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(54) **HVAC&R SYSTEM VALVING**

(75) Inventors: **Jeffrey Lee Tucker**, Wichita, KS (US); **Jeremiah Marshall Horn**, Derby, KS (US); **Jeffrey Norris Nichols**, Wichita, KS (US); **Thomas John Martin**, Goddard, KS (US); **Gregory Ralph Harrod**, Wichita, KS (US); **Kenneth E. Hickman**, York, PA (US)

Correspondence Address:
Johnson Controls, Inc.
c/o Fletcher Yoder PC
P.O. Box 692289
Houston, TX 77269 (US)

(73) Assignee: **Johnson Controls Technology Company**, Holland, MI (US)

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(60) Provisional application No. 61/013,364, filed on Dec. 13, 2007.

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(57) **ABSTRACT**

An HVAC&R system is disclosed that utilizes energy-efficient valving. The valving controls the flow of refrigerant and may be adapted for evaporator or condenser applications, on both AC systems and heat pumps (as well as chillers and other refrigeration systems). The valving may provide simultaneous and individualized control of flow through individual coils or groups of coils for improved control of evaporation, condensation, defrosting and so forth. In some configurations a common sensor may be shared between individual coils or groups of coils and may provide sensed parameters to control circuitry for controlling the valving. Other configurations may include bypass valving to direct fluid around the flow control valving. In yet other configurations, a valve may be used to bypass tapped vapor around a heat exchanger functioning as an evaporator.

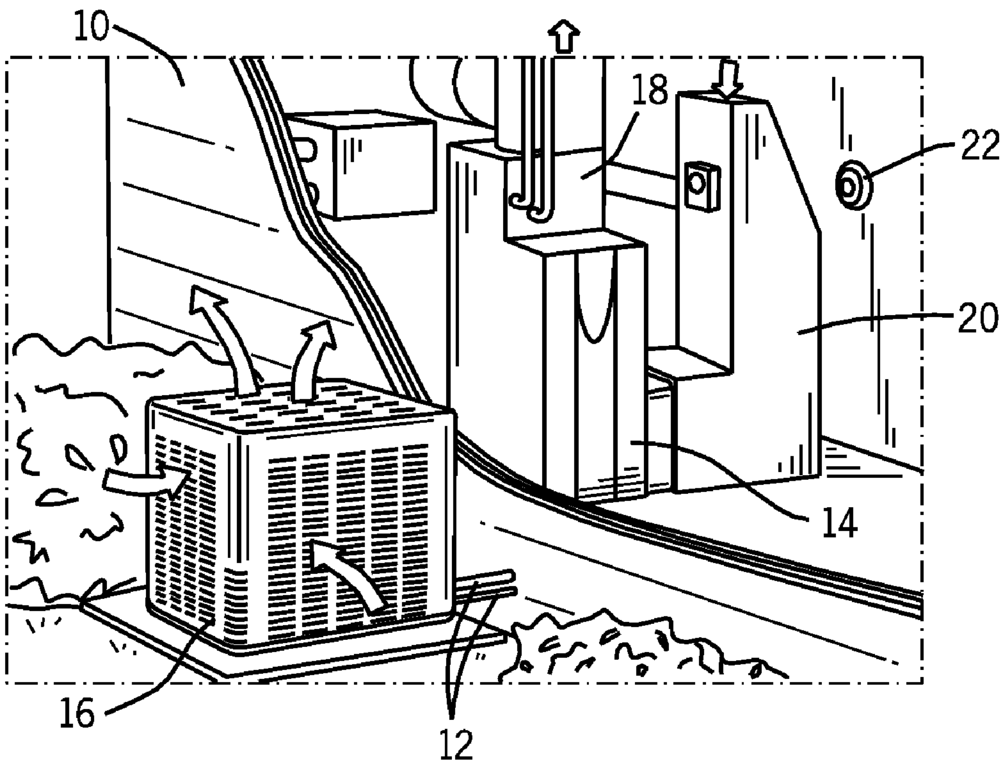
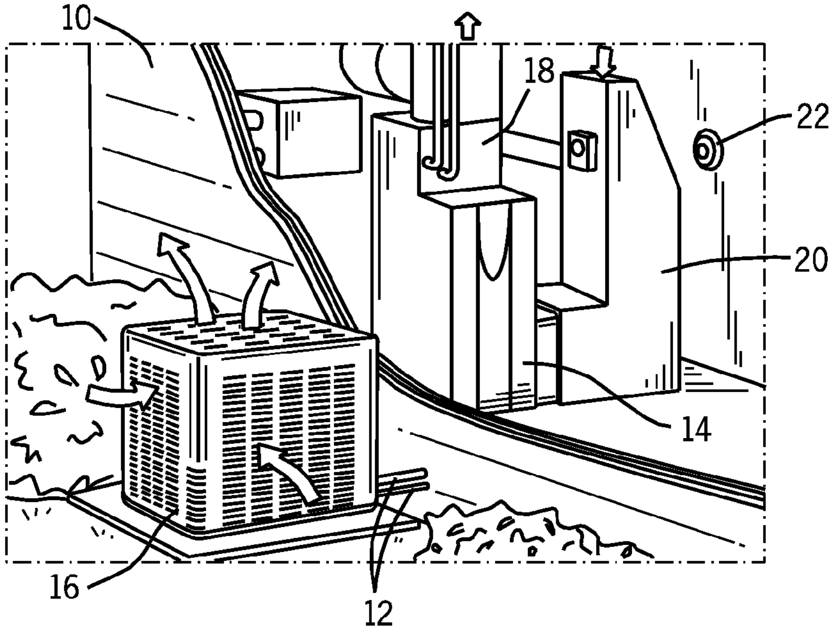


