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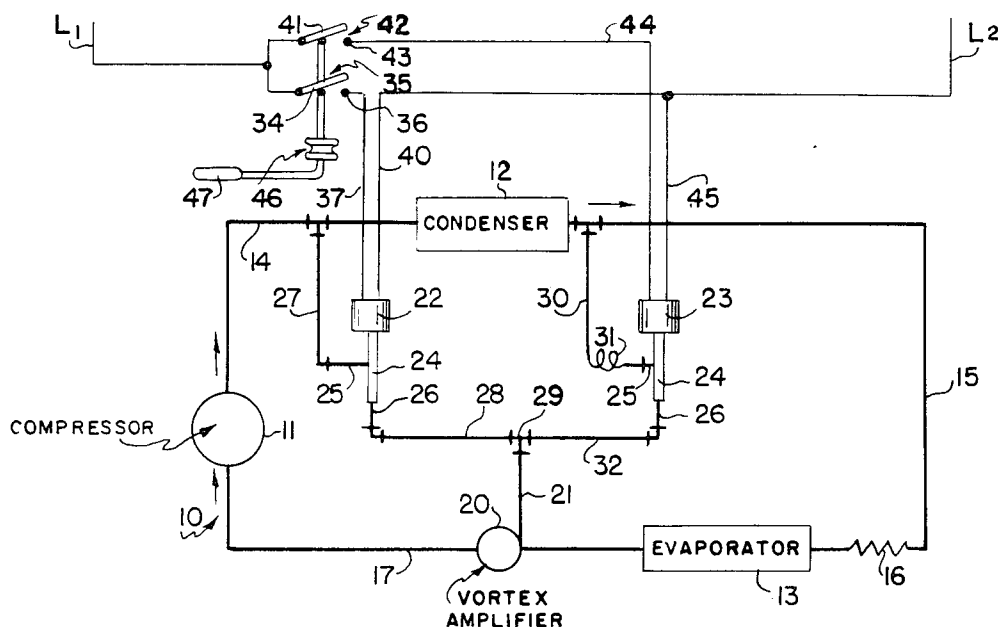
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[54] **STEP-BY-STEP CONTROL OF REFRIGERANT RETURN IN A COMPRESSOR-CONDENSER-EXPANDER SYSTEM**
 6 Claims, 3 Drawing Figs.

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 62/197, 62/217
 [51] Int. Cl. F25b 5/00
 [50] Field of Search 62/160,
 196, 197, 217, 500, 117

[56] **References Cited**
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ABSTRACT: A step-by-step control of the cooling unit of a compressor-condenser-expander-type refrigerating system is provided in which the flow of refrigerant from the evaporator to the compressor is throttled by a vortex amplifier. The signal flow for the vortex amplifier is derived from the high-pressure side of the system and comprises hot gas from ahead of the condenser and condensed gas from the discharge of the condenser. The flows of hot gas and condensed gas are controlled individually by separate temperature responsive valves which open and close at different temperatures so that the vortex amplifier produces different degrees of throttling of flow of refrigerant from the evaporator to the compressor in accordance with the cooling load on the evaporator. In a modified form of the invention, a single valve admits a mixture of hot gas and condensed gas to the signal line of the vortex amplifier to throttle the flow of refrigerant to the compressor.



