



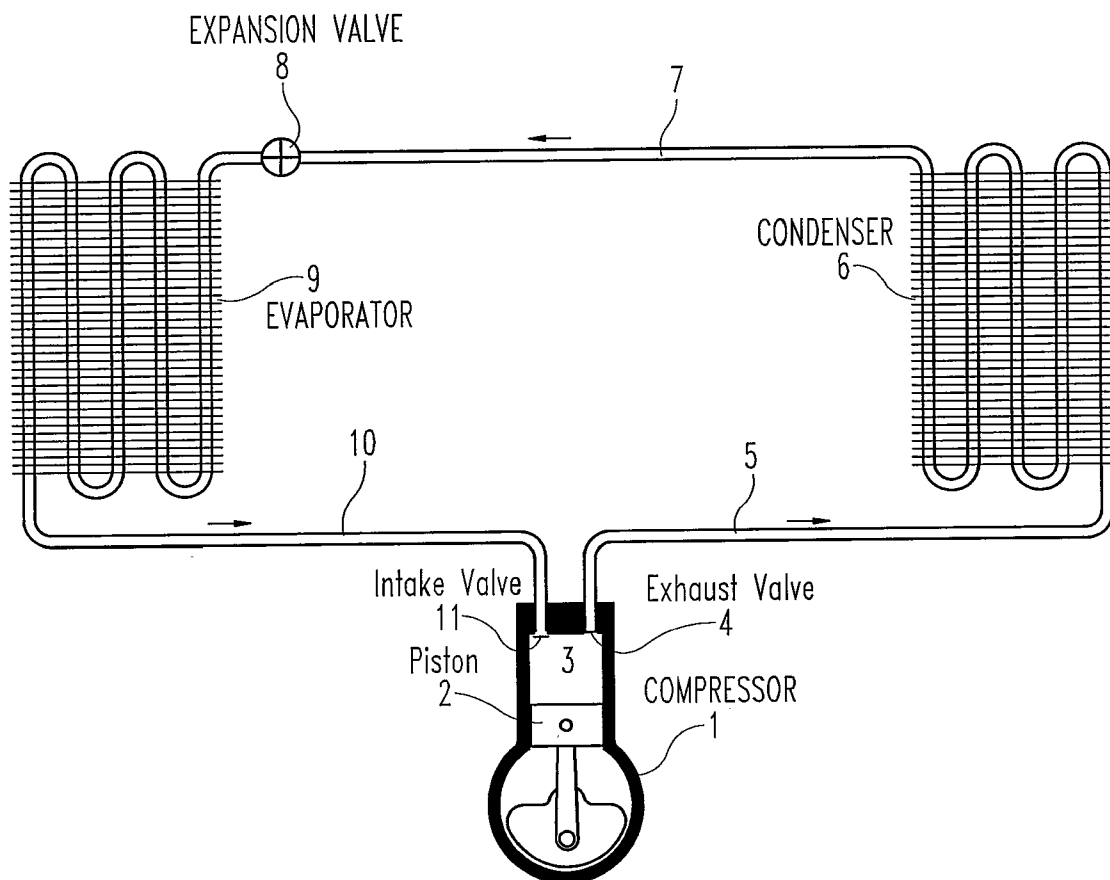
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(19) **United States**(12) **Patent Application Publication**
Albertson(10) **Pub. No.: US 2012/0067070 A1**(43) **Pub. Date: Mar. 22, 2012**(54) **LOW TEMPERATURE HEAT PUMP**(52) **U.S. Cl. 62/126; 62/228.1**(76) Inventor: **Luther D. Albertson**, Sellersburg,
IN (US)(57) **ABSTRACT**(21) Appl. No.: **13/234,521**

A reverse cycle heat pump system having an indoor heat exchange coil, an outdoor heat exchange coil, a compressor, and a compressor discharge line, and operable in an indoor heating mode and an indoor cooling mode. The outdoor coil is substantially larger than the indoor coil, and the compressor is a variable capacity compressor. The system also includes a sensor for determining one or more characteristics of the refrigerant in the compressor discharge line when the system is operating in its indoor heating mode, and a controller that adjusts the capacity of the compressor to maintain a sensor output value within a desired range of values when the system is operating in its indoor heating mode. The variable capacity compressor may be continuously variable, and may use a piston pump. The sensor determines one or more physical parameters of the refrigerant, such as pressure, temperature or density.

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F25B 49/02 (2006.01)

(BASIC REFRIGERATION CIRCUIT)

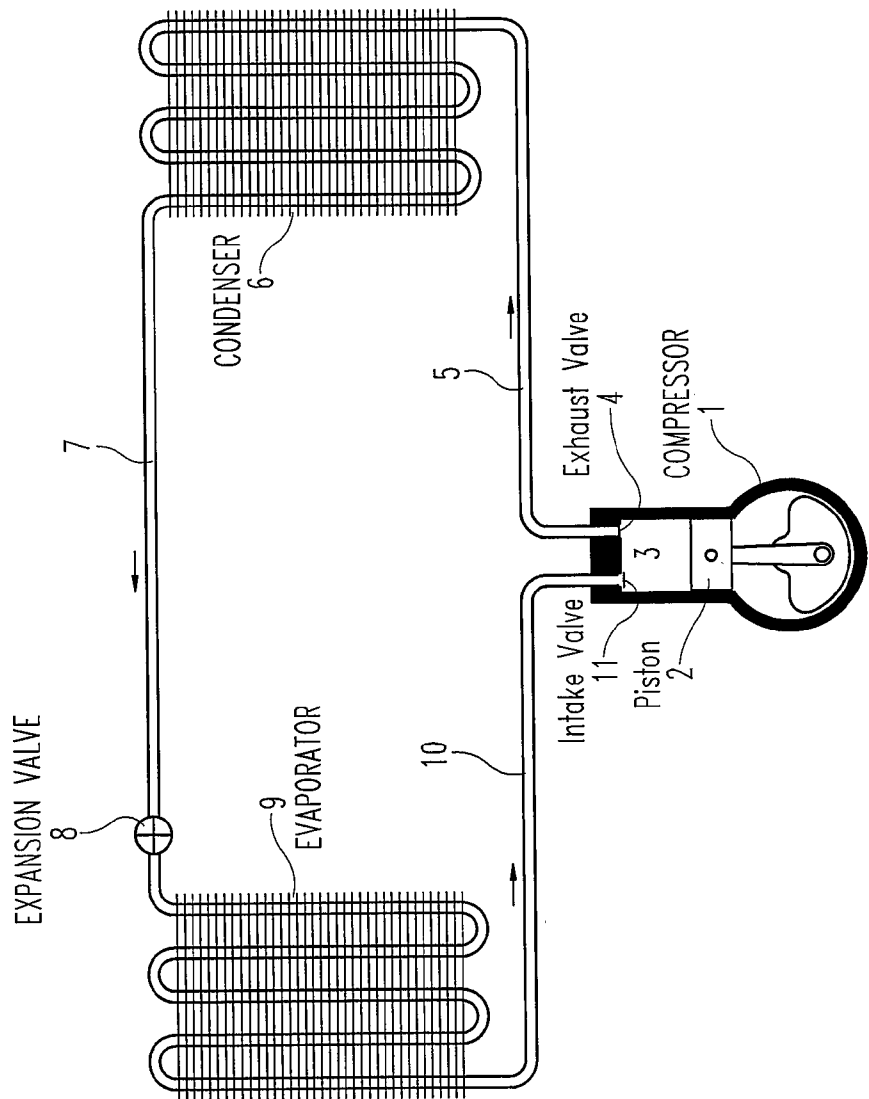


Fig. 1
(BASIC REFRIGERATION CIRCUIT)

