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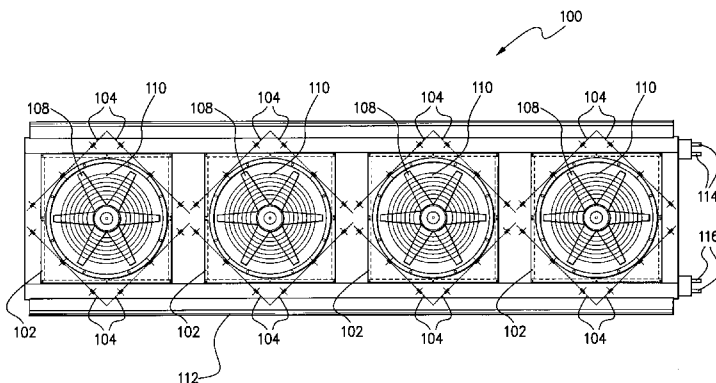


FIG. 6

(57) Abstract: A heat exchange system (100) including at least one first heat exchanger having a closed circuit for cooling fluid, a least one fan arrangement (110) operable to cause air to pass through the first heat exchanger, and, at least one air cooler (112) located upstream of the first heat exchanger, wherein the first heat exchanger includes a microchannel heat exchanger (104).

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## COOLING SYSTEM WITH MICROCHANNEL HEAT EXCHANGER

### Field of the Invention

The present invention generally relates to cooling systems, and in particular a fluid cooling heat exchanger in which fluid is cooled substantially  
5 by convective heat transfer. The invention is particularly suited to cooling systems for relatively large volumes such as, for example, a part of an air conditioning system in large office buildings or commercial refrigeration systems.

### Background of the Invention

10 Heating and cooling systems are used in most modern premises to maintain the temperature in those premises within predetermined limits. One type of system for the cooling of large buildings is a cooling system that incorporates a roof top mounted heat exchanger. In this type of system, the thermal energy from air in the building is transferred through one or more  
15 interconnected heat exchange units within the building to a roof mounted heat exchange unit. In the building, a refrigerant is used to cool air as the air passes through a heat exchange unit (an evaporator). The heated refrigerant is then passed to another heat exchange unit (a condenser) wherein heat is extracted from the refrigerant using a heat exchange fluid such as water. The heated  
20 water is usually then transferred to the roof top mounted heat exchanger which uses ambient air at the roof of the building to cool the water in preparation for further use. The most commonly installed roof top mounted heat exchanger is a type known as an "open" system that incorporates many disadvantages, such as the propensity to generate and transmit sufficient levels of the bacterium  
25 known as *Legionella pneumophila* to cause Legionnaire's disease in people that inhale the bacterium.

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Large buildings typically require the removal of a large heat load particularly during the height of summer. Accordingly, roof top mounted heat exchangers are generally configured to provide a sufficient heat exchange capacity to cope with the largest expected heat load.

5 In view of the problems associated with "open" roof top mounted heat exchangers, there is an increasing trend for building owners to consider "closed" roof top mounted heat exchanger or heat exchanger arrangements wherein the cooling fluid remains within a closed cooling circuit and is not exposed to the atmosphere. A closed circuit heat exchanger avoids the  
10 problems associated with generating and transmitting the Legionella pneumophilia bacterium. However, closed circuit heat exchangers suffer a range of different problems including a substantially reduced heat exchange capacity as compared with an open roof top mounted heat exchanger of similar dimension and weight.

15 To address the problem of a closed circuit heat exchanger providing a substantially reduced heat exchange capacity, in some instances an air cooler is located upstream of the closed circuit heat exchanger. In these configurations, the air cooler effectively cools the ambient air prior to passage of same through and/or over the closed circuit heat exchanger thereby improving the overall  
20 heat exchange capacity.

A significant disadvantage of conventional closed circuit heat exchanger configurations is that, when the fans of the heat exchange system cause air to pass through the heat exchanger, there is a large pressure drop caused by air having to pass through the tube and fin arrangement of the  
25 conventional heat exchanger body. This is particularly the case where an air cooler is disposed upstream of the heat exchanger which has the effect of providing an increased resistance to the airflow passing through the air cooler and subsequently through the heat exchanger body. The large pressure drop necessitates operating the fans at a higher speed, which, in turn, consumes

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more energy and causes the fans to produce more noise. The noise of the fans in such systems can be so loud as to render such cooling systems unsuitable for some installations. This is particularly the case where a closed circuit heat exchanger is required in a location relatively close to residential housing. In  
5 these particular instances, the statutory limitations with respect to the generation of noise can render a typical closed circuit heat exchanger unsuitable for the application. This factor can severely limit the commercial usefulness of these systems.

Another disadvantage of closed circuit heat exchanger configurations is  
10 that the conventional heat exchanger used in these systems is limited to operating with certain types of cooling fluid. Typically these closed circuit heat exchangers cannot support operation with cooling fluids that require a higher operating pressure.

Accordingly, it is desirable to provide an alternative closed circuit heat  
15 exchanger that is quieter than existing closed circuit heat exchange systems incorporating an upstream air cooler. It is further desirable to provide an alternative closed circuit heat exchanger that consumes less energy to operate the fans as compared with existing arrangements incorporating an upstream air cooler.

## 20 **Summary of the Invention**

In one aspect, the present invention provides a heat exchange system including at least one first heat exchanger having a closed circuit for cooling fluid, at least one air cooler located upstream of the at least one first heat exchanger, and at least one fan arrangement operable to cause air to pass  
25 through the at least one first heat exchanger and the at least one air cooler, wherein the at least one first heat exchanger includes a microchannel heat exchanger.

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A microchannel heat exchanger is a heat exchanger with fluid passages that are substantially smaller than those of standard tube and fin closed circuit heat exchangers which increases the heat transfer rate and effectiveness. The increased heat transfer rate and effectiveness allows the microchannel heat exchanger to be smaller and have substantially the same, or even better, performance as compared with standard tube and fin closed circuit heat exchangers.

In one exemplary arrangement having a closed circuit microchannel heat exchanger, the cooling fluid is supplied through a substantially horizontal supply header and is passed from the closed circuit microchannel heat exchanger through another substantially horizontal return header. In one arrangement the supply header is located at or near the top of the closed circuit microchannel heat exchanger and the return header is located at or near the bottom of the closed circuit microchannel heat exchanger such that cooling fluid passes into the closed circuit microchannel heat exchanger at or near the top and passes once through the closed circuit microchannel heat exchanger by the action of gravity and subsequently passing out through the return header, at or near the bottom.

In another embodiment the supply header and the return header are located at or near the vertical sides of the closed circuit microchannel heat exchanger. Typically, cooling fluid flows in through the supply header and passes through the fluid passages of the closed circuit microchannel heat exchanger to the return header where the cooling fluid may flow out of the return header.

In another embodiment, the heat exchange system includes a second microchannel heat exchanger aligned substantially in series with the first microchannel heat exchanger from an air flow perspective thereby forming a microchannel heat exchanger stack. In this embodiment, an increased heat exchange capacity is achieved by use of a stack of microchannel heat

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exchangers although placing two or more microchannel heat exchangers in air flow series to form a stack is expected to increase the resistance of air flow through the stack and hence require a substantially greater supply of air. This in turn increases the electrical energy consumption of the fan arrangement as it  
5 is required to cause air to pass through an arrangement presenting greater air flow resistance as compared with a single heat exchanger. However, it has been surprisingly found that the amount of increased heat exchange capacity sufficiently offsets the amount of increased electrical energy consumption of the fan such that this arrangement presents an unexpected net benefit.

10 In particular, the surprising result achieved by arranging microchannel heat exchangers in a stack in air flow series is that the arrangement provides a substantial improvement in heat exchange capacity without necessitating a substantial increase in the speed of the fan arrangement. As the speed of operation of a fan directly affects the noise generated by the fan, the ability to  
15 retain a relatively low fan speed despite arranging microchannel heat exchangers in a stack results in a dramatic increase in the heat exchange capacity without a substantial increase in the noise associated with the speed of the fan arrangement. This surprising result allows the development of heat exchanger configurations with a sufficient heat exchange capacity to be located  
20 in environments that are subject to noise restrictions that would otherwise not be permitted. This increases the commercial viability of this type of heat exchanger in a broader range of applications.

The ability to form a stack of microchannel heat exchangers is also relevant to the choice of cooling fluid. For example, in the instance of using a  
25 refrigerant or oil as the cooling fluid, it may only be necessary to provide a heat exchanger with a single microchannel heat exchanger to provide the requisite heat exchange capacity whilst retaining the noise generated by the electrical fan arrangement within necessary noise limits. However, in instances where water is the preferred cooling fluid, a single microchannel heat exchanger may

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not provide sufficient heat exchange capacity and a stack arrangement of microchannel heat exchangers may be required. The ability to configure a stack of microchannel heat exchangers without requiring a substantial increase in fan speed thus enables the configuration of a heat exchange system with water as the cooling fluid whilst retaining the noise generated by the electrical fan arrangement to a minimum and potentially within noise limitations.

In some embodiments, the first microchannel heat exchanger is arranged in parallel or in series with one or more further first microchannel heat exchangers.

10 In one embodiment, the air cooler, when in use, has air induced to pass through it caused by a fan arrangement, which may be the first fan arrangement. In this embodiment the air that passes through the air cooler is cooled. The cooled air then passes through the closed circuit microchannel heat exchanger.

15 In another embodiment, the first closed circuit microchannel heat exchanger is configured in a substantially cross-sectional tubular arrangement wherein the first fan arrangement is operable to cause air to pass longitudinally through the internal space of the substantially tubular arrangement of the first closed circuit microchannel heat exchanger. Of course, air may also pass  
20 through the walls of the substantially tubular arrangement thereby assisting the heat exchange process.

In a further embodiment, a second microchannel heat exchanger having a closed circuit for cooling fluid is arranged with the first closed circuit microchannel heat exchanger such that they form a substantially cross-sectional tubular arrangement with an internal space through which air can  
25 pass.

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The fan arrangement can be situated in various locations relative to the first closed circuit microchannel heat exchanger. However, in one exemplary embodiment, the direction of the air flow resulting from the operation of the first fan arrangement is in a direction that is substantially aligned with the longitudinal axis of the tubular arrangement, or is substantially aligned with the longitudinal axis of the arrangement of the first and the second closed circuit microchannel heat exchangers.

Of course, a heat exchange system according to the present invention may include one or more fan arrangements that cause air to pass through the first microchannel heat exchanger. In those embodiments including two or more fan arrangements, the direction of airflow of each fan arrangement may be substantially aligned. In exemplary embodiments of the present invention, the heat exchange system includes a single fan arrangement at one end of the tubular arrangement for forcing air through the first closed circuit microchannel heat exchanger.

When the first closed circuit microchannel heat exchanger is formed in a substantially tubular arrangement, it may have various cross-sectional shapes perpendicular to its nominal longitudinal axis. Suitable shapes include substantially square, hexagonal, octagonal, star-shaped, triangular or similar. In one embodiment, the tubular arrangement has a generally circular or oval cross-section perpendicular to its nominal longitudinal axis. In another exemplary embodiment, the substantially tubular arrangement has a generally square or rectangular cross-section perpendicular to the nominal longitudinal axis. In this embodiment, the generally square or rectangular cross-section has one or more arcuate corners.

The structure of the tubular arrangement can circumferentially extend wholly or partially around the longitudinal axis of the tubular arrangement. Of course, in some arrangements the tubular arrangement forms a continuous body around the longitudinal axis. This forms an enclosed tube around the

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longitudinal axis of the tubular arrangement. In other exemplary embodiments, the first closed circuit microchannel heat exchanger could operate with the substantially tubular arrangement and a microchannel heat exchange body forming the wall of the tubular arrangement extending partially around its longitudinal axis. This would provide a circumferential gap in the body of the tubular arrangement. As can be appreciated, the greater the tubular arrangement of the microchannel heat exchange body extends around the longitudinal axis, the more efficiently the configuration utilises the airflow from the fan arrangement for cooling the cooling fluid contained in the fluid passages in the walls of the tubular arrangement. It is therefore preferable that the tubular arrangement of the microchannel heat exchange body extends around its longitudinal axis to the greatest extent possible to substantially form an enclosure around the longitudinal axis. Of course, two or more separate closed circuit microchannel heat exchangers could be substantially butted together, or situated in close proximity, to form a generally tubular enclosure through which air passes.

The inclusion of a gap in the circumference of the tubular arrangement could occur for numerous reasons. In one embodiment, a gap is provided for the provision of a header arrangement through which cooling fluid enters and exits the closed circuit forming the walls of the tubular arrangement. The header may be provided at one or both of two spaced apart longitudinal ends each of which extend generally parallel to the longitudinal axis of the tubular arrangement. The closed circuits for the cooling fluid circumferentially extend between these ends. In some arrangements, only one of the longitudinal ends includes a header, the other end having connecting sections having a closed end. In other arrangements, each of the longitudinal ends includes a header thereby allowing fluid to flow between the headers or in separate sections of the microchannel heat exchange body connected to the respective headers.

In one exemplary embodiment, cooling fluid flows through the first closed circuit microchannel heat exchanger by entering the header arrangement at the top end of the first closed circuit microchannel heat exchanger and exiting the header arrangement at the base end of the first closed circuit microchannel heat exchanger. In this embodiment, the fan arrangement is preferably configured to cause air to flow first from the bottom and through the substantially enclosed space within the tubular microchannel heat exchanger system oriented vertically with the air being caused to flow axially upwardly to exit from the top end of the first closed circuit microchannel heat exchanger. In another exemplary embodiment a fan arrangement is located proximate to, or at the top of, the first closed circuit microchannel heat exchanger in order to draw air through the first closed circuit microchannel heat exchanger. Either of these embodiments provides a counter-current heat exchange arrangement where the directions of the airflow and cooling fluid flow are in different directions.