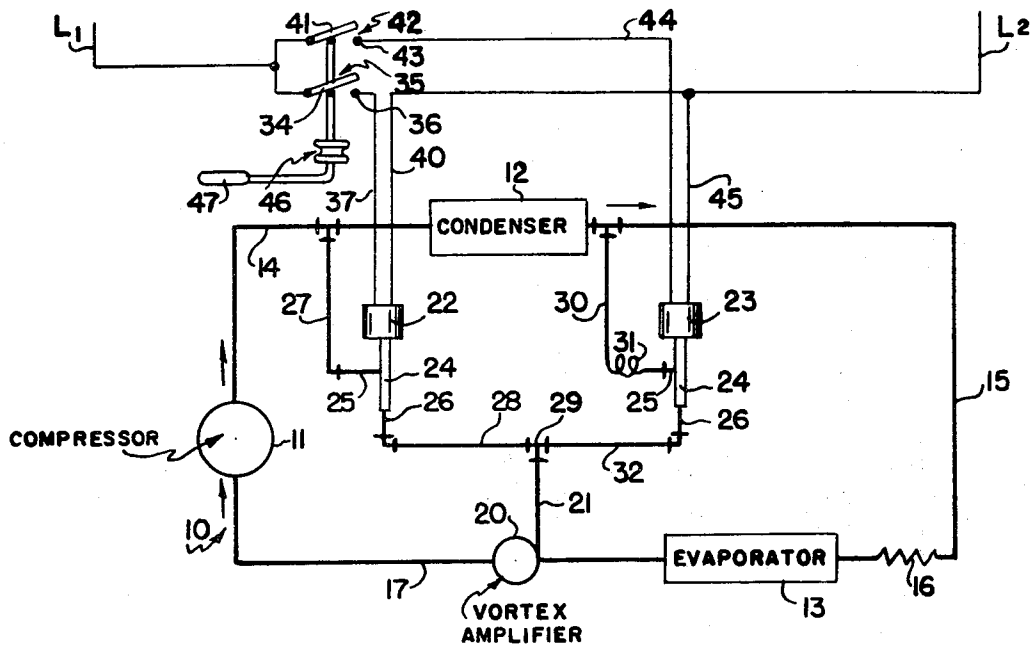


FIG. 1

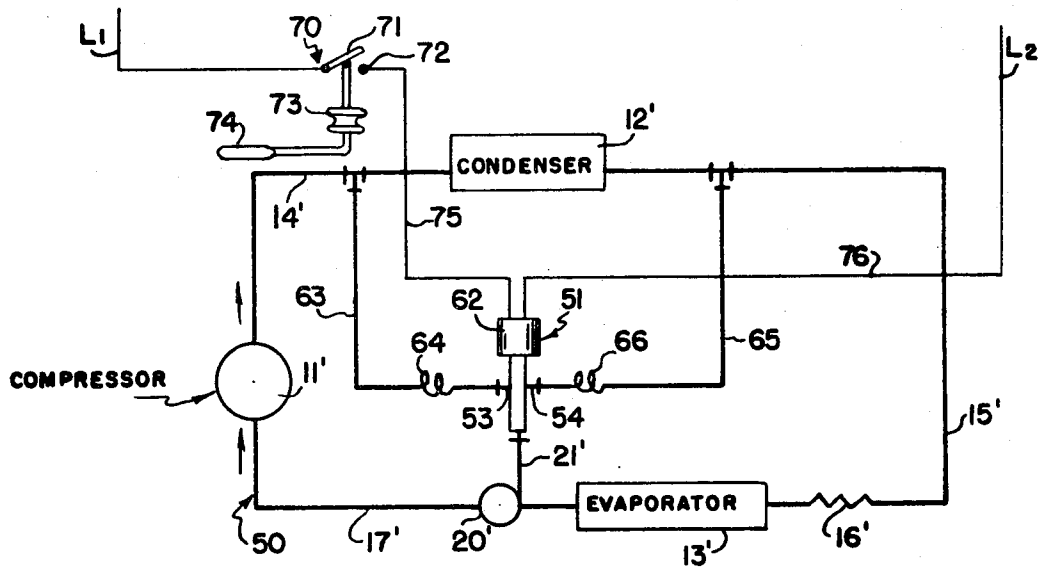


FIG. 2

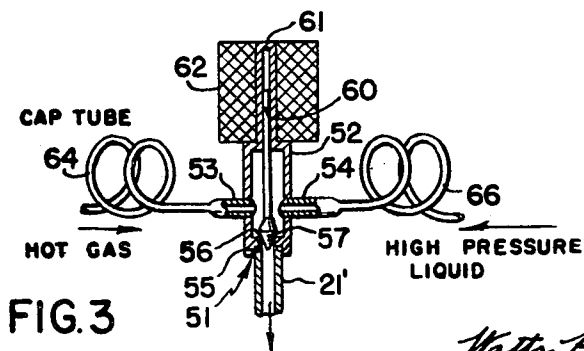


FIG. 3

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STEP-BY-STEP CONTROL OF REFRIGERANT RETURN IN A COMPRESSOR-CONDENSER-EXPANDER SYSTEM