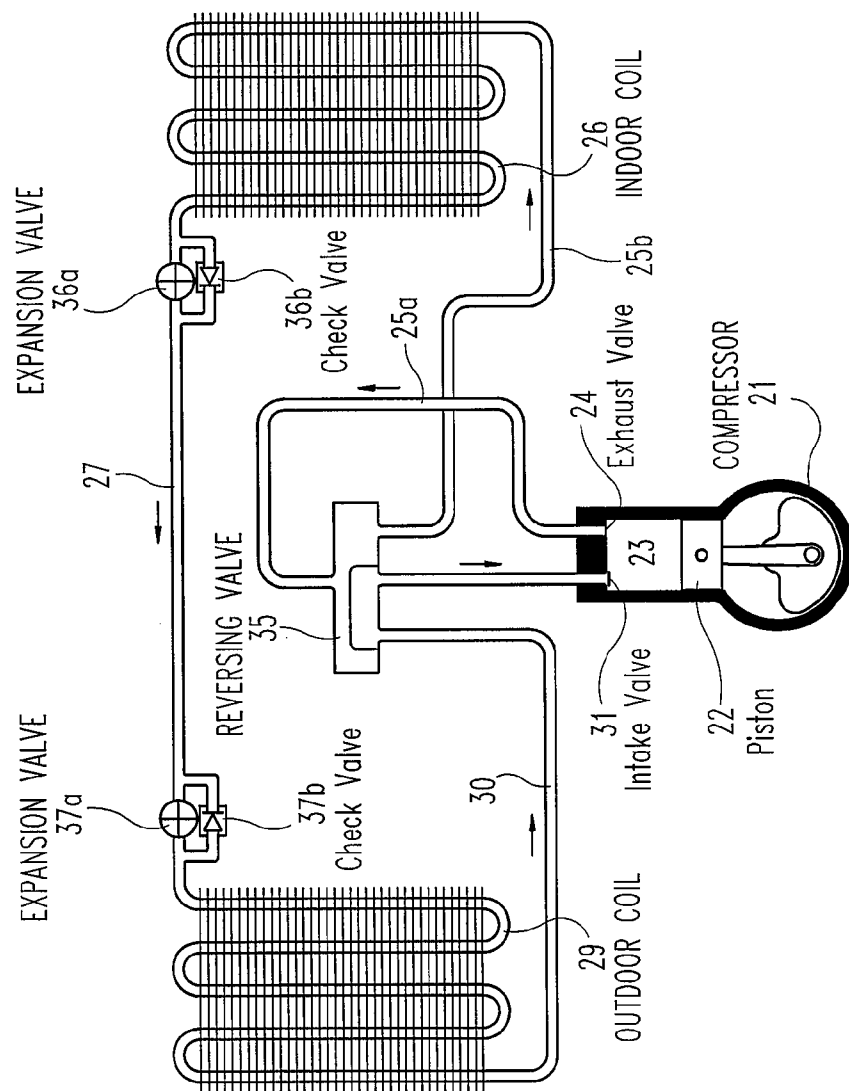


Fig. 2

(HEATING FLOW PATH SHOWN)

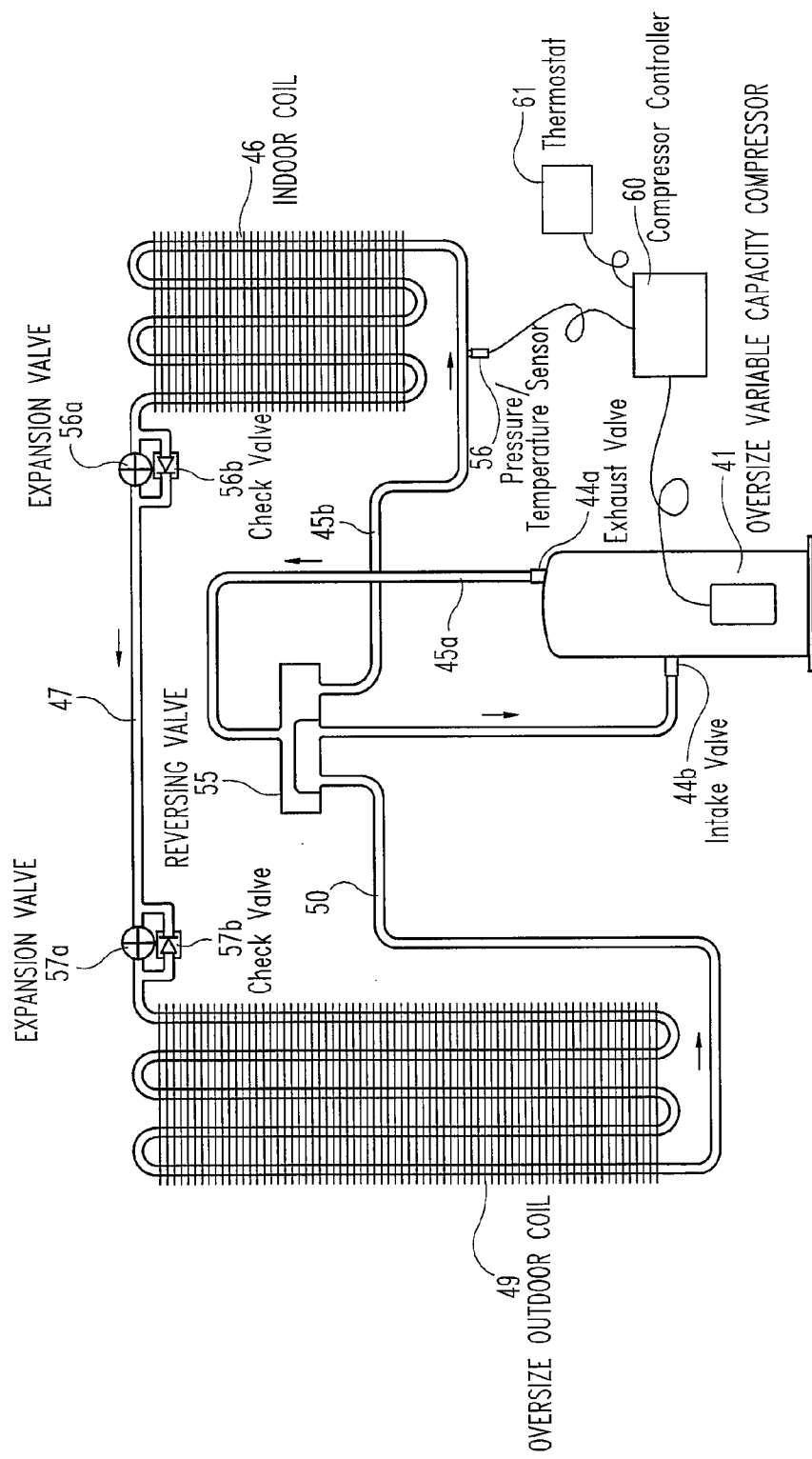


Fig. 3

(HEATING FLOW PATH SHOWN)

