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(54) CONDENSER REFRIGERANT DISTRIBUTION

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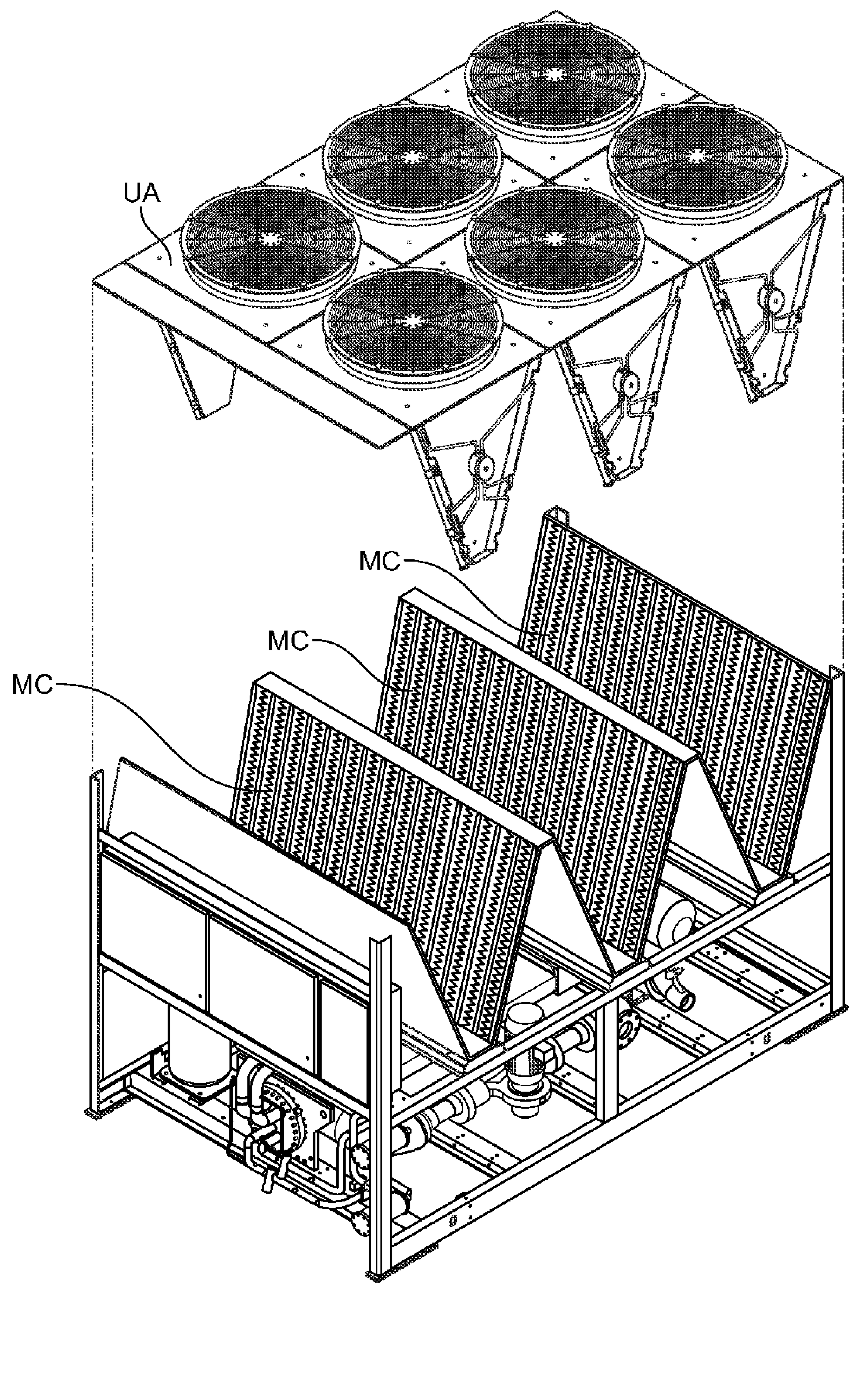
(57) **ABSTRACT**

A flow regulator being disposed in at least one of the outlets of a condenser to regulate the fluid flow in the condenser. The condenser has at least two fluid flow paths and an air flow drawn through the condenser by a condenser fan. The flow regulator regulates the fluid flow to substantially equalize the temperature of the fluid flow in the at least two fluid paths and to provide more efficient cooling of the fluid in the fluid flow paths.



