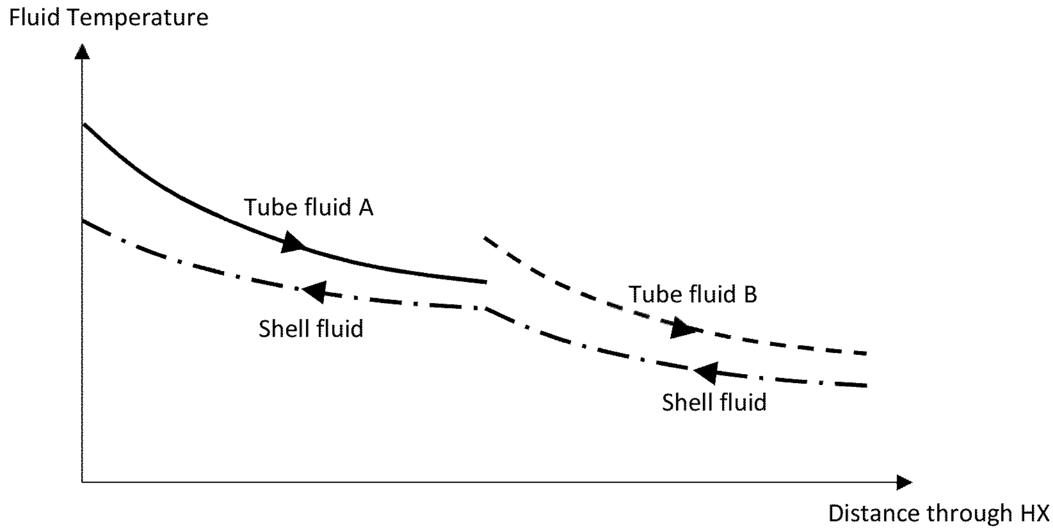

Fig. 1A
(PRIOR ART)

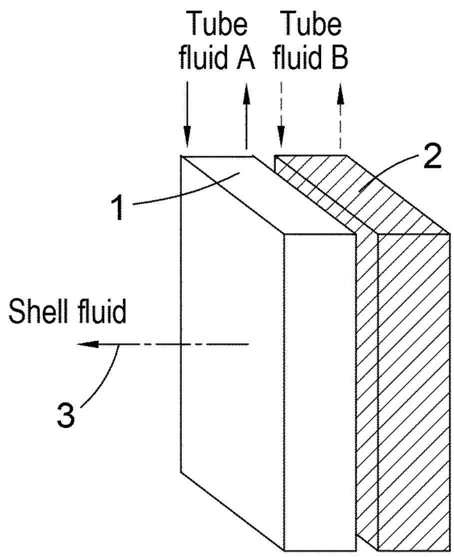

Fig. 1B
(PRIOR ART)

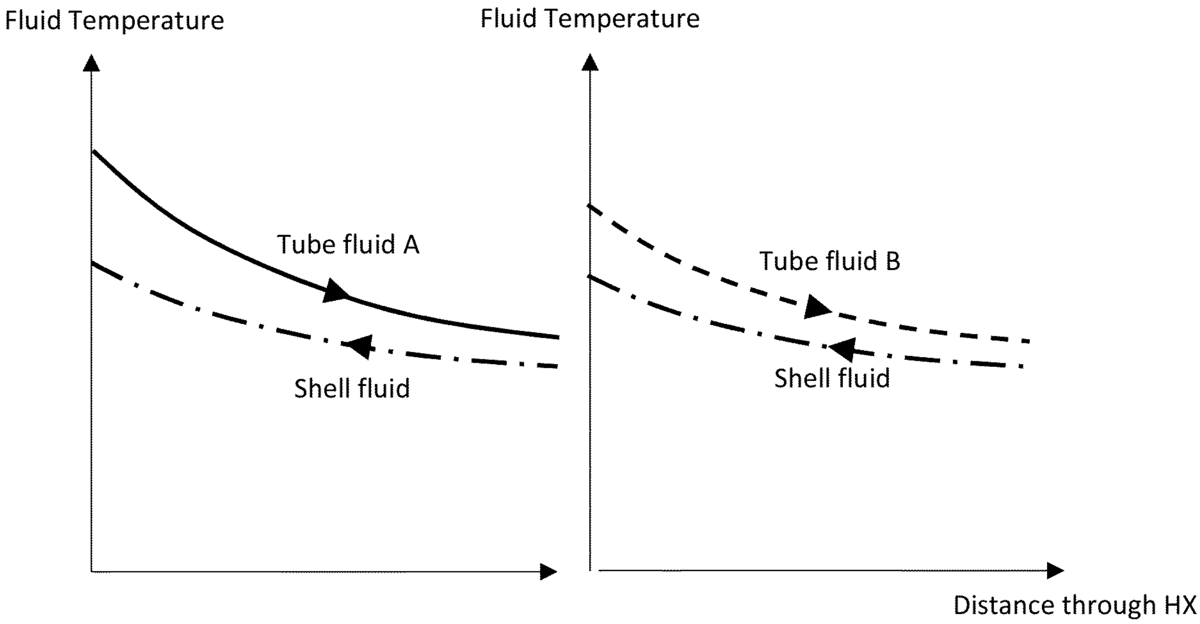

Fig. 2A
(PRIOR ART)