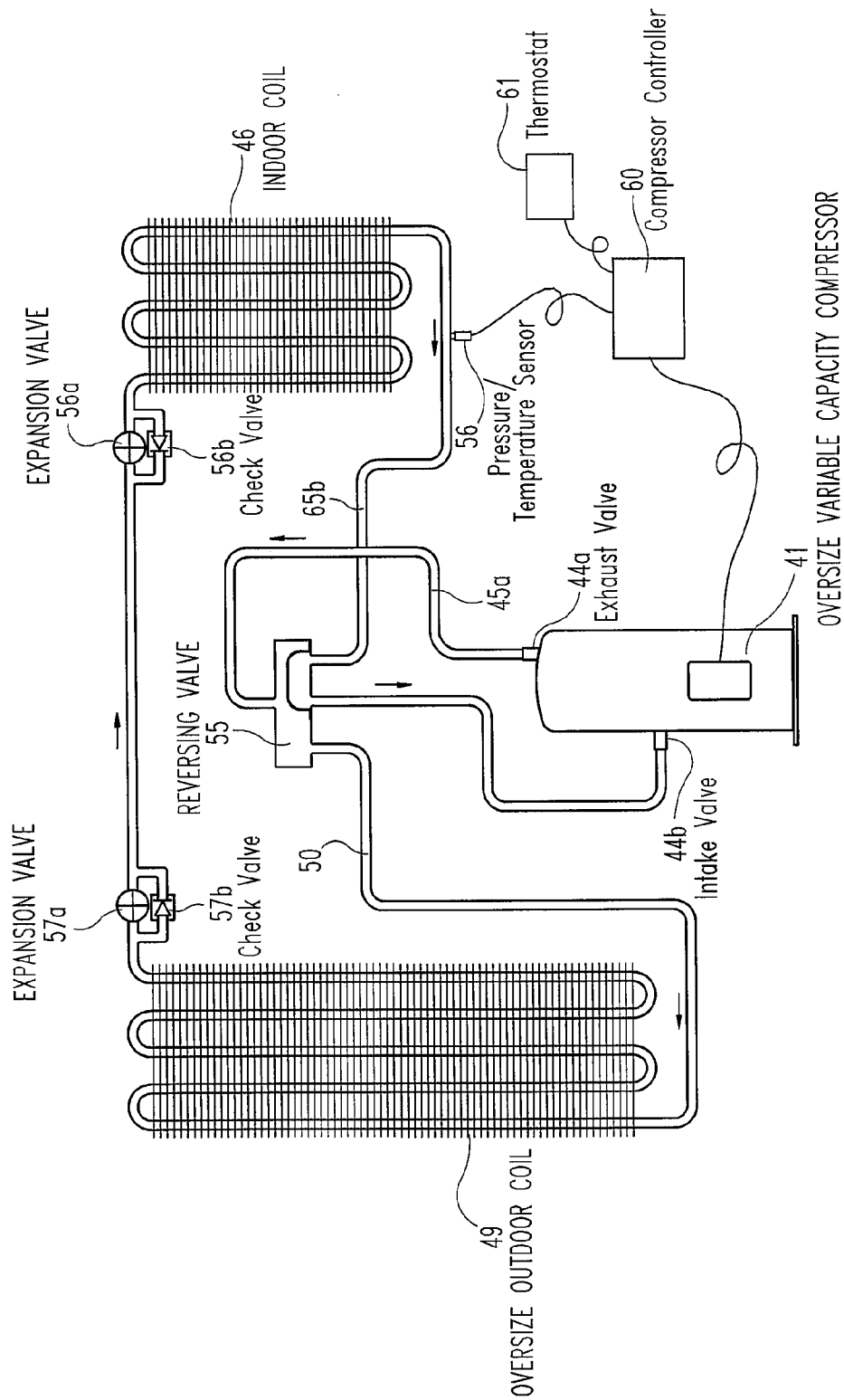


Fig. 4

(COOLING FLOW PATH SHOWN)

LOW TEMPERATURE HEAT PUMP

REFERENCE TO RELATED APPLICATIONS

[0001] The present application claims priority from U.S. Provisional Patent Application Ser. No. 61/383,874, filed Sep. 17, 2010, the entire contents of which is hereby incorporated herein by reference.

FIELD OF THE INVENTION

[0002] The present invention relates generally to heat pumps, and more particularly to heat pumps that operate effectively under low temperature conditions.

BACKGROUND

[0003] Conventional air source heat pumps (ASHP) heat and cool a living space utilizing thermal energy present in outdoor air. These devices extract then compress this low grade heat energy to higher usable energy for heating a living space. Air source heat pumps are commonly used to condition homes and commercial buildings in the southern part of the U.S. and in other parts of the world with similar temperature conditions, but they have always been relatively inefficient and expensive to use when ambient outdoor temperatures are 35° F. and below.

[0004] Prior art heat pumps rapidly decline in compressor-derived heating capacity as outdoor temperatures fall, primarily as a result of large increases in the specific volume (decrease in density) of the vapor generated in the outdoor coil (evaporator in heating mode) as ambient temperature drops. This decrease in heating capacity is opposite the heating requirement which increases as outdoor temperatures decline. Further, with prior art air-source heat pumps there comes a point, typically around 35° F. to 40° F., where heat output becomes insufficient to meet the heating requirement of the conditioned space. This point is called a heat pump's "balance point" and is the point where some form of supplementary heat typically electric resistance heaters, is needed to meet increasing heat demand. This need to frequently utilize supplemental electric heat puts air-source heat pumps at a serious economic disadvantage to the consumer as compared with other forms of heating, such as natural gas and fuel oil.

[0005] A need therefore exists for a heat pump system that heats effectively at low temperatures, while still being efficient for cooling at high temperatures. The present invention addresses that need.

SUMMARY OF THE INVENTION

[0006] In one aspect of the present invention there is provided a reverse cycle air source heat pump system having an indoor heat exchange coil, an outdoor heat exchange coil, a compressor, and a compressor discharge line, and operable in an indoor heating mode and an indoor cooling mode. Ideally, the outdoor coil is substantially larger than the indoor coil, and the compressor is a variable capacity compressor. The system further includes: 1) a sensor for determining one or more characteristics of the refrigerant in the compressor discharge line when the system is operating in its indoor heating mode, and 2) a controller that adjusts the capacity of the compressor to maintain a sensor output value within a desired range of values when the system is operating in its indoor heating mode. The variable capacity compressor is preferably a continuously variable capacity compressor, and may com-

prise a piston pump. The sensor determines one or more physical parameters of the refrigerant, such as pressure, temperature or density.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] FIG. 1 shows a basic refrigeration circuit.

