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(54) **SUPERHEAT CONTROL FOR A REFRIGERANT VAPOR COMPRESSION SYSTEM**

## Publication Classification

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(57) **ABSTRACT**

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A refrigerant vapor compression system includes a compressor, an expansion valve, a compressor speed sensor operatively connected to the compressor, an ambient temperature sensor, and a controller operatively coupled to the expansion valve, compressor speed sensor and ambient temperature sensor. The controller including a superheat control that is configured and disposed to selectively activate the expansion valve to establish a desired superheat value based on a speed of the compressor as sensed by the compressor speed sensor and ambient temperature as sensed by the ambient temperature sensor.

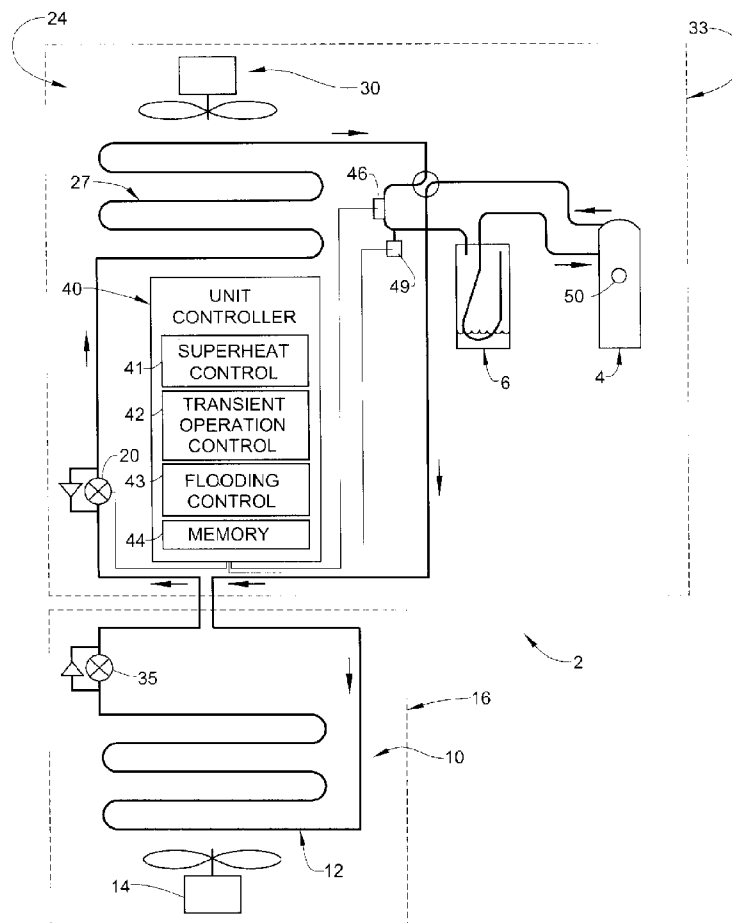


FIG. 1

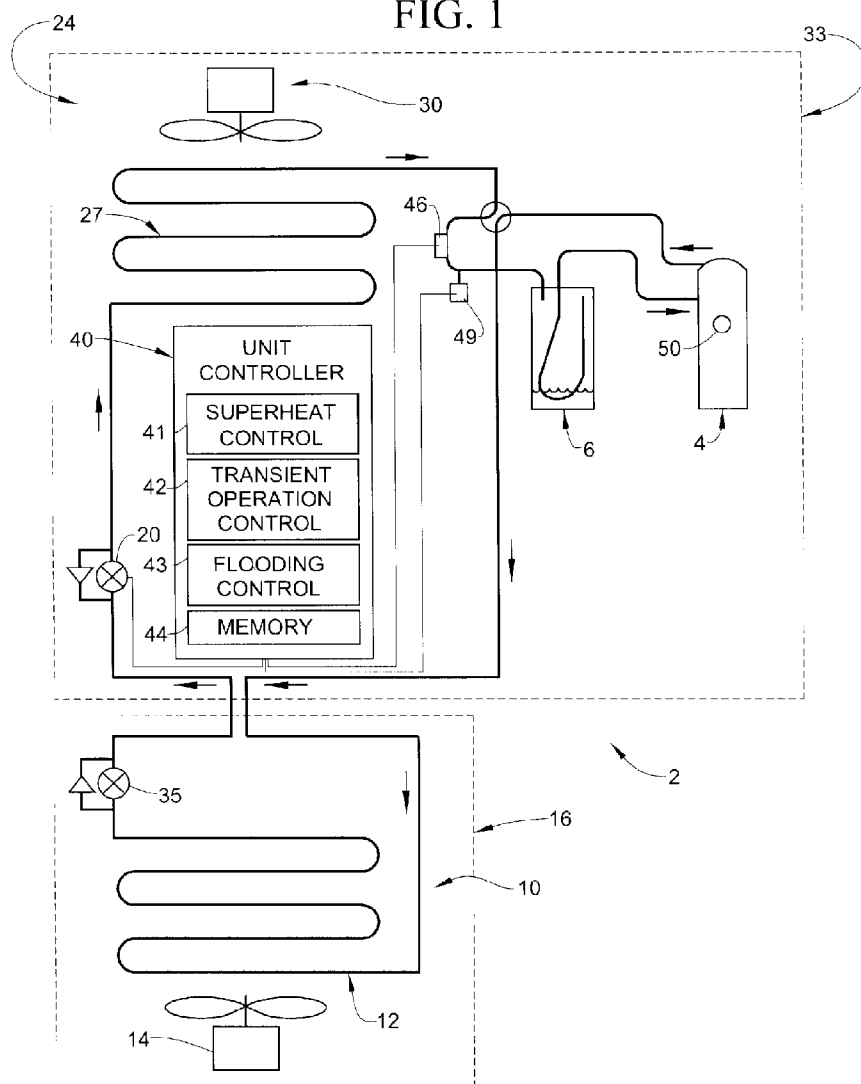
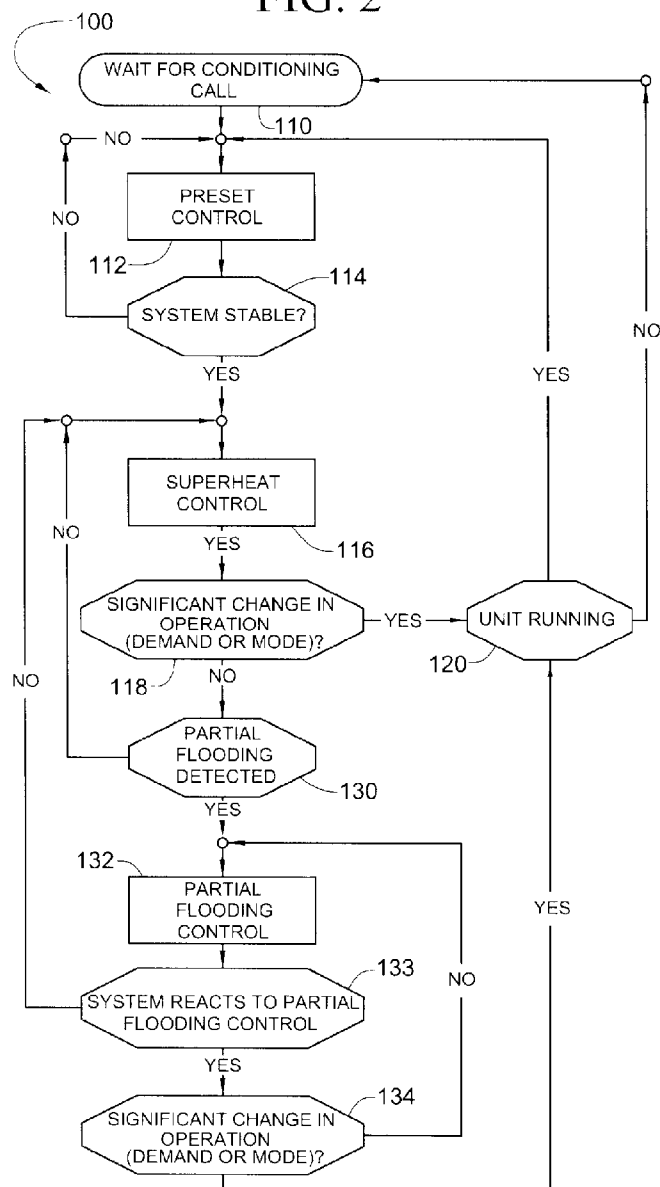