A large variety of types of fluid carrying passages for the first closed circuit microchannel heat exchanger could be used. In one exemplary embodiment, the microchannel heat exchanger includes a closed circuit formed by a plurality of circumferentially arranged passages that are generally laterally arranged in the heat exchange body relative to the longitudinal axis.

The cooling fluid in the closed circuit microchannel heat exchanger may be at a substantially higher pressure than in a conventional tube and fin closed circuit heat exchanger. This may allow the use of such cooling fluids as carbon dioxide.

It should be noted that the at least one first microchannel heat exchanger of the present invention has a closed circuit for the cooling fluid to ensure that the cooling fluid is prevented from exposure to the atmosphere, and in particular, to the air passing through the cooling fluid microchannel heat exchanger. In instances where water is used as the cooling fluid, this separation of cooling fluid as it passes through the microchannel heat exchanger (referred

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to as a "closed circuit" microchannel heat exchanger) from the air passing through the microchannel heat exchanger removes the risk of the distribution of airborne legionella bacterium. In practice, the closed circuit is likely to form part of a loop within a cooling system where the cooling fluid is transported  
5 from a location where the fluid is used to absorb thermal energy and subsequently transported to the cooling fluid microchannel heat exchanger in order to remove the absorbed thermal energy from the cooling fluid.

In some environments where the ambient external temperature can exceed 30° Celsius, the use of a closed circuit heat exchanger system cooled  
10 with ambient air is unable to remove sufficient thermal energy for the air conditioning system to form a commercially viable configuration. In these arrangements, convective cooling is therefore only possible by providing an impractically large primary heat exchanger which is usually a commercially non-viable prospect.

15 In high ambient temperature environments, cooling the ambient air prior to passing same through a microchannel heat exchanger results in a commercially viable configuration. In order to cool the air flowing through the first heat microchannel heat exchanger, the air cooler may be located over or proximate to one or more air inlets through which the fan arrangement causes  
20 cooled air to pass through the first closed circuit microchannel heat exchanger. In one embodiment, the fan arrangement draws cooled air through the walls of the first closed circuit microchannel heat exchanger. In this embodiment, at least one air cooler is arranged radially outwardly of the walls of the first closed circuit microchannel heat exchanger.

25 The air cooler may have a number of arrangements. In one exemplary embodiment, the air cooler includes a moisture absorbent material in the form of moisture absorbent pads, that are, in use, maintained moist such that air passing through the cooler is cooled by the action of evaporation prior to passing over a portion of the closed circuit in the first microchannel heat

exchanger. It has been found that the use of an air cooler with moisture absorbent material significantly improves the cooling capacity of the heat exchange system.

In one embodiment, the moisture absorbent material includes a plurality  
5 of fluted apertures and is arranged generally parallel to one or more of the walls of the body of the first closed circuit microchannel heat exchanger. In this arrangement, the air cooler may include a moisture dispenser that dispenses evaporating moisture onto the moisture absorbent material thus maintaining it moist during operation of the heat exchange system.

#### 10 **Brief Description of the Drawings**

The present invention will now be described with reference to the figures of the accompanying drawings, which illustrate exemplary embodiments of the present invention, wherein:

Fig. 1 is schematic diagram illustrating the main components of a  
15 closed circuit cooling system incorporating an air-cooled roof top mounted heat exchanger;

Fig. 2 is a schematic diagram illustrating a further form of a closed circuit cooling system incorporating an air-cooled roof top mounted heat exchanger illustrating an air cooler including a moisture absorbing pad;

20 Fig. 3 is a plan view of a closed circuit microchannel heat exchanger coil according to one exemplary embodiment of the present invention;

Fig. 4 is a front elevation view of the closed circuit microchannel heat exchanger coil of Fig. 2;

25 Fig. 5 is a right side elevation view of the closed circuit microchannel heat exchanger coil of Fig. 2;

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Fig. 6 is a plan view of one embodiment of a heat exchange system including closed circuit microchannel heat exchangers arranged in "V" shapes.

Fig. 7 is a front elevation view of a microchannel heat exchanger stack including two microchannel heat exchangers.

5 Fig. 8 is a right side elevation view of the microchannel heat exchanger stack of Fig. 7.

Fig. 9 is a front elevation view of a microchannel heat exchanger where the supply and return headers are, respectively, situated at, or near, the top, or the bottom, of the microchannel heat exchanger.

10 Fig. 10 is a plan view of the microchannel heat exchanger of Fig. 9.

Fig. 11 is a front elevation view of a microchannel heat exchanger where the supply and return headers are, respectively, situated at, or near, the sides of the microchannel heat exchanger.

15 Fig. 12 is a right side elevation view of the microchannel heat exchanger of Fig. 11.

Fig. 13 is a top plan view of the microchannel heat exchanger of Fig. 11.

Fig. 14 is a bottom plan view of the microchannel heat exchanger of Fig. 11.

20 Fig. 15 is a diagrammatic representation of an embodiment of a heat exchange system incorporating an existing moisture recirculation system;

Fig. 16 is a diagrammatic representation of an embodiment of a cooling system including a moisture recirculation arrangement according to an embodiment of the invention; and

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Fig. 17 is a diagrammatic representation of the cooling system of Fig. 16 providing a perspective view of some of the components detailed in Fig. 16; and

Fig 18 is a noise chart illustrating noise levels for various embodiments of cooling systems.

### Detailed Description

Referring to Fig. 1, there is shown a schematic diagram of a conventional closed circuit cooling system arrangement (18) which provides cooled air to a building (20). This closed circuit cooling system arrangement (18) includes a roof top mounted heat exchanger (23) which typically includes substantially planar primary heat exchange plates (27, 27A).

The illustrated closed circuit cooling system arrangement (18) comprises a heat exchanger system (21) located at the base of the building (20) designed for exchanging thermal load between an enclosed loop of refrigerant fluid (22) and a water circuit (30). The water circuit (30) is linked to the internal air conditioning system of the building (not shown). Air in the building (20) is generally cooled by drawing air through a duct in which a portion of the chilled water circuit (30) resides. Thermal energy from the air is transferred to the chilled water circuit (30) cooling the air in the building (20). The enclosed loop of refrigerant fluid (22) is used to cool the water circuit (30). This is achieved by passing the refrigerant fluid through a heat exchanger (28) where it absorbs thermal energy from the water circuit (30) which is also moving through the heat exchanger (28) in a counter current flow. The flow of refrigerant fluid through the circuit (22) is driven by a compressor (24) and regulated by expansion valve (26).

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A roof top mounted heat exchanger (23) is situated on the roof of the building (20). The illustrated roof top mounted heat exchanger (23) consists of air cooled condensers (27, 27A), which are configured with electrically driven fans (29 and 31) located at the top of the condensers (27, 27A), which draws  
5 air through the condenser coils of (27, 27A) via side air inlets (not illustrated) and expelling the drawn air through the fans (29 and 31) and out above the roof top mounted heat exchanger (23). It is usual for roof top mounted heat exchanger (23) to be placed upon the roof of a building (10) as heat exchangers are usually large and due to the use of large fans, (29, 31) emit a  
10 substantial amount of noise during operation. The refrigerant fluid is pumped from the basement of the building (20) up to the rooftop of the building (20) and passed through the condenser coils, (27, 27A) where heat is transferred from the refrigerant fluid to the air drawn through the coils, (27, 27A) by the fans (29 and 31).

15 The illustrated air cooled condenser uses induced draught counter-flow to draw air through the tower (23). In this configuration, the fans (29, 30) are located at the air outlet of the condensers (27, 27A). Air enters the tower (23) and is drawn vertically through the condenser (27) in a direction opposite to the flow of cooling fluid through the condensers (27, 27A).

20 Referring now to Fig. 2 there is shown a second form of closed circuit cooling system arrangement (32) which provides air conditioned air to a building (34). This cooling system arrangement (32) can include a roof top mounted heat exchanger (35) with a closed circuit cooling arrangement.

25 The illustrated cooling system arrangement (32) is similar to that described in relation to Fig. 1, in that it includes an enclosed circuit of refrigerant fluid (36) that is passed through a condenser (38) and an evaporator (40) by a compressor (42). The flow of fluid through the enclosed circuit (36) is controlled by an expansion valve (44). The evaporator (40) includes an enclosed water circuit (46) which has thermal energy removed therefrom in

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order for the enclosed water circuit (46) to be used to effect cooling of the air in the building (34) in a similar manner as described previously. The condenser (38) operates as a heat exchanger to extract thermal energy from the closed loop of refrigerant fluid (36).

5           The removal of thermal energy from the enclosed loop of refrigerant fluid (36) in the condenser (38) is effected by the use of cooling fluid which is drawn into the condenser (38) through tubing (50) and carried out of the condenser (38) through tubing (48). Cooling fluid is drawn into the condenser (38) and passed through it under the control of pump (51). Cooling fluid  
10 emitted from the condenser (38) is carried by tubing (48) to the rooftop of the building (34) where it enters a rooftop mounted closed circuit microchannel heat exchanger (52) of the closed circuit roof top mounted heat exchanger (35). The closed circuit roof top mounted heat exchanger (35) includes electrically driven fans (54 and 56) that operate to draw air therethrough.

15           The tubing (not illustrated in any detail in Figs. 1 and 2) of the closed circuit microchannel heat exchanger (52) is generally thermally conductive and disposed in a region that will be subject to air flow as air is caused to pass through the closed circuit heat exchanger (52). As can be appreciated, sections of the tubing can include thermally conductive extensions to improve the  
20 convective heat transfer efficiency as air passes over the tubing. Usually, thermally conductive extensions comprise heat fins that are usually formed from a suitably thermally conductive material. Having passed through a portion of tubing the water is then carried out of the rooftop mounted closed circuit microchannel heat exchanger (52) through down pipe (50) and is pumped into  
25 the condenser (38) using the pump (51).

In addition to passing cooling fluid through a portion of tubing subject to forced airflow, the roof top mounted heat exchanger (35) also includes an air cooler (57). The air cooler (57) includes moistened water absorbent material located upstream of the air inlets of the closed circuit microchannel heat

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exchanger (52). Operation of the fans (54, 56) draws air through the moistened water absorbent material of the air cooler (57) causing moisture in the water absorbent material to evaporate. The energy required to evaporate the moisture is extracted from the air, thus cooling the air prior to passing same through the closed circuit microchannel heat exchanger (52). The resulting cooler air allows for a greater temperature change when passing through the closed circuit heat exchangers (52) and therefore increases the effectiveness of roof top mounted heat exchanger (35) in removing thermal energy from the water flowing through the closed circuit microchannel heat exchanger (52).

10 Figs. 3 to 5 show one exemplary form of a first closed circuit microchannel heat exchanger (60) which can be used in closed circuit roof top mounted heat exchangers (23). As illustrated, the closed circuit microchannel heat exchanger (60), in this embodiment, is configured in a generally tubular shaped coil with a nominal longitudinal axis (62) X-X (best shown in Figs. 4 and 5). The tubular microchannel coil (62) is configured with a generally square lateral cross-sectional area (i.e. perpendicular to the axis X-X) as best shown in Fig. 3. The square lateral cross-section has rounded corners. The tubular microchannel coil (62) does not extend completely around the longitudinal axis X-X, but rather has a longitudinal gap (64) at one corner thereof. At the longitudinal gap (64) there is positioned a longitudinally arranged header arrangement (66) which includes inlet (68) and outlet (70) ports to the microchannel heat exchange coil (60). The header arrangement (66) comprises two longitudinally orientated headers (72) and (73), the supply header (72) having an upper side mounted inlet tube (74) and the return header (73) having a lower side mounted outlet tube (75). Of course, in other embodiments, the inlet tube (74) and outlet tube (75) may be connected by a common header arrangement. The microchannel heat exchange coil (60) and header arrangement are mounted on a square base platform (78), which is typically constructed from galvanised steel, reinforced concrete or the like.

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The gap (66) in the first microchannel heat exchanger (60) forms two longitudinal ends (76) and (77) of the microchannel heat exchange coil (60) between which a plurality of circumferentially arranged thermally conductive microchannel tubing (79) extend. The ends of each circumferential portion of microchannel tubing (79) is interconnected at various parts at each end using a U-bend junction (80) to form a tortuous path carrying water from the supply header (72) to the return header (73). The microchannel tubing (79) is mounted on a frame structure (82) mounted in the base platform (78) which provides a predetermined spacing between each circumferential length of microchannel tubing (79). This spacing is selected to allow air cooled by the air cooler to flow from the outside of the first closed circuit microchannel heat exchanger (60) through the sides of the closed circuit microchannel heat exchanger (60) and over the microchannel tubing (79).

In operation, a cooling fluid such as water, ammonia or Freon enters the closed circuit microchannel heat exchanger (60) through the supply header (72) via inlet tube (74) and flows through the tubing (79). Cooled air is forced over the microchannel tubing (79) through the action of fans (for example fans (29 and 31)) in the embodiment shown in Fig. 1 or fans (54 and 56) in the embodiment shown in Fig. 2 transferring heat from the water in the microchannel tubing (79) to the microchannel tubing (79) (generally conductive heat transfer) through to the air (generally convective heat transfer). The water in the microchannel tubing (79) is cooled and then is emitted from the first closed circuit microchannel heat exchanger (60) through the return header (73) via outlet tube (75).