[0008] FIG. 2 shows a conventional air-source heat pump circuit operating in its heating mode.

[0009] FIG. 3 shows one embodiment of the present invention operating in its heat mode.

[0010] FIG. 4 shows one embodiment of the present invention operating in its cooling mode.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0011] While the present invention may be embodied in many different forms, for the purpose of promoting an understanding of the principles of the present invention, reference will now be made to certain preferred embodiments, and specific language will be used to describe the same. It will nevertheless be understood that no limitation of the scope of the invention is thereby intended, any alterations and further modifications in the described embodiments and any further applications of the principles of the present invention as described herein are contemplated as would normally occur to one skilled in the art to which the invention relates.

[0012] As briefly described above, one aspect of the invention provides a reverse cycle air source heat pump system having an indoor heat exchange coil, an outdoor heat exchange coil, a compressor, and a compressor discharge line. The system is operable in an indoor heating mode and an indoor cooling mode. The outdoor coil is substantially larger than the indoor coil, and the compressor is a variable capacity compressor. The system further includes a sensor for determining one or more characteristics of the refrigerant in the compressor discharge line when the system is operating in its indoor heating mode, and a controller that adjusts the capacity of the compressor to maintain a sensor output value within a desired range of values when the system is operating in its indoor heating mode.

[0013] The variable capacity compressor is preferably a continuously variable capacity compressor. Also, the compressor may comprise a piston pump. Alternatively, the compressor may be a digital scroll variable capacity compressor.

[0014] The sensor may be a sensor that determines one or more physical parameters of the refrigerant, such as its pressure, temperature or density.

[0015] The compressor controller may be adapted to adjust the operating capacity of said compressor along a gradient that includes at least a dozen different operating capacities.

[0016] The refrigeration capacity of the outdoor heat exchange coil is preferably more than 25% greater than the refrigeration capacity of said indoor heat exchange coil. More preferably, the refrigeration capacity of the outdoor heat exchanger is at least 50% greater than the refrigeration capacity of said indoor heat exchanger, and most preferably the refrigeration capacity of the outdoor heat exchanger is at least 100% greater than the refrigeration capacity of said indoor heat exchanger.

[0017] The system typically includes a reversing valve for directing the flow of said refrigerant fluid through said refrigeration circuit in a first direction when operating in an indoor heating mode, and for directing the flow of said refrigerant

fluid through said refrigeration circuit in a second direction when operating in an indoor cooling mode

[0018] The system also typically includes a first check valve and a first expansion valve in the refrigerant line adjacent said outdoor heat exchanger, wherein the first check valve is effective for directing the flow of refrigerant from said indoor heat exchanger through said first expansion valve when operating in an indoor heating mode, and wherein the first check valve is effective for preventing refrigerant from flowing into said first expansion valve when operating in an indoor cooling mode. The system also typically includes a second check valve and a second expansion valve in the refrigerant line adjacent the indoor heat exchanger, with the second check valve being effective for directing the flow of refrigerant from said outdoor heat exchanger through the first expansion valve when operating in an indoor cooling mode, and with the second check valve being effective for preventing refrigerant from flowing into the second expansion valve when operating in an indoor heating mode.

[0019] In some embodiments the reverse cycle heat pump system is operably connected to a forced air system that is ducted to provide heated and/or cooled air into a residential, commercial or industrial space. Most preferably, the space is not a space used to scientifically test or evaluate various heat pump systems or components. The system is therefore used primarily, or even exclusively, to provide heated and/or cooled air to the space, and is not used for testing purposes. In this embodiment, it is preferable that the system comprise only one outdoor heat exchange coil and only one outdoor heat exchange coil, rather than a plurality of coils that may be used for testing purposes. Similarly, the system may be free of the multiplicity of gauges and monitoring equipment that would be appropriate for testing purposes but not for normal home or commercial heating/cooling purposes.

[0020] In another embodiment the reverse cycle heat pump consists essentially of:

- [0021]** a) an indoor heat exchange coil;
- [0022]** b) an outdoor heat exchange coil;
- [0023]** wherein the refrigeration capacity of said outdoor heat exchange coil is greater than the refrigeration capacity of said indoor heat exchange coil;
- [0024]** c) a compressor effective for compressing a refrigerant fluid;
- [0025]** wherein said compressor is operable at a first/lower operating capacity that is substantially equal to the refrigeration capacity of said indoor heat exchange coil; and
- [0026]** wherein said compressor is operable at a second/greater operating capacity that is substantially equal to the refrigeration capacity of said outdoor heat exchange coil;
- [0027]** d) a refrigerant fluid;
- [0028]** e) refrigerant line linking said indoor heat exchanger, outdoor heat exchanger, and compressor in a closed refrigeration circuit containing said refrigerant fluid;
- [0029]** f) a reversing valve for directing the flow of said refrigerant fluid through said refrigeration circuit in a first direction when operating in an indoor heating mode, and for directing the flow of said refrigerant fluid through said refrigeration circuit in a second direction when operating in an indoor cooling mode;
- [0030]** g) a sensor effective for sensing the temperature and/or pressure of the refrigerant fluid in the discharge

line of the compressor when the system is operating in its indoor heating mode, and effective for sending a signal indicating said temperature and/or pressure to a compressor controller;

[0031] h) a compressor controller operationally linked to said sensor and effective for controlling the pumping capacity of said compressor in response to said sensor signal;

[0032] i) a first check valve and a first expansion valve in said refrigerant line adjacent said outdoor heat exchanger, wherein said first check valve is effective for directing the flow of refrigerant from said indoor heat exchanger through said first expansion valve when operating in an indoor heating mode, and wherein said first check valve is effective for preventing refrigerant from flowing into said first expansion valve when operating in an indoor cooling mode, and

[0033] j) a second check valve and a second expansion valve in said refrigerant line adjacent said indoor heat exchanger, wherein said second check valve is effective for directing the flow of refrigerant from said outdoor heat exchanger through said first expansion valve when operating in an indoor cooling mode, and wherein said second check valve is effective for preventing refrigerant from flowing into said second expansion valve when operating in an indoor heating mode;

[0034] wherein said controller is adapted to adjust the operating capacity of said compressor to its first/lower operating capacity when the system is operating in its indoor cooling mode, and

[0035] wherein said controller is adapted to adjust the operating capacity of said compressor to its second/greater operating capacity when the temperature and/or pressure of the refrigerant fluid in the discharge line of the compressor is below a predetermined value when the system is operating in its indoor heating mode.

[0036] Further illustrative discussion of the various components and options is provided below.

[0037] 1. The Indoor Heat Exchanger and the Outdoor Heat Exchanger.