FIG. 1



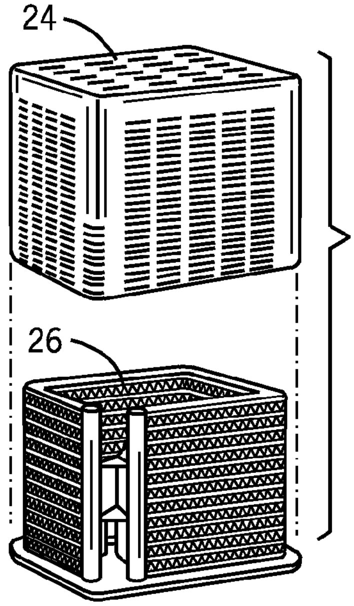


FIG. 2

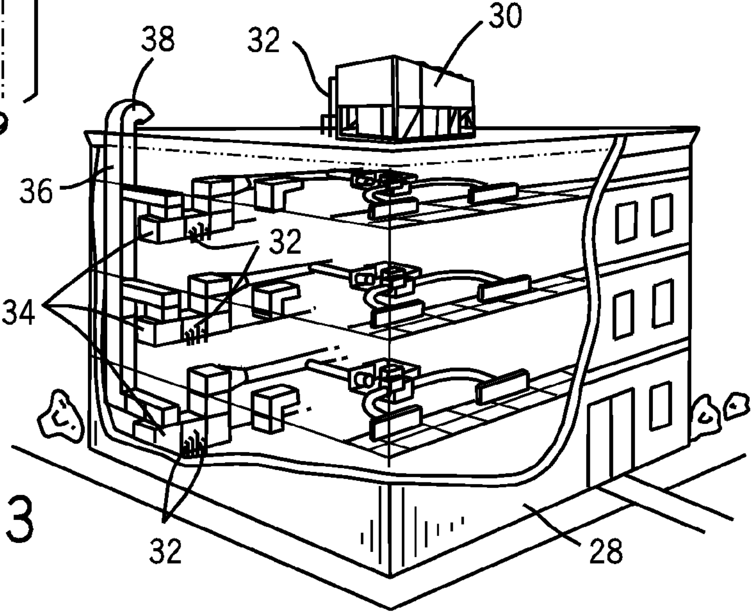


FIG. 3

FIG. 4

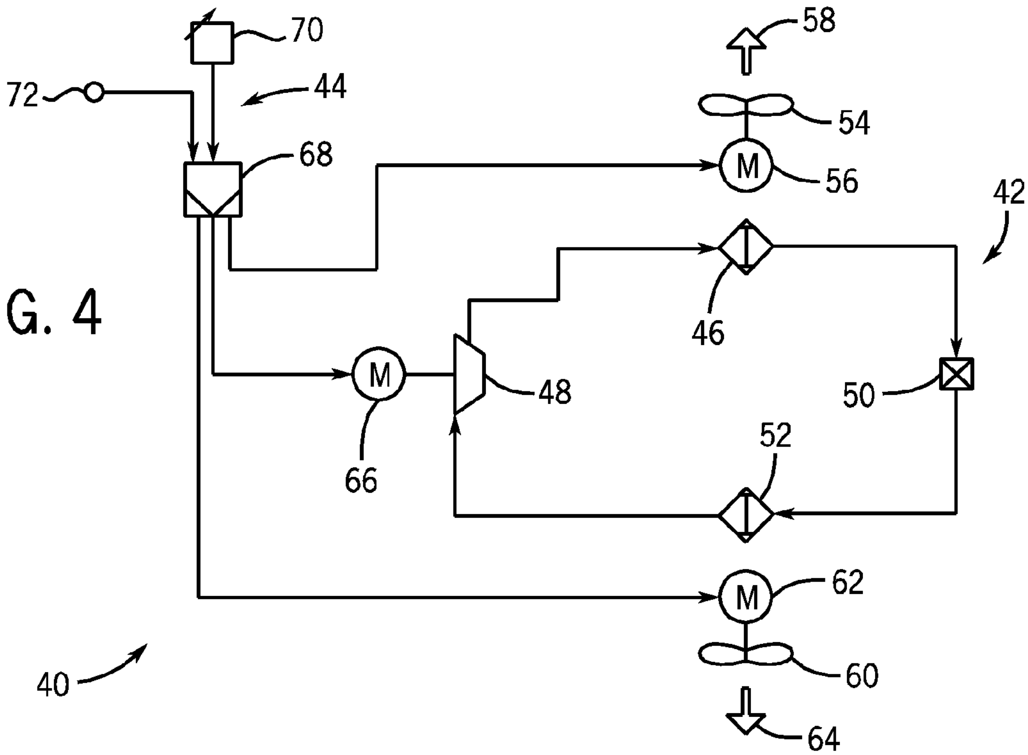

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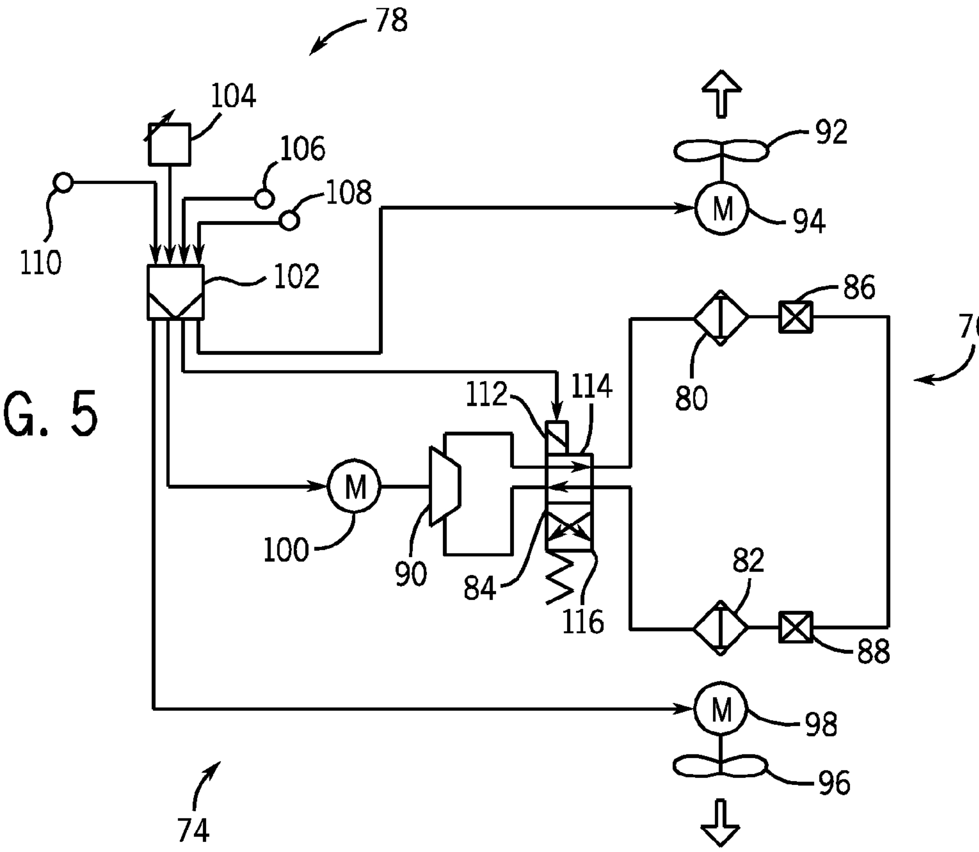
FIG. 5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106
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110
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92
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86
76
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90
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74