FIG. 2



# **SUPERHEAT CONTROL FOR A REFRIGERANT VAPOR COMPRESSION SYSTEM**

## CROSS-REFERENCE TO RELATED APPLICATION

**[0001]** This application is a National Stage Application of PCT Application No. PCT/US11/048948 dated Aug. 24, 2011, the disclosure of which is incorporated by reference herein in its entirety.

## BACKGROUND OF THE INVENTION

**[0002]** Exemplary embodiments pertain to the art of refrigerant vapor compression systems and, more particularly to a system for stabilizing superheat based on ambient temperature and compressor speed to provide enhanced operation.

**[0003]** Superheat, or an amount of heat added to a refrigerant vapor after a change in state is a measure of system performance of a refrigerant vapor compression system. More specifically, super heat is a performance indicator for how well an evaporator portion of the refrigerant vapor compression system is performing. Too much superheat indicates that the evaporator portion is not receiving enough refrigerant. Conversely, too little superheat indicates that the evaporator is being flooded or over-fed with refrigerant. The amount of refrigerant fed to the evaporator is controlled by an expansion valve. The expansion valve is opened/closed to control refrigerant flow to the evaporator based upon steady state control limits. That is, at present, superheat values are fixed targets based on specific ambient temperatures and predetermined operating conditions. Such control limits to not provide for enhanced performance during transient periods such as during start-up, defrost entry and exit, or compressor speed changes.

## BRIEF DESCRIPTION OF THE INVENTION

**[0004]** Disclosed is a refrigerant vapor compression system including a compressor, an expansion valve, a compressor speed sensor operatively connected to the compressor, an ambient temperature sensor, and a controller operatively coupled to the expansion valve, compressor speed sensor and ambient temperature sensor. The controller includes superheat control that is configured and disposed to selectively activate the expansion valve to establish a desired superheat value based on a speed of the compressor as sensed by the compressor speed sensor and ambient temperature as sensed by the ambient temperature sensor.

**[0005]** Also disclosed is a method of controlling superheat in a refrigerant vapor compression system. The method includes sensing ambient temperature, detecting operational speed of a compressor of the refrigerant vapor compression system, and establishing a desired evaporator superheat value based on ambient temperature and operational speed of the compressor.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0006]** The following descriptions should not be considered limiting in any way. With reference to the accompanying drawings, like elements are numbered alike:

**[0007]** FIG. 1 is a schematic representation of a refrigerant vapor compression system shown operating in a heating mode including a superheat control in accordance with an exemplary embodiment; and

**[0008]** FIG. 2 is a flow chart illustrating a method of controlling superheat in accordance with the exemplary embodiment.

## DETAILED DESCRIPTION OF THE INVENTION

**[0009]** A detailed description of one or more embodiments of the disclosed apparatus and method are presented herein by way of exemplification and not limitation with reference to the Figures.

**[0010]** With reference to FIG. 1, a refrigerant vapor compression air conditioning system in accordance with an exemplary embodiment is indicated generally at 2. Refrigerant vapor compression system 2 includes a compressor 4, an accumulator 6, and a condenser assembly 10. In accordance with an aspect of the exemplary embodiment, compressor 4 takes the form of a variable speed compressor. Condenser assembly 10 includes a condenser coil 12 and a condenser fan 14. Condenser coil 12 and condenser fan 14 define an indoor system 16 of refrigerant vapor compression system 2. Refrigerant vapor compression system 2 also includes a heating expansion valve 20 and an evaporator assembly 24. In a manner similar to that described above, evaporator assembly 24 includes an evaporator coil 27 and an evaporator fan 30. Evaporator assembly 24 also includes a distributor (not shown) to divide the refrigerant flow into multiple circuits through condenser coil 12. Compressor 4, accumulator 6, heating expansion valve 20 and evaporator assembly 24 collectively define an outdoor system 33 of refrigerant vapor compression system 2. Compressor 4, accumulator 6, condenser assembly 10, heating expansion valve 20 and evaporator assembly 24 are connected in a serial relationship and in refrigerant flow communication via refrigerant lines (not separately labeled).