Fig. 6 shows another example embodiment of a closed circuit heat exchange system (100) with 16 microchannel heat exchanger plates (104) arranged in "V" formations. Four passages are each defined by two "V" formations. Air is induced to pass through the closed circuit microchannel heat exchangers, and through the passages, by cause of each of the fan arrangements

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(110). Each of the fan arrangements (110) has an electrically driven fan (108). In this particular embodiment air coolers (112) are illustrated on each longitudinal side of the closed circuit heat exchange system (100). Also shown are the inlet (114) and outlet tubes (116), respectively for the supply and return headers. The closed circuit microchannel heat exchangers (104) and header arrangement are mounted on a square base platform (102), which is typically constructed from galvanised steel, reinforced concrete or the like. In order to reduce vibration and noise caused by the operation of the fans (108), the fans (108) are mounted in cylindrical attenuating drums (not illustrated) formed from a dampening material such as rubber or the like.

The different orientations of the microchannel heat exchangers may be used to enhance exposure of the heat exchangers to ambient air or air cooled by the air coolers. This may enhance the inflow and cooling characteristics of the heat exchange system.

Arranged at two sides outward of the side walls of the closed circuit microchannel heat exchangers (104) are located two substantially planar air coolers (112). The air coolers (112) are formed from moisture absorbent material which, which in one embodiment, retains water when moisture is distributed onto the air coolers (112) using a distribution arrangement (not illustrated). The air coolers (112) are suspended over the side walls, which form the air inlets of the closed circuit microchannel heat exchangers (104) such that cooled air passing over the tubing (79) of the microchannel heat exchangers' coils is required to pass first through the air coolers (112). As described previously, evaporation of the moisture extracts thermal energy from the air passing through the air coolers (112) and therefore cools this air. The extent to which air is cooled depends upon the ambient temperature and humidity of the external air.

It should be understood that the air coolers (112) are typically moistened by the application of water to the top of each of the air coolers (112)

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using a moisture distributor (not illustrated) such as for example a control valve or the like. The water applicator typically dispenses water over the top of air coolers (112). The water applied by the water applicator eventually trickles down through the air coolers (112) substantially wetting the entire material of the air coolers (112). In the event that the air coolers (112) do not fully absorb water applied to them, run-off from the bottom of each air cooler (112) may be collected in a tank (not illustrated) that may be returned to the water applicator via a pump (also not illustrated). In some exemplary embodiments, the run-off from the bottom of the air coolers is not recirculated to the top of the air cooler.

10           In some embodiments, the air coolers (112) of the heat exchange system (100) are only operable when the ambient air temperature surrounding the heat exchange system is above a predetermined temperature. In these embodiments, the heat exchange system (100) can include a controller that activates the use of the air coolers (112). For example, the control methodology  
15           could wet the air coolers (112) for a short period of time on a regular or periodic basis when the temperature of the cooling fluid emitted from the closed circuit microchannel heat exchanger rises above a first pre-determined limit. For example, the first predetermined limit could be 24 °C. The air coolers (112) would be wetted when cooling fluid temperature is above the first limit  
20           until such time that the temperature of the cooling fluid emitted from the closed circuit microchannel heat exchanger drops below a second predetermined limit. The second predetermined limit is preferably at least 2 °C below the first predetermined limit temperature to avoid the dispensers being constantly activated and deactivated in response to small fluctuations in the temperature  
25           of the cooling fluid around the predetermined limits.

Alternative control methodologies could be employed with the objective being to operate the air coolers (112) for the least required time to accommodate the requirement for an increased cooling capacity for the period  
30           of time that the increased cooling capacity is required.

- 20 -

In operation, a cooling fluid such as water, ammonia or Freon enters the closed circuit microchannel heat exchangers (104) through the supply header via an inlet tubes (114) and flows through the tubing of the microchannel heat exchangers (104). Cooled air is forced over the microchannel heat exchangers (104) through the action of fans (for example fans (108)) in the embodiment shown in Fig. 1 or fans (54 and 56) in the embodiment shown in Fig. 2 transferring heat from the water in the microchannel heat exchangers (104) to the tubing of the microchannel heat exchanger (104) (generally conductive heat transfer) through to the air (generally convective heat transfer). The water in the tubing is cooled and then is emitted from the first closed circuit microchannel heat exchanger (104) through the return header via outlet tubes (116).

A structure such as that detailed in Fig 6 may be constructed on a roof of a building, such as is illustrated in Figs. 1 and 2.

In this embodiment, the fan arrangement (108) is centrally mounted with its fan (108) rotatable about an axis which is substantially aligned with the longitudinal axes each defined by two "V" formations of the closed circuit microchannel heat exchangers (60). However, in some embodiments, the fan (108) may not be mounted in a cylindrical attenuating drum, but rather a cavity having a larger diameter measurement than the internal diagonal measure of the passages, each defined by two "V" formations of the closed circuit heat exchangers (104). This allows the fan (108) to have a wider blade and therefore draw a higher volumetric flow rate through the closed circuit microchannel heat exchanger (104) as compared with a smaller fan. In addition, the fan (108) is orientated with the fan blades directed upwardly away from the fan motor and the interior of the closed circuit microchannel heat exchanger (104). In other embodiments, variable pitch fans are used to draw air through the first closed circuit heat exchanger and the air coolers.

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A range of cooling fluids other than water could be used in the closed circuit of a microchannel heat exchanger. In one alternative embodiment, the cooling fluid comprises highly concentrated ammonia with a first closed circuit microchannel heat exchanger comprising stainless steel or aluminium tubing effecting passage of the ammonia through the closed circuit microchannel heat exchanger. Further, a range of materials could be used to form the passages for the cooling fluid such as mild steel. As is understood in the art, the improved cooling effect of a heat exchanger according to the present invention enables the construction of a heat exchanger, comprising an ammonia cooling fluid, of a reduced physical size with a similar cooling capacity as that for larger sized conventional heat exchangers. As a result, closed circuit microchannel heat exchangers using ammonia as the cooling fluid become a more economically feasible option for relatively small installations.

In one embodiment the microchannel heat exchanger may be made entirely of aluminium in order to allow it to be more easily recycled at the end of its operating life.

Fig. 7 is a front elevation view of one embodiment of a stacked microchannel heat exchanger (120). In this embodiment the closed circuit microchannel heat exchanger (120) is a stacked closed circuit microchannel heat exchanger which has a first microchannel heat exchanger (122) and a second microchannel heat exchanger (124) which is aligned substantially in series with the first microchannel heat exchanger (122) from an air flow perspective so that air which is caused to pass through the closed circuit microchannel heat exchanger passes over both the microchannel heat exchangers. Cooling fluid flows in at a first supply header (138) via inlet tubes (126) which then flows up the first microchannel heat exchanger (122) until it reaches a first outlet header (134). This first outlet header (134) is in cooling fluid communication via tubes (130) with a second supply header (132) for the second microchannel heat exchanger (124). The second supply header (132)

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allows cooling fluid to flow down through the second microchannel heat exchanger (124) until it reaches a return header (136). The cooling fluid may then flow to another closed circuit microchannel heat exchanger in the heat exchanger system (100), alternatively it may flow to another closed circuit heat exchanger in another heat exchanger system (not shown), further alternatively it may flow out to another part of a cooling system arrangement as shown in Figs. 1 or 2. In some embodiments the stacked closed circuit heat exchanger may have a third, fourth and more heat exchangers in the stack.

Fig. 8 is a right side elevation view of an embodiment of a stacked closed circuit microchannel heat exchanger of Fig. 8. The flow of the cooling fluid through the microchannel heat exchangers is shown by arrows. The flow of the cooling fluid in the first microchannel heat exchanger (122) is in an upwards direction (123) and the flow of the cooling fluid in the second microchannel heat exchanger (124) is in an downwards direction (125). Other embodiments of the stacked microchannel heat exchanger may have more than two microchannel heat exchangers in the stack.

Fig. 9. is a front elevation view of another embodiment of the closed circuit microchannel heat exchanger (140) where the supply header (150) is situated at, or near, the top of the microchannel heat exchanger passages (142) and is positioned generally horizontally. The return header (152) is situated at, or near, the bottom of the microchannel heat exchanger passages (142) and is also positioned generally horizontally. Cooling fluid, when in use, flows in through the inlet tubes (144) to the supply header (150) and flows from the supply header to the passages in the microchannel heat exchanger (142). Cooling fluid flows in a downward direction through the passages in the microchannel heat exchanger (142) marked by arrows (148) to the return header (152) and flows from the return header via the outlet tubes (146). In this embodiment, the cooling fluid generally flows only once through the

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passages (142) when flowing through the closed circuit microchannel heat exchanger (140).

Fig. 10 is a plan view of an embodiment of the microchannel heat exchanger shown in Fig. 9.

5 Fig. 11. is a front elevation view of another embodiment of the closed circuit microchannel heat exchanger (160) where a first header (164) is situated at, or near, the side of microchannel heat exchanger passages (170) and is positioned generally vertically. A second header (168) is situated at, or near, an opposite side relative to the supply header of the microchannel heat exchanger passages (170) and is also positioned generally vertically. Cooling fluid, when in use, flows in through an inlet tube (162) to the first header (164) and flows from the first header to the passages in the microchannel heat exchanger (170). Cooling fluid flows generally in a single direction through the passages in the microchannel heat exchanger (170) marked by arrows (148) 10 between the first header (164) and the second header (168). Cooling fluid then flows from the second header via an outlet tube (166). In this embodiment, the cooling fluid generally flows a single time through the passages (142) when flowing through the closed circuit microchannel heat exchanger (140). 15

Fig. 12 is an end elevation view of the embodiment of the closed circuit 20 microchannel heat exchanger shown in Fig. 11. This is illustrated with the second header (168) foremost.

Figs. 13 and 14 are top and bottom plan views of the embodiment of the closed circuit microchannel heat exchanger shown in Fig. 11.

25 With reference to Figure 15, a diagrammatic representation of a heat exchange system arrangement is provided wherein cooling fluid is passed through closed circuit microchannel heat exchangers (225, 230) through an supply pipe (215) and subsequent to passing through the closed circuit

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microchannel heat exchangers (225, 230) is emitted through an return pipe (220). The cooling fluid may be water or a refrigerant fluid that is used to transfer thermal energy such as Freon. Further, where the cooling fluid is water, additives such as Glycol may be added to attempt to prevent freezing of the cooling fluid. The cooling fluid is supplied to the closed circuit microchannel heat exchangers (225, 230) through the supply pipe (215) for the purpose of cooling the cooling fluid and during the passage through the closed circuit microchannel heat exchangers (225, 230) thermal energy is extracted from the cooling fluid such that the fluid emitted through the return pipe (220) has a substantially lower temperature and hence may be returned to a part of the cooling system that uses the fluid for the purpose of absorbing and transferring thermal energy.

During periods where the ambient air temperature is sufficiently low, air is drawn through the closed circuit microchannel heat exchangers (225, 230) without the operation of the air cooler. In this instance, the heat exchange system (210) is described as running in the "dry" mode and thermal energy is extracted from the cooling fluid solely by the action of passing air through the closed circuit microchannel heat exchangers (225, 230) as the cooling fluid (water/refrigerant) passes through the closed circuit microchannel heat exchangers (225, 230).

However, during periods where the ambient air temperature is not sufficiently low, or an increased heat exchange capacity is required that may not be effected by operating a closed circuit microchannel heat exchanger in the "dry" mode, moisture absorbent material in the form of air coolers (235, 240) are moistened (preferably with water) in order to effect evaporative cooling of the air prior to the passage of same through the closed circuit microchannel heat exchangers (225, 230).

In the event that the air cooler is completely dry and has no water in the troughs (255, 260) then the water make-up solenoid valve (270) is opened in

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order to introduce external make-up water into the troughs (255, 260) through conduits (267, 265). The external make-up water is provided to the water make-up solenoid valve (270) through an inlet conduit (272). A back pressure flow prevention device (273) may be included depending upon local  
5 installation regulations.

The troughs (255, 260) include a water level monitoring device generally in the form of a flotation device that monitors the water level in the troughs (255, 260). Once there is a sufficient water level in the troughs to maintain a positive head of pressure to the inlet of the pump (245) then the  
10 pump may be operated to pump water through a conduit (246) and provide same to water distribution arrangements (247, 250) for distribution of the water to the upper portions of the air coolers (235, 240).

Of course, as water trickles down through the air coolers (235, 240) under the action of gravity the moisture absorbent material in the air cooler  
15 absorbs the water and once saturated any additional water provided to the air coolers (235, 240) will run-off the moisture absorbent material. Ultimately, any run-off water will be collected in the troughs (255, 260). The troughs (255, 260) have an overflow mechanism (280, 285) in the event that there is a continuing supply of run-off water entering the troughs (255, 260) despite the  
20 float monitoring device detecting a sufficient water level in the trough and deactivating the water make-up solenoid valve (270). Over time, as the evaporative cooling system operates, water is evaporated as it cools the ambient air passing through the air coolers (235, 240) and any water lost through vaporization is replaced by operation of the water make-up solenoid  
25 valve (270) in conjunction with the float monitoring device in the troughs (255, 260). The moisture recirculation system continues to operate as long as the heat exchange system (210) is required to operate in "wet" mode.