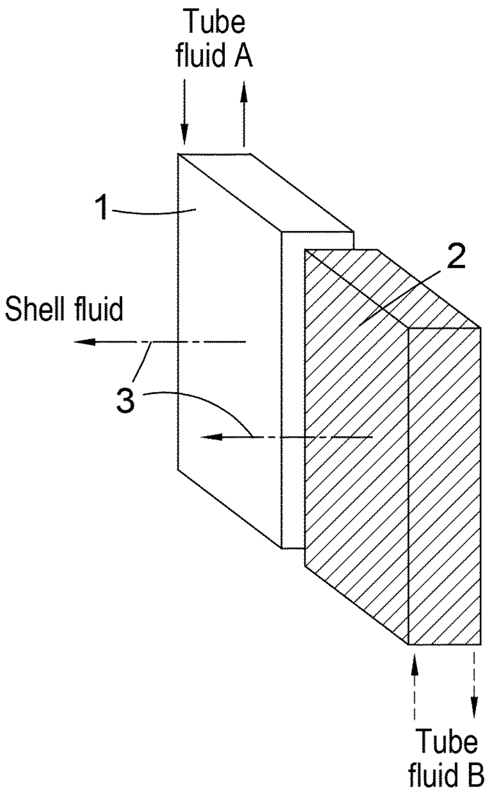

Fig. 2B
(PRIOR ART)

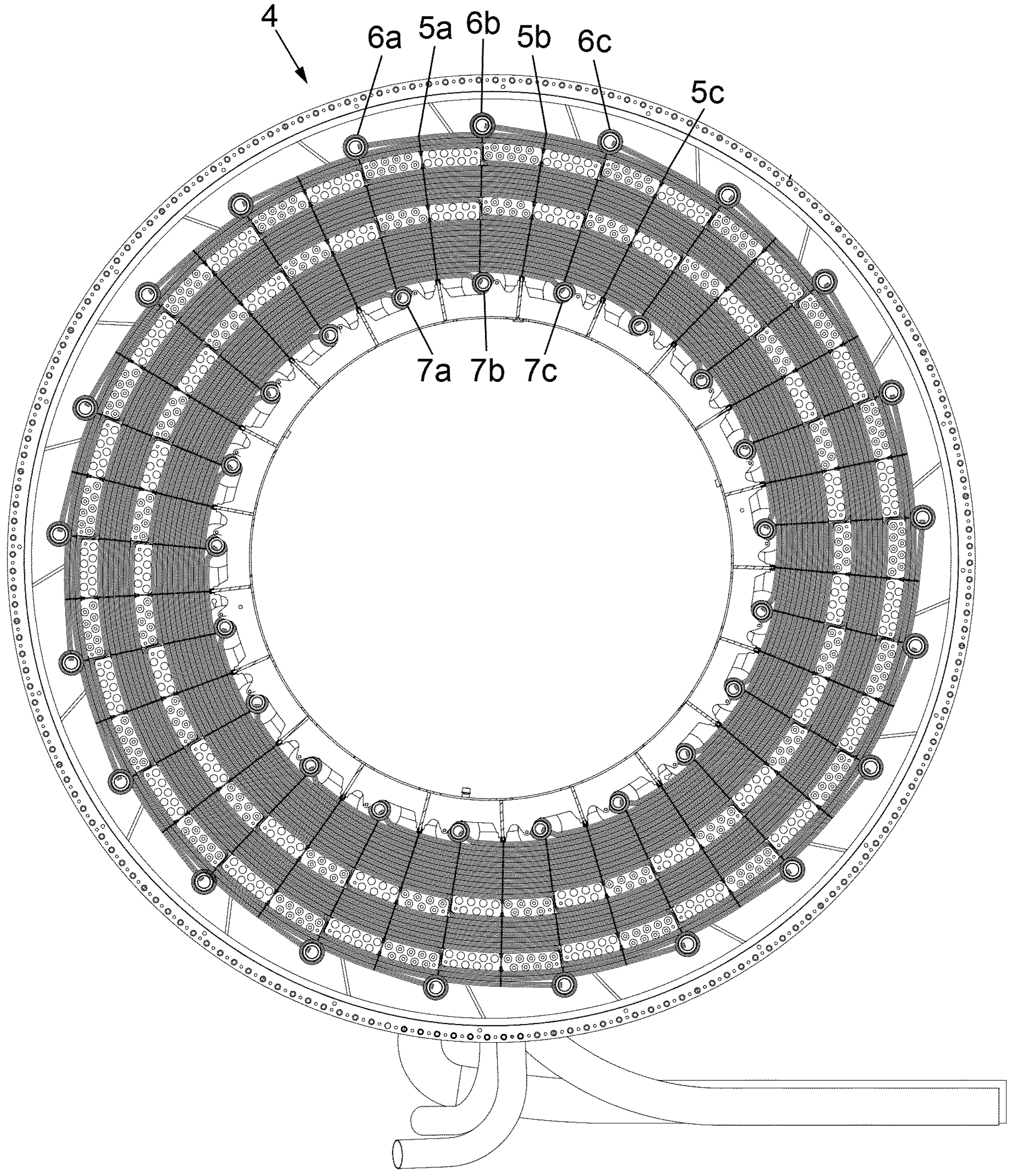

Fig. 3
(PRIOR ART)

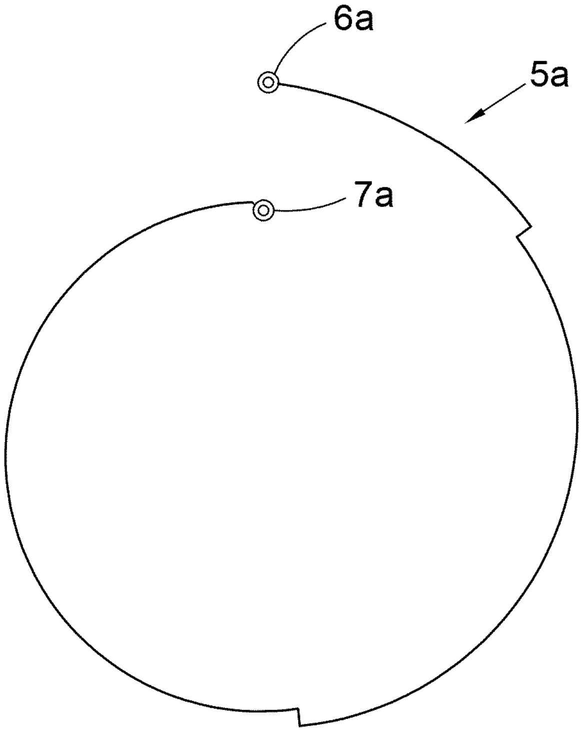

Fig. 4
(PRIOR ART)