**[0011]** In operation, refrigerant, for example R12, R22, R134a, R404A, R410A, R407C, R717, R744 or other compressible fluids pass through evaporator coil 27 in a heat exchange relationship with outdoor air. As the outdoor air is passed over evaporator coil 27 by evaporator fan 30. The refrigerant absorbs heat and is transformed into a refrigerant vapor. The refrigerant vapor then passes through accumulator 6 and onto compressor 4. Compressor 4 pressurizes the refrigerant vapor. The pressurized refrigerant vapor is then passed into condenser coil 12. Indoor air is passed over condenser coil 12 in a heat exchange relationship by condenser fan 14. The indoor air is heated by the refrigerant vapor and is directed into living spaces (not shown). Exchanging heat with the indoor air transforms the refrigerant vapor into a pressurized liquid refrigerant. The pressurized liquid refrigerant passes from condenser assembly 10 to heating expansion valve 20 wherein the pressurized liquid refrigerant is transformed to a lower pressure, lower temperature liquid refrigerant, typically to a saturated liquid prior to entering evaporator assembly 24 where the process begins anew. The above described process refers to a heating mode of operation. It should be understood that the flow of refrigerant can be reversed to operate in a cooling mode. In such a case, the refrigerant bypasses expansion valve 20 and, instead, flows through a cooling expansion valve 35.

**[0012]** At this point it should be appreciated that expansion valve 20 and possibly cooling expansion valve 35 is, in accordance with an exemplary embodiment, an electronic variable orifice type expansion valve (EEV). In the heating mode, heating electronic expansion valve 20 regulates an amount of liquid refrigerant entering evaporator assembly 24 in

response to a superheat condition of the refrigerant entering compressor 4. In order to ensure a proper regulation of liquid refrigerant entering evaporator assembly 24 for all temperature and all speeds of compressor 4, refrigerant vapor compression system 2 includes a controller 40. In accordance with one aspect of the exemplary embodiment, controller 40 takes the form of a proportional-integrated-derivative (PID) controller and includes a superheat control 41, a transient operation control 42, a flooding control 43, and a memory 44. That is, instead of operating refrigerant vapor compression system 2 based on a single superheat value, the exemplary embodiment provides an adaptive superheat control that regulates liquid refrigerant passing into evaporator assembly 24 based on a wide range of ambient temperature values and compressor speeds.

[0013] In accordance with the exemplary embodiment, controller 40 includes a memory 42 and is operatively coupled to heating expansion valve 20, cooling expansion valve 35 and a plurality of sensors. More specifically, refrigerant vapor compression system 2 includes a temperature sensor 46 and a pressure sensor 49 compressor provided on the refrigerant line at an outlet of evaporator coil 27. In addition, a 4 includes a compressor speed sensor 50. At this point it should be understood that the particular type of sensors can vary. For example, compressor speed sensor 50 need not be an actual physical sensor. Speed could be sensed by reading voltage and/or current passing through motor windings of compressor 4. In addition, it should be understood that refrigerant vapor compression system 2 may include additional temperature and pressure sensors arranged to detect superheat when in the cooling mode.