A water dump valve (275) is also connected to the troughs (255, 260) by a conduit (265). The water dump valve is operated on a regular basis for the

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purpose of dumping the contents of the troughs (255, 260) to reduce the potential for the generation and growth of bacteria that may result from an increase in concentration of sediment and/or impurities in the troughs (255, 260). This is particularly the situation when water is used as the moisture.

5           The particular arrangement of a recirculation system detailed in Figure 15 is very common and has been used successfully for many decades. However, this standard arrangement of a moisture recirculation system has disadvantages including a relatively large trough capacity. In this respect, Figure 15 is an end perspective and the troughs (255, 260) extend the entire  
10 length of the air coolers (235, 240). In the event that the closed circuit microchannel heat exchanger is relatively long, the sump capacity is commensurably large and in order to maintain a positive head of water pressure at the inlet side of the pump (245) it is necessary to maintain a minimum depth of water in the troughs (255, 260). For a relatively long trough, maintaining  
15 the minimum depth may represent a substantial amount of water. Further, a separate disadvantage of existing arrangements is the relatively long period of time that is required to transition the heat exchange system (210) from "dry" to "wet" mode as a result of the supply of external make-up water to the troughs (255, 260).

20           An embodiment of the present invention with a moisture recirculation system for wetting the air coolers is detailed in Figure 16 which provides a diagrammatic representation from a similar end perspective as that of Figure 15.

25           With reference to Figure 16, a cooling fluid that requires cooling is provided to closed circuit microchannel heat exchangers (325, 330) through a supply pipe (315). As the fluid passes through the closed circuit microchannel heat exchangers (325, 330) thermal energy is extracted therefrom and cooled cooling fluid is emitted from the bottom of the closed circuit microchannel heat exchangers (325, 330). Cooled cooling fluid is returned through a return pipe

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(320). Just as for the arrangement detailed in Figure 15, the heat exchange system (300) extracts thermal energy from the cooling fluid by passing same through the closed circuit microchannel heat exchangers (325, 330) whilst passing ambient air through the closed circuit microchannel heat exchangers.

5 In the event that the ambient air temperature is not sufficiently low, or an increased heat exchange capacity is required, the device detailed in Figure 16 is transitioned from "dry" mode to "wet" mode by the application of moisture (preferably water) to the air coolers (335, 340) such that the air coolers evaporatively cool the ambient air. The cooled air then passes through the

10 closed circuit microchannel heat exchangers (325, 330).

In the arrangement detailed in Figure 16, when seeking to transition the arrangement to "wet" mode, the water make-up solenoid valve (370) is activated to allow external water that is supplied through conduit (372) to pass through conduits (346 and 349) until the external make-up water reaches and

15 passes through the water distribution arrangements (348, 350). The external make-up water then trickles down through the adiabatic material of the air coolers (335, 340) and is absorbed by same. As ambient air passes through the air coolers (335, 340) the air is cooled by the action of evaporation as the water that was initially absorbed by the adiabatic material is then vapourised and

20 converted from liquid to gaseous form.

In order to ensure that the air coolers (335, 340) are completely saturated, a sufficient amount of water is provided to the water distribution arrangements (348, 350) such that water trickles down through the evaporative air coolers (335, 340) and runs-off the air coolers into the respective collecting

25 troughs (355, 360). The collecting troughs (355, 360) act as a temporary and intermediate collection of run-off water which is then provided through conduits to the sump (365). The sump does not need to extend the full length of the air coolers (335, 340) and may be dimensioned to have a capacity that is substantially smaller as compared with the standard trough capacity (as

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detailed in Figure 15). The sump (365) collects the run-off water from the collecting troughs (355, 360) and upon collecting enough run-off water to provide a sufficient head of pressure to the intake of the pump (345) then the pump may be activated to pump run-off water up through conduits (346, 349) and re-distribute the water collected in the sump (365) to the water distribution arrangements disposed above the air coolers (348, 350). A back pressure flow prevention device (347) may be included.

The water make-up solenoid valve (370) may be activated as a result of a water level monitoring device in the form of a flotation device in the sump (365). A back pressure flow prevention device (371) may be included. In any event, as water is depleted from the evaporative air cooling system, the water level in the sump (365) decreases and when sufficiently low (such that a positive head of pressure will not be maintained at the pump intake) the make-up solenoid valve (370) is activated to introduce replacement make-up water into the system. In the embodiment of Figure 16, the make-up water is deposited directly onto the top of the air coolers where it is most directly needed. As run-off is collected in the collecting troughs (355, 360) and passed to the sump (365), the water level in the sump increases.

Again, as for the apparatus detailed in Figure 15, upon expiry of a period of time the water dump valve (375) is activated to release the entire contents of the sump (365) to reduce the likelihood of the generation and growth of bacteria and slime in the sump (365). However, as the sump (365) is dimensioned to have a substantially lower capacity as compared with the sump of a standard arrangement, the amount of water that is discharged as a result of a dumping operation is commensurately substantially less.

In embodiments where the make-up water is provided directly to the water distribution arrangements (348, 350) thus effectively by-passing the sump (365), the arrangement provides even less delay in achieving fully saturated air coolers (335, 340) as compared with the existing arrangements.

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With reference to Figure 17, a perspective view of the cooling system of Figure 16 is provided. The same parts in Figures 16 and 17 are identified by use of the same identification number.

Figure 17 details various parts of the cooling system in perspective and of particular importance is the extension of the collecting troughs (355, 360) extending the entire length of the air coolers (335, 340). Further, the water collected by the collecting troughs (355, 360) is subsequently passed to the sump (365) for collection and storage. As will be noted in Figure 17, the dimensions of the sump (365) are substantially smaller as compared with the dimensions of the collecting troughs (355, 360) and therefore, the sump (365) has a significantly reduced volumetric capacity as compared with the collecting troughs (355, 360). Accordingly, if the troughs (355, 360) were used to collect and store run-off, it would require substantially more water (as compared with the sump (365)) to maintain a minimum head of pressure at the intake of a pump.

In industrial and commercial applications, the air coolers (335, 340) can be relatively large. In these applications, it is not unusual for the air coolers (335, 340) to comprise a number of smaller cooling pads that are placed in abutment with one another thus forming a wall that extends for a sufficient length and height to substantially conform with the dimensions of the closed circuit microchannel heat exchangers (325, 330). Accordingly, the collecting troughs (355, 360) must extend along the full length of the air coolers (335, 340) in order to collect any water run-off from the air coolers (335, 340).

However, in the embodiment of Figures 16 and 17, the collecting troughs (355, 360) may act as a temporary collection and storage means for water run-off and may pass run-off water to the sump (365) for collection and storage. As a result, the volumetric water holding capacity of the collecting troughs (355, 360) can be substantially reduced as compared with existing

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collection and storage troughs that must both collect and store run-off water and maintain a sufficient head of pressure at a pump intake.

Having passed run-off water to the sump (365) the water is pumped (345) up through backflow pressure prevention device (347) and through the conduits to the water distribution arrangements (348, 350) whereby water is distributed to the upper portion of the air coolers (335, 340).

Fig. 18 is a noise chart (400) illustrating noise levels for various configurations of cooling systems. The "X" axis of the chart (402) shows Heat Of Rejection (HOR) capacity measured in kilowatts (kW) on a scale of just below 110 kW to just above 1232 kW. This scale on this axis (402) is represented unevenly for a more convenient representation. The "Y" axis of the chart (404) shows Sound Pressure Level (SPL) at 3 metres dBA on a scale of 60 dBA to 85 dBA.

On the chart (400) there is shown the noise levels three different configurations of heat exchange systems with different numbers of fans for each configuration:

The first measurements (408) are for a smaller configuration of heat exchange system with a conventional closed circuit tube and fin heat exchanger. The measurements shown for this configuration are:

- with one fan (408a) at about 67 dBA giving an HOR capacity of about 110 kW;
- with two fans (408b) at about 70 dBA giving an HOR capacity of about 218 kW;
- with three fans (408c) at about 72 dBA giving an HOR capacity of about 339 kW, and;

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- with four fans (408d) at about 73 dBA giving an HOR capacity of about 439 kW.

The second measurements (410) are for a larger configuration of heat exchange system with a conventional closed circuit tube and fin heat exchanger. The measurements are shown for two types of conventional closed circuit tube and fin heat exchanger: one which comprises coils in an arrangement 4 rows deep with respect to the direction of airflow over the coils of the heat exchanger; the other is an arrangement of coils 6 rows deep with respect to the direction of airflow over the coils of the heat exchanger. The measurements shown are for this configuration are:

- with two fans and four rows of coils (410a) at about 78 dBA giving an HOR capacity of about 441 kW;
- with two fans and six rows of coils (410b) at about 78 dBA giving an HOR capacity of about 546 kW;
- 15 • with three fans and four rows of coils (410c) at about 80 dBA giving an HOR capacity of about 719 kW;
- with three fans and six rows of coils (410d) at about 80 dBA giving an HOR capacity of about 820 kW;
- 20 • with four fans and six rows of coils (410e) at about 81 dBA giving an HOR capacity of about 1170 kW.

The third representation on the chart (400) are predicted measurements for a closed circuit microchannel heat exchanger. The predicted measurements for an arrangement of the closed circuit microchannel heat exchanger are:

- 25 • with one fan (406a) to be 65 dBA giving an HOR capacity of about 308 kW;

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- with two fans (406b) to be 68 dBA giving an HOR capacity of about 616 kW;
- with three fans (406c) to be 70 dBA giving an HOR capacity of about 924 kW, and;
- 5 • with four fans (406d) to be 71 dBA giving an HOR capacity of about 1232 kW.

As can be seen from the chart and the measurements above for the heat exchange systems (408 and 410), these configurations are relatively noisy and would therefore be unsuitable for some applications. This will particularly be  
10 the case where quiet air conditioning is required due to statutory noise limitations.

In contrast, the predicted measurements for the system including the closed circuit microchannel heat exchanger shows this system will have significantly lower Sound Pressure Level with respect to Heat Of Rejection  
15 capacity when compared with the heat exchange systems using conventional tube and fin closed circuit heat exchangers.

Those skilled in the art will appreciate that the invention described herein is susceptible to variations and modifications other than those specifically described. It is understood that the invention includes all such  
20 variations and modifications which fall within the spirit and scope of the present invention.

The reference to any prior art in this specification is not, and should not be taken as, an acknowledgment or any form or suggestion that the prior art forms part of the common general knowledge of persons skilled in the relevant  
25 field of technology at the priority date of the claims herein.

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CLAIMS

1. A heat exchange system including:
  - at least one first heat exchanger having a closed  
5 circuit for cooling fluid;
  - at least one air cooler located upstream of the at least  
one first heat exchanger; and
  - at least one fan arrangement operable to cause air to  
pass through the at least one first heat exchanger and the at  
10 least one air cooler,wherein the at least one first heat exchanger includes  
a microchannel heat exchanger.
  
2. A heat exchange system according to claim 1 wherein the  
15 cooling fluid is supplied through a substantially horizontal supply header and  
the cooling fluid is passed from the closed circuit microchannel heat exchanger  
through a substantially horizontal return header.
  
3. A heat exchange system according to claim 2 wherein the  
20 supply header is located at or near the top of the closed circuit microchannel  
heat exchanger and the return header is located at or near the bottom of the  
closed circuit microchannel heat exchanger, such that cooling fluid passes into  
the closed circuit microchannel heat exchanger at or near the top and passes  
once through the closed circuit microchannel heat exchanger by the action of  
25 gravity and passes out through the return header at or near the bottom of the  
closed circuit microchannel heat exchanger.
  
4. A heat exchange system according to claim 1, wherein a supply  
header and a return header are located at or near vertical sides of the closed  
30 circuit microchannel heat exchanger.

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5. A heat exchange system according to claim 4, wherein cooling fluid flows in through the supply header and passes through the fluid passages of the closed circuit microchannel heat exchanger before passing to the return header, such that the cooling fluid flows out of the return header.

6. A heat exchange system according to any one of claims 1 to 5, wherein the microchannel heat exchanger includes fluid passages that extend between vertical sides of the microchannel heat exchanger.

10

7. A heat exchange system according to any one of claims 1 to 6, further including a second microchannel heat exchanger.

8. A heat exchange system according to claim 7, wherein the first and second microchannel heat exchangers are aligned substantially in series, with respect to air flow, such that the first and second microchannel heat exchangers form a microchannel heat exchanger stack.

9. A heat exchange system according to any one of claims 1 to 8, wherein the first microchannel heat exchanger is arranged in series with one or more further first microchannel heat exchangers.

10. A heat exchange system according to any one of claims 1 to 9, wherein the air cooler, when in use, includes a fan arrangement that causes air to pass through the air cooler and the one or more heat exchangers.

25

11. A heat exchange system according to any one of claims 1 to 10, wherein the first closed circuit microchannel heat exchanger is configured in a substantially cross-sectional tubular arrangement.

30

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12. A heat exchange system according to claim 11, wherein the first fan arrangement is operable to cause air to pass longitudinally through the internal space of the substantially tubular arrangement of the first closed circuit microchannel heat exchanger.