[0038] The inventive heat pump system includes an indoor heat exchange coil and an outdoor heat exchange coil. As is known to the art, the indoor heat exchange coil acts as a condenser coil when the system is operating in its indoor heating mode, and as an evaporator coil when the system is operating in its indoor cooling mode. The outdoor does the reverse, acting as an evaporator coil when the system is operating in its indoor heating mode, and as a condenser coil when the system is operating in its indoor cooling mode.

[0039] The heat exchange coils are adapted to exchange heat with air flowing over the coils, to absorb or give off heat as the case may be. The particulars of heat exchange coils are well known to the art.

[0040] The heat exchange coils of the present invention are sized such that the outdoor coil is larger than the indoor coil. By larger it is meant that the outdoor coil has a greater heat exchange capacity. For example, the indoor coil may be a 24,000 Btu coil, and the outdoor coil may be a 48,000 Btu coil.

[0041] In the preferred embodiments the outdoor coil is substantially larger than the indoor coil. By substantially larger it is meant that the outdoor coil has a heat exchange capacity that is at least 25% greater than the heat exchange capacity of the indoor coil (making the heat exchange capac-

ity of the outdoor coil 125% of the heat exchange capacity of the indoor coil). In some more preferred embodiments the outdoor coil has a heat exchange capacity that is at least 50% greater than the heat exchange capacity of the indoor coil, while in other more preferred embodiments the outdoor coil has a heat exchange capacity that is at least 100% greater than the heat exchange capacity of the indoor coil. Embodiments in which the outdoor coil has a heat exchange capacity that is at least 150% greater than the heat exchange capacity of the indoor coil, or even at least 200% greater than the heat exchange capacity of the indoor coil, can also be made.

[0042] 2. The Refrigerant, the Refrigerant Line(s), and Associated Valves.

[0043] The inventive heat pump system uses a fluid refrigerant, as is known to the art. Without limiting the fluid refrigerant that may be used, common examples that may be used where not prohibited by environmental regulations include R-22, R-410A, R-600A, R-404A, R-407C, R-422C, R-507, KDD5, KDD6, and DME.

[0044] The refrigerant is typically contained in a closed refrigerant line when passing through the system (except when the refrigerant is in one of the system components, such as the compressor or a coil or a valve). The refrigerant line connects the various system components and allows the refrigerant to flow from the compressor to the coils and vice versa, passing through valves, such as a flow direction reversing valve or an expansion valve, when appropriate.

[0045] In one preferred embodiment, when the system is in its indoor heating mode the refrigerant line delivers refrigerant from the compressor via a compressor output/discharge line, to a flow direction reversing valve, past the sensor, and then to the indoor coil. The refrigerant then flows through the indoor coil, through a first check valve, then through an expansion valve and through the outdoor coil. The refrigerant line then passes the refrigerant back through the flow reversing valve and back to the compressor input.

[0046] When the system is in its indoor cooling mode the refrigerant line delivers refrigerant from the compressor via a compressor output/discharge line, to a flow direction reversing valve, and then to the outdoor coil. The refrigerant line then directs the refrigerant through the outdoor coil, through a second check valve, then through an expansion valve and through the indoor coil. The refrigerant line then passes the refrigerant back through the sensor, through the flow reversing valve, and back to the compressor input.

[0047] 3. The Compressor.

[0048] To handle the larger vapor volume that may be provided by an oversized outdoor heat exchange coil, a larger capacity compressor may be utilized. The compressor is a variable capacity compressor, and is more preferably a continuously variable compressor. The compressor's ability to modulate pumping capacity is important to balance the capacities of the two different capacity coils at varying operating conditions.

[0049] In one embodiment, a Copeland Digital Scroll compressor may be used as the variable capacity compressor. The Copeland Digital Scroll compressor utilizes axial scroll compliance to achieve capacity modulation by forcing the scrolls to separate, causing compression of the refrigerant to stop without stopping the compressor motor. In another embodiment the variable capacity may comprise a variable capacity piston pump, such as one driven by a variable speed electric motor. Regardless of what type of variable capacity compressor is used, the compressor is preferably able to modulate

capacity between 10% and 100%, making it possible to couple differently sized coils together to achieve a desired combination of heating and cooling capacities.

[0050] 4. The Refrigerant Sensor.

[0051] A sensor is provided in the refrigerant line to sense one or more physical characteristics of the refrigerant at the sensor location. For example, the sensor may detect the refrigerant pressure, or its temperature, or its density at the sensor location. In one preferred embodiment the sensor measures pressure with a pressure transducer. In another the sensor measures temperature with a thermistor or thermocouple, for examples. In yet another embodiment the sensor detects refrigerant mass density by measuring the optical index of refraction or the dielectric constant of the refrigerant, for examples.

[0052] The sensor is preferably located in the refrigerant line at a location that is in the compressor discharge line when the system is operating in its indoor heating mode. By in the compressor discharge line is meant that the refrigerant the sensor measures is in sufficiently close communication with fluid in the discharge line so as to provide a sensed value representative of what is directly in the discharge line. The compressor discharge line is the line that passes refrigerant from the compressor, through the reversing valve, and to the indoor coil when the system is in its heating mode.

[0053] In one preferred embodiment the sensor is in the compressor discharge line between the reversing valve and the indoor coil. With this embodiment (illustrated in FIGS. 3 and 4), the sensor is in the refrigerant line between the indoor coil and the reversing valve when the system is operating in its cooling mode. In another embodiment the sensor is in the compressor discharge line between the compressor and the reversing valve. With this embodiment (not illustrated), the sensor is not in the refrigerant line between the indoor coil and the reversing valve when the system is operating in its cooling mode.

[0054] 5. The Compressor Controller.

[0055] A compressor controller is used to receive information from the sensor and to use that information to control the compressor output. The controller may cause the compressor to operate at its minimum operating capacity or at its maximum operating capacity, or at some operating capacity between the minimum and maximum.

[0056] In one embodiment the compressor controller causes the compressor to operate at a capacity approximately equal to the refrigeration capacity of the indoor coil. This is typically done when the system is operating in its indoor cooling mode. In other embodiments the compressor controller causes the compressor to operate at a capacity approximately equal to the maximum capacity of the outdoor coil. This is typically done when the system is operating in its indoor heating mode and the outdoor temperature is below about 10° F. In other embodiments the compressor controller causes the compressor to operate at a capacity that is greater than the capacity of the indoor coil, but less than the maximum capacity of the outdoor coil. This is typically done when the system is operating in its indoor heating mode and the outdoor temperature is below about 35° F., but above about 10° F.

[0057] A thermostat may be connected to the compressor controller and/or to the reversing valve to assist in controlling air flow.

[0058] 6. Air Flow.

[0059] The present invention is part of an air source heat pump system that utilizes a forced air system and associated ducts to transfer heat into or out of the heat exchange coils. The indoor heat exchange coil is therefore positioned in an air flow space that is ducted to a living or working space such as a home living space or a commercial or industrial work space.

[0060] 7. Benefits and Advantages.