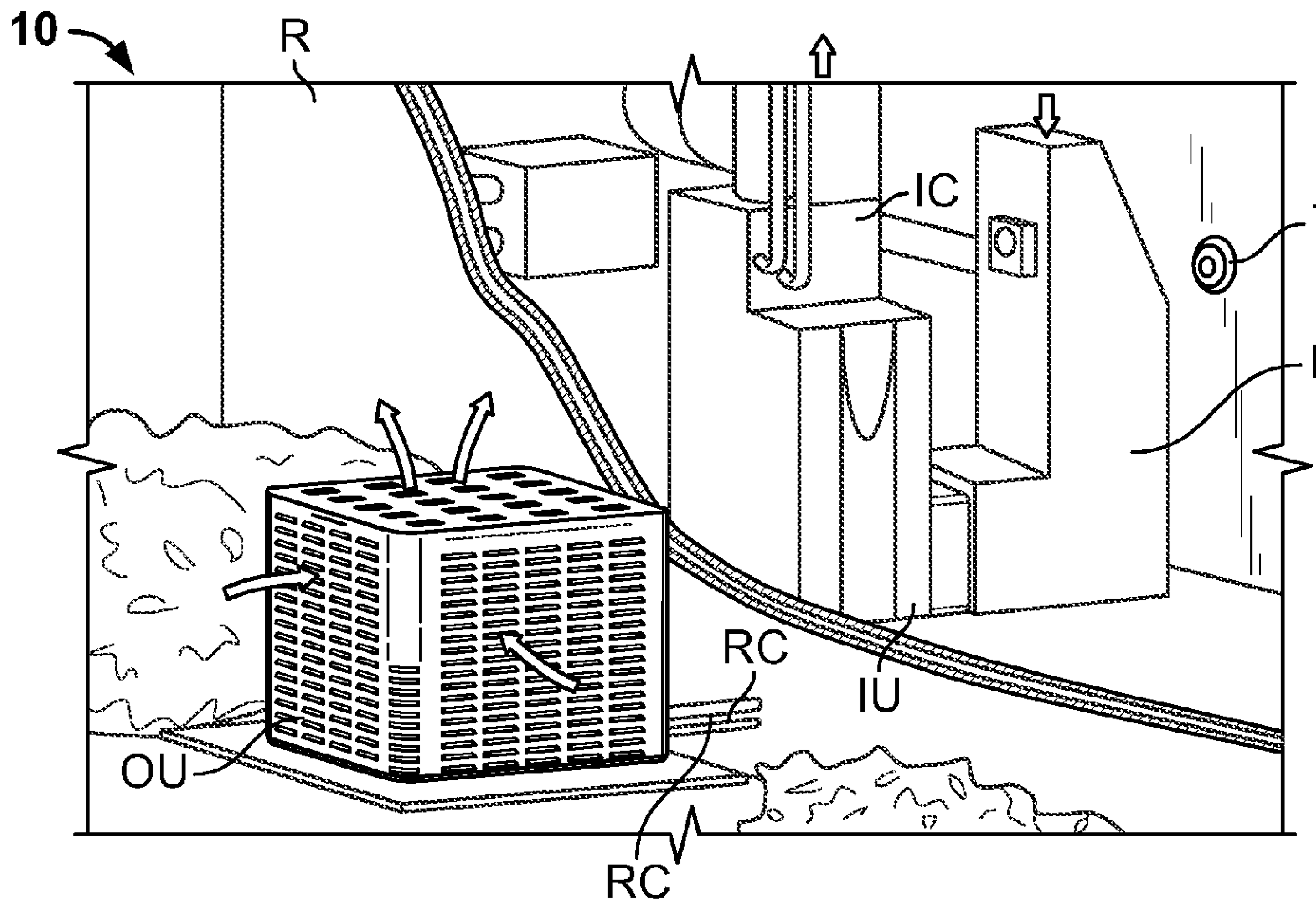


FIG. 1

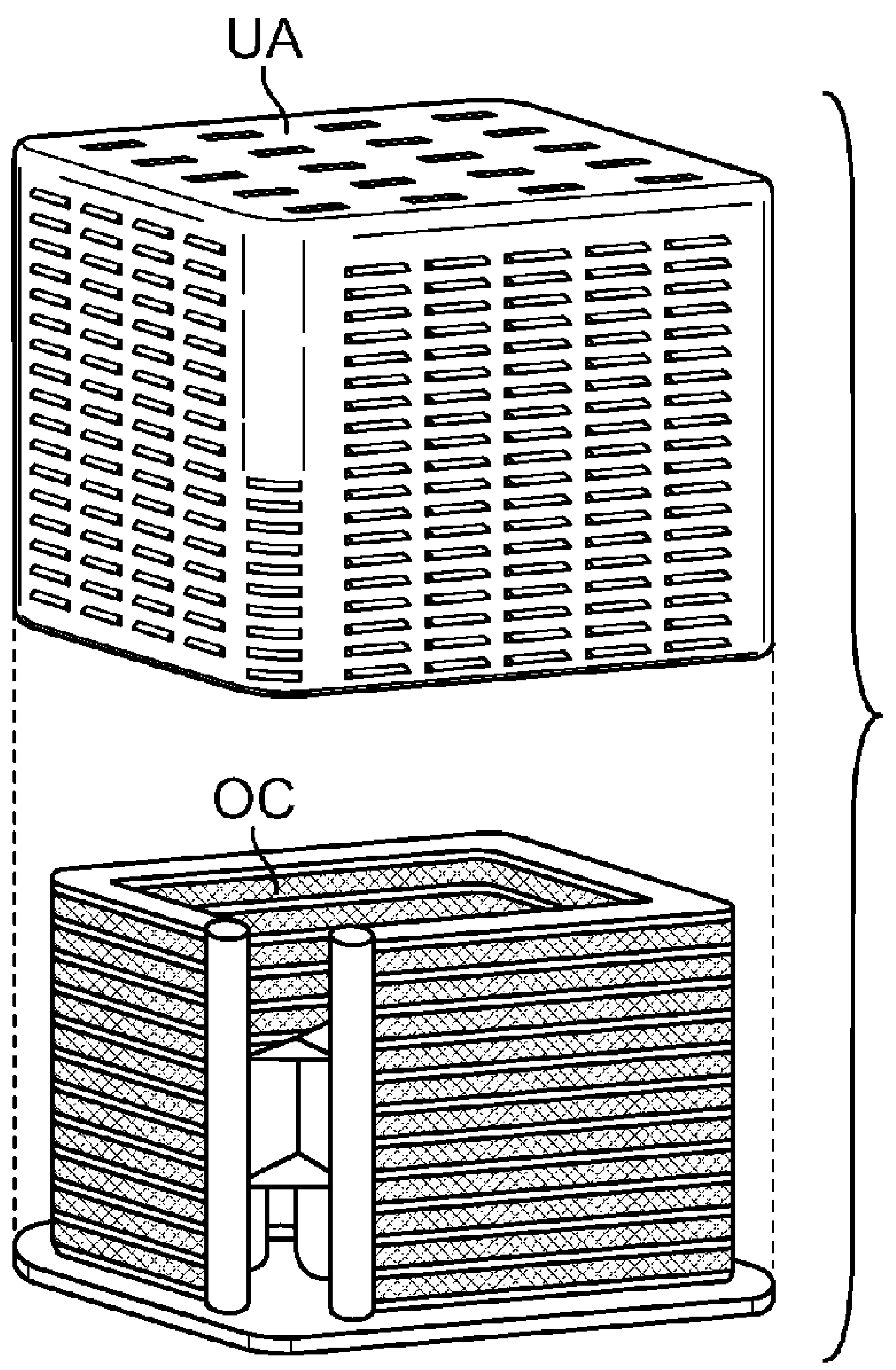


FIG. 2

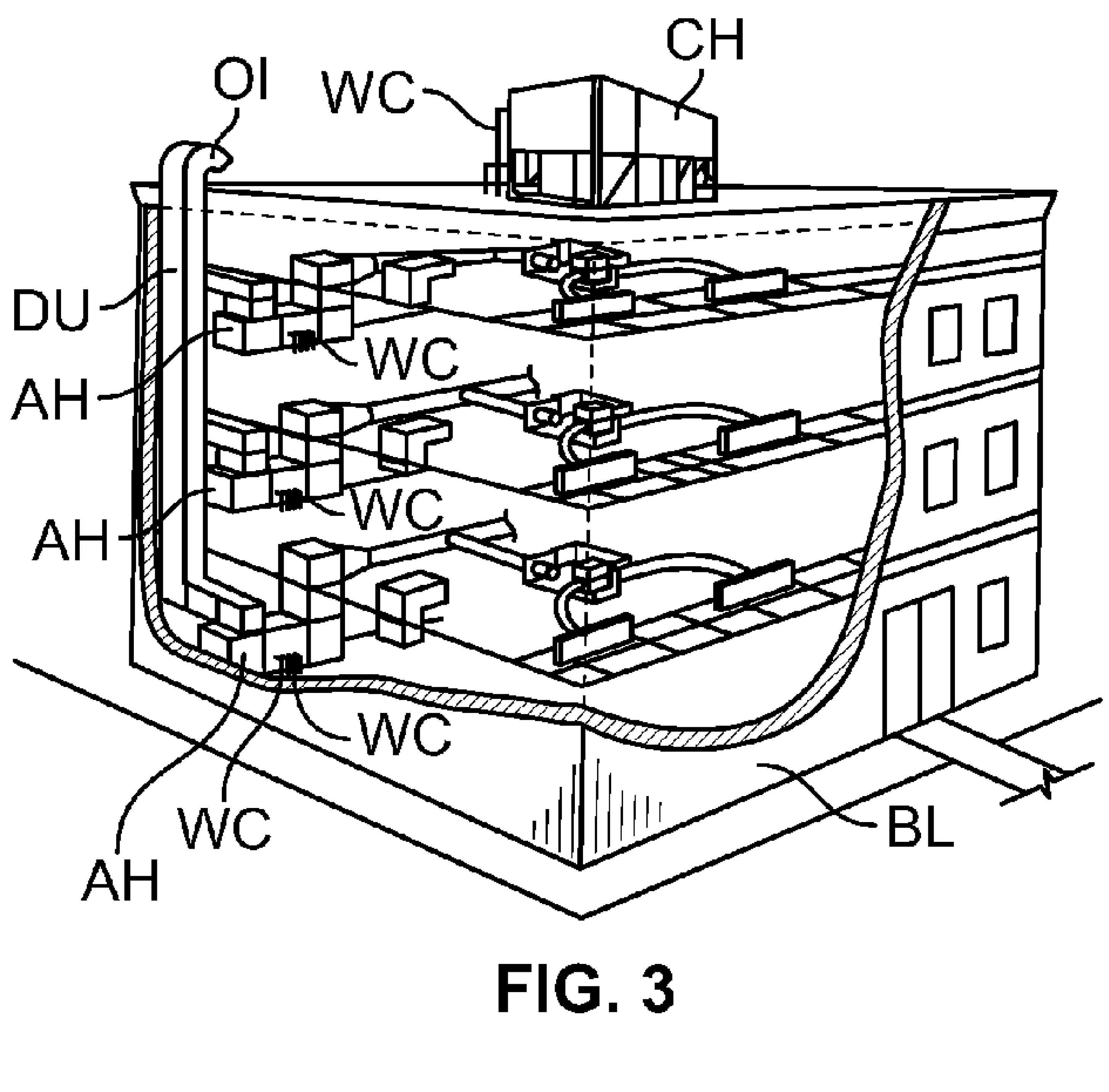


FIG. 3

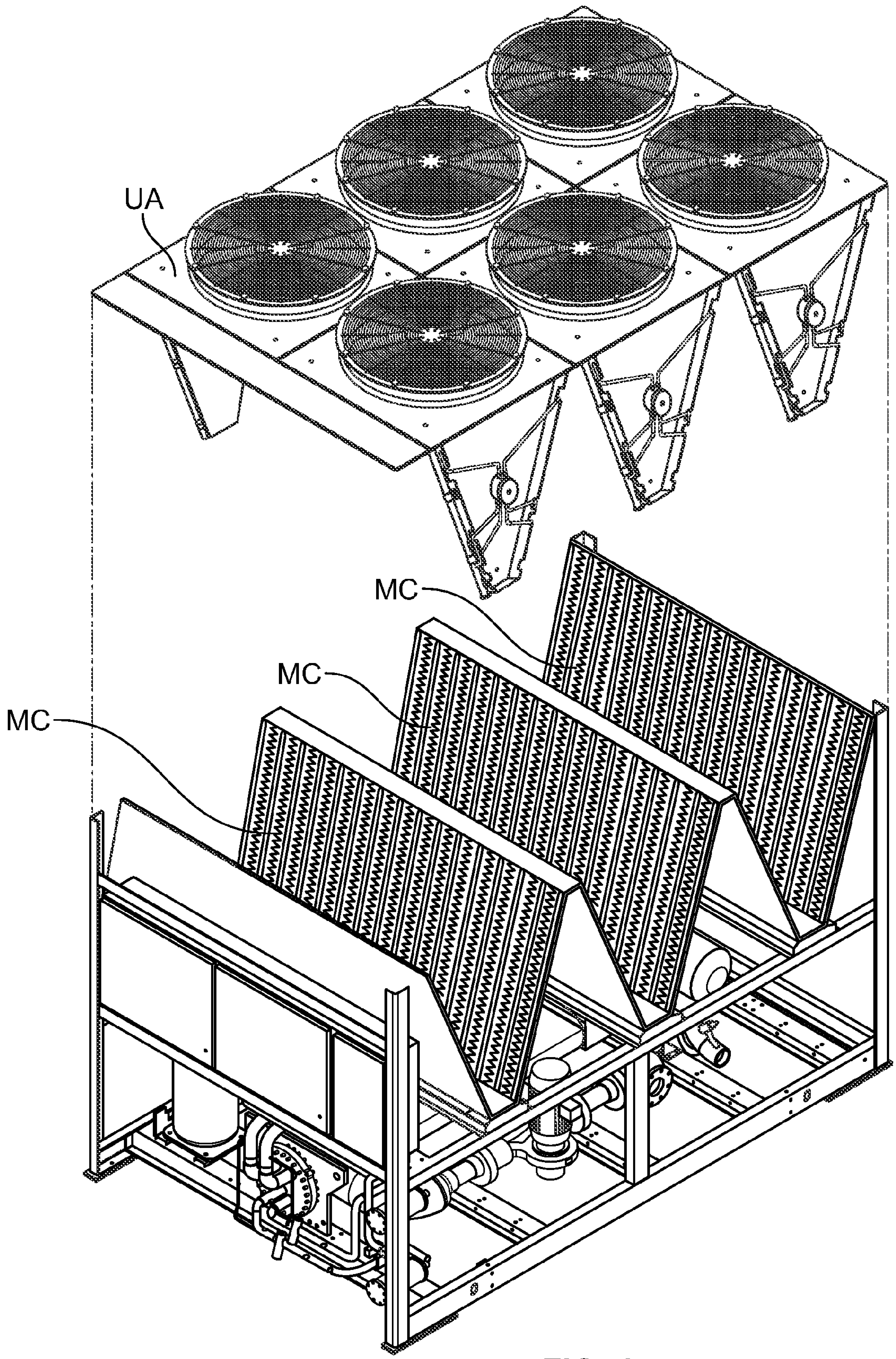


FIG. 4