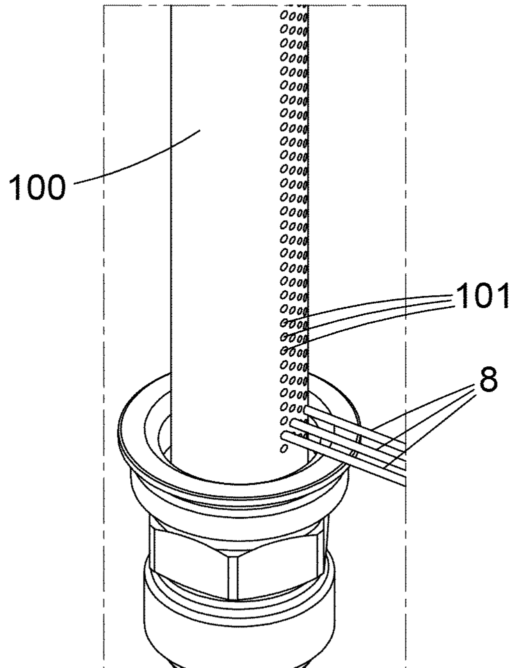

Fig. 5
(PRIOR ART)

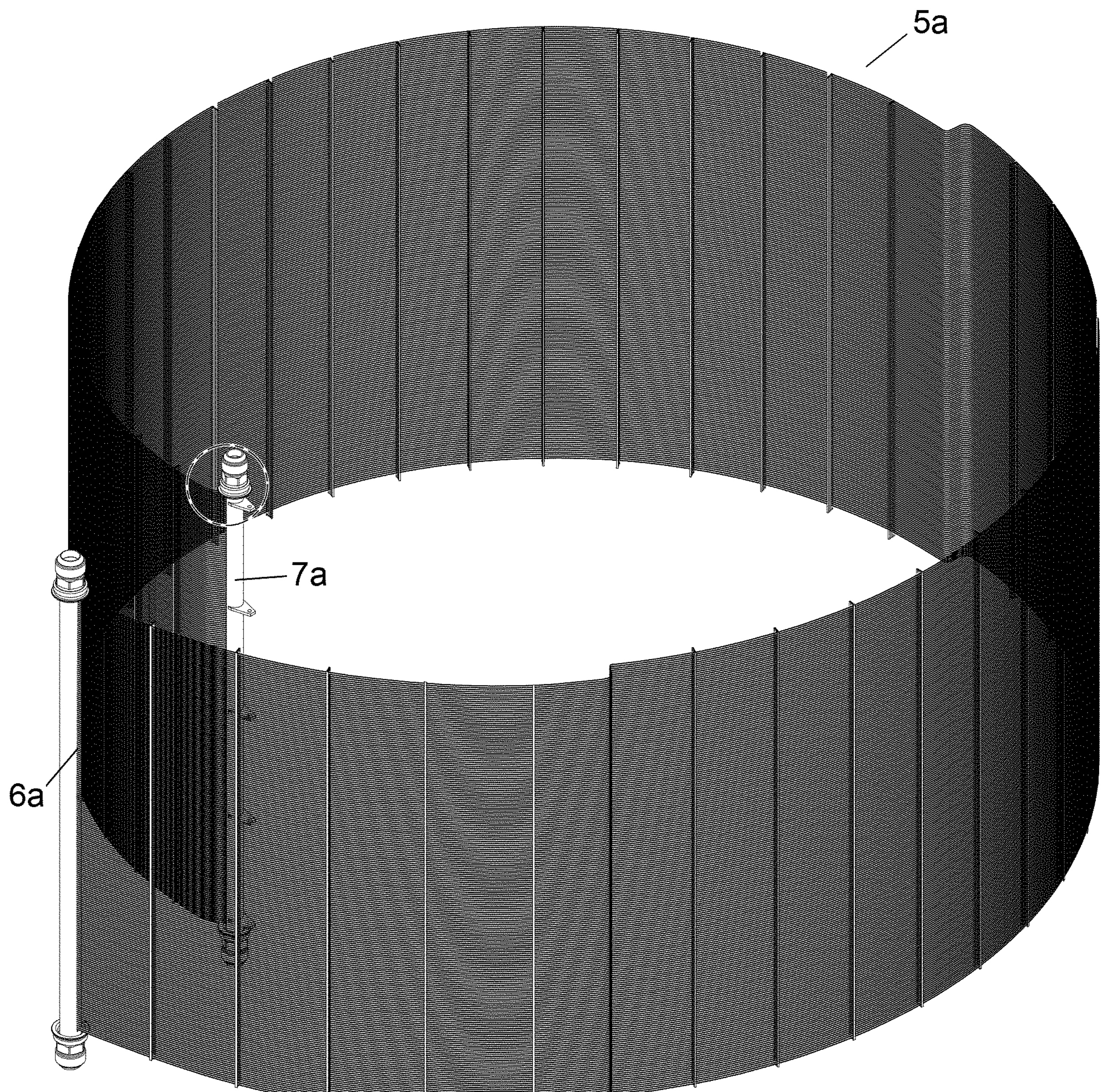

Fig. 6
(PRIOR ART)