[0061] The present invention overcomes the shortcomings of the prior art, wherein the size (capacity) of the outdoor coil is increased, typically by a factor of 1.5 to 2 times or more the capacity of the indoor coil. The larger outdoor coil promotes generation of a greater volume of refrigerant vapor at colder outdoor ambient temperature.

[0062] This configuration of system elements can increase heating Btu capacity 100% or more down to 0° F. or lower while maintaining normal design Btu capacity in the cooling mode. Thus, the present invention is a dual variable capacity heat pump with two independent heat moving capacities, one capacity for heating and a different capacity for cooling.

[0063] To provide one example of the benefits of the present invention, the present dual variable capacity heat pump can be sized to provide 24,000 Btu cooling at 100° F. ambient in the summer and 24,000 Btu at 0° F. ambient in the dead of winter, something heretofore not possible with a single capacity heat pump unit. This may be accomplished by using an outdoor coil and compressor with about twice the capacity for heating, i.e. 48,000 Btu, as the capacity of the indoor coil for cooling, i.e., a 24,000 Btu cooling load. When operating in the cooling mode the variable capacity compressor modulates pumping capacity between minimum capacity and approximately 50% capacity and in the heating mode the variable capacity compressor modulates pumping capacity between minimum capacity and 100% capacity. Thus, in the cooling mode at 100° F. outdoor design condition the heat pump delivers its nominal 24,000 Btu capacity, but when the outdoor temperature drops to 10° F. the heat pump is still able to deliver 24,000 Btu in heating mode.

[0064] Another benefit of the present invention is that the efficiency of the inventive heat pump system is improved because the variable capacity compressor will operate at its required load under changing load conditions. Also, the compressor starts and stops less often, avoiding the wasteful current requirements of compressor motor starting.

[0065] 8. Reference to the Drawings.

[0066] Reference will now be made to the drawings, and specific language will be used to describe the same. It will nevertheless be understood that no limitation of the scope of the invention is thereby intended, any alterations and further modifications in the described embodiments and any further applications of the principles of the present invention as described herein are contemplated as would normally occur to one skilled in the art to which the invention relates.

[0067] FIG. 1 illustrates a basic vapor compression refrigeration cycle. The system comprises a compressor 1 with a piston 2, a compression chamber 3, and an exhaust port 4. A compressor discharge line portion 5 of the refrigerant line connects the compressor to high pressure heat exchange coil 6 (which is a condenser). Similarly, a liquid line portion 7 of the refrigerant line connects the condenser to expansion valve 8 (pressure reducer) which is immediately adjacent low pressure coil 9 (evaporator). A vapor line 10 connects the evaporator to the compressor intake 11.

[0068] The refrigeration cycle consists of the following steps. First, compressor 1 pumps compressed refrigerant vapor into high pressure coil 6 (condenser) where it gives off its latent heat of condensation to air passing over the coil and condenses to high pressure liquid. The air passing over coil 6 is typically outside air. Next, the condensed liquid refrigerant flows to expansion valve 8 where the pressure is reduced and the refrigerant enters the evaporator. As the refrigerant flows through the evaporator at low pressure the liquid refrigerant absorbs its latent heat of vaporization from air flowing over the coil and vaporizes (boils), thus cooling the air. The air flowing over evaporator coil 9 is typically indoor air, which may then be circulated into a living space to cool the space. The vapor generated in the evaporator flows back into the compressor through intake valve 11 where it is drawn into compressor cylinder 3 on the down stroke (suction intake) of piston 2. On upstroke of piston 2 (compression stroke) the volume of the vapor in cylinder 3 is compressed into a very small space between the top of piston 2 and the top of cylinder 3, increasing its pressure and temperature. The compressed refrigerant is discharged through exhaust valve 4 into condenser 6, and the cycle repeats.

[0069] FIG. 2 shows the prior art heat pump refrigeration circuit in the heating mode. Fundamental operation of the heat pump refrigeration circuit is the same as the basic refrigeration circuit described in FIG. 1 except that the refrigeration cycle is reversible, wherein, in the heat mode the flow is in one direction and in the cooling mode the flow is in the opposite direction. The direction of flow is controlled by a flow direct reversing valve (frequently called a 4-way reversing valve), hence called a reverse cycle refrigeration circuit.

[0070] Referring to FIG. 2, a heating flow path is illustrated. Compressor 21 includes a piston 22, a compression chamber 23, and an exhaust port 24. A compressor discharge line portion 25a of the refrigerant line connects the compressor to reversing valve 35. Compressor discharge line portion 25b of the refrigerant line connects reversing valve 35 to indoor heat exchange coil 26 (which is a condenser when the system is in its heating mode, and is an evaporator when the system is in its cooling mode). Expansion valve 36a and check valve 36b are provided near the output line of indoor coil 26. Portion 27 of the refrigerant line connects indoor coil 26 condenser to outdoor coil 29. Portion 30 of the refrigerant line connects the outdoor coil to the compressor.

[0071] The heat pump indoor heating cycle illustrated in FIG. 2, consists of the following steps. First, compressor 21 pumps compressed refrigerant vapor through compressor discharge line 25a and into reversing valve 35. From there, the refrigerant is directed through portion 25b of the refrigerant line to indoor coil 26 (condenser) where it gives off its latent heat of condensation to air passing over the coil. In this process the refrigerant condenses to high pressure liquid.

[0072] The condensed liquid refrigerant flows to expansion valve 37a where the pressure is reduced and the refrigerant enters the evaporator. As the refrigerant flows through the evaporator at low pressure the liquid refrigerant absorbs its latent heat of vaporization from air flowing over outdoor coil 28 and vaporizes (boils). The vapor generated in outdoor coil 29 flows back into the compressor through intake valve 31 where it is drawn into compressor cylinder 23 on the down stroke (suction intake) of piston 22. On upstroke of piston 22 (compression stroke) the volume of the vapor in cylinder 23 is compressed into a very small space between the top of piston 22 and the top of cylinder 23, increasing its pressure and

temperature. The compressed refrigerant is discharged through exhaust valve 24, and the cycle repeats.

[0073] A heat pump indoor cooling cycle may also be appreciated by reference to FIG. 2. In that cycle, compressor 21 pumps compressed refrigerant vapor through compressor discharge line 25a and into reversing valve 35. From there, the refrigerant is directed to indoor coil 29, where condensation occurs. The condensed liquid refrigerant flows to expansion valve 36a where the pressure is reduced and the refrigerant enters indoor coil/evaporator 26. As the refrigerant flows through the evaporator at low pressure the liquid refrigerant absorbs its latent heat of vaporization from air flowing over the coil 28 and vaporizes (boils). The vapor generated in outdoor coil 29 flows back into the compressor through intake valve 31 where it is drawn into compressor cylinder 23 on the down stroke (suction intake) of piston 22. On upstroke of piston 22 (compression stroke) the volume of the vapor in cylinder 23 is compressed into a very small space between the top of piston 22 and the top of cylinder 23, increasing its pressure and temperature. The compressed refrigerant is discharged through exhaust valve 24, and the cycle repeats.