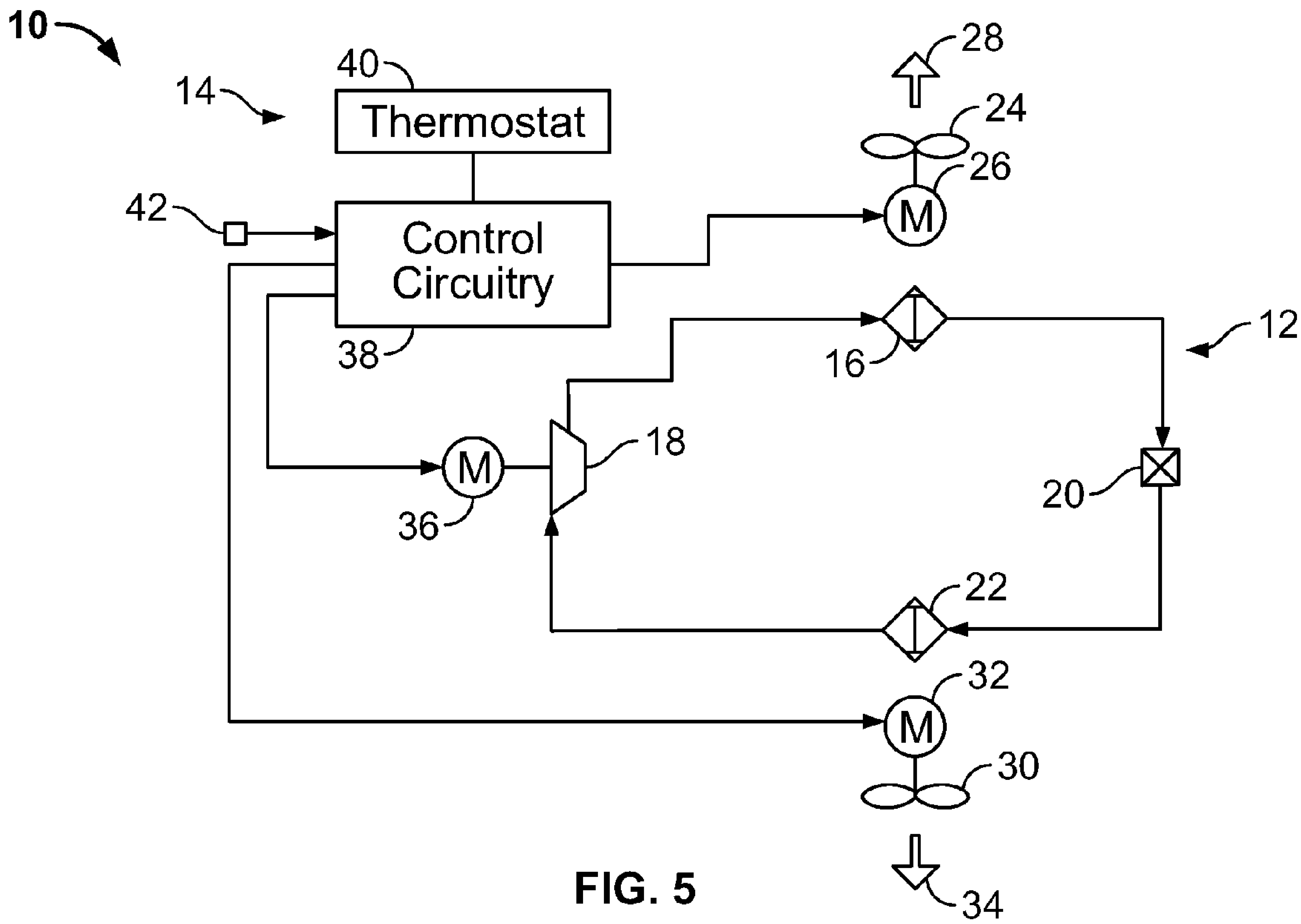

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FIG. 5

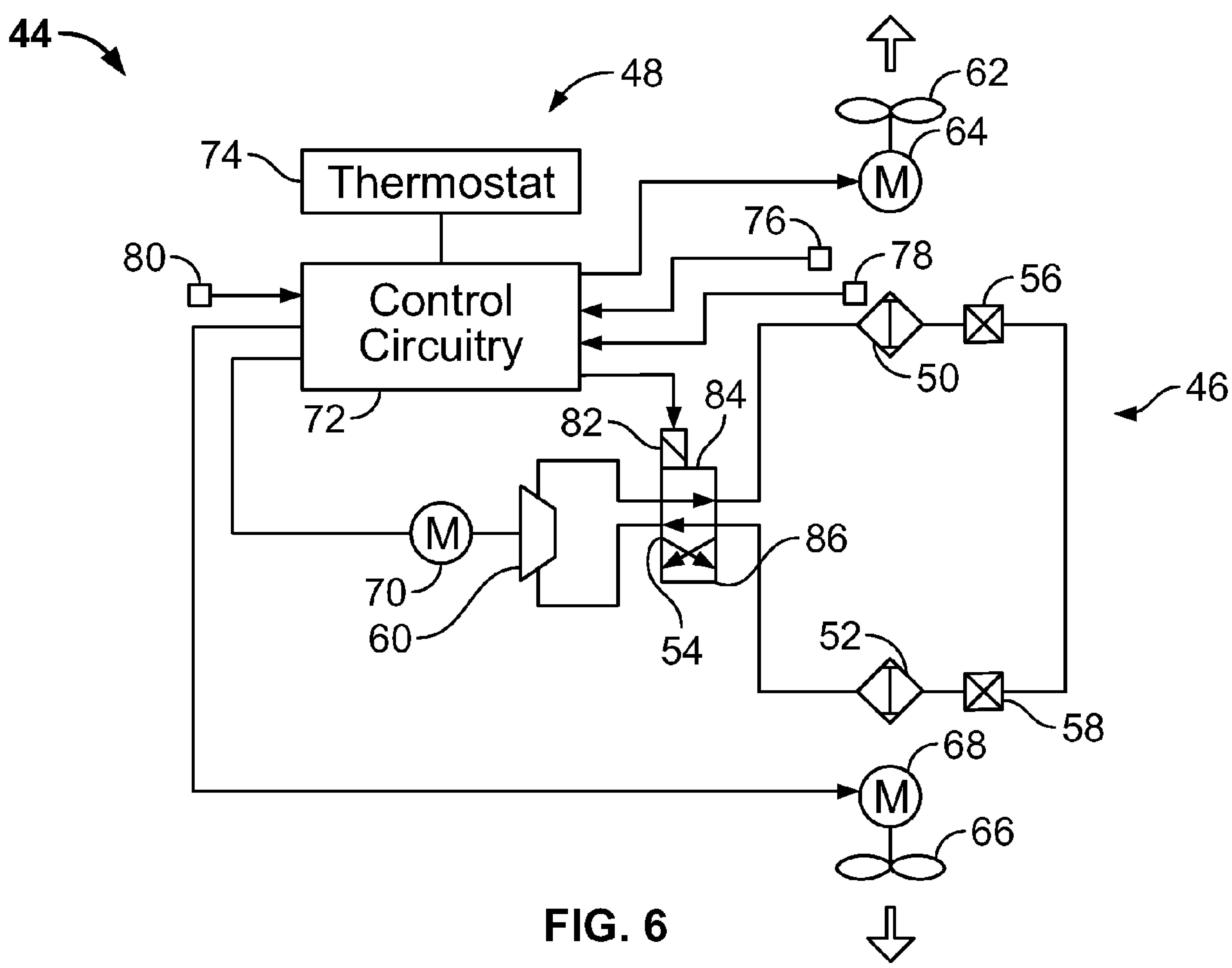
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FIG. 6