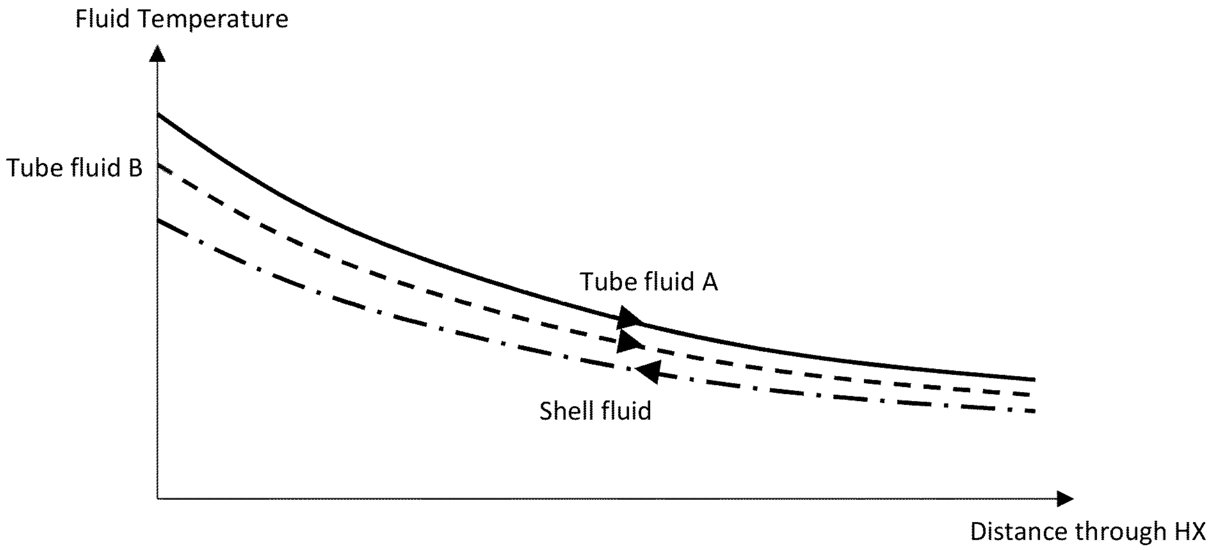
Fluid Temperature
Tube fluid B
Tube fluid A
Shell fluid
Distance through HX

Fig. 7A

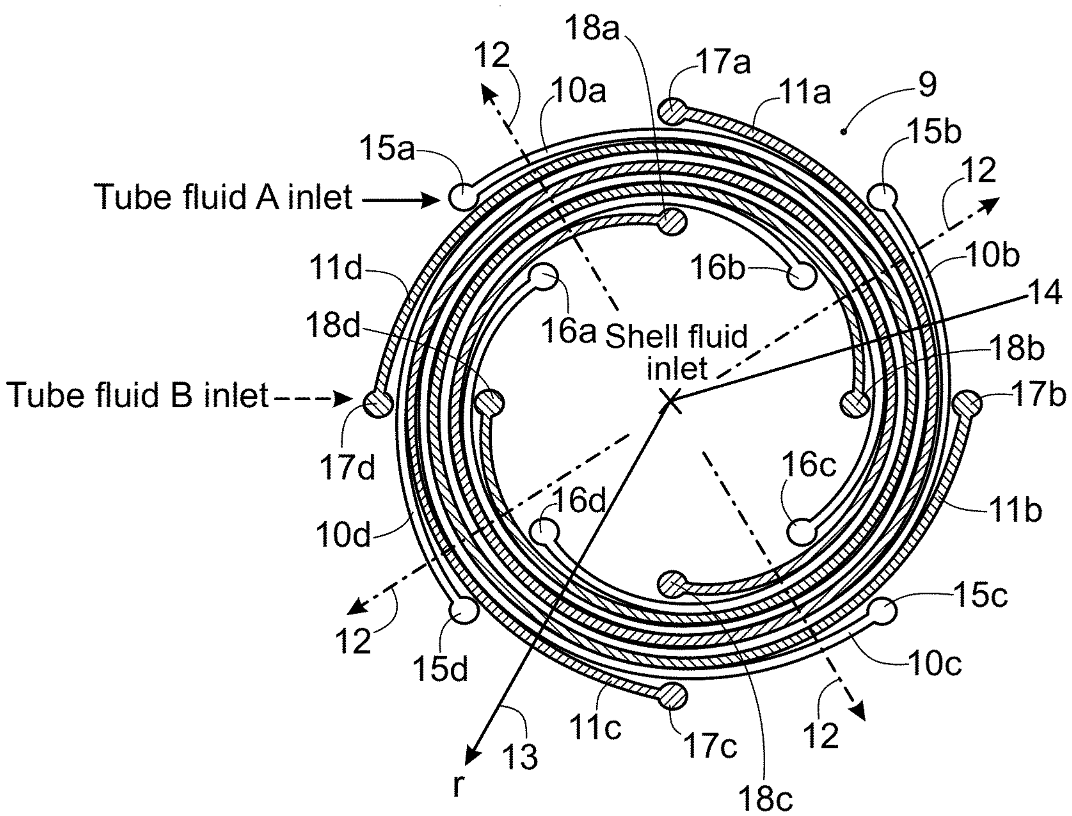
18a
12
17a
11a
9
10a
15a
15b
Tube fluid A inlet
12
16b
10b
11d
14
18d
16a
Shell fluid inlet
18b
Tube fluid B inlet
17b
17d
16c
16d
11b
10d
15c
12
15d
10c
11c
17c
12
13
r
18c