5

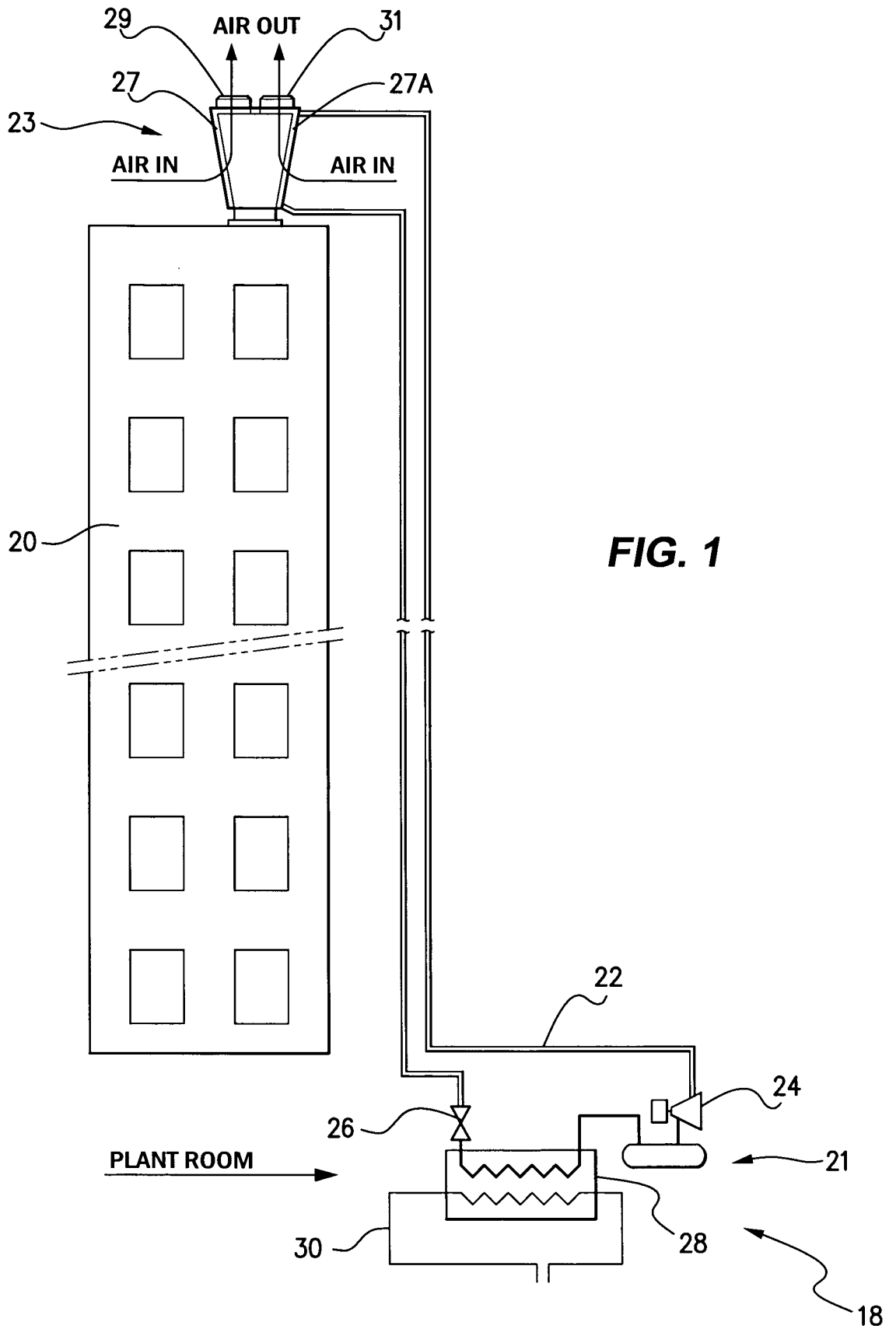
13. A heat exchange system according to claim 12, wherein air also passes through the walls of the substantially tubular arrangement.

14. A heat exchange system according to any one of claims 1 to 13, where further including a second microchannel heat exchanger having a closed circuit for cooling fluid, wherein the second microchannel heat exchanger is arranged with first microchannel heat exchanger such that they form a substantially cross-sectional tubular arrangement with an internal space through which air passes.

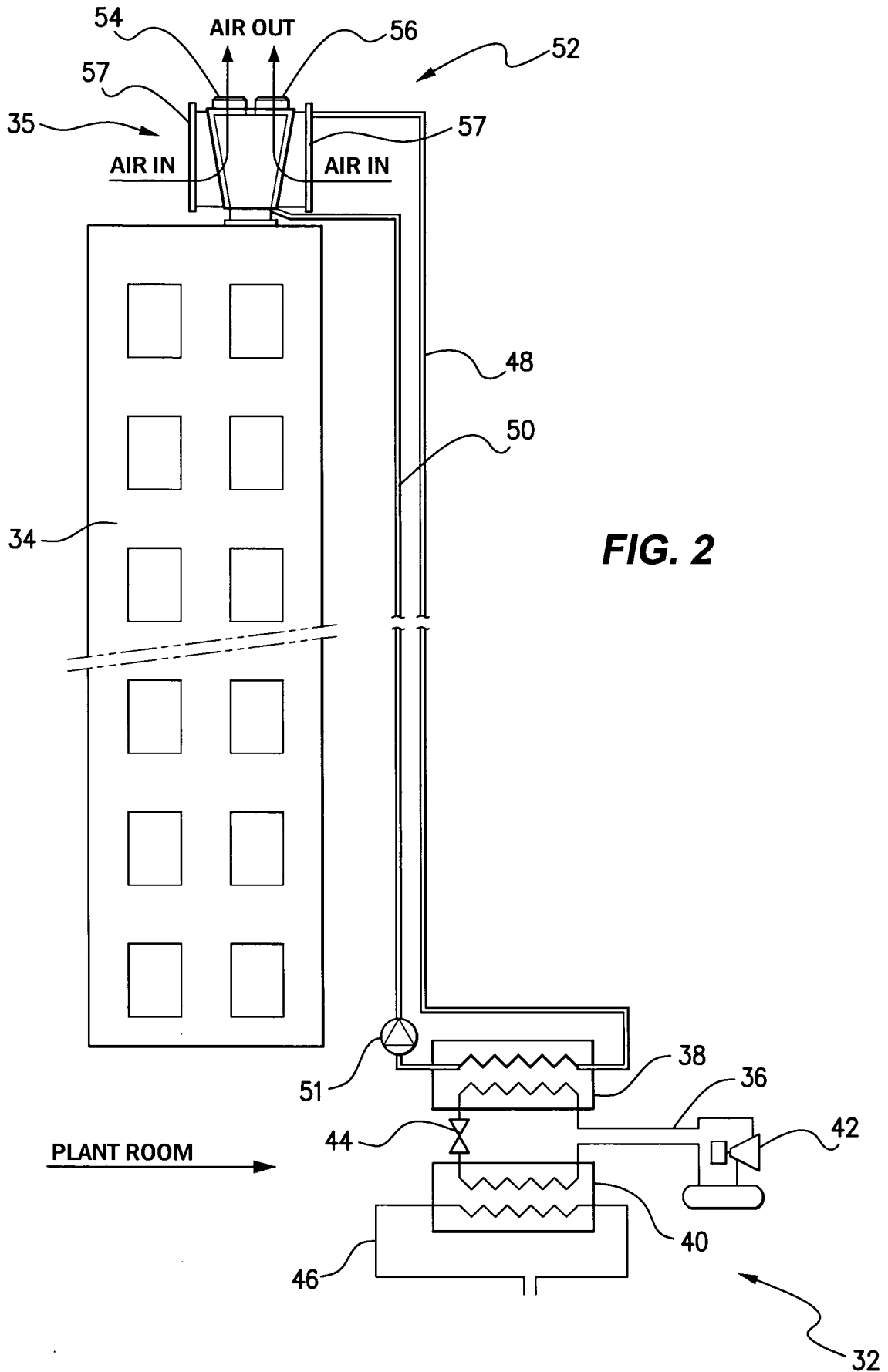
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15. A heat exchange system according to any one of claims 1 to 14, wherein, during use, the cooling fluid in the closed circuit microchannel heat exchanger operates at a substantially higher pressure than cooling fluid in a conventional tube and fin closed circuit heat exchanger.

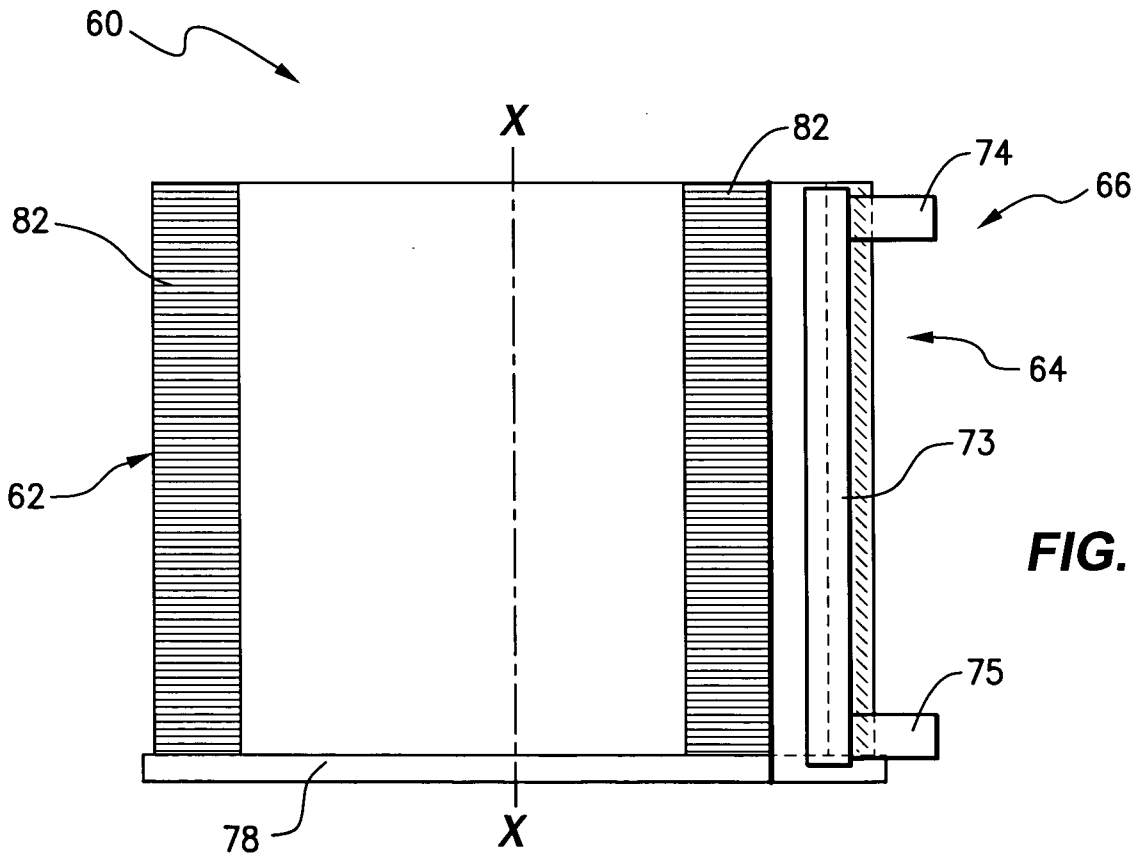
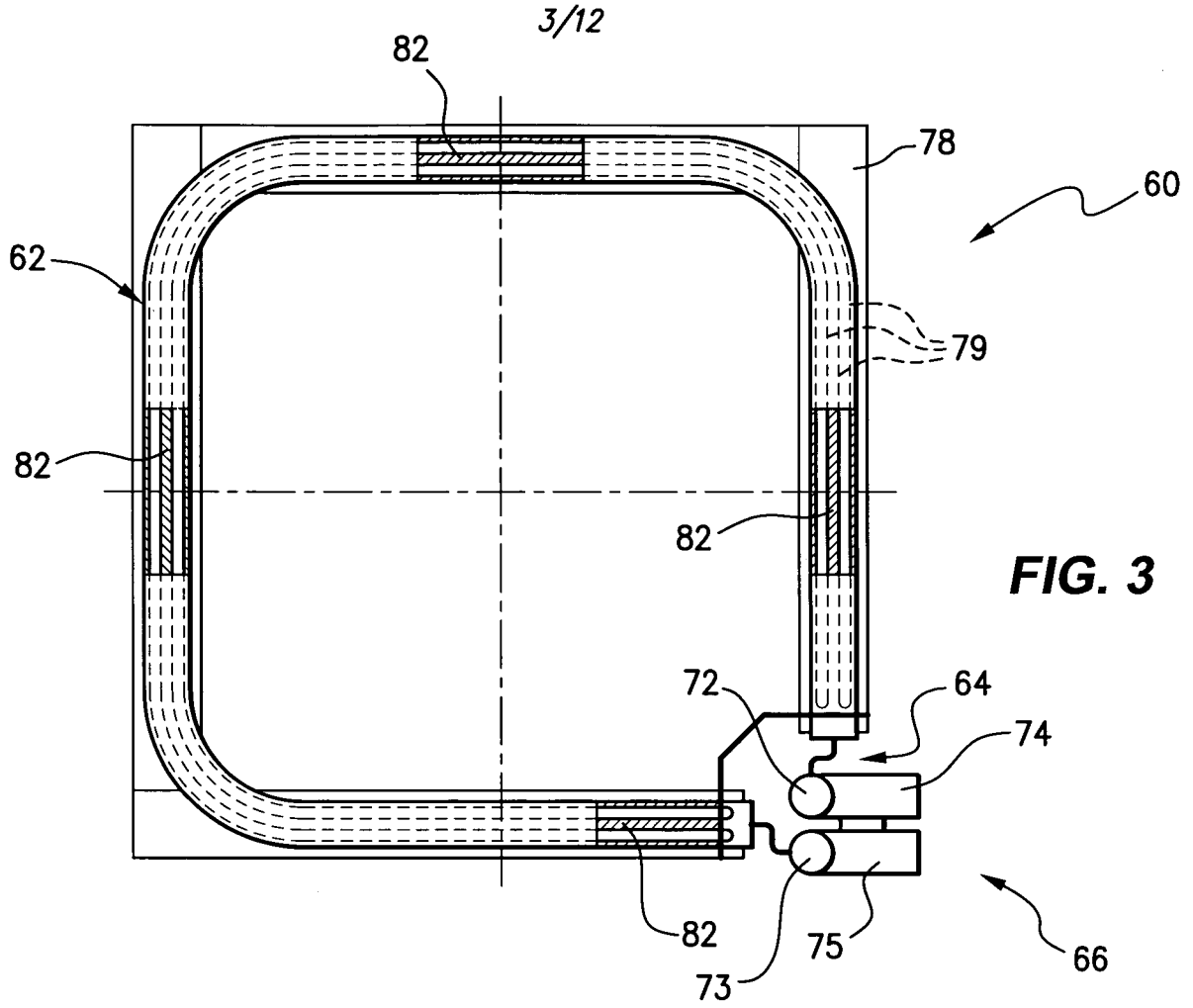
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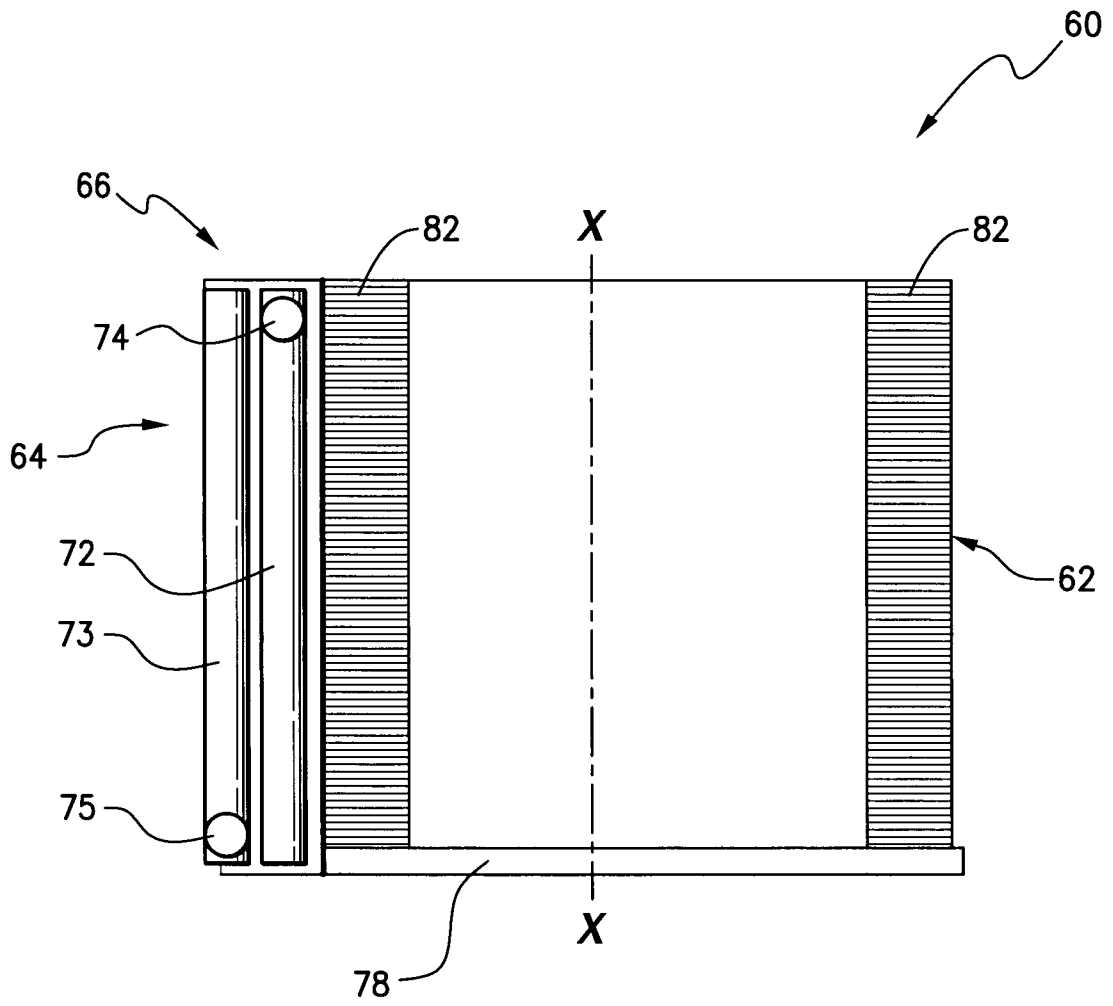