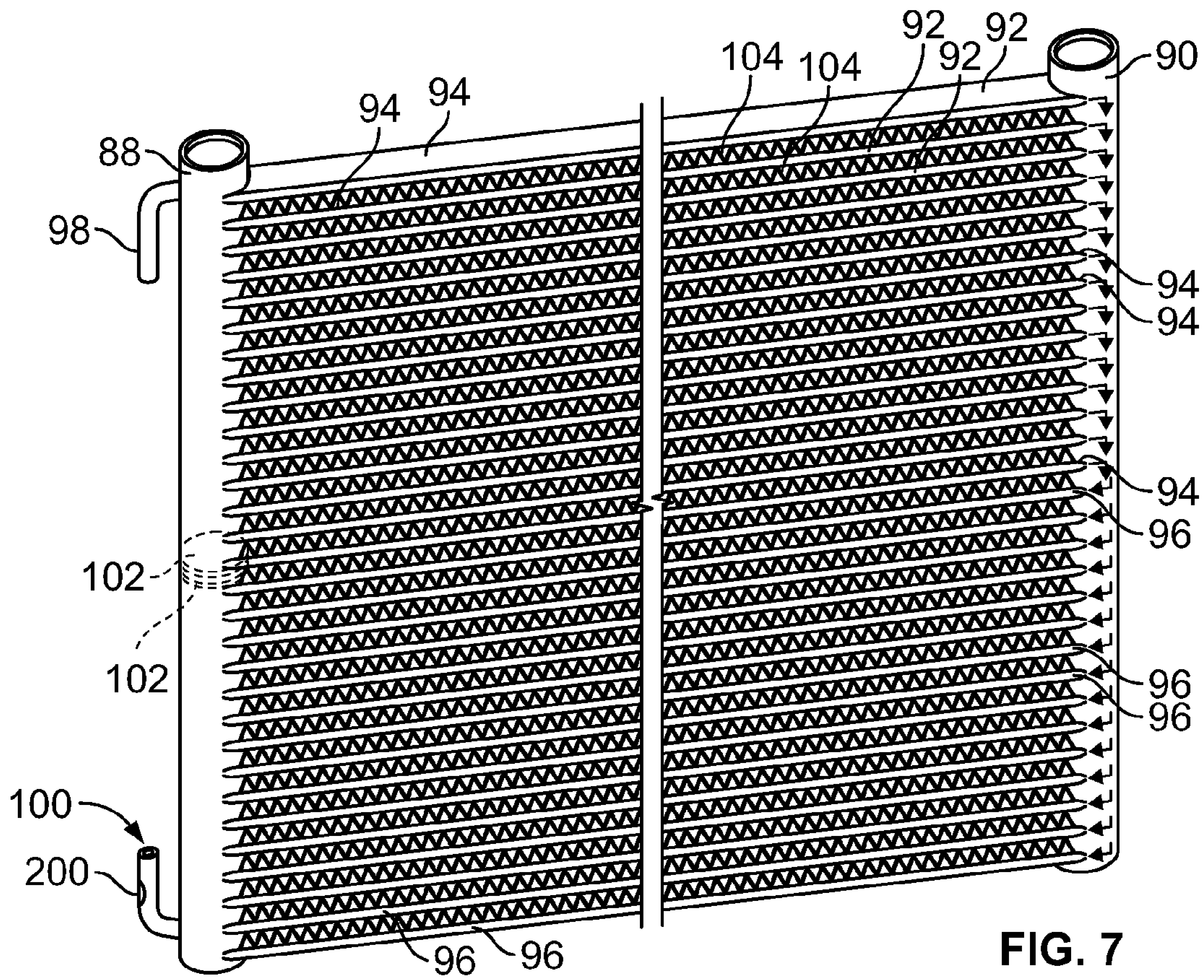

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FIG. 7

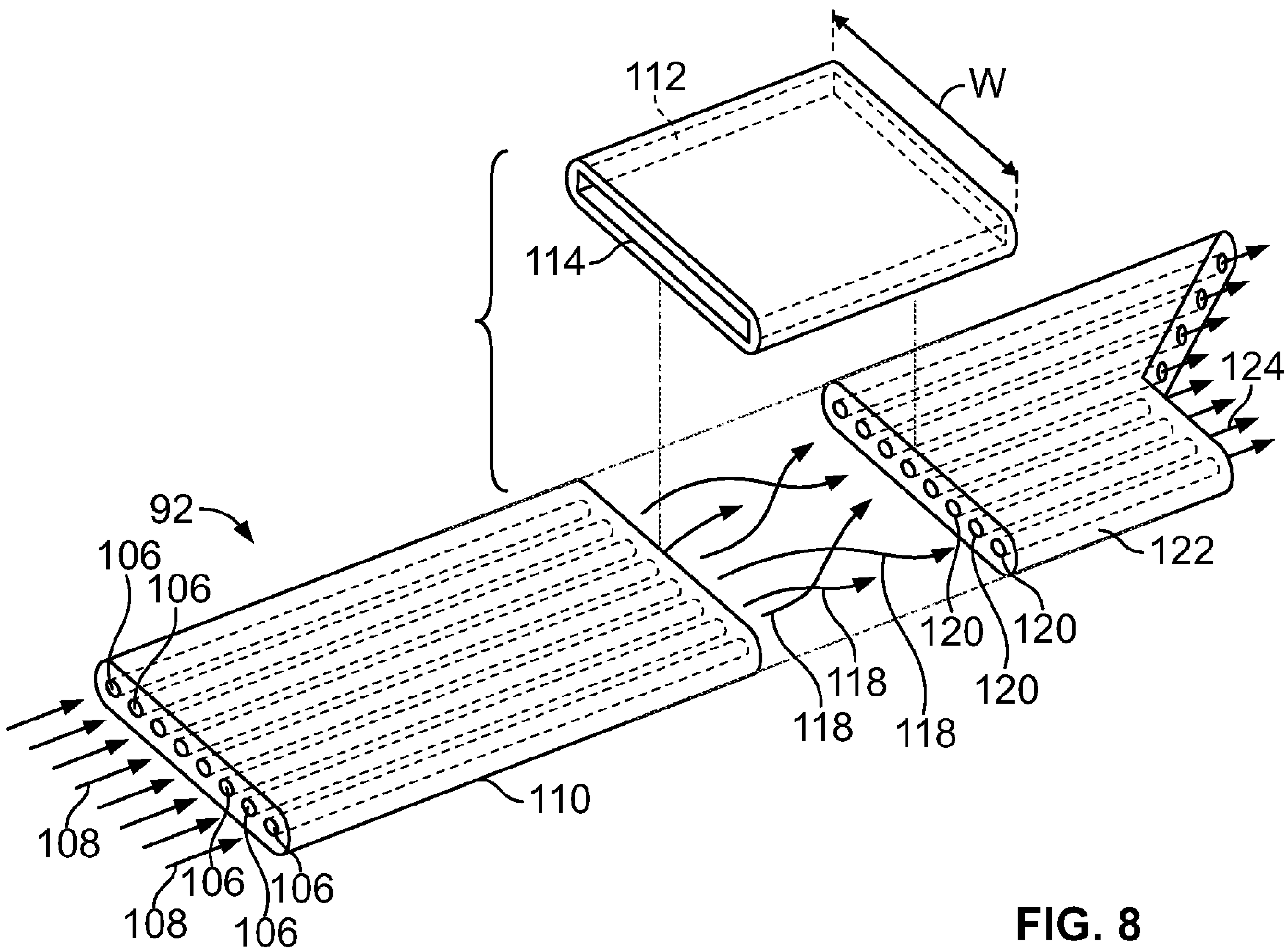

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FIG. 8

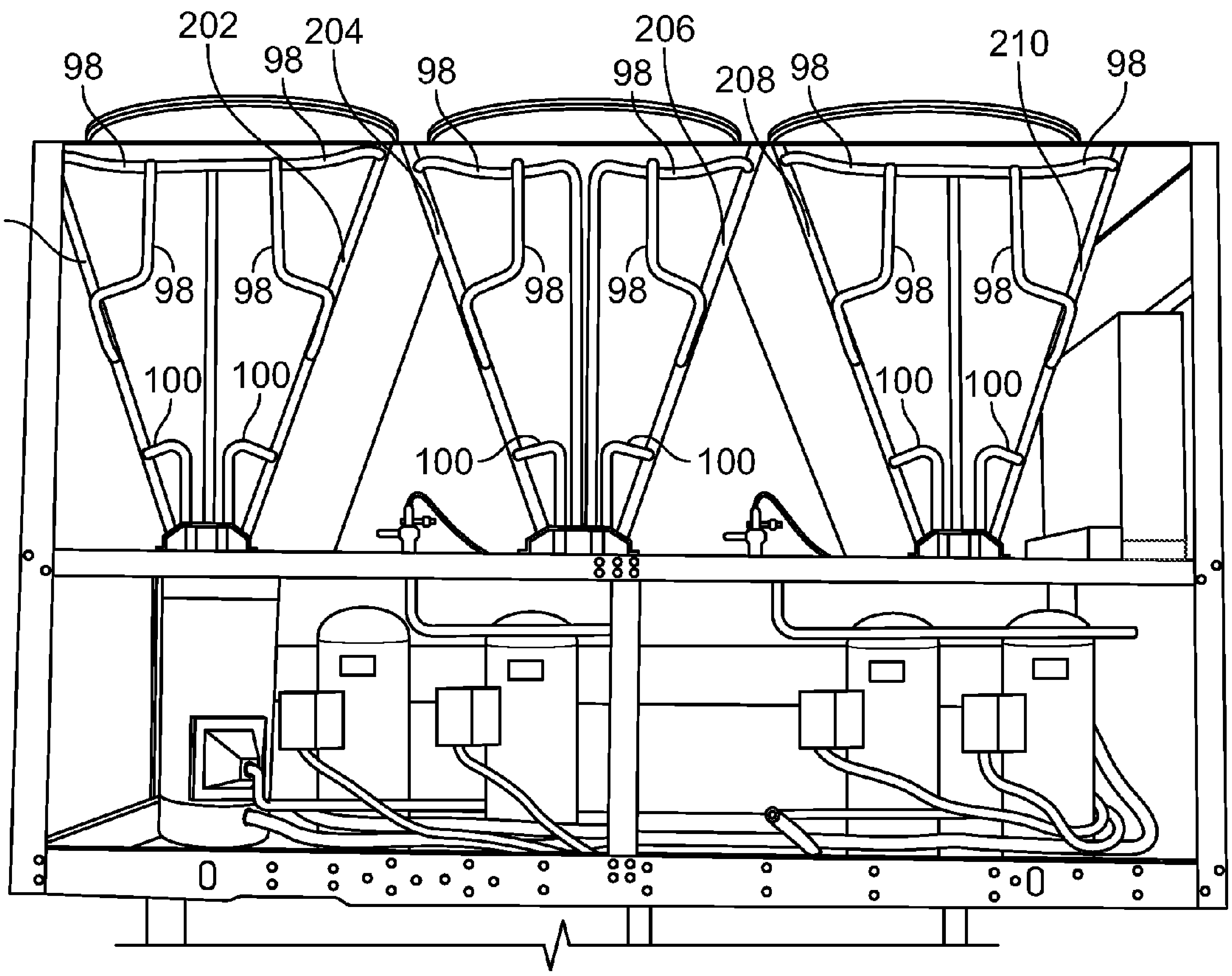
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FIG. 9

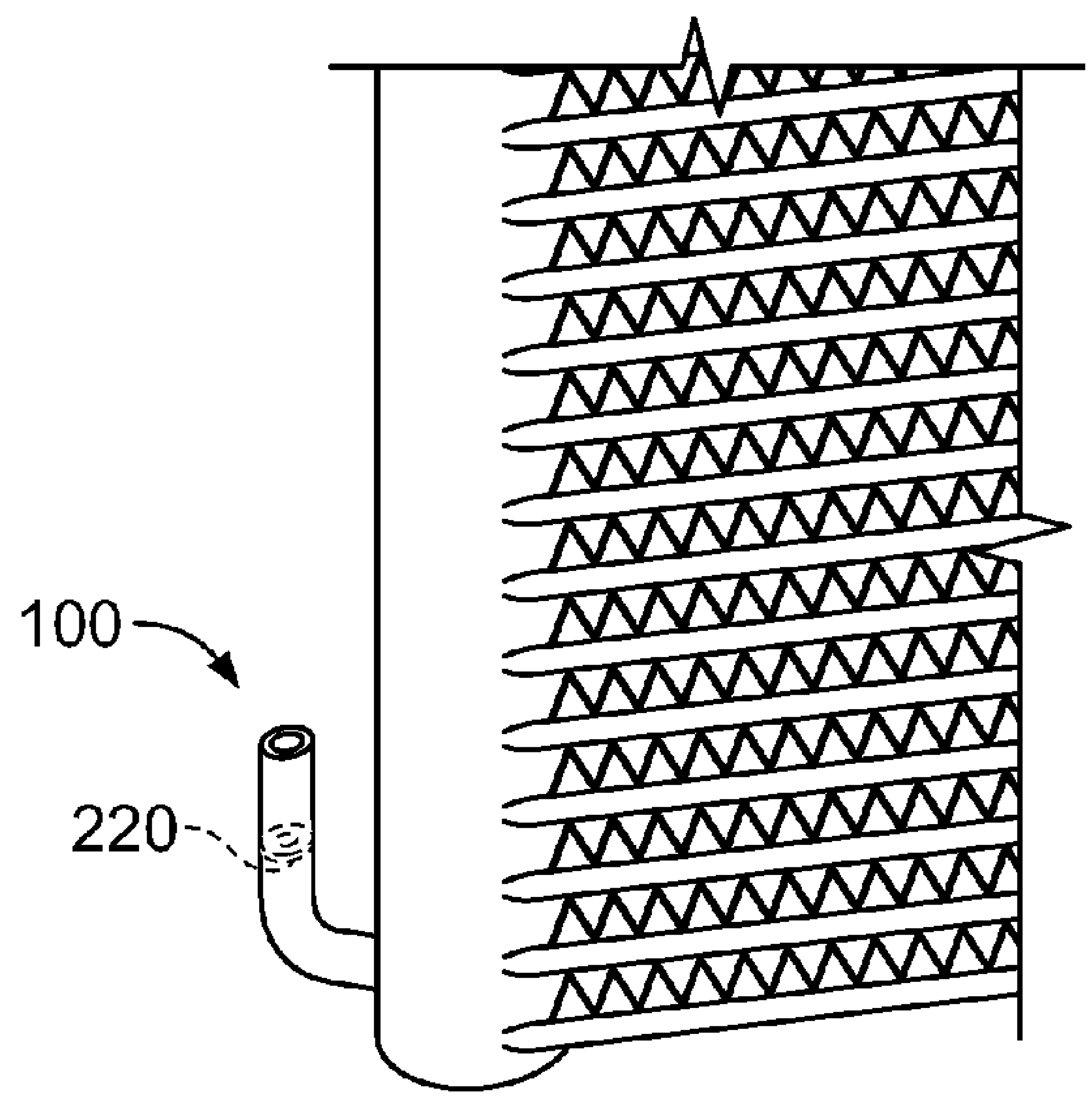
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FIG. 10