[0074] FIG. 3 shows an indoor heating mode for one embodiment of the present invention. This embodiment solves problems with prior art air-source heat pumps by using an oversize outdoor coil 49 and a variable capacity compressor 41. The variable capacity compressor is controlled by controller 60 that is operably linked to sensor 56. Sensor 56 detects physical properties of the refrigerant, such as its pressure, temperature, or density, and communicates that information to controller 60. Controller 60 then adjusts the operating capacity of variable capacity compressor to provide the correct amount of compressed refrigerant.

[0075] In some embodiments compressor 41 and coil 49 may have essentially the same capacity, which may be 1.5 or 2 times, or more, the capacity of indoor coil 46. Compressor 41 can be either a multi-stage type or preferably a variable capacity compressor such as the digital scroll variable capacity compressor manufactured by Emerson Climate Technologies. The digital scroll has a modulating range typically between 10% and 100% of its capacity, with 100% capacity being essentially equal to the capacity of oversized outdoor coil 49. Capacity control and operation of the refrigerant circuit is accomplished by controller 60, preferably a microprocessor controller, and at least one pressure or temperature sensor 56.

[0076] FIG. 3 illustrates a typical heat mode of operation. In the illustrated mode, compressor controller 60 responds to a call for heating by starting variable capacity compressor 41 at a low capacity, such as a 10% capacity. Compressor 41 preferably starts at a low capacity to minimize compressor motor inrush current, thereby increasing operating efficiency. Following compressor start-up controller 60 begins ramping up compressor 41 capacity in response to pressure and/or temperature at hot gas discharge line 45a. The pressure and/or temperature are sensed by pressure/temperature sensor 56, and a voltage signal proportional to sensed pressure and/or temperature and/or density is sent to controller 60.

[0077] Upon reaching a predetermined and preset pressure and/or temperature and/or density, controller 60 ceases the ramping process and holds the compressor capacity at that level. A typical parameter may be 110° F. air temperature leaving coil 46. Thus, if sensor 56 is a temperature sensor, compressor will modulate compressor 41 capacity as necessary to maintain a constant 110° F. temperature. If sensor 56

is a pressure sensor, compressor controller will modulate compressor 41 capacity as necessary to maintain a constant pressure, such as a 364 psia pressure if the system refrigerant is R-410a.

[0078] Thus, compressor 41 pumps only the volume of refrigerant vapor from oversize coil 49 as is necessary to maintain coil 46 at 110° F. at all times. If the heating load in the condition space changes, causing a corresponding change in coil 46, temperature compressor controller 60 will adjust compressor 41 capacity accordingly to maintain 110° F. This capability alone is a major improvement in heat pump art.

[0079] In conventional heat pump art the availability of heat laden vapor is limited to that which is generated in the outdoor coil (evaporator) of equal capacity. Thus, the volume of vapor available in a conventional 2-Ton heat pump system is limited to that which 24,000 Btu can generate relative to outdoor ambient temperature. A typical conventional 2-Ton heat pump will provide its full nominal capacity of 24,000 Btu down to about 47° F. ambient temperature. However, as ambient temperature drops evaporator Btu capacity drops correspondingly. At about 0° F. the 24,000 Btu coil will now only produce about 40% of its capacity, about 10,000 Btu. This is why in conventional heat pump systems the discharge air temperature coming from the ducts declines as outdoor ambient temperature drops. Air from a typical heat pump averages from high 90° F. in mild temperature down to the mid 80° F. range in cold weather resulting in the one major complaint about air-source heat pumps, cool drafty air.

[0080] To provide sufficient volume of heat laden vapor to indoor coil 46 in order to maintain 110° F. at any outdoor temperature, the increased capacity of outdoor coil 49 may be utilized by allowing compressor 41 to operate at a greater capacity. In order to configure a heat pump that would deliver 24,000 Btu down to a design temperature of 10° F. ambient would require upsizing the outdoor coil from 24,000 Btu to 48,000, and upsize the compressor accordingly.

[0081] In the above configuration the capacity of compressor 41 is continually modulated to pump the required refrigerant vapor from outdoor coil 49 necessary to satisfy the prevailing heat load at indoor coil 46. Thus, in the above example outdoor coil 49 will be able to meet the Btu load at coil 46 down to about 10° F. outdoor ambient temperature. Below this temperature Btu capacity will begin to decline with declining ambient temperature below 10° F. just as in a conventional heat pump system. However, with the oversized capacity coil and compressor even at -10° F. the Btu output will still be about 13,000 Btu which is twice what it would be with prior heat pump art.

[0082] FIG. 4 shows a cooling mode of operation of the illustrated embodiment of the present invention. Upon a call for cooling compressor controller 60 starts variable capacity compressor 41 at minimum 10% capacity. Compressor 41 preferably starts at minimum capacity to minimize compressor motor inrush current thereby increasing operating efficiency. Immediately following compressor start-up controller 60 begins incrementally ramping up compressor 41 capacity in response to either pressure or temperature at indoor coil 46 as sensed by pressure/temperature sensor 56, wherein a voltage signal proportionate to sensed pressure or temperature is sent to controller 60. Upon reaching predetermined and preset pressure/temperature parameter controller 60 ceases the ramping process and holds the compressor capacity at that percentage. A typically parameter may be 45° F. coil 46 temperature or 130 psig coil 46 pressure. Thus, if sensor 56 is

a temperature sensor compressor will modulate compressor **41** capacity as necessary to maintain a constant 45° F. coil temperature. If sensor **56** is a pressure sensor and the system refrigerant is R-410a compressor controller will modulate compressor **41** capacity as necessary to maintain a constant 130 psia coil pressure.

[0083] Thus, compressor **41** pumps only the volume of refrigerant vapor from oversized coil **49** necessary to maintain coil **46** at 45° F. at all times. If the cooling load in the condition space changes causing a corresponding change in coil **46** temperature compressor controller **60** will adjust compressor **41** capacity accordingly to maintain 45° F.

[0084] While the invention has been illustrated and described in detail in the drawings and foregoing description, the same is to be considered as illustrative and not restrictive in character, it being understood that only some embodiments have been shown and described, and that all changes and modifications that come within the spirit of the invention are desired to be protected.

1. A reverse cycle heat pump system having an indoor heat exchange coil, an outdoor heat exchange coil, a compressor, and a compressor discharge line, and operable in an indoor heating mode and an indoor cooling mode;

wherein the outdoor coil is substantially larger than the indoor coil, and the compressor is a variable capacity compressor; and

wherein the system includes: a) a sensor for determining one or more characteristics of the refrigerant in the compressor discharge line when the system is operating in its indoor heating mode, and b) a controller that adjusts the capacity of the compressor to maintain a sensor output value within a desired range of values when the system is operating in its indoor heating mode.

2. The system of claim 1 wherein said variable capacity compressor is a continuously variable capacity compressor.

3. The system of claim 1 wherein said compressor comprises a piston pump.

4. The system of claim 1 wherein said compressor is a digital scroll variable capacity compressor.

5. The system of claim 1 wherein said sensor determines one or more of pressure, temperature and density.

6. The system of claim 5 wherein said sensor determines the pressure of the refrigerant in the compressor discharge line.