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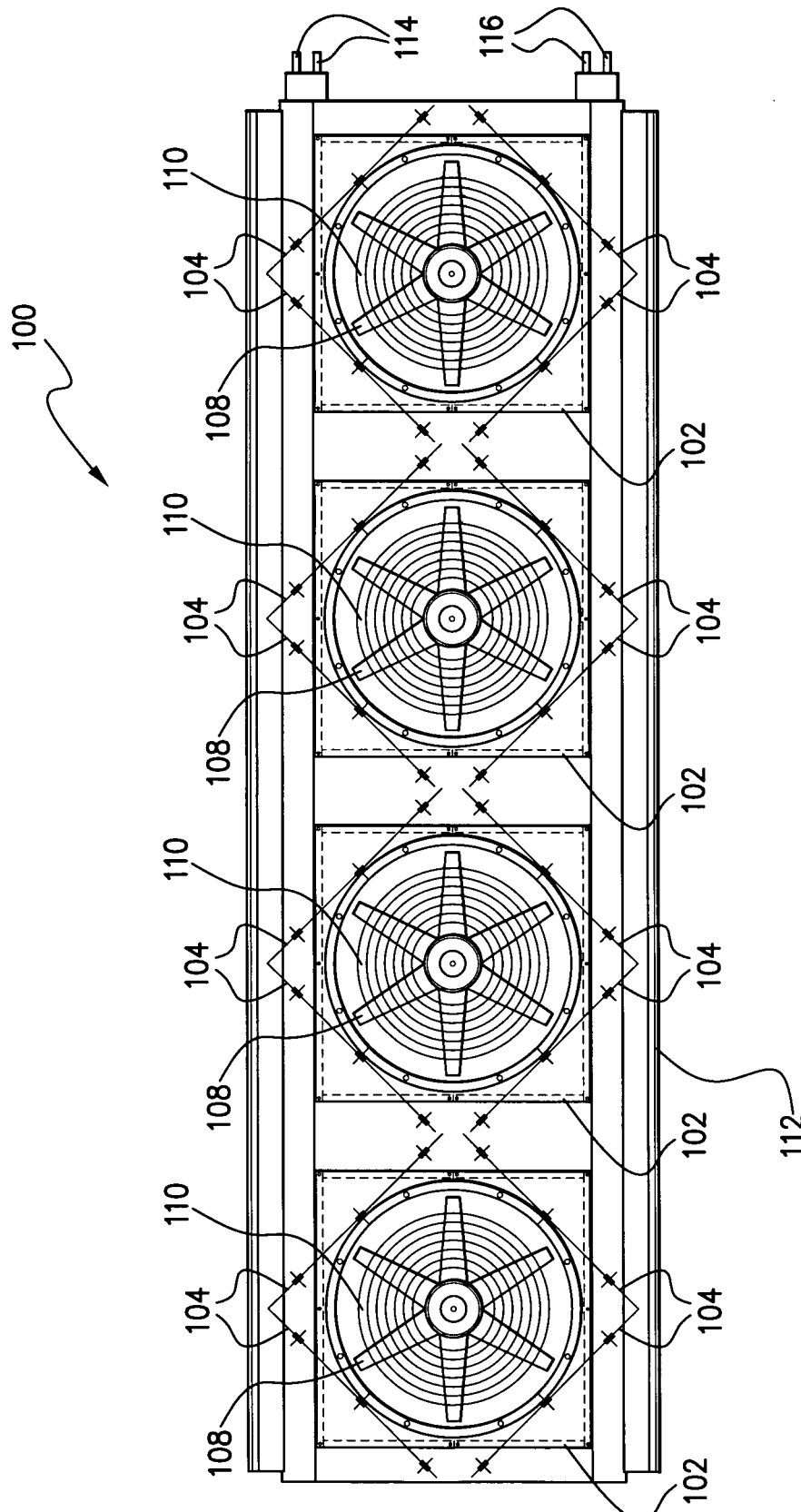