BACKGROUND OF THE INVENTION

Compressor-condenser-expander-type refrigerating systems for cooling the air in rooms or buildings are generally cycled on and off to maintain a desired temperature. This type of control produces undesirably wide fluctuations in room temperature. To provide a more uniform temperature it has been proposed heretofore to control the cooling capacity of this type of refrigerating system by more or less throttling the flow of refrigerant from the expander or evaporator to the compressor by a vortex amplifier. The vortex amplifier comprises a cylindrical chamber through which refrigerant passes on its return to the compressor. The gas enters the chamber through a side and exits the chamber through an axial opening. By introducing a signal flow of fluid tangentially into the signal flow entering the chamber, a swirling action was imparted to the refrigerant passing through the chamber. This swirling action restricts the flow and lowers the refrigerating or cooling capacity of the system. Heretofore the signal flow was controlled by a modulating valve, in some cases having its inlet connected to the refrigerant line between the discharge of the compressor and the inlet of the condenser. The signal flow then comprised hot refrigerant gas. In other instances the signal flow was derived from the refrigerant line between the condenser and the evaporator and the signal would comprise liquefied refrigerant. The compressors in such systems generally comprise a hermetically sealed casing enclosing a pump and an electric motor for driving the pump. The refrigerant returning from the evaporator was directed into the casing for compression and the cool refrigerant would serve to maintain the motor windings cool. In the use of hot gas flow signals for the vortex amplifier, under certain conditions the signal flow entered the refrigerant returning to the compressor and would cause overheating of the motor windings. Where the vortex amplifier signal flow comprised liquefied refrigerant, liquid introduced into the refrigerant returning to the compressor was apt to cause slugging and damage to the refrigerant pump.

Another disadvantage of the use of a vortex amplifier was the fact that suitable modulating valves for controlling the signal flow were expensive and difficult to accurately control.

THE PRESENT INVENTION

The present invention provides a new method and apparatus for step control of the cooling capacity of the evaporator of a compressor-condenser-expander-type refrigerating system by use of a vortex amplifier to control the flow of refrigerant from the evaporator to the compressor and providing a signal flow for the amplifier made up of a combination of hot gas and condensed gas taken from opposite sides of the condenser. In one form of the invention, condition responsive valves are arranged to individually control the flow of hot gas and the flow of condensed gas to the signal inlet of the amplifier. The valves are operated sequentially according to a change in a condition, such as a drop in temperature affected by the evaporator, so that hot gas alone is utilized as the amplifier signal for relatively slight reduction in cooling capacity, and when further reduction in cooling capacity is required the liquid flow control valve is opened so that the maximum signal flow is comprised of a mixture of hot gas and cooler liquefied gas. The rate of flow of hot gas into the vortex amplifier is sufficiently limited to prevent overheating the refrigerant returning to the compressor and yet provides a degree of restriction in the amplifier. When a high degree of restriction to the flow through the amplifier is required, the signal flow will be a mixture of hot gas and liquid. The hot signal gas vaporizes the liquid signal fluid and is also reduced in temperature. Thus liquid slugging and excessive temperatures in the return line of the compressor are obviated. By using two signal flow valves as described the valves may be of inexpensive and reliable valve structures and yet provide a fine degree of control.

RELATED CASES

The patent to Fineblum, U.S. Pat. No. 3,498,074 discloses a refrigerating system in which the flow of refrigerant from the evaporator to the compressor is throttled by a vortex amplifier of the type contemplated in the present disclosure.

Other objects and advantages of the invention will be apparent from the following description of preferred embodiments thereof, reference being made to the accompanying drawings wherein:

FIG. 1 is a schematic view of a refrigerating system embodying the invention;

FIG. 2 is a schematic view of a refrigerating system embodying a second form of the invention; and

FIG. 3 is a fragmentary view of the system shown in FIG. 2, showing the control valve on a large scale and broken away.