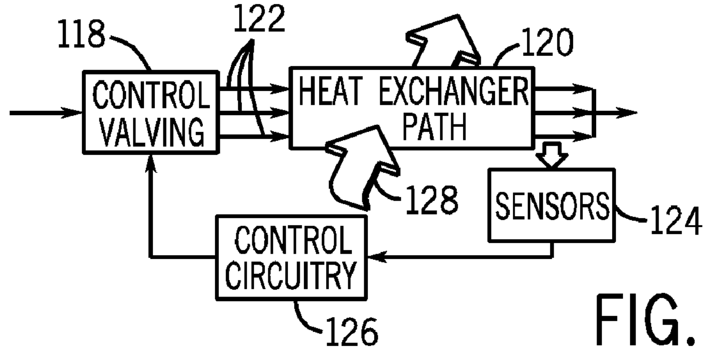


FIG. 6

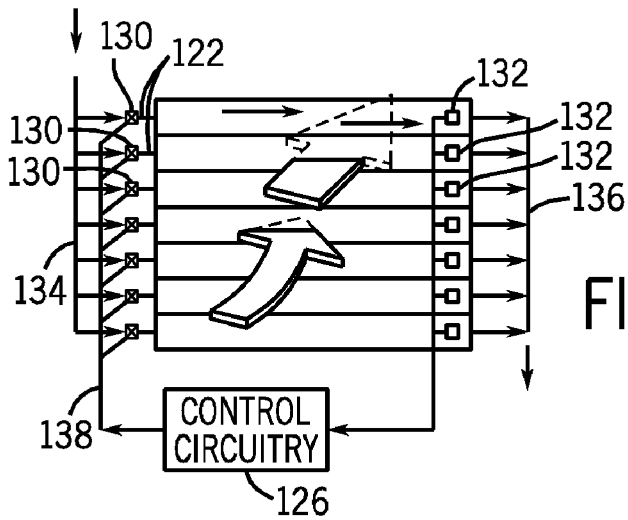


FIG. 7

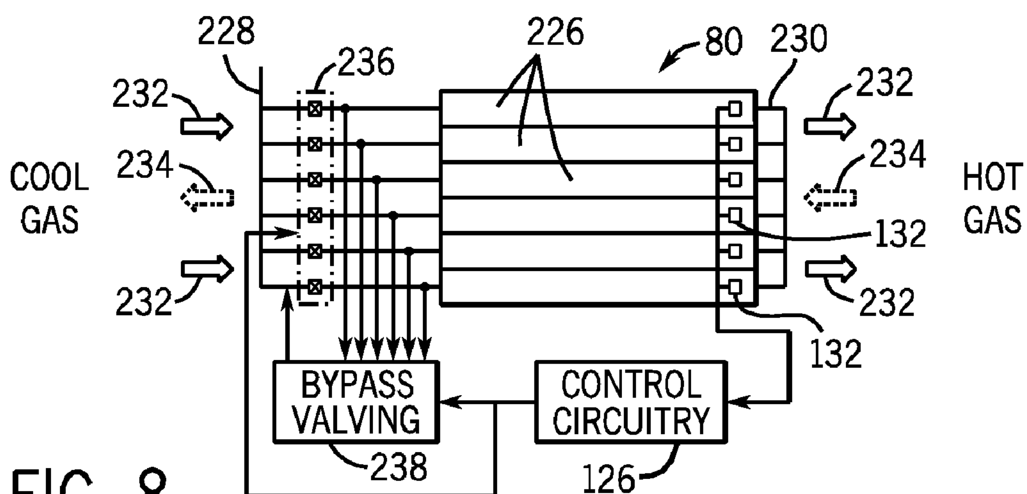
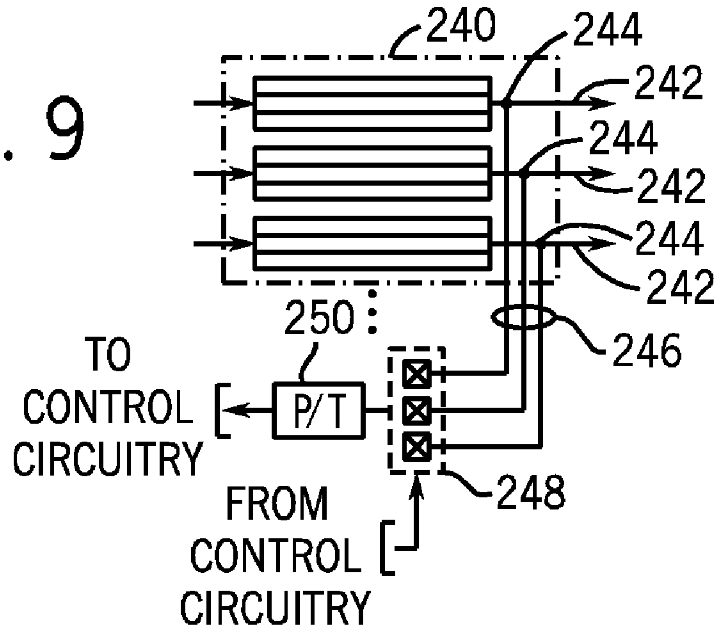


FIG. 8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TO
CONTROL
CIRCUITRY
P/T
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FROM
CONTROL
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FIG. 9

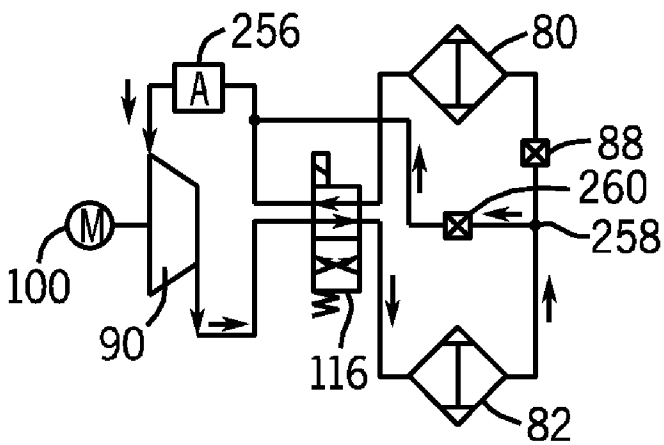
256
A
80
88
260
258
M
100
90
116
82

FIG. 10

HVAC&R SYSTEM VALVING

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority from and the benefit of U.S. Provisional Application Ser. No. 61/013,364, entitled "HVAC&R SYSTEM EMPLOYING UNIQUE VALVING," filed Dec. 13, 2007; and PCT Application Serial No. PCT/US08/86665, entitled "HVAC&R SYSTEM VALVING," filed Dec. 12, 2008 which are hereby incorporated by reference.

BACKGROUND

[0002] The present invention relates generally to heating, ventilating, air conditioning and refrigeration systems, and more particularly to techniques for controlling fluid flow in such systems.

[0003] A wide range of applications exist for heating, ventilating, air conditioning and refrigeration (HVAC&R) systems. For example, residential, light commercial, commercial and industrial systems are used to control temperatures and air quality in residences and buildings. Such systems often are dedicated to either heating or cooling, although systems are common that perform both of these functions. Very generally, these systems operate by implementing a thermal cycle in which fluids are heated and cooled to provide the desired temperature in a controlled space, typically the inside of a residence or building. Similar systems are used for vehicle heating and cooling, and as well as for general refrigeration.