Fig. 7B

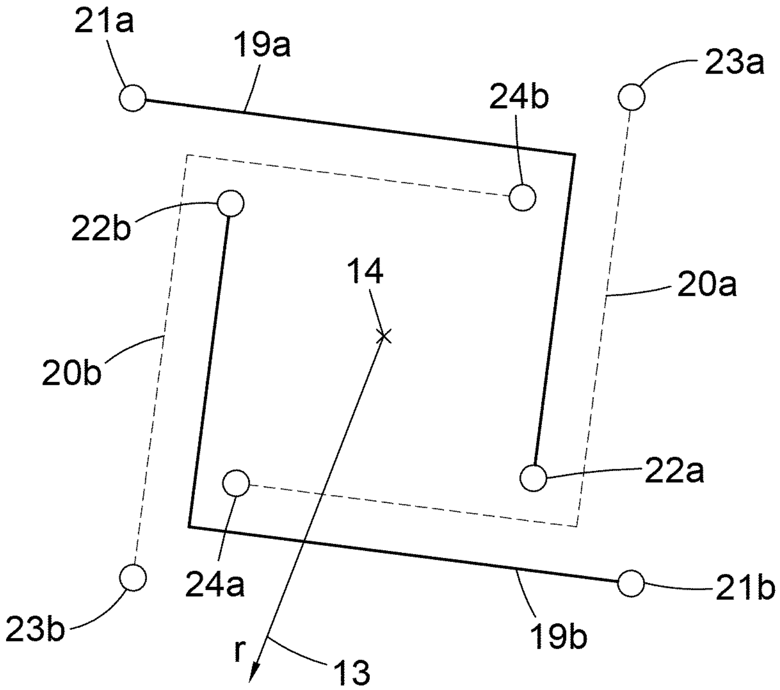

Fig. 8

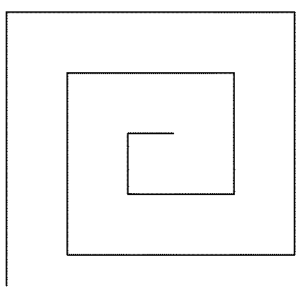

Fig. 9A

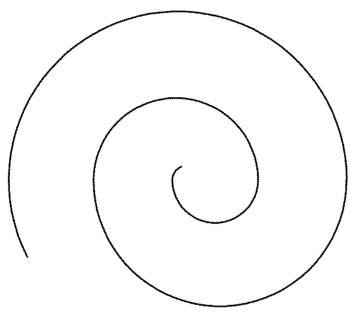