7. The system of claim 6 wherein said sensor is a pressure transducer.

8. The system of claim 5 wherein said sensor determines the temperature of the refrigerant in the compressor discharge line.

9. The system of claim 5 wherein said sensor determines the density of the refrigerant in the compressor discharge line.

10. The system of claim 1 wherein said controller is adapted to adjust the operating capacity of said compressor along a gradient that includes at least a dozen different operating capacities.

11. The system of claim 1 wherein the refrigeration capacity of said outdoor heat exchange coil is more than 25% greater than the refrigeration capacity of said indoor heat exchange coil.

12. The system of claim 1 wherein the refrigeration capacity of said outdoor heat exchanger is at least 50% greater than the refrigeration capacity of said indoor heat exchanger.

13. The system of claim 1 wherein the refrigeration capacity of said outdoor heat exchanger is at least 100% greater than the refrigeration capacity of said indoor heat exchanger.

14. The system of claim 1 and further including a reversing valve for directing the flow of said refrigerant fluid through said refrigeration circuit in a first direction when operating in an indoor heating mode, and for directing the flow of said refrigerant fluid through said refrigeration circuit in a second direction when operating in an indoor cooling mode.

15. The system of claim 1 and further including:

i) a first check valve and a first expansion valve in said refrigerant line adjacent said outdoor heat exchanger, wherein said first check valve is effective for directing the flow of refrigerant from said indoor heat exchanger through said first expansion valve when operating in an indoor heating mode, and wherein said first check valve is effective for preventing refrigerant from flowing into said first expansion valve when operating in an indoor cooling mode, and

ii) a second check valve and a second expansion valve in said refrigerant line adjacent said indoor heat exchanger, wherein said second check valve is effective for directing the flow of refrigerant from said outdoor heat exchanger through said first expansion valve when operating in an indoor cooling mode, and wherein said second check valve is effective for preventing refrigerant from flowing into said second expansion valve when operating in an indoor heating mode.

16. A reverse cycle heat pump system operably connected to a forced air system ducted to provide heated and/or cooled air into a residential, commercial or industrial space other than a space used to test or evaluate heat pump systems or components;

wherein said system has an indoor coil, an outdoor coil, and a compressor, and is operable in an indoor heating mode and an indoor cooling mode for the residential, commercial or industrial space;

wherein the outdoor coil is substantially larger than the indoor coil, and the compressor is a variable capacity compressor; and

wherein the system includes: a) a sensor for determining one or more characteristics of the refrigerant in the compressor discharge line when the system is operating in its indoor heating mode, and b) a controller that adjusts the capacity of the compressor to maintain a sensor output value within a desired range of values when the system is operating in its indoor heating mode.

17. A reverse cycle heat pump having an indoor heating mode and an indoor cooling mode, comprising:

a) an indoor heat exchanger (condenser/evaporator coil);

b) an outdoor heat exchanger (condenser/evaporator coil);

wherein the refrigeration capacity of said outdoor heat exchanger is greater than the refrigeration capacity of said indoor heat exchanger;

c) a compressor effective for compressing a refrigerant fluid;

wherein said compressor is operable at a first/lower operating capacity that is substantially equal to the refrigeration capacity of said indoor heat exchanger; and

wherein said compressor is operable at a second/greater operating capacity that is substantially equal to the refrigeration capacity of said outdoor heat exchanger;

d) a refrigerant fluid;

e) refrigerant line linking said indoor heat exchanger, outdoor heat exchanger, and compressor in a closed refrigeration circuit containing said refrigerant fluid;

f) a reversing valve for directing the flow of said refrigerant fluid through said refrigeration circuit in a first direction when operating in an indoor heating mode, and for directing the flow of said refrigerant fluid through said refrigeration circuit in a second direction when operating in an indoor cooling mode;

g) a sensor effective for sensing the temperature and/or pressure of the refrigerant fluid in the discharge line of the compressor when the system is operating in its indoor heating mode, and effective for sending a signal indicating said temperature and/or pressure to a compressor controller; and

h) a compressor controller operationally linked to said sensor and effective for controlling the pumping capacity of said compressor in response to said sensor signal, wherein said controller is adapted to adjust the operating capacity of said compressor to its first/lower operating capacity when the system is operating in its indoor cooling mode, and

wherein said controller is adapted to adjust the operating capacity of said compressor to its second/greater operating capacity when the temperature and/or pressure of the refrigerant fluid in the discharge line of the compressor is below a predetermined value when the system is operating in its indoor heating mode.

18. A reverse cycle heat pump having an indoor heating mode and an indoor cooling mode, the heat pump having functional elements consisting essentially of:

a) an indoor heat exchange coil;

b) an outdoor heat exchange coil;

wherein the refrigeration capacity of said outdoor heat exchange coil is greater than the refrigeration capacity of said indoor heat exchange coil;

c) a compressor effective for compressing a refrigerant fluid;

wherein said compressor is operable at a first/lower operating capacity that is substantially equal to the refrigeration capacity of said indoor heat exchange coil; and

wherein said compressor is operable at a second/greater operating capacity that is substantially equal to the refrigeration capacity of said outdoor heat exchange coil;

d) a refrigerant fluid;

e) refrigerant line linking said indoor heat exchanger, outdoor heat exchanger, and compressor in a closed refrigeration circuit containing said refrigerant fluid;

f) a reversing valve for directing the flow of said refrigerant fluid through said refrigeration circuit in a first direction when operating in an indoor heating mode, and for directing the flow of said refrigerant fluid through said refrigeration circuit in a second direction when operating in an indoor cooling mode;

g) a sensor effective for sensing a parameter selected from the group consisting of temperature, pressure, density, and a combination thereof, as to the refrigerant fluid in the discharge line of the compressor when the system is operating in its indoor heating mode, and effective for sending a signal indicating said temperature and/or pressure to a compressor controller;

h) a compressor controller operationally linked to said sensor and effective for controlling the pumping capacity of said compressor in response to said sensor signal;

i) a first check valve and a first expansion valve in said refrigerant line adjacent said outdoor heat exchanger, wherein said first check valve is effective for directing the flow of refrigerant from said indoor heat exchanger through said first expansion valve when operating in an indoor heating mode, and wherein said first check valve is effective for preventing refrigerant from flowing into said first expansion valve when operating in an indoor cooling mode, and

j) a second check valve and a second expansion valve in said refrigerant line adjacent said indoor heat exchanger, wherein said second check valve is effective for directing the flow of refrigerant from said outdoor heat exchanger through said first expansion valve when operating in an indoor cooling mode, and wherein said second check valve is effective for preventing refrigerant from flowing into said second expansion valve when operating in an indoor heating mode;

wherein said controller is adapted to adjust the operating capacity of said compressor to its first/lower operating capacity when the system is operating in its indoor cooling mode, and

wherein said controller is adapted to adjust the operating capacity of said compressor to its second/greater operating capacity in response to the output of said sensor.

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