[0014] Reference will now be made to FIG. 2 in describing a superheat control algorithm 100 of controlling superheat in refrigerant vapor compression system 2. Initially, controller 40 waits to receive a conditioning call in block 110. For purposes of the foregoing discussion, controller 40 will receive a call for heating. Once the conditioning call is received in block 110, controller 40 dictates various operating parameters in block 112. For example, controller 40 establishes compressor speed, fan operation, electronic expansion valve setting and the like based on ambient temperature and indoor demand (a desired temperature selected versus the actual indoor temperature) in the call). At this point, refrigerant vapor compression system 2 is monitored to determine, in block 114, when a steady-state or stable operation is achieved. If stable operation is not achieved, controller 40 adjusts the preset parameters in block 112.

[0015] Once refrigerant vapor compression system 2 is stable, superheat control 41 sets a desired superheat value in block 116. The desired superheat value is dependent upon ambient temperature as sensed by temperature sensor 46 and compressor speed as sensed by compressor speed sensor 50. In accordance with one aspect of the exemplary embodiment, superheat control 41 refers to a look-up table stored in memory 44. The look-up table includes a plurality of data points representing a range of ambient temperatures and range of compressor speeds each correlated to desired superheat values. Thus, for each ambient temperature and compressor speed combination, there is listed a desired superheat value. In the event that ambient temperature and/or compressor speed falls between data points, superheat control 41 interpolates the desired superheat value. Once the desired superheat value is chosen, expansion valve 20 is set to establish the desired superheat. Once established, controller 40

monitors the superheat through temperature sensor 46 and pressure sensor 49. If necessary, expansion valve 20 is adjusted to maintain the desired superheat. With this arrangement, superheat control 41 establishes an adaptive superheat value that is employed to regulate liquid refrigerant passing into evaporator based on existing conditions. In this manner, superheat control 41 enhances operation of refrigerant vapor compression system 2.

[0016] After the desired superheat is established in block 116, controller 40 monitors for transient system changes in block 118. Transient system changes may include sudden changes in demand, sudden system initialization, entry into or exit from a defrost mode, and/or changes in compressor speed. If a transient system change is detected, transient operation control 42 establishes an opening of expansion valve 20 based on the sensed transient system change in block 118. If, for example, compressor 4 changes to a higher speed, transient operation control 42 sets the desired superheat value based on steady state operation at the higher speed and establishes the opening for the expansion valve 20. Once the a post transient position is set for expansion valve 20, controller 40 provides a waiting period, for example two minutes, to allow refrigerant vapor compression system 2 to return to stable operation. If after the waiting period refrigerant vapor compression system 2 is not stable or operation changes, controller 40 resets the position of expansion valve 20. If the system returns to stable operation after the waiting period superheat is controlled as discussed above. If no transient system changes are detected, controller 40 monitors for a flooding condition in evaporator assembly 24 in block 130.

[0017] The partial flooding of evaporator is described as a relatively few number of evaporator circuits flooding when a majority of the evaporator circuits are still in a superheated condition. This partial flooding is detected by, for example, sensing a rapid change in superheat with a small change of position of expansion valve 20. The partial flooding condition is most often caused by frost forming on the outdoor coil in heating mode. Because frosting does not form evenly across the coil, heat ultimately is absorbed into the refrigerant circuits unevenly. Other conditions that may cause the partial flooding condition in either cooling or heating modes include debris on the evaporator or non-uniform airflow across the evaporator. If controller 40 detects partial flooding in evaporator assembly 24, flooding control 43 slows down controller response to allow refrigerant vapor compression system 2 to achieve a stable operation. Flooding control 43 continues until flooding cannot be stopped by the slowed closing of expansion valve 20 in block 133, and a defrost mode is entered or refrigerant vapor compression system 2 is deactivated in block 134.

[0018] At this point it should be understood that heating expansion valve 20 and cooling expansion valve 35 can take on a variety of forms. For example, if the superheat control algorithm is only used in one mode, i.e., heating or cooling, the expansion device for the other mode may take on any variety of forms including fixed orifice valves, thermostatic expansion valves (TXV), electronic expansion valves (EEV) and/or pulse-type solenoid valves.

