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[54] HEATING AND COOLING REFRIGERATION APPARATUS

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[52] **U.S. Cl.** **62/196,** 62/217, 62/510

[51] **Int. Cl.** **F25b 41/00**

[58] **Field of Search** 62/159, 196, 217, 238, 506, 62/510; 165/62, 63

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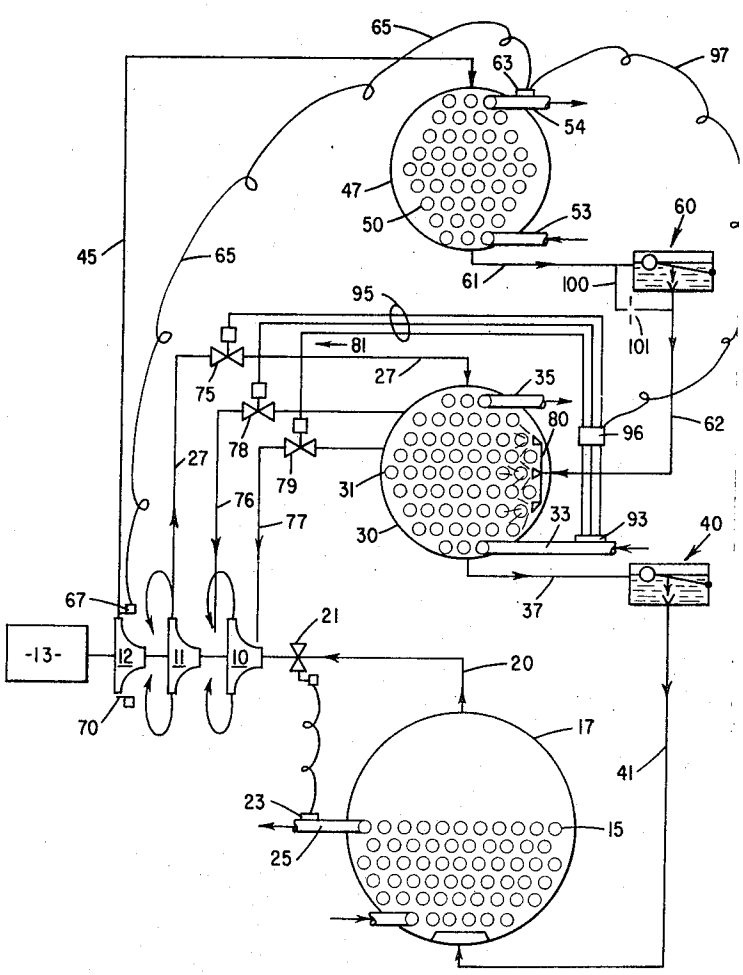
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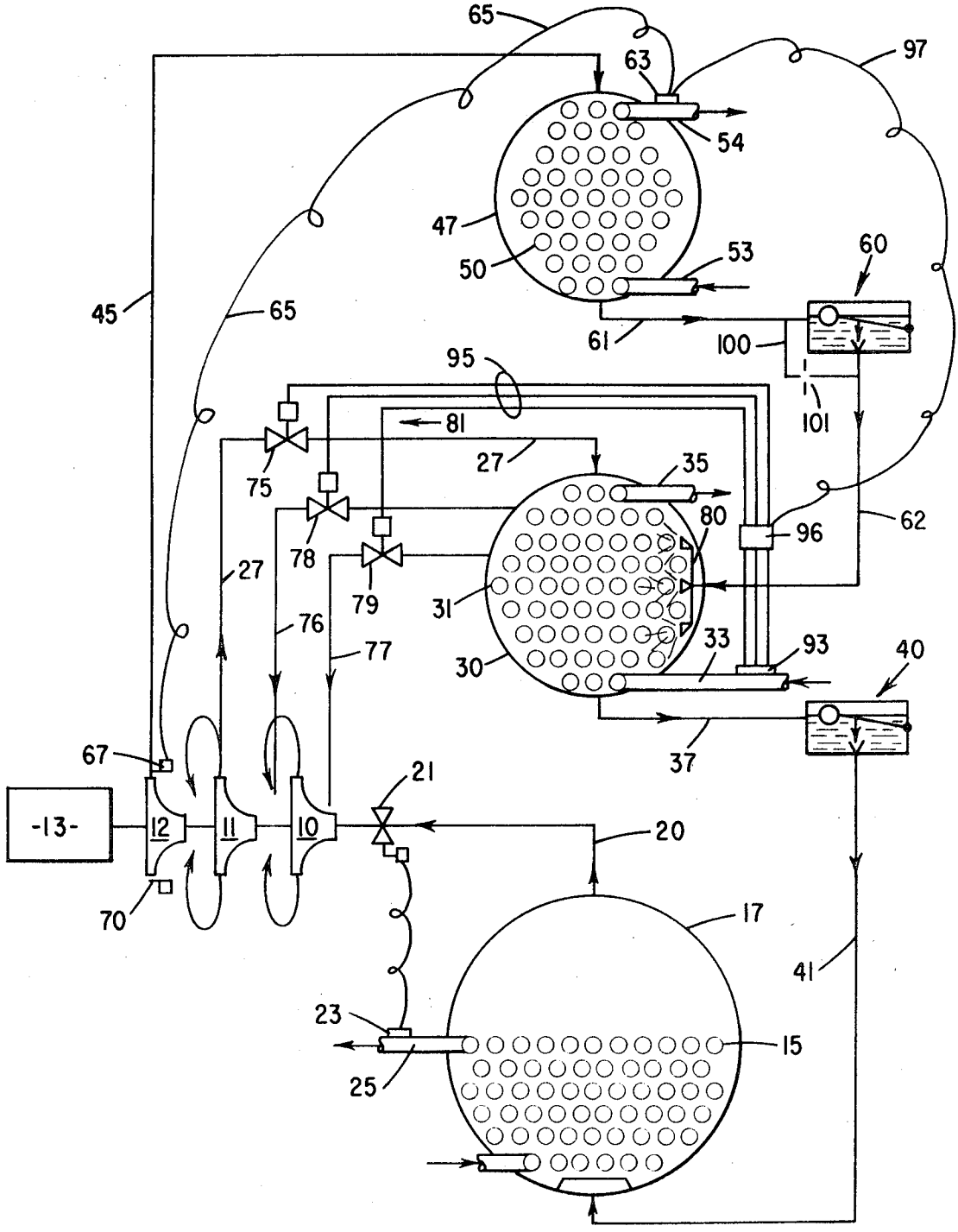
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[57] **ABSTRACT**