Fig. 9B

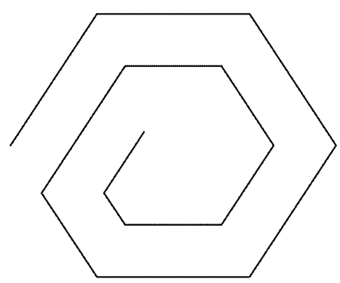

Fig. 9C

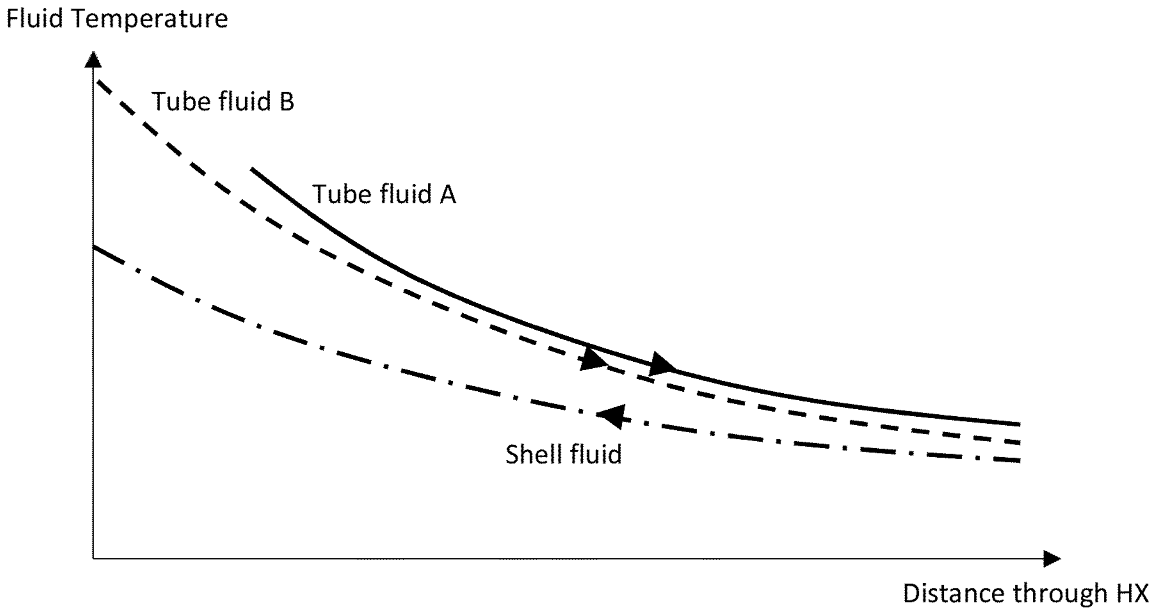

Fig. 10A

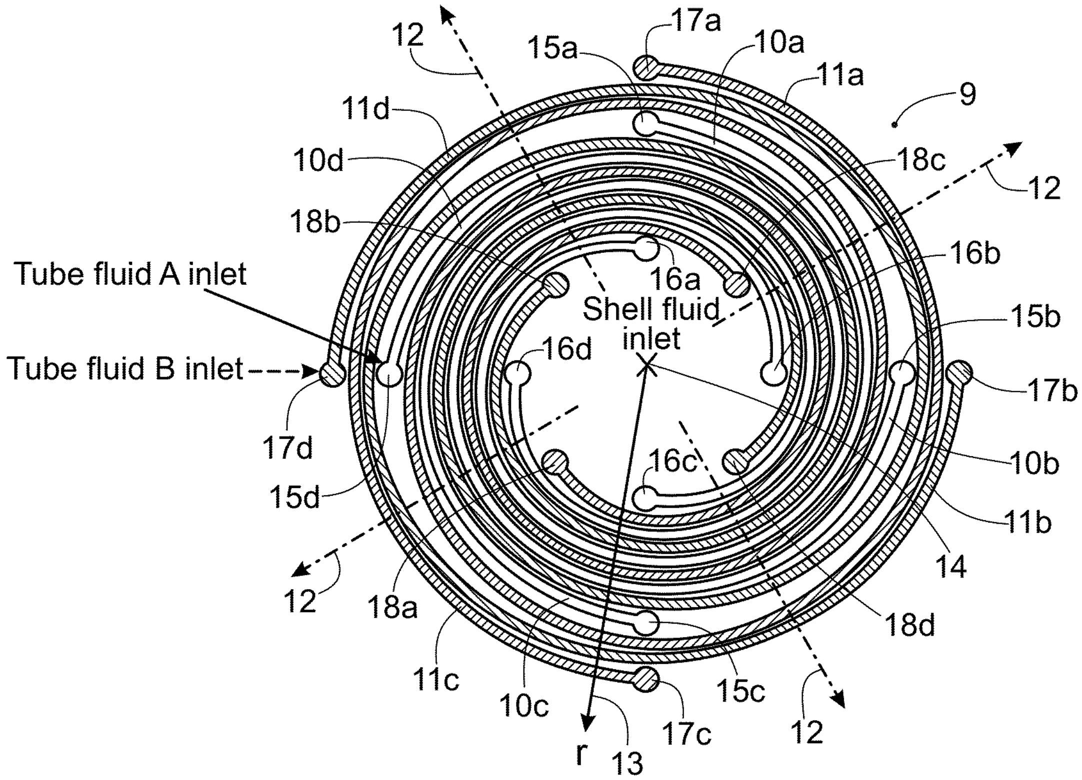

Fig. 10B