**FIG. 2**



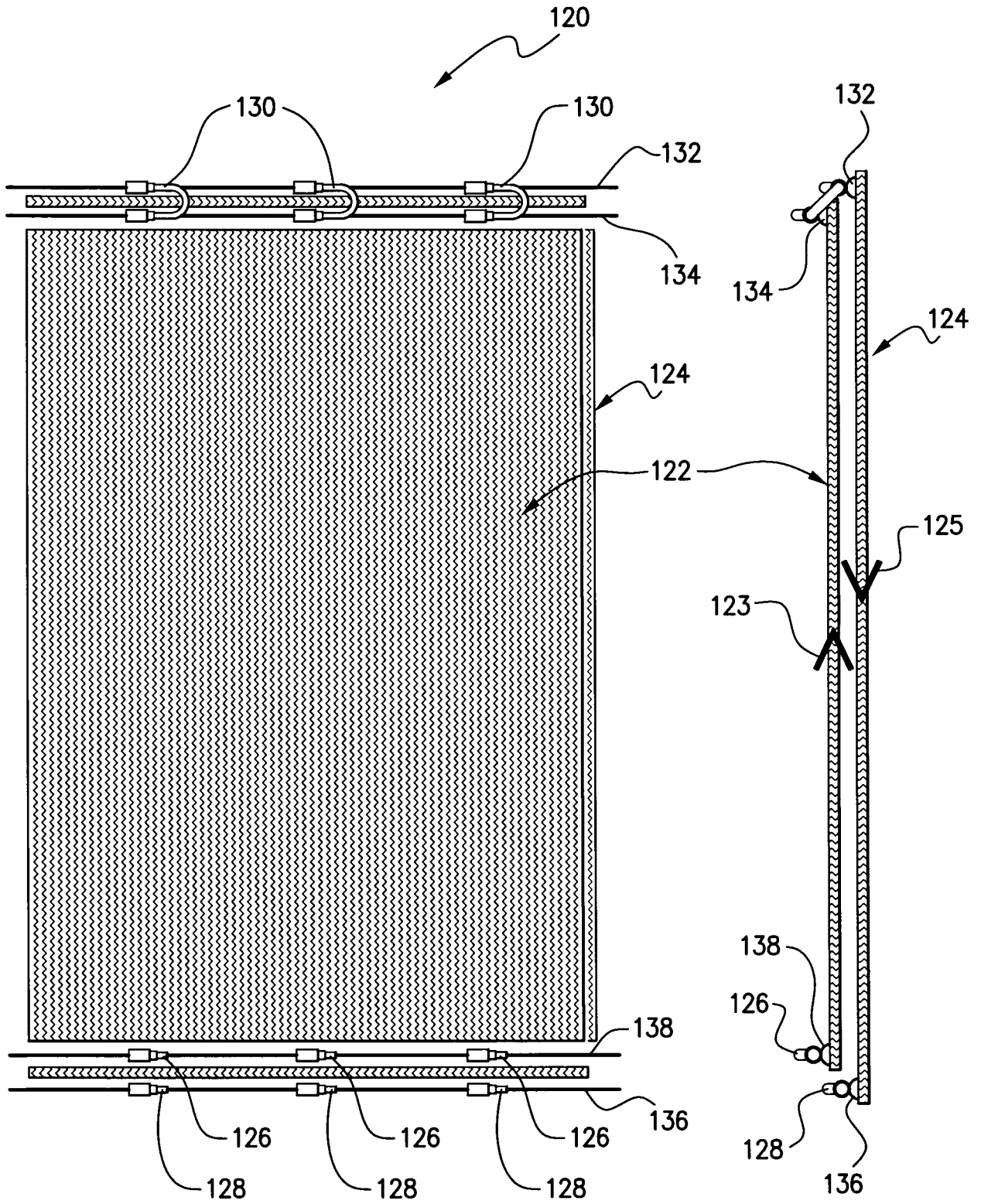


**FIG. 5**



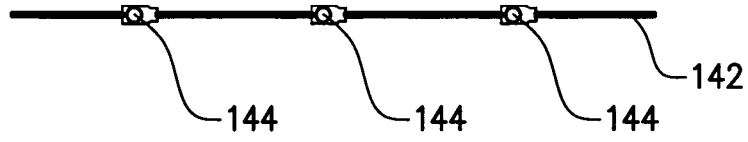
**FIG. 6**

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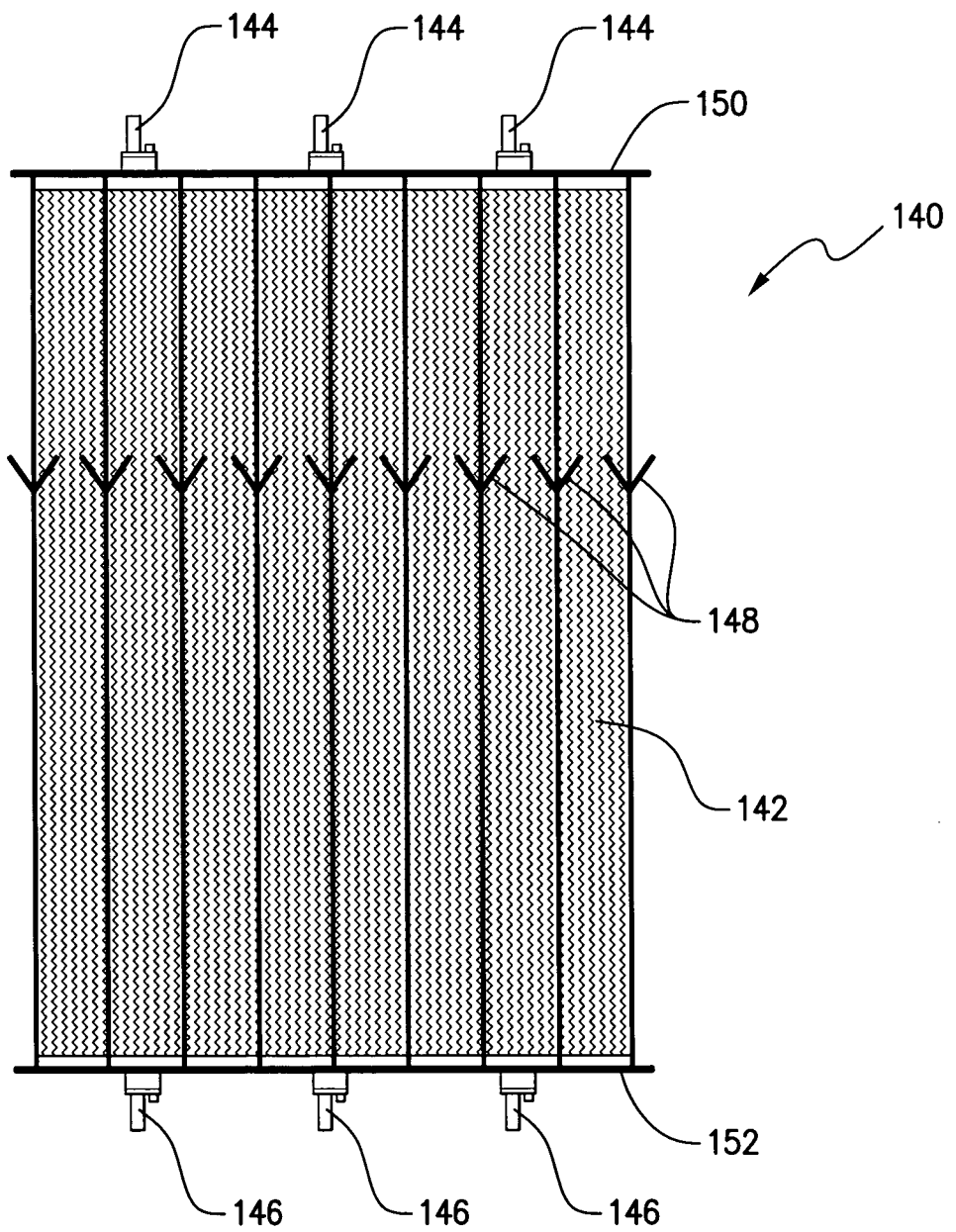


**FIG. 7**

**FIG. 8**



**FIG. 10**



**FIG. 9**

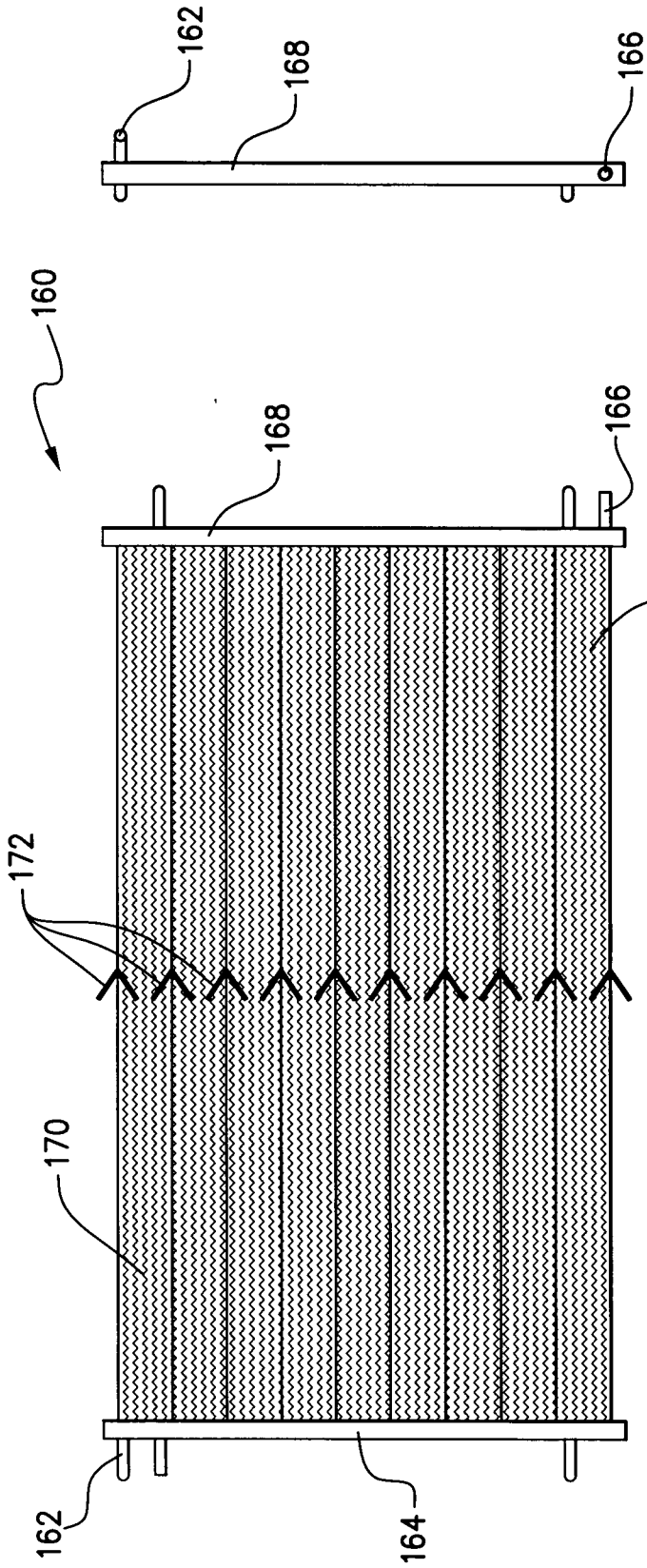


FIG. 12

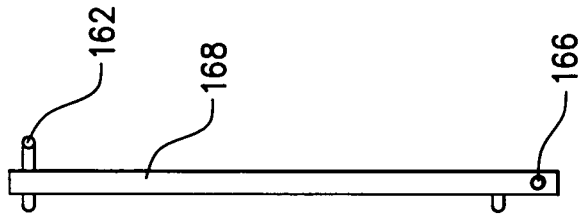
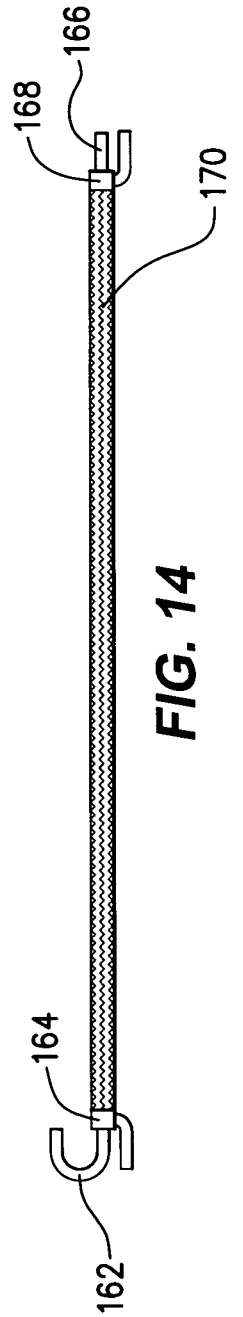


FIG. 13



FIG. 14



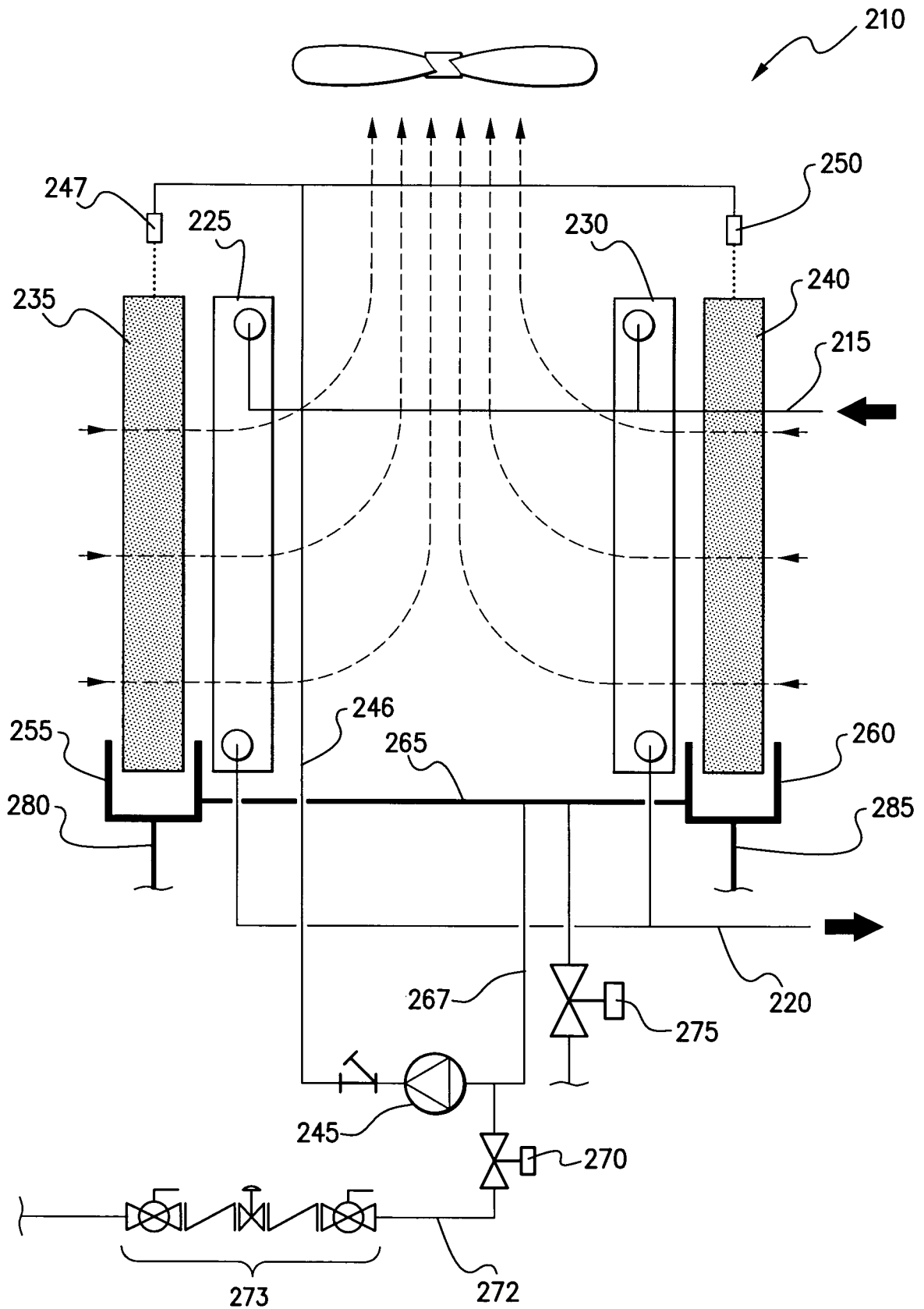
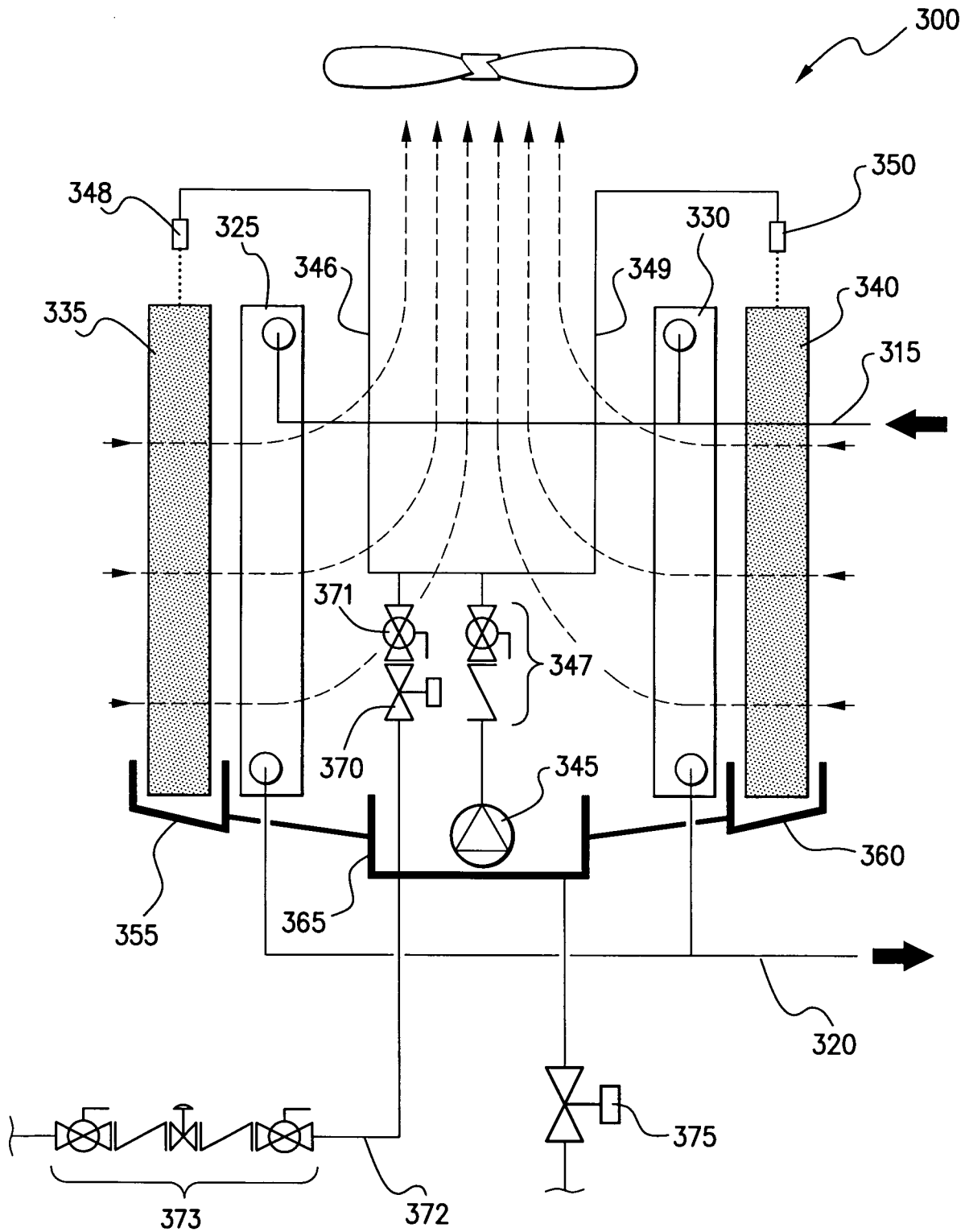