[0004] Controlled fluids within such systems are typically confined with enclosed circuits and include various refrigerants. Refrigerants are specifically formulated to undergo phase changes within the normal operating temperatures and pressures of the systems so that considerable quantities of heat can be exchanged by virtue of the latent heat of vaporization of the circulated refrigerant. In most such systems, for example, the refrigerant is evaporated in one heat exchanger to draw heat from air circulating through the heat exchanger for cooling purposes. Conversely, the refrigerant is then condensed in a different heat exchanger to release heat from the refrigerant and thereby heat an air stream. Depending upon whether the evaporating heat exchanger and condensing heat exchanger are inside of the controlled space or outside of the controlled space, the system will function to heat or cool the air within the space.

[0005] A number of locations in such systems are subject to careful control of the flow of circulating refrigerant. For example, a distributor is commonly provided upstream of the evaporating heat exchanger to form separate paths for refrigerant flowing through that device. Other locations of fluid control include reversing valves used to change the direction of flow in heat pumps, valves used to control the flow direction of refrigerant for defrosting external evaporating coils during winter months (typically also the reversing valve of a heat pump) and so forth.

[0006] While such fluid control devices are useful and offer highly efficient and functional systems, further improvement is desired. For example, it would be desirable to allow for a higher degree of control of individual circuits, and control of existing circuits in a way that would use less energy or provide a more cost-effective solution.

SUMMARY

[0007] The present invention relates to a heat exchanger system with a plurality of valves for simultaneously and independently metering fluid flow through heat exchanger tubes in a first direction. The system includes bypass valving coupled fluidly around the plurality of valves and control circuitry coupled to the bypass valving. The control circuitry is configured to selectively open the bypass valving when the fluid is flowing through the heat exchanger in a second direction opposite to the first direction to direct the fluid around the plurality of valves.

[0008] The present invention also relates to a heat exchanger system with a plurality of valves each fluidly coupled to a respective heat exchanger tube or tube group and each configured to simultaneously and independently meter fluid flow through the respective heat exchanger tube or tube group. The system includes bypass valving coupled fluidly around the plurality of valves and configured to selectively bypass the plurality of valves in response to a signal from control circuitry.

[0009] The present invention further relates to a method for promoting heat exchange to or from a fluid. The method includes circulating a refrigerant through a plurality of valves to regulate flow through heat exchanger tubes in a first direction when the heat exchanger is functioning as an evaporator, circulating the refrigerant through the plurality of valves to regulate flow through the heat exchanger tubes in a second direction to defrost the heat exchanger tubes, and bypassing the plurality of vavles by circulating the refrigerant through a bypass valving coupled fluidly around the plurality of valves to flow refrigerant through the heat exchanger tubes in a second direction opposite to the first direction when the heat exchanger is functioning as a condenser.

[0010] The present invention further relates to a heat exchanger system with a plurality of flow paths for circulating a fluid through a heat exchanger, each of the plurality of flow paths having a first valve for metering fluid flow through the flow path. The system also includes a valve bank fluidly coupled to each of the plurality of flow paths and configured to selectively direct the fluid from each of the plurality of the flow paths to a sensor.

[0011] The present invention further relates to a heat pump system with a compressor configured to compress a refrigerant, a heat exchanger configured to evaporate the refrigerant in a heat pump mode of operation and to condense the refrigerant in an air conditioning mode of operation, an accumulator configured to store the refrigerant in the heat pump mode of operation, and bypass valving coupled fluidly around the heat exchanger and configured to tap vapor phase refrigerant upstream of the heat exchanger and to circulate the tapped vapor phase refrigerant to the accumulator in the heat pump mode of operation.

DRAWINGS

[0012] FIG. **1** is an illustration of an exemplary residential air conditioning or heat pump system of the type that might employ valving arrangements.

[0013] 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 components of the system.

[0014] 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 valving arrangements.

[0015] FIG. **4** is a diagrammatical overview of an exemplary air conditioning system that may employ valving arrangements for flow control.

[0016] FIG. **5** is a diagrammatical overview of an exemplary heat pump system that also may employ valving arrangements for flow control.

[0017] FIG. **6** is a diagrammatical representation of an exemplary individualized, closed-loop control scheme for regulating the flow of refrigerant through parallel heat exchange paths.

[0018] FIG. **7** is a somewhat more detailed view of an arrangement of the type shown in FIG. **6**.

[0019] FIG. **8** is a diagrammatical illustration of an arrangement for individually controlling parallel fluid flow paths in a defrost cycle of an evaporator.

[0020] FIG. **9** is a diagrammatical representation of a technique for sampling pressures via individually controlled fluid flow lines.

[0021] FIG. **10** is a diagrammatical representation of valving used to circulate refrigerant to an accumulator, such as in a heat pump system.

DETAILED DESCRIPTION

[0022] FIGS. **1** to **3** depict exemplary applications for circuiting configurations employing unique valving. The systems may include heat exchangers fluidly coupled to valving and/or distributors that provide individualized flow control through heat exchanger tubes or groups of tubes. In certain embodiments, the valving may include a plurality of valves, each coupled to flow paths through one or more heat exchangers. Such systems, 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.

[0023] FIGS. **1** through **3** depict exemplary applications for heat exchangers. Such systems, in general, may be applied in a range of settings, both within the HVAC&R field and outside of that field. In presently contemplated applications, however, heat exchanges 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 heat exchanges may be used in industrial applications, where appropriate, for basic refrigeration and heating of various fluids. FIG. **1** illustrates a residential heating and cooling system. In general, a residence **10**, will include refrigerant conduits **12** that operatively couple an indoor unit **14** to an outdoor unit **16**. Indoor unit **14** may be positioned in a utility room, an attic, a basement, or other location. Outdoor unit **16** is typically situated adjacent to a side of residence **10** and is covered by a shroud to protect the system components and to prevent leaves and other contaminants from entering the unit. Refrigerant conduits **12** transfer refrigerant between indoor unit **14** and outdoor unit **16**, typically transferring primarily liquid refrigerant in one direction and primarily vaporized refrigerant in an opposite direction.

[0024] When the system shown in FIG. **1** is operating as an air conditioner, a coil in outdoor unit **16** serves as a condenser for recondensing vaporized refrigerant flowing from indoor unit **14** to outdoor unit **16** via one of the refrigerant conduits **12**. In these applications, a coil of the indoor unit, designated by the reference numeral **18**, serves as an evaporator coil. Evaporator coil **18** receives liquid refrigerant (which may be expanded by an expansion device, not shown) and evaporates the refrigerant before returning it to outdoor unit **16**.

[0025] Outdoor unit **16** draws in environmental air through its sides as indicated by the arrows directed to the sides of the unit, 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 when it entered the sides. Air is blown over indoor coil **18** and is then circulated through residence **10** by means of ductwork **20**, as indicated by the arrows entering and exiting ductwork **20**. The overall system operates to maintain a desired temperature as set by a thermostat **22**. 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.

[0026] When the unit in FIG. **1** operates as a heat pump, the roles of the coils are simply reversed. That is, the coil of outdoor unit **16** will serve as an evaporator to evaporate refrigerant and thereby cool air entering outdoor unit **16** as the air passes over the outdoor unit coil. Indoor coil **18** will receive a stream of air blown over it and will heat the air by condensing a refrigerant.