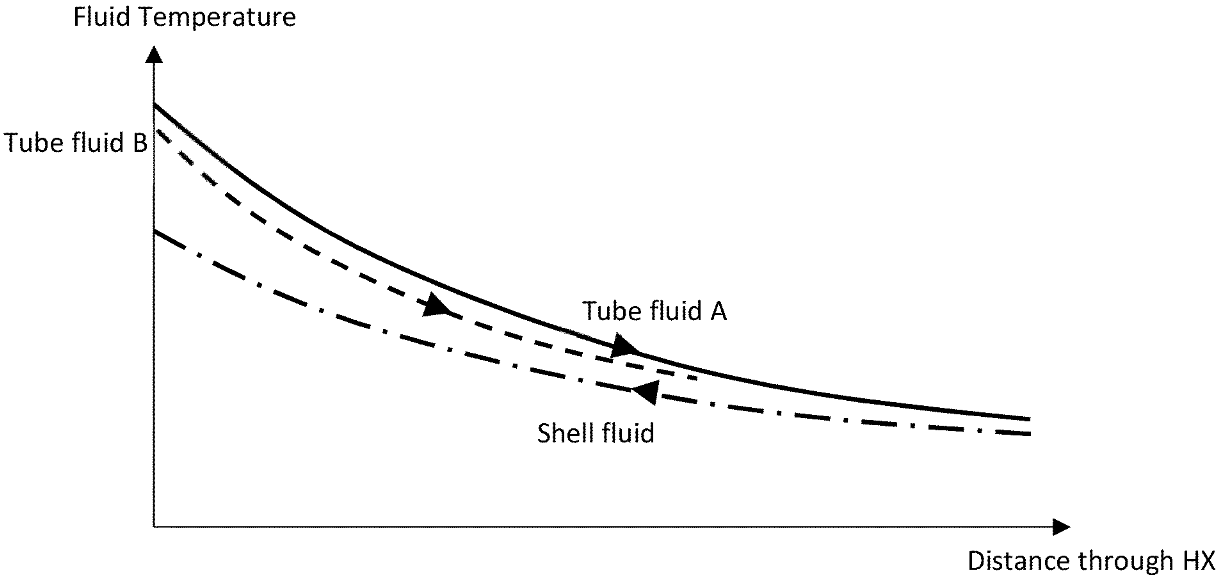

Fig. 11A

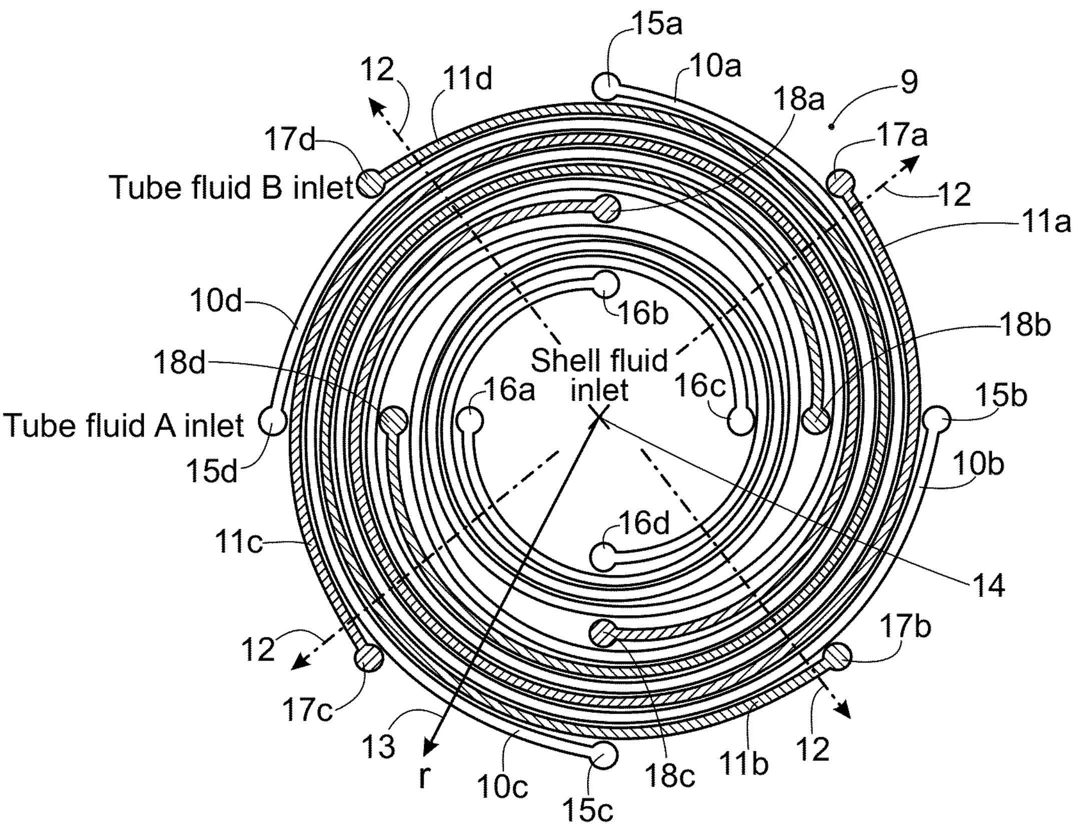

Fig. 11B

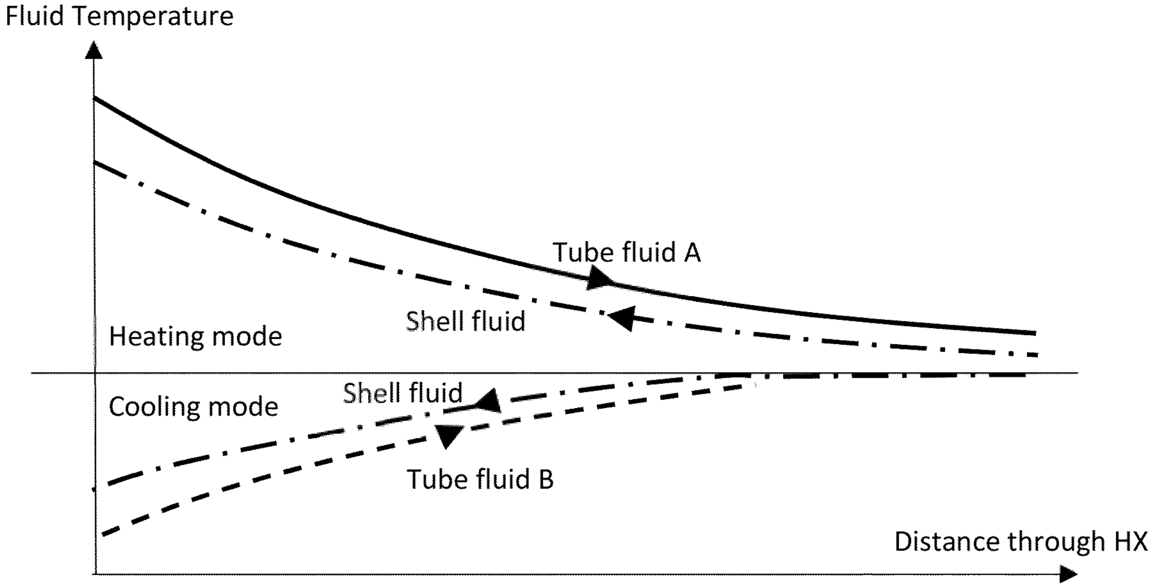

Fig. 12A