CONDENSER REFRIGERANT DISTRIBUTION

CROSS REFERENCE TO RELATED PATENT APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Patent Application Nos. 60/882,033 filed on Dec. 27, 2006; 60/914,489 filed on Apr. 27, 2007 and 60/952,280 and filed on Jul. 27, 2007, all of which relate to multichannel technology and are hereby incorporated by reference in their entirety into this application.

BACKGROUND

[0002] The application generally relates to multichannel heat exchanger applications in HVAC&R systems. The application relates more specifically to improved refrigerant distribution in a condenser that uses multichannel heat exchangers.

[0003] In a typical multichannel heat exchanger or coil slab, a series of tube sections are connected (physically and thermally) by fins that are configured to permit airflow through the heat exchanger in order to provide for heat transfer between the airflow and a circulating fluid, e.g., water or refrigerant. The tube sections of the heat exchanger are oriented to extend either horizontally or vertically and each tube section has several tubes or channels that are used to circulate the fluid. The outside of the tube section is a continuous surface typically having a rectangular shape.

[0004] Multichannel heat exchangers can offer significant cost and performance advantages when used in an air-cooled condenser of a HVAC&R system compared to conventional round-tube condenser coils. One performance advantage offered by a multichannel heat exchanger is a reduced air pressure drop through the condenser compared to a conventional round-tube coil. The multichannel heat exchanger can be designed so that a single heat exchanger or row performs the de-superheating and sub-cooling process in the condenser based on the number of passes in the heat exchanger. In a two-pass design, the two phase refrigerant exiting the first pass is mixed in an intermediate header before entering the second pass where condensation is completed and sub-cooling is done. Further, a multichannel heat exchanger may be constructed of aluminum, which can reduce material cost and enhance performance in a refrigeration system. The reduced air pressure drop in a multichannel heat exchanger forces and uneven air distribution between the coils. This uneven air distribution in multichannel coils results in large variations in refrigerant liquid temperature. Therefore, what is needed is a system and method for more evenly distributing the refrigerant flow in multichannel coils, thereby improving the distribution of refrigerant liquid temperature as well.

[0005] Intended advantages of a system and/or method satisfy one or more of these needs or provide other advantageous features. Other features and advantages will be made apparent from the present specification. The teachings disclosed extend to those embodiments that fall within the scope of the claims, regardless of whether they accomplish one or more of the aforementioned needs.

SUMMARY

[0006] One embodiment is directed to an HVAC&R system having a compressor, a condenser, an evaporator, and an expansion valve connected in a closed refrigerant loop. The condenser has at least two fluid flow paths that are cooled by an air flow drawn through the condenser by at least one condenser fan. The at least two fluid flow paths each have an inlet and an outlet and a fluid flow between the inlet and the outlet. The at least two fluid flow paths have a variable air flow for cooling the fluid in the at least two fluid flow paths. At least one flow regulator is disposed in at least one outlet to regulate at least one fluid flow in response to the variable air flow in the condenser. The flow regulator regulates the fluid flow in the at least two flow paths to provide a fluid having a substantially equal temperature in the at least two flow paths.

[0007] Another embodiment is directed to a condenser has at least two fluid flow paths that are cooled by an air flow drawn or directed through the condenser by at least one condenser fan. The at least two fluid flow paths each have an inlet and an outlet and a fluid flow between the inlet and the outlet. The at least two fluid flow paths have a variable air flow for cooling the fluid flow in the at least two fluid flow paths. At least one flow regulator is disposed in at least one outlet to regulate at least one fluid flow in response to the variable air flow in the condenser. The flow regulator regulates the fluid flow in the at least two flow paths to provide a fluid having a substantially equal temperature in the at least two flow paths.

[0008] Yet another embodiment is directed to a condenser, which has a multichannel heat exchanger. The multichannel heat exchanger has at least two fluid flow paths that are cooled by an air flow drawn or otherwise directed through the condenser by at least one condenser fan. The at least two fluid flow paths each have an inlet and an outlet and a fluid flow between the inlet and the outlet. The at least two fluid flow paths have a variable air flow for cooling the fluid in the at least two fluid flow paths. At least one flow regulator is disposed in at least one outlet to regulate at least one fluid flow in response to the variable air flow in the condenser. The flow regulator regulates the fluid flow in the at least two flow paths to provide a fluid having a substantially equal temperature in the at least two flow paths.

[0009] One advantage is improved liquid subcooling temperatures of the refrigerant to assure reliable performance of the expansion valve.

[0010] Another advantage is improved protection against equipment performance degradation.

[0011] Yet another advantage is increased chiller cooling capacity.

[0012] Still another advantage is a reduced cost system and increased system efficiency, when compared to conventional systems.

[0013] Alternative exemplary embodiments relate to other features and combinations of features as may be generally recited in the claims.

BRIEF DESCRIPTION OF THE FIGURES

[0014] These and other features, aspects, and advantages of the present invention will become better understood when the following detailed description is read with reference to the accompanying drawings in which like characters represent like parts throughout the drawings, wherein:

[0015] FIG. **1** is an illustration of an exemplary residential air conditioning or heat pump system of the type that might employ a heat exchanger made or configured in accordance with the present techniques;

[0016] FIG. **2** is a partially exploded view of the outside unit of the system of FIG. **1**, with an upper assembly lifted to expose certain of the system components, including a heat exchanger;

[0017] FIG. **3** is an illustration of an exemplary commercial or industrial HVAC&R system that employs a chiller and air handlers to cool a building and that may also employ heat exchangers in accordance with the present techniques;

[0018] FIG. **4** is a partially exploded view of the exemplary commercial or industrial HVAC&R system that employs a chiller and air handlers to cool a building of FIG. **3**, with the fan assembly lifted to expose certain system components, including a heat exchanger;

[0019] FIG. **5** is a diagrammatical overview of an exemplary air conditioning system which may employ one or more heat exchangers with internal tube configurations in accordance with aspects of the invention;

[0020] FIG. **6** is a diagrammatical overview of an exemplary heat pump system which may employ one or more heat exchangers with internal tube configurations in accordance with aspects of the invention;

[0021] FIG. **7** is a perspective view of an exemplary heat exchanger containing internal tube configurations in accordance with one aspect of the invention;

[0022] FIG. **8** is a partially exploded detail perspective view of an exemplary multichannel tube;

[0023] FIG. **9** is an end view of a condenser of FIG. **3**;

[0024] FIG. **10** is an enlarged view of the outlet with an orifice;

[0025] Wherever possible, the same reference numbers will be used throughout the drawings to refer to the same or like parts.

DETAILED DESCRIPTION OF THE EXEMPLARY EMBODIMENTS

[0026] Turning now to the drawings, and referring first to FIGS. **1-3**, exemplary applications for aspects of the invention are illustrated. The invention, in general, may be applied in a wide range of settings, both within the HVAC&R field and outside of that field. In presently contemplated applications, however, the invention may be used in residential, commercial, light industrial, industrial and in any other application for heating or cooling a volume or enclosure, such as a residence, building, structure, and so forth. Moreover, the invention may be used in industrial applications, where appropriate, for basic refrigeration and heating of various fluids. The particular application illustrated in FIG. **1** is for residential heating and cooling. In general, a residence, designated by the letter R, will be equipped with an outdoor unit that is operatively coupled to an indoor unit. The outdoor unit is typically situated adjacent to a side of the residence and is covered by a shroud to protect the system components and to prevent leaves and other contaminants from entering the unit. The indoor unit may be positioned in a utility room, an attic, a basement, and so forth. The outdoor unit is coupled to the indoor unit by refrigerant conduits RC, which transfer primarily liquid refrigerant in one direction and primarily vaporized refrigerant in an opposite direction.

[0027] In operation, when the system shown in FIG. **1** is operating as an air conditioner, a coil in the outdoor unit serves as a condenser for recondensing vaporized refrigerant flowing from the indoor unit IU to the outdoor unit OU via one of the refrigerant conduits. In these applications, a coil of the indoor unit, designated by the reference characters IC, serves as an evaporator coil. The evaporator coil receives liquid refrigerant (which may be expanded by an expansion device described below) and evaporates the refrigerant before returning it to the outdoor unit.

[0028] In operation, the outdoor unit draws in environmental air through sides as indicated by the arrows directed to the sides of unit OU, forces the air through the outer unit coil by a means of a fan (not shown) and expels the air as indicated by the arrows above the outdoor unit. When operating as an air conditioner, the air is heated by the condenser coil within the outdoor unit and exits the top of the unit at a temperature higher than it entered the sides. On the contrary, air is circulated over the indoor coil IC, and is then circulated through the residence by means of duct work D, as indicated by the arrows in FIG. **1**. The overall system operates to maintain a desired temperature as set by a thermostat T. When the temperature sensed inside the residence is higher than the set point on the thermostat (plus a small amount) the air conditioner will become operative to refrigerate additional air for circulation through the residence. When the temperature reaches the set point (minus a small amount) the unit will stop the refrigeration cycle temporarily.