[0027] FIG. **2** illustrates a partially exploded view of one of the units shown in FIG. **1**, in this case outdoor unit **16**. In general, the unit may be thought of as including an upper assembly **24** 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. An outdoor coil **26** is housed within this shroud and is generally deposed to surround or at least partially surround other system components, such as a compressor, an expansion device, a control circuit.

[0028] FIG. **3** illustrates another exemplary application, in this case an HVAC&R system for building environmental management. A building **28** is cooled by a system that includes a chiller **30**, which is typically disposed on or near the building, or in an equipment room or basement. Chiller **30** is an air-cooled device that implements a refrigeration cycle to cool water. The water is circulated to building **28** through water conduits **32**. The water conduits are routed to air handlers **34** at individual floors or sections of the building. The air handlers are also coupled to ductwork **36** that is adapted to blow air from an outside intake **38**.

[0029] Chiller **30**, 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 ductwork.

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 ductwork to maintain desired temperatures at various locations in the structure.

[0030] FIG. **4** illustrates an air conditioning system **40**, which may employ multichannel tube heat exchangers. Refrigerant flows through system **40** within closed refrigeration loop **42**. 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-744) or ammonia (R-717). Air conditioning system **40** includes control devices **44** that enable the system to cool an environment to a prescribed temperature.

[0031] System **40** cools an environment by cycling refrigerant within closed refrigeration loop **42** through a condenser **46**, a compressor **48**, an expansion device **50**, and an evaporator **52**. The refrigerant enters condenser **46** as a high pressure and temperature vapor and flows through the multichannel tubes of the condenser. A fan **54**, which is driven by a motor **56**, draws air across the multichannel tubes. The fan may push or pull air across the tubes. As the air flows across the tubes, heat transfers from the refrigerant vapor to the air, producing heated air **58** and causing the refrigerant vapor to condense into a liquid. The liquid refrigerant then flows into an expansion device **50** where the refrigerant expands to become a low pressure and temperature liquid. Typically, expansion device **50** will be a thermal expansion valve (TXV); however, according to other exemplary embodiments, the expansion device may be an orifice or a capillary tube. After the refrigerant exits the expansion device, some vapor refrigerant may be present in addition to the liquid refrigerant.

[0032] From expansion device **50**, the refrigerant enters evaporator **52** and flows through the evaporator multichannel tubes. A fan **60**, which is driven by a motor **62**, draws air across the multichannel tubes. As the air flows across the tubes, heat transfers from the air to the refrigerant liquid, producing cooled air **64** and causing the refrigerant liquid to boil into a vapor. According to certain embodiments, the fan may be replaced by a pump that draws fluid through the evaporator. The evaporator may be a shell-and-tube heat exchanger, brazed plate heat exchanger, or other suitable heat exchanger.

[0033] The refrigerant then flows to compressor **48** as a low pressure and temperature vapor. Compressor **48** 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, or turbine compressor. Compressor **48** is driven by a motor **66** that receives power from a variable speed drive (VSD) or a direct AC or DC power source. According to an exemplary embodiment, motor **66** receives fixed line voltage and frequency from an AC power source although in certain 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 compressor **48** as a high temperature and pressure vapor that is ready to enter the condenser and begin the refrigeration cycle again.

[0034] The control devices **44**, which include control circuitry **68**, an input device **70**, and a temperature sensor **72**, govern the operation of the refrigeration cycle. Control circuitry **68** is coupled to the motors **56**, **62**, and **66** that drive condenser fan **54**, evaporator fan **60**, and compressor **48**, respectively. Control circuitry **68** uses information received from input device **70** and sensor **72** to determine when to operate the motors **56**, **62**, and **66** that drive the air conditioning system. In certain applications, the input device may be a conventional thermostat. However, the input device is not limited to thermostats, and more generally, any source of a fixed or changing set point may be employed. These may include local or remote command devices, computer systems and processors, and mechanical, electrical and electromechanical devices that manually or automatically set a temperature-related signal that the system receives. For example, in a residential air conditioning system, the input device may be a programmable 24-volt thermostat that provides a temperature set point to the control circuitry. Sensor **72** determines the ambient air temperature and provides the temperature to control circuitry **68**. Control circuitry **68** then compares the temperature received from the sensor to the temperature set point received from the input device. If the temperature is higher than the set point, control circuitry **68** may turn on motors **56**, **62**, and **66** to run air conditioning system **40**. The control circuitry may execute hardware or software control algorithms to regulate the air conditioning system. According to exemplary embodiments, the control circuitry 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.

[0035] FIG. **5** illustrates a heat pump system **74** that may employ multichannel tube heat exchangers. Because the heat pump may be used for both heating and cooling, refrigerant flows through a reversible refrigeration/heating loop **76**. The refrigerant may be any fluid that absorbs and extracts heat. The heating and cooling operations are regulated by control devices **78**.

[0036] Heat pump system **74** includes an outside coil **80** and an inside coil **82** that both operate as heat exchangers. The coils may function either as an evaporator or a condenser depending on the heat pump operation mode. For example, when heat pump system **74** is operating in cooling (or "AC") mode, outside coil **80** functions as a condenser, releasing heat to the outside air, while inside coil **82** functions as an evaporator, absorbing heat from the inside air. When heat pump system **74** is operating in heating mode, outside coil **80** functions as an evaporator, absorbing heat from the outside air, while inside coil **82** functions as a condenser, releasing heat to the inside air. A reversing valve **84** is positioned on reversible loop **76** between the coils to control the direction of refrigerant flow and thereby to switch the heat pump between heating mode and cooling mode.

[0037] Heat pump system **74** also includes two metering devices **86** and **88** for decreasing the pressure and temperature of the refrigerant before it enters the evaporator. The metering devices also regulate the refrigerant flow entering the evaporator so that the amount of refrigerant entering the evaporator equals, or approximately equals, the amount of refrigerant exiting the evaporator. The metering device used depends on the heat pump operation mode. For example, when heat pump system **74** is operating in cooling mode, refrigerant bypasses metering device **86** and flows through metering device **88** before entering inside coil **82**, which acts as an evaporator. In another example, when heat pump system **74** is operating in heating mode, refrigerant bypasses metering device **88** and flows through metering device **86** before entering outside coil **80**, which acts as an evaporator. According to other exemplary embodiments, a single metering device may be used for both heating mode and cooling mode. The metering devices typically are thermal expansion valves (TXV), but also may be orifices or capillary tubes.

[0038] The refrigerant enters the evaporator, which is outside coil **80** in heating mode and inside coil **82** in cooling mode, as a low temperature and pressure liquid. Some vapor refrigerant also may be present as a result of the expansion process that occurs in metering device **86** or **88**. 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 flowing across 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.