Referring to FIG. 1, a refrigerating system 10 is shown which may be employed for chilling the air in an air-conditioning system for a building or a room, for example. The system 10 is a conventional compressor-condenser-expander-type and includes a motor-driven compressor 11, a condenser 12 and an evaporator 13. The discharge of the compressor 11 is connected with the condenser by a conduit 14. The outlet of the condenser is connected with the evaporator 13 through a conduit 15, which includes a suitable conventional capillary restriction tube 16 adjacent the inlet of the evaporator. The output of the evaporator is connected with the inlet of the compressor by a conduit 17. A fluid vortex amplifier device 20 is connected in the conduit 17 and is adapted to throttle the flow of refrigerant through the conduit 17 when a signal flow of fluid enters the device 20 through a conduit 21.

The compressor 11 is driven by an electric motor, the operation of which is controlled by a thermostatic switch. Because the motor and its control are well-known expedients in the art, they are not shown. In the present instance, the thermostatic switch would respond to the temperature of room air passing to the evaporator 13 for cooling and would operate to start the compressor at a desired maximum air temperature and would terminate operation of the compressor at a lower level.

The vortex amplifier 20 is similar to that described in the aforementioned Fineblum patent. Suffice to say the amplifier includes a cylindrical chamber with a refrigerant fluid inlet at one side and a fluid outlet coaxial with the axis of the cylinder. A signal fluid is injected tangentially into the cylindrical chamber and transverse of the refrigerant flow into the chamber whereby a vortex is created in the cylindrical chamber which restricts flow of fluid through the chamber. The velocity of the vortex and consequently the degree of restriction to the flow of refrigerant to the compressor is proportional to the flow of fluid through the signal conduit 21.

The signal flow is supplied to the conduit 21 through a pair of solenoid-operated valves 22 and 23. The valves 22 and 23 may be identical and they each include a valve body 24 having an inlet port 25 and an outlet port 26. A valve seat is located between the inlet and outlet ports and a movable valve plunger normally rests on the seat to close the valve. An electrically energized solenoid is effective to move the valve plunger from the valve seat when the solenoid is energized. Solenoid valves of the type mentioned are well known and to avoid unnecessary description the details are not described or shown. The inlet port 25 of valve 22 is connected by conduit 27 to the conduit 14. The outlet port 26 of the valve 22 is connected with a conduit 28 which leads to a The outlet port 26 of 29, the stem of which is connected with signal conduit 21.

The inlet port 25 of the valve 23 is connected by a conduit 30 to the conduit 15 and it includes a coiled capillary section 31 which restricts the flow of liquid to the valve body. The outlet port 26 of the valve 23 is connected by a conduit 32 to one arm of the T-fitting 29.

It will be seen that the valve 22 admits a flow of hot discharge gas from the compressor into the signal conduit 21 when the solenoid thereof is energized and the valve is opened. It will also be apparent that the valve 23 likewise ad-

mits a flow of condensed liquefied gas leaving the condenser into the signal flow tube 21 when the solenoid of the valve is energized.

The solenoid of valve 22 is energized by a circuit which includes a powerline L1 of a conventional two-line power supply system, a contact arm 34 of a switch 35, contact 36 of switch 35 and wire 37 to one side of the solenoid. The other side of the solenoid for the valve 22 is connected by wire 40 to line L2 of the two-wire power supply.

The circuit for the solenoid which operates valve 23 includes line L1, switch contact arm 41 of switch 42, contact 43, wire 44 to one side of the solenoid and wire 45 to line L2 of the power source.

The switches 35 and 42 are operated by a temperature responsive bellows 46 which has a temperature-sensing bulb 47 associated therewith. The bellows and bulb are charged with a suitable fluid which causes expansion and contraction of the bellows in response to increases and decreases in temperature at the bulb 47. The bulb 47 is located to respond to the same air temperature to which the compressor motor control switch responds. When the temperature at the bulb 47 is at the maximum temperature desired, switches 35 and 42 will be open. When the compressor motor is operated by closure of the thermostatic switch and the temperature at the bulb 47 commences to reduce from the maximum limit, the switch 35 closes the circuit to the solenoid for the valve 22 and upon further reduction in temperature the collapse of the bulb 47 causes switch 42 to close the circuit for the solenoid in the valve 23. The temperature at which the switch 42 closes is slightly above the temperature at which operation of the compressor 11 is terminated. As the temperature increases at the bulb 47 switch 42 will be initially opened to deenergize the solenoid for valve 23. Upon further increase in temperature at the bulb 47 switch 35 is opened to deenergize the solenoid for valve 22. This last temperature is preferably slightly below the temperature at which the compressor operation is initiated by the thermostatic switch mentioned for controlling the compressor motor.