FIG. 15



**FIG. 16**

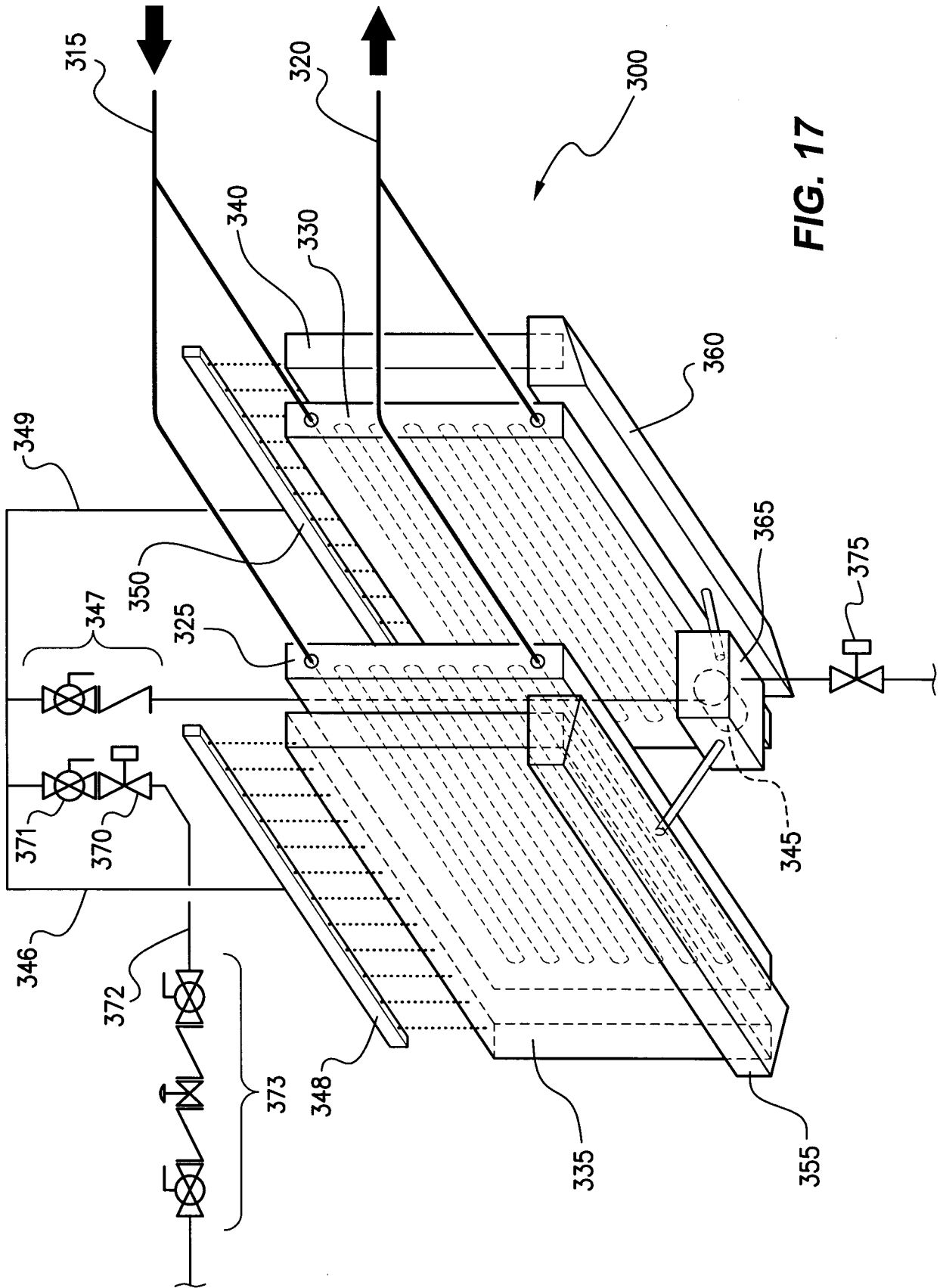


FIG. 17

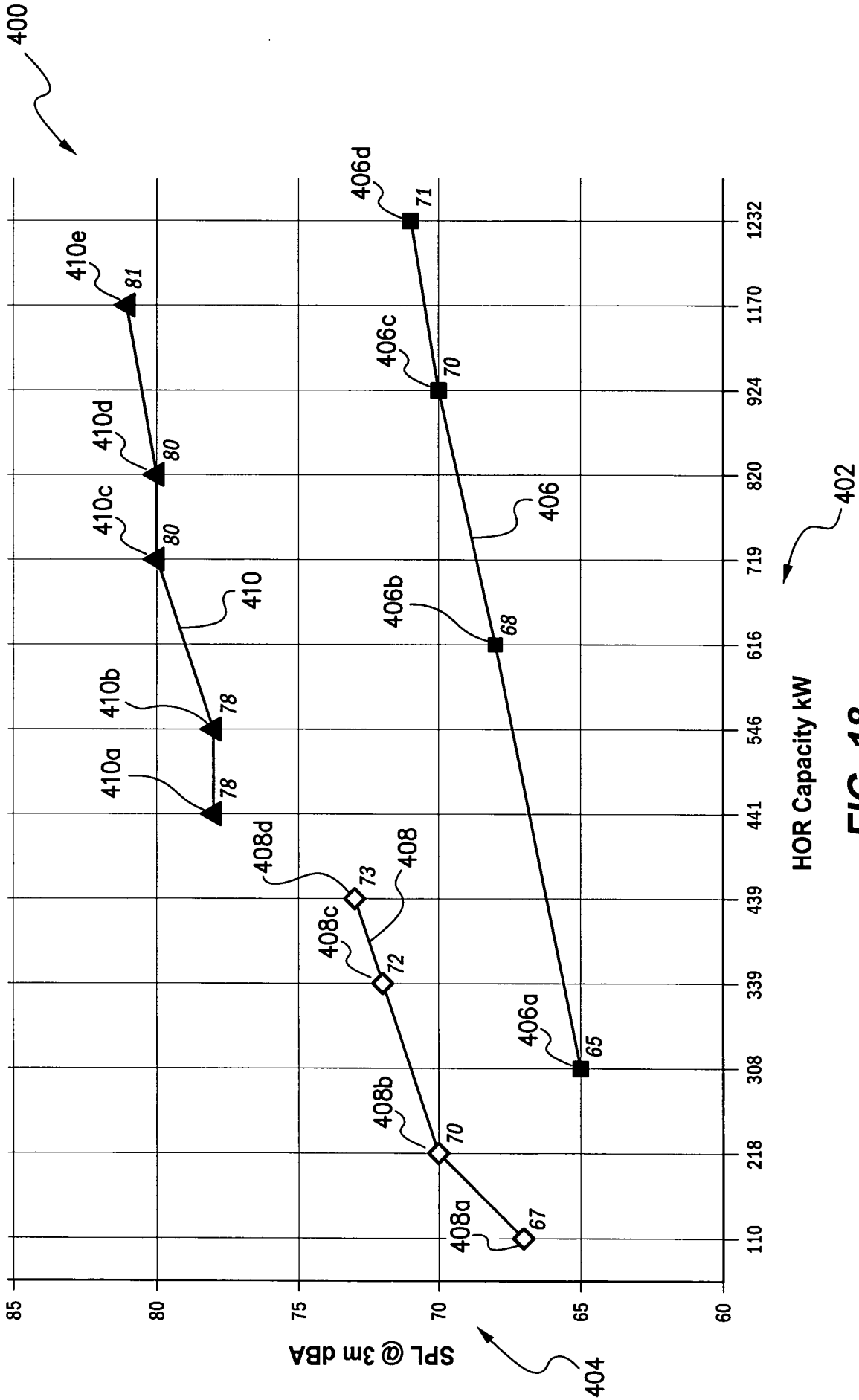


FIG. 18

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/AU2009/001292

A. CLASSIFICATION OF SUBJECT MATTER		
Int. Cl.		
F28F 7/00 (2006.01) F28F 1/00 (2006.01)		
F24F 13/30 (2006.01) F28F 3/02 (2006.01)		
According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED		
Minimum documentation searched (classification system followed by classification symbols)		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)		
EPOQUE (WPI/EPODOC): F28F/IC/EC; MICRO_CHANNEL+ OR MICRO_PASSAG+ OR MICRO_TUB+ OR MICRO_PATH? OR MICRO_SCAL+ OR MICRO_STRUCTUR+ OR MICRO_HEAT+; (FAN+ OR BLOWER+ OR BLOW+ OR FORCED OR FORCING OR PUSH+).		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 7367384 B2 (MADARA et al.) 6 May 2008. See abstract; figures 1- 4; column 1, lines 14- 19; column 1, line 65- column 2, line 41; column 2, line 56- column 4, line 56; and claims.	1- 10, 15
X	US 2006/0130517 A1 (MERKYS et al.) 22 June 2006. See abstract; figures 1- 6b, 8b, 10, and 11; paragraphs [0004], [0005], [0010]- [0026]; [0031]- [0033], [0039]- [0049], [0051]- [0055], [0060]- [0069]; and claims.	1, 2, 4- 10, 15
X	KR 20070072213 A (LG ELECTRONICS INC.) 4 July 2007. English abstract retrieved from EPODOC database. See abstract.	1- 10, 15
<input checked="" type="checkbox"/> Further documents are listed in the continuation of Box C <input checked="" type="checkbox"/> See patent family annex		
* Special categories of cited documents:	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention	
"A" document defining the general state of the art which is not considered to be of particular relevance	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone	
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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&" document member of the same patent family	
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"P" document published prior to the international filing date but later than the priority date claimed		
Date of the actual completion of the international search 18 January 2010	Date of mailing of the international search report 21 JAN 2010	
Name and mailing address of the ISA/AU AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA E-mail address: pct@ipaustralia.gov.au Facsimile No. +61 2 6283 7999	Authorized officer PETER ELLIS AUSTRALIAN PATENT OFFICE (ISO 9001 Quality Certified Service) Telephone No : (02) 6225 6106	

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/AU2009/001292

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 1439365 A2 (LG ELECTRONICS INC.) 21 July 2004. See abstract; paragraphs [0001], [0008]- [0017], [0019]- [0034], [0039]- [0041]; claims; and figures 1- 3.	
A	US 7331378 B2 (BHATTI et al.) 19 February 2008. See abstract; figures 1- 3 and 6; column 1, line 31- column 2, line 6; column 3, lines 43- 59; and claims.	
A	US 2002/0195240 A1 (KRAAY et al.) 26 December 2002. See abstract; figures 1 and 5; paragraphs [0001], [0005]- [0022], [0027]- [0030], [0032]; and claims.	

## INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/AU2009/001292

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Member					
US	7367384	CN	101044811	EP	1810558	US	2006102322
		US	2008251240	WO	2006055387		
US	2006130517	NONE					
KR	20070072213	NONE					
EP	1439365	AU	2003261553	CN	1517660	JP	2004219052
		KR	20040065626	US	2004188076		
US	7331378	CN	101005753	EP	1808892	JP	2007227902
		US	2007163750				
US	2002195240	CA	2450306	CN	1516804	EP	1395786
		US	2004134226	WO	02103270		
Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.							
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