[0039] After exiting the evaporator, the refrigerant passes through reversing valve **84** and into a compressor **90**. Compressor **90** decreases the volume of the refrigerant vapor, thereby, increasing the temperature and pressure of the vapor. The compressor may be any suitable compressor such as a screw compressor, reciprocating compressor, rotary compressor, swing link compressor, scroll compressor, or turbine compressor.

[0040] From compressor **90**, 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 **80** (acting as a condenser). A fan **92**, which is powered by a motor **94**, draws air across the multichannel tubes containing refrigerant vapor. According to certain exemplary embodiments, the fan may be replaced by a pump that 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 **82** (acting as a condenser). A fan **96**, which is powered by a motor **98**, draws air across 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.

[0041] After exiting the condenser, the refrigerant flows through the metering device (**86** in heating mode and **88** in cooling mode) and returns to the evaporator (outside coil **80** in heating mode and inside coil **82** in cooling mode) where the process begins again.

[0042] In both heating and cooling modes, a motor **100** drives compressor **90** and circulates refrigerant through reversible refrigeration/heating loop **76**. The motor may receive power either directly from an AC or DC power source or from a variable speed drive (VSD). 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.

[0043] The operation of motor **100** is controlled by control circuitry **102**. Control circuitry **102** receives information from an input device **104** and sensors **106**, **108**, and **110** and uses the information to control the operation of heat pump system **74** in both cooling mode and heating mode. For example, in cooling mode, input device **104** provides a temperature set point to control circuitry **102**. Sensor **110** measures the ambient indoor air temperature and provides it to control circuitry **102**. Control circuitry **102** then compares the air temperature to the temperature set point and engages compressor motor **100** and fan motors **94** and **98** to run the cooling system if the air temperature is above the temperature set point. In heating mode, control circuitry **102** compares the air temperature from sensor **110** to the temperature set point from input device **104** and engages motors **94**, **98**, and **100** to run the heating system if the air temperature is below the temperature set point.

[0044] Control circuitry **102** also uses information received from input device **104** to switch heat pump system **74** between heating mode and cooling mode. For example, if input device **104** is set to cooling mode, control circuitry **102** will send a signal to a solenoid **112** to place reversing valve **84** in an air conditioning position **114**. Consequently, the refrigerant will flow through reversible loop **76** as follows: the refrigerant exits compressor **90**, is condensed in outside coil **80**, is expanded by metering device **88**, and is evaporated by inside coil **82**. If the input device is set to heating mode, control circuitry **102** will send a signal to solenoid **112** to place reversing valve **84** in a heat pump position **116**. Consequently, the refrigerant will flow through the reversible loop **76** as follows: the refrigerant exits compressor **90**, is condensed in inside coil **82**, is expanded by metering device **86**, and is evaporated by outside coil **80**.

[0045] The control circuitry may execute hardware or software control algorithms to regulate heat pump system **74**. According to exemplary embodiments, the control circuitry may include an analog to digital (A/D) converter, a microprocessor, a non-volatile memory, and an interface board.

[0046] The control circuitry also may initiate a defrost cycle when the system is operating in heating mode. When the outdoor temperature approaches freezing, moisture in the outside air that is directed over outside coil **80** may condense and freeze on the coil. Sensor **106** measures the outside air temperature, and sensor **108** measures the temperature of outside coil **80**. These sensors provide the temperature information to the control circuitry which determines when to initiate a defrost cycle. For example, if either sensor **106** or **108** provides a temperature below freezing to the control circuitry, system **74** may be placed in defrost mode. In defrost mode, solenoid **112** is actuated to place reversing valve **84** in air conditioning position **114**, and motor **94** is shut off to discontinue air flow over the multichannel tubes. System **74** then operates in cooling mode until the increased temperature and pressure refrigerant flowing through outside coil **80** defrosts the coil. Once sensor **108** detects that coil **80** is defrosted, control circuitry **102** returns the reversing valve **84** to heat pump position **116**. 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.

[0047] It should be noted that while reference is made in the present discussion to "multichannel" tubes used in HVAC&R systems, other types and configurations of tubes may be used in conjunction with certain embodiments described herein, particularly those relating to valving and the control of flow to enhance system performance.

[0048] Flow through either or both of the heat exchangers in the systems described above may be performed in a closed-loop and individualized manner as illustrated diagrammatically in FIG. **6**. In the embodiment illustrated, control valving **118** provides flow to a multiple-path heat exchanger **120** that may serve as an evaporator or as a condenser. The heat exchanger receives individually controlled flow as indicated by reference numeral **122** in FIG. **6** that is directed through individual flow paths within the heat exchanger. In practice, the flow paths may include a group of tubes, or as few as a single tube. In certain embodiments, each tube group may include approximately 1 to 90 tubes, or more specifically, each tube group may include approximately 1 to 10 tubes. However, in other embodiments, any number of tubes may be included within a group, and the number of tubes within each tube group may vary. Moreover, the tubes may be of various types, such as multichannel tubes, conventional copper or aluminum tubing, and so forth.

[0049] As discussed in greater detail below, the control valving **118** may include small individually controlled valves which regulate the flow through each of the flow paths of the heat exchanger. The control valving **118** may be housed within a common distributor, provided as separate components, or housed within other structures. In certain embodiments, the small individually controlled valves may include pneumatic or hydraulic silicon valves with orifices ranging from approximately 0.01 mm to 1.75 mm. However, in other embodiments, the valves may be constructed of other suitable materials and may have orifices of any size. Further, the valves may allow for proportional control, on/off control, and the like. The system also includes one or more sensors as indicated by reference numeral **124**, which may include sensors for both temperature and pressure. In certain embodiments, individual sensors may be provided for each group of tubes, or even for individual tubes of the heat exchanger. In certain other embodiments a single temperature and pressure sensor may be provided. The number of sensors may be varied in specific embodiments based upon the degree of individualized controlled desired for the flow of refrigerant.

[0050] The sensors are coupled to control circuitry **126** for directing signals representative of the sensed parameters to the control circuitry. Such control circuitry may include any suitable processors, memory, computers, field programmable gate arrays, and so forth. More generally, the control circuitry may be independent of or the same as the control circuitry used for regulating the overall operation of the system as described above. In certain embodiments, specific and separate control circuitry may be provided (e.g., local to the associated heat exchanger) that can nevertheless be interfaced with the overall control circuitry, such that control circuitry **126** receives the sensed parameter signals and regulates operation of the control valving **118** in a closed-loop manner. In operation, then, the control valving **118** is commanded to open or close flow paths (or to meter flow) to circulate refrigerant through the heat exchanger, with air, as indicated by arrow **128** being drawn or forced through the heat exchanger to heat or cool the air as described above.