[0019] It should also be appreciated that the exemplary embodiments enhance operation of a refrigerant vapor compression system by establishing superheat values based on actual operating conditions. That is, instead of using a pre-programmed superheat value that is idealized for steady state conditions, the exemplary embodiment sets the superheat

value based on actual operating conditions. In addition, the exemplary embodiment adjusts and refines the superheat value based on transient system changes and corrects for flooding conditions by adjusting the expansion valve independently from the desired superheat value. Adaptive control of the superheat enhances system efficiency, enhances reliability and reduces energy costs. It should further be appreciated that while described in a heating mode, the superheat control algorithm can also be employed in a cooling mode.

**[0020]** While the invention has been described with reference to an exemplary embodiment or embodiments, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from the essential scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiment disclosed as the best mode contemplated for carrying out this invention, but that the invention will include all embodiments falling within the scope of the claims.

What is claimed is:

1. A refrigerant vapor compression system comprising:  
a compressor;  
an expansion valve;  
a compressor speed sensor operatively connected to the compressor;  
an ambient temperature sensor; and  
a controller control operatively coupled to the expansion valve, compressor speed sensor and ambient temperature sensor, the controller including a superheat control configured and disposed to selectively activate the expansion valve to establish a desired superheat value based on a speed of the compressor as sensed by the compressor speed sensor and ambient temperature as sensed by the ambient temperature sensor.
2. The refrigerant vapor compression system according to claim 1, wherein the controller includes a memory having stored therein a look-up table, the look-up table including a plurality of superheat values that are correlated to ambient temperature and compressor speed.
3. The refrigerant vapor compression system according to claim 2, wherein the expansion valve is a variable orifice expansion valve.
4. The refrigerant vapor compression system according to claim 1, wherein the controller includes a transient operation control that establishes the predicted expansion valve position to provide the desired superheat value following a transient system change.
5. The refrigerant vapor compression system according to claim 4, wherein the transient system change includes one of a compressor speed change, a system initialization, and an exit from a defrost mode.
6. The refrigerant vapor compression system according to claim 1, wherein the controller includes a flooding control

that selectively operates the expansion valve based upon a sensed partial flooding condition of the evaporator.

7. The refrigerant vapor compression system according to claim 6, wherein the flooding control shifts the expansion valve toward a closed position upon detecting a partial flooding condition.

8. The refrigerant vapor compression system according to claim 1, wherein the superheat control comprises a proportional-integrated-derivative (PID) controller.

9. A method of controlling superheat in a refrigerant vapor compression system, the method comprising:

- sensing ambient temperature;
- detecting operational speed of a compressor of the refrigerant vapor compression system; and
- establishing a desired superheat value based on ambient temperature and operational speed of the compressor.

10. The method of claim 9, wherein establishing the desired superheat value comprises selectively operating an expansion valve of the refrigerant vapor compression system.

11. The method of claim 10, wherein selectively operating the expansion valve of the refrigerant vapor compression system comprises establishing a desired orifice of the expansion valve.

12. The method of claim 9, further comprising: retrieving the desired superheat value from a look-up table stored in a memory, the superheat value being correlated to compressor speed and ambient temperature in the look-up table.

13. The method of claim 12, further comprising: interpolating the desired superheat value.

14. The method of claim 9, further comprising: establishing a predicted superheat value following a transient system change.

15. The method of claim 14, wherein the predicted superheat value is established for a predetermined period of time.

16. The method of claim 14, wherein the predicted superheat value is established following one of a compressor speed change, a system initialization, and one of an entry into and an exit from a defrost mode.

17. The method of claim 14, wherein the predicted superheat value is based upon a predicted steady state operation of the refrigerant vapor compression system following the transient operating parameter change.

- 18. The method of claim 9, further comprising:  
detecting a partial evaporator flooding condition; and  
shifting an evaporator valve of the refrigerant vapor compression system toward a closed position based on the detected partial evaporator flooded condition.

19. The method of claim 18, wherein detecting a partial evaporator flooded condition comprises detecting a frosted condition on at least a portion of the evaporator.

20. The method of claim 18, further comprising: maintaining the expansion valve in the closed position until the refrigerant vapor compression system enters a defrost mode.

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