OPERATION

When the compressor 11 is started valves 22 and 23 are closed and the full flow of refrigerant through the condenser and evaporator is effective causing maximum chilling of air by the evaporator 13. As the temperature to be controlled commences to reduce at the bulb 47, the switch 35 is closed which causes valve 22 to open. Hot gas discharging from the compressor 11 is directed into the signal conduit 21 of the vortex amplifier 20 through the valve 22. The amount of hot gas discharged into the vortex amplifier by opening of the valve 22 is relatively light in volume and causes a mild vortex and a relatively mild restriction to the flow of refrigerant from the evaporator to the compressor. This restriction or throttling of flow of refrigerant reduces slightly the cooling effect of the evaporator 13 so that the rate of reduction of temperature at the bulb 47 should be reduced. At the same time, the amount of hot gas directed into the vortex amplifier is limited so as to be absorbed into the steam of refrigerant returning to the compressor and cooled without causing undue temperature increase of the compressor motor.

Should the cooling effect of the evaporator 13 be such as to cause continued decrease in the temperature at the bulb 47, switch 42 will be closed causing opening of the control valve 23. Relatively cool liquefied gas will then flow through the conduit 30 through the valve 23 and into the signal conduit 21 where it is mixed with the hot gas issuing from the valve 22. The hot gas and liquefied gas combines in the conduit 21 and causes a reduction in temperature of the hot gas and at the same time will tend to "flash" or vaporize the liquefied refrigerant present in the signal conduit. This increases the amount of signal fluid entering the amplifier 20 which causes a more violent vortex action and hence further reduces or throttles the flow of refrigerant back to the compressor. Thus, a

maximum throttling is provided which substantially reduces the effectiveness of the evaporator in cooling air. The capacities of the valves 22, 23 are such that the mixture forming the signal fluid will neither cause slugging or wetness in the refrigerant passing to the intake of the compressor, nor will the temperature of the signal fluid be sufficiently high to interfere with the efficient operation of the compressor.

A second form of the invention is shown in FIGS. 2 and 3. In this disclosure, an air-conditioning or refrigerating system 50 is shown which is substantially like the air-conditioning system of 10 except that the vortex amplifier for controlling the flow of refrigerant from the evaporator to the compressor is controlled by a different form of valve. For sake of simplicity all parts of the refrigerating system 50 which are like those of the system 10 are referred to by the same reference characters having a prime affixed thereto.

In the system 50 the flow of signal fluid through the conduit 21' to the vortex amplifier 20' is controlled by a single-solenoid valve 51. The valve 51 comprises a hollow tubular body 52 which has two inlet ports 53 and 54 and an outlet port 55. A valve seat or port 56 is formed between the two inlets 53, 54 and the outlet 55 and which seat is arranged to be normally closed by a valve member 57. The valve member 57 is supported at one end of an armature 60 which extends into a neck portion 61 of the housing 52, the upper end of which neck portion is closed. The valve body 52 including the neck portion 61, is preferably formed of a nonmagnetic material such as brass. A solenoid coil 62 is disposed about the neck 61 and is arranged to draw the armature 60 upwardly when the solenoid is energized. This opens the valve seat 56 to permit flow of fluid through the ports 53, 54 and out the port 55. When the solenoid is deenergized the valve member drops to close the outlet port 55.