[0051] FIG. **7** illustrates a somewhat more detailed view of one embodiment of the individualized control arrangement. In the embodiment shown in FIG. **7**, individual control valves **130** are provided in line with the individually controlled flow paths **122**. Each valve is coupled to the control circuitry **126**. In particular, the individual control valves **130** are provided upstream of the heat exchanger to regulate the flow of fluid through the heat exchanger. Individual sensors **132** may also be provided along each of the flow paths for closed-loop control of the respective valve. In certain embodiments, the individual sensors may sense parameters, such as temperature or pressure, that are internal to or external to the flow paths. For example, the sensors may sense a temperature or pressure of a fluid flowing within the flow paths, or the sensors may sense an external temperature of the flow paths, such as the external temperature of a heat exchanger tube. In operation, fluid is received in a first manifold **134** and circulates through the valves **130** and parallel flow paths of the heat exchanger to an opposite manifold **136**. As will be appreciated by those skilled in the art, the manifolds and flow paths may be configured to provide multiple passes through the heat exchanger (e.g., from manifold **134** to manifold **136** and returning back to manifold **134**). The control circuitry **126**, then, receives signals from the sensors and causes the individual valves **130** to open and close to control flow through the heat exchanger based upon the sensed signals. The control circuitry will typically provide power and control signals to the valving via communication links **138**. In certain embodiments, the communication links **138** may include wired, wireless, networked and/or non-networked communication links.

[0052] As noted above, the individualized control of fluid flow through the heat exchanger flow paths can be performed on an individual tube basis, or on a group of tubes. In general, a balance will be struck between the quality of control desired, with generally superior or optimized control being provided with individual regulation of flow through individual flow paths each instrumented separately, and the cost of such control. Where component costs can be sufficiently reduced, for example, optimal control may be provided by individual valving on each individual flow tube which may also be equipped with its own sensors for closed-loop regulation. Acceptable compromises might include, however, grouping tubes together for full control and for sensing purposes. Moreover, any suitable devices may be utilized for regulating the control of fluid flow, with a presently contemplated devices including small MEMS valves of the type commercially available from Microstaq Inc. of Austin, Tex. Such valves require very little energy for control purposes, and can regulate or meter flow based upon a simple control input from the control circuitry.

[0053] FIG. **8** illustrates a refrigerant control configuration particularly designed for a defrost cycle of an outdoor heat exchanger of a heat pump. As will be appreciated by those skilled in the art, in heat pump mode, the outside heat exchanger of a heat pump functions as an evaporator. Because heat is drawn into the refrigerant by passing air, the heat exchanger may have a tendency to cause precipitation of condensate on exterior surfaces of the heat exchanger tubes, heat exchanging fins, and so forth. Periodically, then, the heat exchanger may be placed in a defrost cycle in which the direction of flow of the refrigerant is reversed by means of a reversing valve (see the discussion above of FIG. **5**). During such defrost cycles, hot gas is circulated through the frozen heat exchanger to defrost (melt) the condensate from the exterior surfaces. Once a desired temperature is reached, then, the reversing valve may be switched back to heat pump mode and operation of the unit as a heat pump may continue.

[0054] In the arrangement of FIG. **8**, then, the heat exchanger **80** includes parallel flow paths **226** between a first manifold **228** and a second manifold **230** during heat pump mode. Flow through the heat exchanger is from manifold **228** to manifold **230** as indicated by arrows **232** in FIG. **13**. When the system detects that freezing of condensate on the surface of the heat exchanger has occurred (e.g., via appropriate temperature sensors, such as sensors **132**), the system is triggered by control circuitry **126** to shift the reversing valve to reverse flow through the heat exchanger. When flow is reversed, the defrost mode or defrost cycle flow is reversed as indicated by broken arrows **234** such that hot gas enters the heat exchanger via manifold **230** and liquid refrigerant exits the heat exchanger via manifold **228**.

[0055] To facilitate optimal defrosting, then, control valving is provided for optimizing flow through the various flow paths. In a presently contemplated embodiment, an individual control valve bank **236** includes a series of flow control valves which may be generally of the type described above with respect to FIGS. **6** and **7**. That is, the flow control valves of the valve bank **236** are individually connected to individual flow paths **226** which, again, may be individual tubes or groups of tubes of the heat exchanger. Each valve is coupled to control circuitry **126** and may be individually controlled based upon feedback from a temperature sensor **132**. As will be appreciated by those skilled in the art, such temperature sensors will typically indicate the temperature of the tube which will be heated by the hot gas flow. Because the tubes may not otherwise defrost at the same or at an optimal rate, then, the control circuitry can regulate or meter flow through each of the valves to optimize defrosting. Such optimization may, for example, promote defrosting of the tubes at a similar rate, or may favor defrosting certain tubes faster than others depending upon their relative position in the heat exchanger.

[0056] Bypass valving **238** is also provided to permit flow to bypass the valve bank **236**. In certain embodiments, bypass valving **238** may include small individually controlled valves that provide for on/off control, proportional control, and the like. However, any suitable type of valves may be employed in the bypass valving. Such bypass valving may, in practice, be built mechanically into the valve bank **236**, or separate valving may be provided. The bypass valving **238** allows for regulation of flow through the separate flow path of the heat exchanger during the defrost cycle operation as described above, but allows metering via the valve bank **236** to be avoided during normal AC mode operation of the heat pump. That is, as will be appreciated by those skilled in the art, during AC mode operation, the flow of refrigerant through the heat exchanger will be reversed as compared to direction of arrows **232** in FIG. **8**. However, no individual metering via valve bank **236** will generally be necessary. Accordingly, bypass valving **238** may be open during AC mode operation to allow the valve bank **236** to be bypassed. The bypass valving **238** will generally be closed when the system is operating in the defrost cycle. During normal operation in heat pump mode, then, the flow may be directed through bypass valving **238** which may be maintained open or through the valve bank **236** if the valve bank permits relatively free flow in that direction.

[0057] FIG. **9** illustrates a further configuration of a fluid flow application in HVAC&R system. As shown in FIG. **9**, a heat exchanger **240** may be an evaporator, a condenser, or a heat exchanger that functions both as an evaporator or a condenser, such as in a heat pump. The circuit configuration, then, is designed to allow for sharing of a common pressure sensor and/or a common temperature sensor. That is, each of a plurality of flow paths **242** through the heat exchanger is provided with a sensor tap **244**. As will be appreciated by those skilled in the art, such taps may be simple apertures formed in the tubing that defines each flow path. A fluid line extends from each of these taps as indicated by reference numeral **246** in FIG. **9**. These lines, which may be very small fluid lines brazed or otherwise sealed to each tap point, are channeled to a valve bank **248**. The valves within the valve bank **248** may be similar to the valves described above. The valves within the valve bank **248** are also coupled to control circuitry such that each valve can receive a signal from the control circuitry to open, communicating pressurized fluid to a common pressure sensor **250**. Signals from the common sensor can be then redirected to the control circuitry. Arrangements such as that shown in FIG. **9** may assist in permitting the use of one pressure sensor to monitor pressure at multiple and various locations within the refrigeration system. When used in conjunction with the flow control approached described above, then, a further benefit of the configuration of FIG. **9** is the ability individually to control flow through parallel paths of the heat exchanger while avoiding the cost and complexity of individual pressure sensors. In other embodiments, the common sensor may include a temperature sensor instead of, or in addition to, pressure sensor **250**. The common sensor may sense the temperature of the fluid and send corresponding signals to the control circuitry to regulate flow through flow paths **242**.