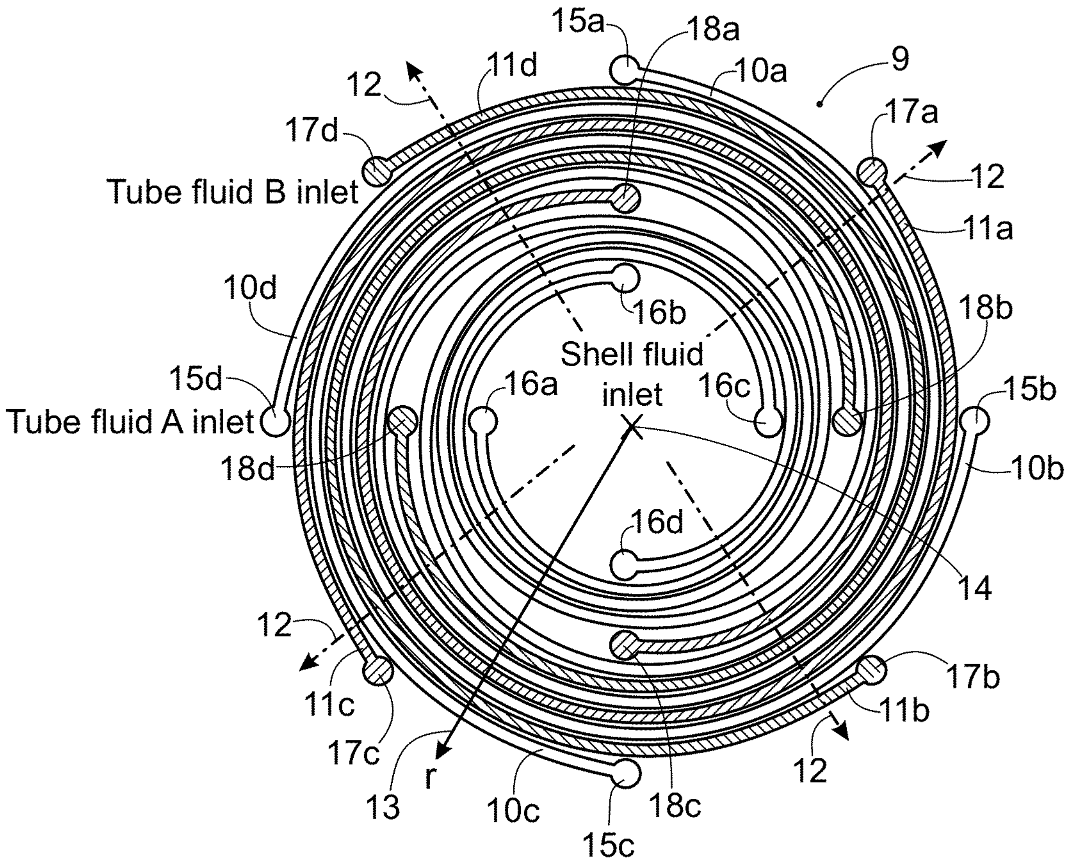

Fig. 12B

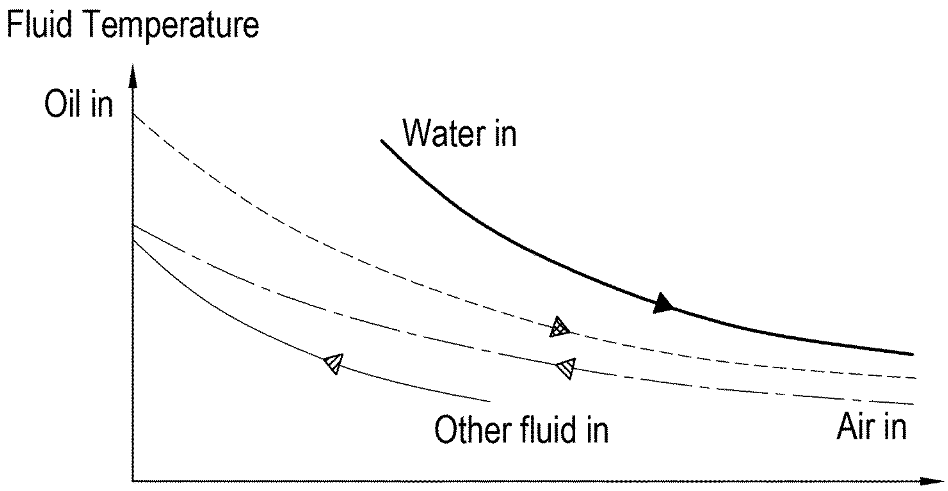

Fig. 13A

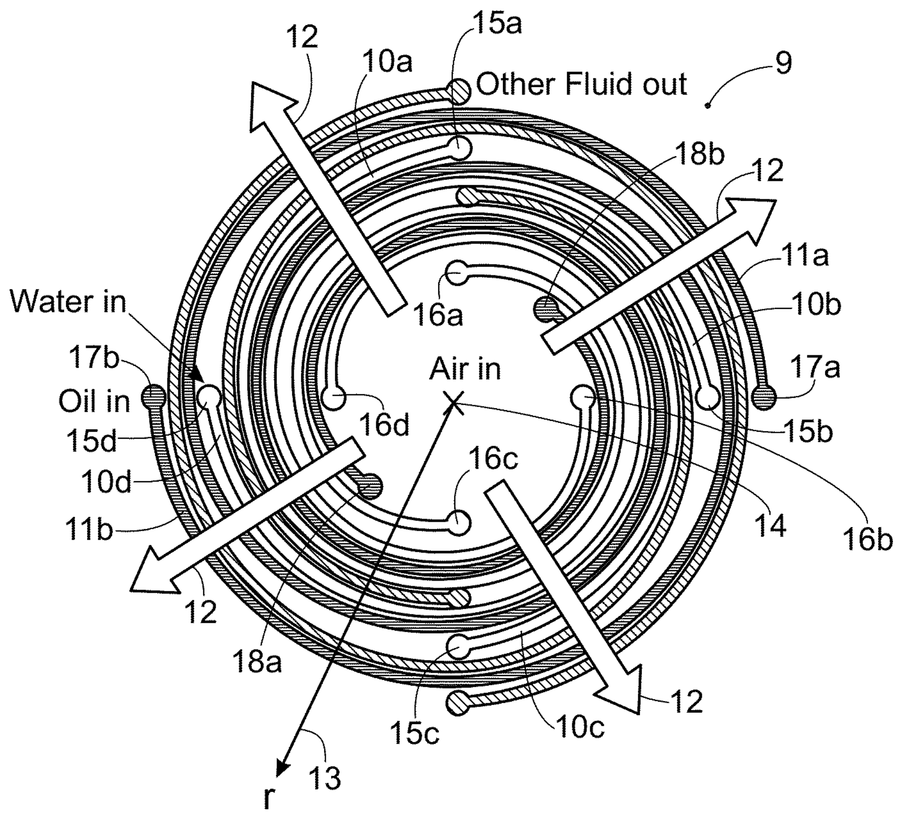

Fig. 13B