[0029] When the unit in FIG. **1** operates as a heat pump, the roles of the coils are simply reversed. That is, the coil of the outdoor unit will serve as an evaporator to evaporate refrigerant and thereby cool air entering the outdoor unit as the air passes over the outdoor unit coil. On the contrary, the indoor coil IC will receive a stream of air blown over it and will heat the air by condensing a refrigerant.

[0030] FIG. **2** illustrates a partially exploded view of one of the units shown in FIG. **1**, in this case the outdoor unit OU. In general, the unit may be thought of as including an upper assembly UA made up of a shroud, a fan assembly, a fan drive motor, and so forth. In the illustration of FIG. **2**, the fan and fan drive motor are not visible because they are hidden by the surrounding shroud. The outdoor coil OC is housed within this shroud and is generally disposed to surround or at least partially surround other system components, such as a compressor, an expansion device, a control circuit, and so forth as described more fully below.

[0031] FIG. **3** illustrates another exemplary application for the present invention, in this case an HVAC&R system for building environmental management. In the embodiment, illustrated in FIG. **3**, a Building BL is cooled by a system that includes a chiller CH, which is typically disposed on or near the building, or in an equipment room or basement. In the embodiment illustrated in FIG. **3**, the chiller CH is a roof top air-cooled device that implements a refrigeration cycle to cool water. The water is circulated to a building through water conduits WC. The water conduits are routed to air handlers AH at individual floors or sections of the building. The air handlers are also coupled to duct work DU that is adapted to blow air from an outside intake OI.

[0032] In operation, the chiller, which includes heat exchangers for both evaporating and condensing a refrigerant as described above, cools water that is circulated to the air handlers. Air blown over additional coils that receive the water in the air handlers causes the water to increase in temperature and the circulated air to decrease in temperature. The cooled air is then routed to various locations in the building via additional duct work. Ultimately, distribution of the air is routed to diffusers that deliver the cooled air to offices, apartments, hallways, and any other interior spaces within the building. In many applications, thermostats or other command devices (not shown in FIG. **3**) will serve to control the flow of air through and from the individual air handlers and duct work to maintain desired temperatures at various locations in the structure.

[0033] FIG. **4** illustrates a partially exploded view of one of the units as shown in FIG. **3**, in this case an HVAC&R system for building environmental management. In general, the unit may be thought of as including an upper assembly UA made up of a shroud, a fan assembly, a fan drive motor, and so forth. In the illustration of FIG. **4**, the fan is visible on top of the surrounding shroud. The multichannel coils MC are housed within this shroud and are generally deposed on top or at least partially on top of other system components, such as a compressor, an expansion device, a control circuit, and so forth as described more fully below. The multichannel coils MC are disposed at an angle to provide more efficient cooling of the coils and to assist with draining or liquid buildup from rain and the like.

[0034] FIG. **5** illustrates the air conditioning system **10**, which uses multichannel tubes. Refrigerant flows through the system within closed refrigeration loop **12**. The refrigerant may be any fluid that absorbs and extracts heat. For example, the refrigerant may be hydrofluorocarbon (HFC) based R-410A, R-407, or R-134a, or it may be carbon dioxide (R-744a) or ammonia (R-717). The air conditioning system **10** includes control devices **14** which enable the system **10** to cool an environment to a prescribed temperature.

[0035] The system **10** cools an environment by cycling refrigerant within the closed refrigeration loop **12** through condenser **16**, compressor **18**, expansion device **20**, and evaporator **22**. The refrigerant enters the condenser **16** as a high pressure and temperature vapor and flows through the multichannel tubes of the condenser **16**. A fan **24**, which is driven by a motor **26**, draws air across the multichannel tubes. The fan **24** may push or pull air across the tubes. Heat transfers from the refrigerant vapor to the air producing heated air **28** while causing the refrigerant vapor to condense into a liquid. The liquid refrigerant then flows into an expansion device **20** where the refrigerant expands to become a low pressure and temperature liquid. Typically, the expansion device **20** will be a thermal expansion valve (TXV); however, in other embodiments, the expansion device may be an orifice or a capillary tube. As those skilled in the art will appreciate, after the refrigerant exits the expansion device, some vapor refrigerant may be present in addition to the liquid refrigerant.

[0036] From the expansion device **20**, the refrigerant enters the evaporator **22** and flows through the evaporator multichannel tubes. A fan **30**, which is driven by a motor **32**, draws air across the multichannel tubes. Heat transfers from the air to the refrigerant liquid producing cooled air **34** and causing the refrigerant liquid to boil into a vapor. As will be appreciated by those skilled in the art, the fan may be replaced by a pump, which draws fluid across the multichannel tubes.

[0037] The refrigerant then flows to compressor **18** as a low pressure and temperature vapor. The compressor **18** reduces the volume available for the refrigerant vapor, consequently, increasing the pressure and temperature of the vapor refrigerant. The compressor may be any suitable compressor such as a screw compressor, reciprocating compressor, rotary compressor, swing link compressor, scroll compressor, centrifugal compressor or turbine compressor. The compressor **18** is driven by a motor **36**, which receives power from a variable speed drive (VSD) or a direct AC or DC power source. In one embodiment, the motor **36** receives fixed line voltage and frequency from an AC power source although in some applications the motor may be driven by a variable voltage or frequency drive. The motor may be a switched reluctance (SR) motor, an induction motor, an electronically commutated permanent magnet motor (ECM), or any other suitable motor type. The refrigerant exits the compressor **18** as a high temperature and pressure vapor that is ready to enter the condenser and begin the refrigeration cycle again.

[0038] The operation of the refrigeration cycle is governed by control devices **14** which include control circuitry **38**, a thermostat **40**, and a temperature sensor **42**. The control circuitry **38** is coupled to motors **26**, **32**, **36** which drive the condenser fan **24**, the evaporator fan **30**, and the compressor **18**, respectively. The control circuitry uses information received from the thermostat **40** and the sensor **42** to determine when to operate the motors **26**, **32**, **36** that drive the air conditioning system. For example, in a residential air conditioning system, the thermostat **40** may be a programmable 24 volt thermostat that provides a temperature set point to the control circuitry **38**. The sensor **42** determines the ambient air temperature and provides the temperature to the control circuitry **38**. The control circuitry **38** then compares the temperature received from the sensor to the temperature set point received from the thermostat. If the temperature is higher than the set point, the control circuitry may turn on the motors **26**, **32**, **36** to run the air conditioning system **10**. Additionally, the control circuitry may execute hardware or software control algorithms to regulate the air conditioning system. In some embodiments, the control circuitry **38** may include an analog to digital (A/D) converter, a microprocessor, a non-volatile memory, and an interface board. Other devices may, of course, be included in the system, such as additional pressure and/or temperature transducers or switches that sense temperatures and pressures of the refrigerant, the heat exchangers, the inlet and outlet air, and so forth.

[0039] FIG. **6** illustrates a heat pump system **44** that uses multichannel tubes. Because the heat pump may be used for both heating and cooling, refrigerant flows through a reversible refrigeration/heating loop **46**. The refrigerant may be any fluid that absorbs and extracts heat. Additionally, the heating and cooling operations are regulated by control devices **48**.

[0040] The heat pump system **44** includes an outside coil **50** and an inside coil **52** that both operate as heat exchangers. As noted above, the coils may function as either an evaporator or a condenser depending on the heat pump operation mode. For example, when the heat pump system **44** is operating in cooling (or "AC") mode, the outside coil **50** functions as a condenser, releasing heat to the outside air, while the inside coil **52** functions as an evaporator, absorbing heat from the inside air. On the contrary, when the heat pump system **44** is operating in heating mode, the outside coil **50** functions as an evaporator, absorbing heat from the outside air, while the inside coil **52** functions as a condenser, releasing heat to the inside air. A reversing valve **54** is positioned on the reversible loop **46** between the coils to control the direction of refrigerant flow and thereby to switch the heat pump between heating mode and cooling mode.

[0041] The heat pump system **44** also includes two metering devices **56**, **58** for decreasing the pressure and temperature of the refrigerant before it enters the evaporator. As will be appreciated by those skilled in the art, the metering device also acts to regulate refrigerant flow into the evaporator so that the amount of refrigerant entering the evaporator equals the amount of refrigerant exiting the evaporator. The metering device used depends on the heat pump operation mode. For example, when the heat pump system is operating in cooling mode, refrigerant bypasses metering device **56** and flows through metering device **58** before entering the inside coil **52**, which acts as an evaporator. Similarly, when the heat pump system is operating in heating mode, refrigerant bypasses metering device **58** and flows through metering device **56** before entering the outside coil **50**, which acts as an evaporator. In other embodiments, a single metering device may be used for both heating mode and cooling mode. The metering devices **56**, **58** typically are thermal expansion valves (TXV), but also may be orifices or capillary tubes.

[0042] The refrigerant enters the evaporator, which is the outside coil **50** in heating mode and the inside coil **52** in cooling mode, as a low temperature and pressure liquid. As will be appreciated by those skilled in the art, some vapor refrigerant may also be present as a result of the expansion process that occurs in the metering device **56**, **58**. The refrigerant flows through multichannel tubes in the evaporator and absorbs heat from the air changing the refrigerant into a vapor. In cooling mode, the indoor air passing over the multichannel tubes also may be dehumidified. The moisture from the air may condense on the outer surface of the multichannel tubes and consequently be removed from the air.

[0043] After exiting the evaporator, the refrigerant passes through the reversing valve **54** and into the compressor **60**. The compressor **60** decreases the volume of the refrigerant vapor, consequently, increasing the temperature and pressure of the vapor. Here again, the compressor may be any suitable compressor such as a screw compressor, reciprocating compressor, rotary compressor, swing link compressor, scroll compressor, centrifugal compressor or turbine compressor.