[0058] FIG. **10** illustrates a further embodiment of a fluid control system based upon valving of the type described above. In the implementation of FIG. **10**, a heat pump operating in heat pump mode utilizes an accumulator **256** for excess refrigerant. As will be appreciated by those skilled in the art, heat pumps operating in heat pump mode may not require the amount (volume) of refrigerant circulated through the system as in AC mode. However, because the system is closed, refrigerant may need to be stored in the system during a heat pump mode operation. In the embodiment illustrated in FIG. **10**, the accumulator **256** is positioned upstream of the compressor **90** and receives flow from the reversing valve **116** which circulates fluid through heat exchangers **80** and **82** (see the discussion above with reference to FIG. **5**). In the implementation illustrated in FIG. **10**, then, a vapor tap **258** is provided between heat exchangers **80** and **82** upstream of metering device **88**. The tap serves to communicate vapor from this location to the line coupled immediately upstream of the accumulator **256** in heat pump mode operation. A small, energy-efficient valve **260** is provided in this line to communicate vapor to a point just upstream of the accumulator **256**. In certain embodiments, the small energy-efficient valve may include a pneumatic or hydraulic silicon valve. However, in other embodiments, the valve may be constructed of other suitable materials and may allow for proportional control, on/off control, and the like.

[0059] As will be appreciated by those skilled in the art, because heat exchanger **80** in heat pump mode will function as an evaporator, there is no need for vapor present in the line at the location of vapor tap **258** to be circulated through this heat exchanger. In fact, tapping of vapor upstream of this heat exchanger will improve the efficiency and performance of the system, by avoiding the unnecessary super heating of the vapor and promoting more efficient phase change heating of the liquid entering the heat exchanger. When the system operates in AC mode, then, valve **260** may be closed and the system may operate normally, drawing stored refrigerant from the accumulator **256** for circulation. In certain embodiments, control circuitry, such as described above with respect to FIGS. **4** and **5**, may govern operation of valve **260**.

[0060] While only certain features of the invention have been illustrated and described herein, many modifications and changes will occur to those skilled in the art. It is, therefore, to be understood that the appended claims are intended to cover all such modifications and changes as fall within the true spirit of the invention.

1. A heat exchanger system comprising:
 a plurality of valves for simultaneously and independently metering fluid flow through heat exchanger tubes in a first direction;
 bypass valving coupled fluidly around the plurality of valves;
 control circuitry coupled to the bypass valving and configured to selectively open the bypass valving when the fluid is flowing through the heat exchanger in a second direction opposite to the first direction to direct the fluid around the plurality of valves.

2. The system of claim **1**, wherein the plurality of valves comprises electromechanical valves each configured to meter flow of the fluid through an individual heat exchanger tube.

3. The system of claim **1**, wherein the plurality of valves comprises electromechanical valves each configured to meter flow of the fluid through a group of heat exchanger tubes.

4. The system of claim **1**, wherein the control circuitry is configured to circulate the fluid through the bypass valving when the fluid is flowing in the second direction and the heat exchanger system is operating in an air conditioning mode.

5. The system of claim **1**, wherein the control circuitry is configured to circulate the fluid through the plurality of valves when the fluid is flowing in the second direction and the heat exchanger system is operating in a heat pump mode.

6. The system of claim **1**, wherein the control circuitry is configured to circulate the fluid through the plurality of valves when the fluid is flowing in the first direction and the heat exchanger system is operating in a heat pump mode.

7. The system of claim **1**, wherein the control circuitry is configured to circulate the fluid through the plurality of valves when the heat exchanger system is operating in a defrost mode.

8. The system of claim **1**, wherein the control circuitry is operably coupled to the plurality of valves and configured to meter the fluid flow to reduce frosting on the heat exchanger tubes.

9. A heat exchanger system comprising:
 a plurality of valves each fluidly coupled to a respective heat exchanger tube or tube group and each configured to simultaneously and independently meter fluid flow through the respective heat exchanger tube or tube group; and
 bypass valving coupled fluidly around the plurality of valves and configured to selectively bypass the plurality of valves in response to a signal from control circuitry.

10. A method for promoting heat exchange to or from a fluid, the method comprising:
 circulating a refrigerant through a plurality of valves to regulate flow through heat exchanger tubes in a first direction when the heat exchanger is functioning as an evaporator;
 circulating the refrigerant through the plurality of valves to regulate flow through the heat exchanger tubes in a second direction to defrost the heat exchanger tubes; and
 bypassing the plurality of valves by circulating the refrigerant through a bypass valving coupled fluidly around the plurality of valves to flow refrigerant through the heat exchanger tubes in a second direction opposite to the first direction when the heat exchanger is functioning as a condenser.

11. A heat exchanger system comprising:
 a plurality of flow paths for circulating a fluid through a heat exchanger, each of the plurality of flow paths having a first valve for metering fluid flow through the flow path; and
 a valve bank fluidly coupled to each of the plurality of flow paths and configured to selectively direct the fluid from each of the plurality of the flow paths to a sensor.

12. The system of claim **11**, wherein the valve bank comprises a plurality of second valves, each configured to direct the fluid from an individual flow path of the plurality of flow paths to the sensor.

13. The system of claim **11**, wherein the sensor is configured to sense a pressure or temperature of the fluid.

14. The system of claim **11**, comprising control circuitry configured to control each of the first valves based on a sensed parameter received from the sensor.

15. The system of claim **11**, wherein each of the plurality of flow paths comprise a tube or group of tubes within the heat exchanger.

16. A heat pump system comprising:
 a compressor configured to compress a refrigerant;
 a heat exchanger configured to evaporate the refrigerant in a heat pump mode of operation and to condense the refrigerant in an air conditioning mode of operation;
 an accumulator configured to store the refrigerant in the heat pump mode of operation; and
 bypass valving coupled fluidly around the heat exchanger and configured to tap vapor phase refrigerant upstream of the heat exchanger and to circulate the tapped vapor phase refrigerant to the accumulator in the heat pump mode of operation.

17. The system of claim **16**, wherein the compressor is configured to receive the refrigerant from the accumulator in the heat pump mode of operation and in the air conditioning mode of operation.

18. The system of claim **16**, comprising an additional heat exchanger configured to evaporate the refrigerant in the air conditioning mode of operation and to condense the refrigerant in the heat pump mode of operation.

19. The system of claim **18**, wherein the accumulator is configured to receive the refrigerant from the bypass valving and from the heat exchanger in the heat pump mode of operation and wherein the accumulator is configured to receive the refrigerant from the additional heat exchanger in the air conditioning mode of operation.

20. The system of claim **18**, comprising an expansion device configured to reduce pressure of the condensed refrigerant in the heat pump mode of operation and wherein the bypass valving is configured to tap the condensed refrigerant upstream of the expansion device in the heat pump mode of operation.

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