The inlet port 53 is connected with the high pressure conduit 14' through a conduit 63 which includes a capillary section 64. The inlet port 54 is connected with the refrigerant line 15' through a conduit 65 which includes a capillary portion 66. The outlet port 55 is connected with the signal fluid conduit 21'. The solenoid 62 is controlled by a thermostatic switch 70. The thermostatic switch is of conventional construction and includes a movable contact 71 and a fixed contact 72. The contact 71 moves from and to the contact 72 in accordance with expansion and contraction of a bellows 73, respectively. The bellows 73 is connected by a tube with a bulb 74 which is disposed in the air which is affected by operation of the air-conditioning system 50. When the temperature of the bulb attains a predetermined maximum temperature the switch 70 is opened and the valve 51 is closed. When the temperature of the bulb drops below the predetermined temperature the solenoid is energized and the valve 51 is opened. The switch contact 71 is connected with L1 of the power supply and contact 72 is connected by a wire 75 to one side of the solenoid. The opposite side of the solenoid is connected by a wire 76 to line L2.

It will be understood that the compressor 11' is controlled so as to start a cooling cycle when the temperature of the air is at or above the temperature at which switch 70 opens. The compressor is stopped when the air temperature falls below the temperature at which the switch 70 closes.

When the valve 51 is closed the flow of refrigerant through the vortex amplifier 20' is unimpeded and the cooling capacity of the evaporator 13' is at its maximum. As soon as the temperature at the bulb 74 decreases to a given degree the solenoid 62 is energized and the valve 51 is opened. This causes an intermingling of hot gas from the conduit 14' to enter the body 52 of the valve. At the same time cool liquid from the conduit 15' enters the opposite side of the valve body through the port 54. The hot gas entering the valve body through the inlet port 53 imparts heat to the cool liquid causing it to vaporize and the resultant fluid is directed through the conduit 21' into the vortex amplifier 20'. This mixture of gas and liquefied gas imparts a substantial or relatively rapid swirl to the refrigerant passing through the cylindrical body of the fluid amplifier,

thereby restricting the flow of refrigerant returning to the compressor 11' and reducing the cooling capacity of the evaporator 13'.

The restrictive effects of the signal fluid provide a relatively high degree of throttling of the refrigerant flow through the vortex without imparting an objectionable high temperature to the refrigerant entering the suction side of the compressor. ON the other hand, the hot signal gas tends to vaporize the cool liquid signal fluid from the discharge side of the condenser so that slugging of the compressor is avoided. The capillary tubes 64 and 66 are sized to provide an ideal proportionate flow of hot gas and cool liquid into the valve body so as to prevent overheating and excessive liquid in the gas entering the valve into the signal line 21'.

I claim:

1. In a refrigerating system comprising a compressor, a condenser and an evaporator connected in a refrigerating circuit, a vortex amplifier in said circuit between said evaporator and compressor for controlling the flow of refrigerant from the evaporator to the compressor, said amplifier including a signal flow conduit, and means for providing a signal flow through said conduit, said flow comprising first means to introduce relatively hot compressed gas refrigerant from said refrigerating circuit into said conduit and second means to introduce condensed refrigerant from said refrigerating circuit into said conduit.

2. A refrigerating system as defined in claim 1 further characterized by valve means responsive to temperature con-

ditions affected by operation of said refrigerating system for controlling the flows of said hot compressed gas refrigerant and condensed refrigerant into said conduit.

3. A refrigerating system as defined in claim 1 further characterized by a first valve to control the flow of said hot compressed gas refrigerant into said conduit, a second valve to control the flow of condensed refrigerant into said conduit, and temperature responsive means to control said first and second valves for operation at different temperatures.

4. A refrigerating system as defined in claim 3 further characterized by said first valve adapted to open and close at given temperatures and said second valve adapted to open and close at temperatures lower than said given temperatures, respectively.

5. The method of controlling the cooling capacity of a compressor-condenser-expander-type refrigerating system having a vortex amplifier in the refrigerant circuit between the expander and the compressor, which method comprises supplying a signal flow to the vortex amplifier by mixing refrigerant gas directly from the hot gas discharge of the compressor and from condensed refrigerant directly from the condenser.

6. The method defined in claim 5 further characterized by regulating the volumes of mixed gas and condensed refrigerant to cause substantially complete vaporization of the condensed refrigerant as it passes through said vortex amplifier.

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