[0044] From the compressor, the increased temperature and pressure vapor refrigerant flows into a condenser, the location of which is determined by the heat pump mode. In cooling mode, the refrigerant flows into outside coil **50** (acting as a condenser). A fan **62**, which is powered by a motor **64**, draws air over the multichannel tubes containing refrigerant vapor. As will be appreciated by those skilled in the art, the fan may be replaced by a pump, which draws fluid across the multichannel tubes. The heat from the refrigerant is transferred to the outside air causing the refrigerant to condense into a liquid. In heating mode, the refrigerant flows into inside coil **52** (acting a condenser). A fan **66**, which is powered by a motor **68**, draws air over the multichannel tubes containing refrigerant vapor. The heat from the refrigerant is transferred to the inside air causing the refrigerant to condense into a liquid.

[0045] After exiting the condenser, the refrigerant flows through the metering device (**56** in heating mode and **58** in cooling mode) and returns to the evaporator (outside coil **50** in heating mode and inside coil **52** in cooling mode) where the process begins again.

[0046] In both heating and cooling modes, a motor **70** drives the compressor **60** and circulates refrigerant through the reversible refrigeration/heating loop **46**. The motor may receive power either directly from an AC or DC power source or from a variable speed drive (VSD). As in the previous example, the motor may be a switched reluctance (SR) motor, an induction motor, an electronically commutated permanent magnet motor (ECM), or any other suitable motor type.

[0047] The operation of the motor **70** is controlled by control circuitry **72**. The control circuitry **72** receives information from a thermostat **74** and sensors **76**, **78**, **80** and uses the information to control the operation of the heat pump system **44** in both cooling mode and heating mode. For example, in cooling mode, the thermostat provides a temperature set point to the control circuitry **72**. The sensor **80** measures the ambient indoor air temperature and provides it to the control circuitry **72**. The control circuitry **72** then compares the air temperature to the temperature set point and engages the compressor motor **70** and fan motors **64** and **68** to run the cooling system if the air temperature is above the temperature set point. Likewise, in heating mode, the control circuitry **72** compares the air temperature from the sensor **80** to the temperature set point from the thermostat **74** and engages the motors **64**, **68**, **70** to run the heating system if the air temperature is below the temperature set point.

[0048] The control circuitry **72** also uses information received from the thermostat **40** to switch the heat pump system **44** between heating mode and cooling mode. For example, if the thermostat is set to cooling mode, the control circuitry **72** will send a signal to a solenoid **82** to place the reversing valve **54** in the air conditioning position **84**. Consequently, the refrigerant will flow through the reversible loop **46** as follows: the refrigerant exits compressor **60**, is condensed in outside coil **50**, is expanded by metering device **58**, and is evaporated by inside coil **52**. On the contrary, if the thermostat is set to heating mode, the control circuitry **72** will send a signal to solenoid **82** to place the reversing valve **54** in the heat pump position **86**. Consequently, the refrigerant will flow through the reversible loop **46** as follows: the refrigerant exits compressor **60**, is condensed in inside coil **52**, is expanded by metering device **56**, and is evaporated by outside coil **50**.

[0049] The control circuitry **72** may execute hardware or software control algorithms to regulate the heat pump system **44**. In some embodiments, the control circuitry may include an analog to digital (A/D) converter, a microprocessor, a non-volatile memory, and an interface board.

[0050] The control circuitry also may initiate a defrost cycle when the system **44** is operating in heating mode. When the outdoor temperature approaches freezing, moisture in the outside air that is directed over outside coil **50** may condense and freeze on the coil. The sensor **76** measures the outside air temperature, and the sensor **78** measures the temperature of the outside coil **50**. These sensors provide the temperature information to the control circuitry which determines when to initiate a defrost cycle. For example, if either of the sensors **76**, **78** provides a temperature below freezing to the control circuitry, the system **44** may be placed in defrost mode. In defrost mode, the solenoid **82** is actuated to place the reversing valve **54** to air conditioning position **84**, and the motor **64** is shut off to discontinue air flow over the multichannels. The system **44** then operates in cooling mode until the increased temperature and pressure refrigerant flowing through the outside coil defrosts the coil **50**. Once the sensor **78** detects that the coil **50** is defrosted, the control circuitry **72** returns the reversing valve **54** to heat pump position **86**. As will be appreciated by those skilled in the art, the defrost cycle can be set to occur at many different time and temperature combinations.

[0051] FIG. **7** is a perspective view of an exemplary heat exchanger, which may be used in an air conditioning system **10** or a heat pump system **44**. The exemplary heat exchanger may be a condenser **16**, an evaporator **22**, an outside coil **50**, or an inside coil **52**, as shown in FIGS. **5** and **6**. It should also be noted that in similar or other systems, the heat exchanger may be used as part of a chiller or in any other heat exchanging application. The heat exchanger includes manifolds **88**, **90** that are connected by multichannel tubes **92**. Although 30 tubes are shown in FIG. **7**, the number of tubes may vary. The manifolds and tubes may be constructed of aluminum or any other material that promotes good heat transfer. Refrigerant flows from the manifold **88** through first tubes **94** to the manifold **90**. The refrigerant then returns to the manifold **88** through second tubes **96**. In some embodiments, the heat exchanger may be rotated approximately 90 degrees so that the multichannel tubes run vertically between a top manifold and a bottom manifold. Additionally, the heat exchanger may be inclined at an angle relative to the vertical. Furthermore, although the multichannel tubes are depicted as having an oblong shape, the tubes may be any shape, such as tubes with a cross-section in the form of a rectangle, square, circle, oval, ellipse, triangle, trapezoid, or parallelogram. In some embodiments, the tubes may have a diameter ranging from 0.5 mm to 3 mm. It should also be noted that the heat exchanger may be provided in a single plane or slab, or may include bends, corners, contours and so forth.

[0052] In some embodiments, the construction of the first tubes **94** may differ from the construction of the second tubes **96**. Tubes may also differ within each section. For example, the tubes may all have identical cross sections, or the tubes in the first section may be rectangular while the tubes in the second section are oval. The internal construction of the tubes, as described below with regard to FIG. **8** may also vary within and across tube sections.

[0053] Returning to FIG. **7**, refrigerant enters the heat exchanger through an inlet **98** and exits the heat exchanger through an outlet **100**. Although FIG. **7** depicts the inlet at the top of the manifold **88** and the outlet at the bottom of the manifold, the inlet and outlet positions may be interchanged so that fluid enters at the bottom and exits at the top. The fluid may also enter and exit the manifold from multiple inlets and outlets positioned on bottom, side, or top surfaces of the manifold. Baffles **102** separate the inlet **98** and outlet **100** portions of the manifold **88**. Although a double baffle **102** is illustrated, any number of one or more baffles may be employed to create separation of the inlet **98** and the outlet **100**.

[0054] Fins **104** are located between the multichannel tubes **92** to promote the transfer of heat between the tubes **92** and the environment. In one embodiment, the fins are constructed of aluminum, brazed or otherwise joined to the tubes, and disposed generally perpendicular to the flow of refrigerant. However, in other embodiments the fins may be made of other materials that facilitate heat transfer and may extend parallel or at varying angles with respect to the flow of the refrigerant. Additionally, the fins may be louvered fins, corrugated fins, or any other suitable type of fin.

[0055] As noted above, in a typical evaporator heat exchanger application, the majority of the heat transfer occurs due to a phase change of the refrigerant. Refrigerant exits the expansion device as a low pressure and temperature liquid and enters the evaporator. As the liquid travels through the first multichannel tubes **94**, the liquid absorbs heat from the outside environment causing the liquid to warm from its subcooled temperature (i.e., a number of degrees below the boiling point). Then, as the liquid refrigerant travels through the second multichannel tubes **96**, the liquid absorbs more heat from the outside environment causing it to boil into a vapor. Although evaporator applications typically use liquid refrigerant to absorb heat, some vapor may be present along with the liquid due to the expansion process. The amount of vapor may vary based on the type of refrigerant used. In some embodiments, the refrigerant may contain approximately 15% vapor by weight and 90% vapor by volume. This vapor has a lower density than the liquid, causing the vapor to separate from the liquid within the manifold **88**. Consequently, certain flow channels of tubes **92** may contain only vapor.

[0056] FIG. **8** shows a perspective view of a tube **92** shown in FIG. **7**. Refrigerant flows through flow channels **106** contained within the tubes **94**. The flow channels **106** may be parallel to one another. The direction of fluid flow **108** is from manifold **88** shown in FIG. **7** to manifold **90** shown in FIG. **7** within the first tubes. The direction of fluid flow is reversed within the second tubes. Because the refrigerant within manifold **88** is a mixture of liquid phase and vapor phase refrigerant, the flow channels **106** may contain some liquid and some vapor. Additionally, because of the density difference, which causes separation of phases, some flow channels within the channel section **110** may contain only vapor phase refrigerant while other flow channels may contain only liquid phase refrigerant. The flow channels containing only vapor phase refrigerant are not able to absorb as much heat because the refrigerant has already changed phases. The fluid in the flow channels may be refrigerant, brine, or other fluid capable of the necessary phase change.

[0057] After flowing through the channel section **110**, the refrigerant reaches the open section **112**. In the open section, the interior walls that form the flow channels have been removed or interrupted. Consequently, the open section includes an open channel **114** spanning the width W of the tube **92** where mixing of the two phases of refrigerant can occur. Mixed flow **118** occurs within this section causing the fluid flow **108** from the flow channels **106** to cross paths and mix. Thus, flow channels containing all (or primarily) vapor phase may mix with flow channels containing all (or primarily) liquid phase, providing a more homogenous distribution of refrigerant. Additionally, flow channels containing different percentages of vapor and liquid may also mix.

[0058] From the open section **112**, the refrigerant enters flow channels **120** contained within channel section **122**. The fluid flow **124** through these channels may contain a more even distribution of vapor and liquid phases due to the mixed flow **118** that occurred within the open channel **114**. The tube **92** may contain any number of open sections **112** where mixing may occur. Thus, rather than allowing vapor alone to be channeled through certain flow paths, the internal wall interruptions permit mixing of the phases, allowing increased phase change to occur in all of the flow paths (through which an increasingly mixed phase flow will be channeled). The internal wall interruptions also allow the tubes to be segregated into sections for repair purposes. For example, if a flow channel contained within channel section **110** becomes blocked, plugged, or requires repair, that section of the flow channel may be removed from service or bypassed while the corresponding flow channel within channel section **122** continues to receive refrigerant flow.

[0059] In the arrangement shown in FIG. **9**, the outer coils, **200**, **210** can have a much higher air flow than the interior coils **202**, **204**, **206**, **208** because of the placement on the outside of the system. Higher air flow through a coil provides better coil performance, resulting in lower refrigerant liquid temperatures within the flow channels. The lower the refrigerant liquid temperatures, the more efficient the system is during the cooling mode of operation. Air flow rates through the outer coils **200**, **210** can be almost twice as high as that through the inside coils **202**, **204**, **206**, **208**. Table 1, below, provides sample refrigerant temperatures at the exit of each coil in a conventional condenser. The temperatures of each coil vary greatly, which results in an inefficient chiller system.

TABLE 1

	Coil number					
	200	202	204	206	208	210
Sample Temp. (Degrees Fahrenheit)	96.7	109.4	103.3	106.3	113.6	102.6

[0060] To regulate the flow of refrigerant in the coils a valve or orifice **220** may be disposed in the outlet **100** of at least one of the coils. The valve or orifice **220** provides the necessary refrigerant flow for each individual coil, depending on the amount of air flow the coil receives. The refrigerant is regulated to allow the air flow to cool the refrigerant in the flow channel and provide a more efficient chiller. FIG. **10** illustrates a valve or orifice **220** as disposed in the outlet **100** of at least one of the coils. The valve or orifice **220** restricts the refrigerant flow in the flow channel, and provide a control of the refrigerant flow. The restriction of the refrigerant flow allows the air to cool the refrigerant better, thereby providing a lower liquid temperature in the coils. The valve or orifice **220** may also allow more refrigerant flow, thereby providing a pressure drop in the corresponding liquid line of the coil and allowing more refrigerant to flow. In other embodiments, a reduced line size, e.g., venturi, or other flow-restricting component may be interchanged with the valve or orifice **220**. The sizing or positioning of the valve or orifice **220** is adjustable to obtain the desired pressure drop or the desired refrigerant liquid temperature exiting that particular coil. The valve or orifice **220** may be controlled by an automatic control, using circuitry or microprocessors. Another embodiment includes the valve or orifice **220** being controlled manually according to the amount of air flow throughout the condenser.

[0061] In one embodiment, one or more valves or orifices **220** may be incorporated in coils **200**, **202**, **204**, **206**, **208**, and **210** as a unitary part of the coil. Table 2, below, provides sample refrigerant temperatures at the exit of each coil in which coils **202** and **208** include a valve or orifice **220** in the discharge connection. The temperatures of the coils are now closer in range, resulting in a more efficient chiller system.

TABLE 2

	Coil number					
	200	202	204	206	208	210
Sample Temp. (Degrees Fahrenheit)	98.7	101.3	103.5	103.4	102.8	101.3

[0062] The incorporation of one or more valves or orifices **220** with the discharge connections of the coils can substantially lower refrigerant liquid temperature entering the expansion valve by approximately 1.5 deg. Fahrenheit with no change in condensing temperature. The resulting lower liquid temperature gives an approximate substantially 1% increase in both chiller capacity and efficiency. In addition, the lower liquid temperature substantially eliminates vapor from exiting some of the coils. This is important because refrigerated vapor can create operational problems with expansion valves. Lastly, the incorporation of one or more orifices with the discharge connections of the coils may be incorporated with multichannel and conventional channel applications with uneven air distribution. It should be noted that while reference has been made to air flow cooling the fluid in the flow tubes **106**, any type of non volatile fluid may be used, e.g. water. The examples provided above in Table 1 and Table 2 include condensers with six microchannel coils, however, one of ordinary skill in the art would appreciate that any number of coils may be used for the microchannel in the condenser.

[0063] It is understood that the present discussion describes the use of the invention in condensers with multiple microchannel coils. The invention may also be used with other types of condenser applications. These condenser applications include, but are not limited to, conventional round-tube coils, water-cooled condensers, individual tubes within condensers or any condenser with tube-side condensation, flow distribution issues, or other problems or issues that create an imbalance in condenser performance.

[0064] It is also understood that while the orifice or valve is described as being disposed in the outlet or near the exit of the condenser, the orifice or valve may be placed in liquid headers, at an the outlet individual tubes, in coils with reduced air flow, in coils with higher air temperatures, or in coils with reduced heat transfer. Likewise, the orifice or valve may be applied to water-cooled condensers with tube-side condensation or sections of the condenser with reduced heat transfer or reduced water flow. The invention may also apply to any application with issues or problems with condenser performance.

[0065] It should be noted that the present discussion makes use of the term “multichannel” tubes or “multichannel heat exchanger” to refer to arrangements in which heat transfer tubes include a plurality of flow paths between manifolds that distribute flow to and collect flow from the tubes. A number of other terms may be used in the art for similar arrangements. Such alternative terms might include “microchannel” (sometimes intended to imply having fluid passages on the order of a micrometer and less), and “microport”. Other terms sometimes used in the art include “parallel flow” and “brazed aluminum”. However, all such arrangements and structures are intended to be included within the scope of the term “multichannel”. In general, such “multichannel” tubes will include flow paths disposed along the width or in a plane of a generally flat, planar tube, although, again, the invention is not intended to be limited to any particular geometry unless otherwise specified in the appended claims.

[0066] It should also be noted that while the present discussion refers to the condenser as being a part of a multichannel heat exchanger or an HVAC&R system, the condenser could be used in any suitable application, such as a chemical process. Further, one of ordinary skill in the art would appreciate that while the term refrigerant is used as the fluid in the coils, any suitable fluid may be used, such as, but not limited to, propane or chlorine. The fluid used on the outside of the tubes may be any suitable liquid or gas such as, but not limited to air, water or brine.

[0067] It should also be understood that the application is not limited to the details or methodology set forth in the following description or illustrated in the figures. It should also be understood that the phraseology and terminology employed herein is for the purpose of description only and should not be regarded as limiting.

[0068] While the exemplary embodiments illustrated in the figures and described herein are presently preferred, it should be understood that these embodiments are offered by way of example only. Accordingly, the present application is not limited to a particular embodiment, but extends to various modifications that nevertheless fall within the scope of the appended claims. The order or sequence of any processes or method steps may be varied or re-sequenced according to alternative embodiments.

[0069] It is important to note that the construction and arrangement of the multichannel coil as shown in the various exemplary embodiments is illustrative only. Although only a few embodiments have been described in detail in this disclosure, those skilled in the art who review this disclosure will readily appreciate that many modifications are possible (e.g., variations in sizes, dimensions, structures, shapes and proportions of the various elements, values of parameters, mounting arrangements, use of materials, colors, orientations, etc.) without materially departing from the novel teachings and advantages of the subject matter recited in the claims. For example, elements shown as integrally formed may be constructed of multiple parts or elements, the position of elements may be reversed or otherwise varied, and the nature or number of discrete elements or positions may be altered or varied. Accordingly, all such modifications are intended to be included within the scope of the present application. The order or sequence of any process or method steps may be varied or re-sequenced according to alternative embodiments. In the claims, any means-plus-function clause is intended to cover the structures described herein as performing the recited function and not only structural equivalents but also equivalent structures. Other substitutions, modifications, changes and omissions may be made in the design, operating conditions and arrangement of the exemplary embodiments without departing from the scope of the present application.

What is claimed is:

1. An HVAC&R system comprising:

a compressor, a condenser, an evaporator, and an expansion valve connected in a closed refrigerant loop;

the condenser further comprising:

at least two fluid flow paths being cooled by air flow forced through the condenser by at least one condenser fan, the at least two fluid flow paths each having an inlet and an outlet and a fluid flow between the inlet and the outlet, and the at least two fluid flow paths having an air flow for cooling the fluid in the at least two fluid flow paths, the air flow being variable across the condenser;

at least one flow regulator being disposed in at least one outlet to regulate at least one fluid flow in response to the variable air flow and to regulate the fluid flow in the at least two flow paths to achieve a substantially equal fluid temperature.

2. The HVAC&R system of claim **1** wherein the fluid regulator is an orifice.

3. The HVAC&R system of claim **1** wherein the fluid regulator is a valve.

4. The HVAC&R system of claim **1** wherein the condenser comprises a multichannel heat exchanger.

5. The HVAC&R system of claim **4** wherein the multichannel heat exchanger has six coils.

6. The HVAC&R system of claim **5** wherein a flow regulator is disposed in the outlet of two of the six coils.

7. The HVAC&R system of claim **1** wherein the flow regulator is a unitary piece of outlet.

8. The HVAC&R system of claim **1** wherein the fluid is refrigerant.

9. A condenser comprising:

at least two fluid flow paths being cooled by air flow drawn through the condenser by at least one condenser fan, the at least two fluid flow paths having an inlet and an outlet and a fluid flow between the inlet and the outlet, and the at least two fluid flow paths having an air flow for cooling the fluid in the at least two fluid flow paths, the air flow being variable across the condenser;

at least one flow regulator being disposed in at least one outlet to regulate at least one fluid flow in response to the variable air flow and to regulate the fluid flow in the at least two flow paths to achieve a substantially equal fluid temperature.

10. The condenser of claim **9** wherein the fluid regulator is an orifice.

11. The condenser of claim **9** wherein the fluid regulator is a valve.

12. The condenser of claim **9** wherein the condenser comprises a multichannel heat exchanger.

13. The condenser of claim **12** wherein the multichannel heat exchanger has six coils.

14. The condenser of claim **13** wherein a flow regulator is disposed in the outlet of two of the six coils.

15. The condenser of claim **12** wherein the flow regulator is a unitary piece of outlet.

16. The condenser of claim **12** wherein the fluid is refrigerant.

17. A condenser comprising:

a multichannel heat exchanger;

at least two fluid flow paths in the multichannel heat exchanger being cooled by air flow drawn through the condenser by at least one condenser fan, the at least two fluid flow paths having an inlet and an outlet and a fluid flow between the inlet and the outlet, and the at least two fluid flow paths having an air flow for cooling the fluid in the at least two fluid flow paths, the air flow being variable across the condenser;

at least one flow regulator being disposed in at least one outlet to regulate at least one fluid flow in response to the variable air flow and to regulate the fluid flow in the at least two flow paths to achieve a substantially equal fluid temperature.

18. The condenser of claim **17** wherein the fluid regulator is an orifice.

19. The condenser of claim **17** wherein the fluid regulator is a valve.

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