Refrigerant is passed from a stage other than the last stage of a multistage centrifugal compressor to a waste heat condenser for liquefying refrigerant and returning it to a cooling load evaporator. The latent heat of the refrigerant, along with the heat of compression, is rejected to the atmosphere as by a cooling tower and interconnecting water circuit. There is capacity control means for regulating refrigerant flow from the evaporator to the compressor in accordance with the cooling load imposed on the evaporator. A line is provided for passing refrigerant vapor from the last stage of the compressor to a second condenser, which serves as a heat exchanger for heating a medium for satisfying a heating load demand. A refrigerant line extends from the second condenser to the first condenser. The compressor includes flow control means, as a diffuser sleeve valve, in the last stage operable to regulate the passage of refrigerant vapor to the second condenser in accordance to the heat load imposed thereon. A refrigerant vapor line including a flow control valve extends from the vapor area of the first condenser to the inlet of each stage of the compressor. The flow control valves are operated sequentially according to the pressure in the first condenser to provide a sufficient supply of refrigerant vapor for passage from the last compressor stage to the second condenser to satisfy the heat load impressed thereon.

7 Claims, 1 Drawing Figure





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HEATING AND COOLING REFRIGERATION APPARATUS

BACKGROUND OF THE INVENTION

In the co-pending application of James W. Endress and Carl M. Anderson, Ser. No. 54,175 filed July 13, 1970, there is disclosed an improved heating and cooling apparatus of the type which functions to simultaneously provide cooling to one portion of a building, such as the interior area of the building, and heating to another portion of the building, such as the peripheral area. According to the invention disclosed in said application, a multistage centrifugal compressor is employed to provide refrigerant vapor from an intermediate stage of a compressor to a waste heat condenser. The liquid refrigerant is passed from the condenser to an evaporator or liquid chiller. The refrigerant vapor return from the evaporator to the compressor includes means for varying the flow of the refrigerant vapor and therefore to vary the capacity of the compressor according to the colling demand imposed on the system as determined by a temperature sensor on the outgoing chilled water line.

If the system is required to satisfy a heat load, the refrigerant vapor output from the last stage of the compressor is passed to a heat exchanger which includes a tube bundle connected to the hot water heating circuit. The amount or volume of refrigerant vapor passed from the last stage of the compressor to the heat exchanger is in proportion to the heating demand.

The condensed liquid refrigerant in the heat exchanger is conveyed to the waste heat condenser.

If the cooling load is relatively light and, simultaneously, there is a high heating demand load, the waste heat condenser serves in that case as a flash economizer providing reverse flow of refrigerant vapor to the inlet of the last stage of the compressor. With this system, additional refrigerant vapor is supplied to the last stage of the compressor during high heating demand, all whereby that system is capable of handling a much higher heating demand load in ratio to the cooling demand than obtained by prior arrangements.

SUMMARY OF THE INVENTION

This invention is an improvement over that disclosed in the application above referred to in that a refrigerant vapor passage line is provided from the vapor area of the waste heat condenser to the inlet of each stage of the compressor. Also, the liquid refrigerant conveyed from the heating condenser is sprayed over the tube bundle in the waste heat condenser, effecting a more rapid and thorough flashing of the liquid refrigerant with greater absorption of heat from the condensing water supplied to the waste heat condenser. Accordingly, an abundant supply of refrigerant vapor, at elevated temperature, is made available for compression through selected stages of the compressor for greater temperature rise in the second condenser to satisfy a greater heating demand. Each flow line for passage of refrigerant vapor from the condenser to each stage of the compressor includes a flow control valve, and means is provided for operating these valves sequentially according to the pressure in the condenser to make certain a sufficient supply of refrigerant vapor is passed to the compressor for discharge by the last stage to meet the heating demand. In other words, with the apparatus arrangement of our invention, the lift provided by all three stages of the compressor may be applied to the second condenser to handle a high heat load relative to a given cooling load. Accordingly, the heating to cooling capability of the apparatus can achieve a level of approximately 1.8 to 1.

BRIEF DESCRIPTION OF THE DRAWING

The drawing is a schematic diagram illustrating the apparatus arrangement embodying our invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

In the drawing, there is disclosed a three stage compressor having impellers **10**, **11**, and **12** operated by a driver **13**. The cooling load imposed on the system is handled by a cooling medium such as water or brine circulated in a tube bundle **15** mounted in a cooler shell **17**. Refrigerant vapor is drawn from the cooler **17** through a line **20** to the inlet of the compressor. Capacity control means **21**, such as inlet guide vanes, are arranged at the inlet to the compressor and are operated by a temperature sensor **23** affixed in heat exchanging relation to the output line **25** of the cooler.

A refrigerant vapor line **27** extends from the discharge of the second stage **11** of the compressor to a waste heat condenser **30**. The condenser **30** includes a tube bundle **31** having an inlet line **33** extending from a source of cooling water such as a water tower. The return line is indicated at **35**.

A liquid refrigerant line **37** extends to a float control metering valve mechanism **40** from which liquid refrigerant is discharged through line **41** to the cooler **17**. This portion of the equipment functions in conventional manner as a two stage centrifugal compressor refrigeration system.

A line **45** extends from the discharge of the third compressor stage **12** to a heat exchanger **47**. The heat exchanger is provided with a tube bundle **50** through which a medium for carrying away heat, such as water, is circulated, the inlet line **53** and outlet line **54** being connected to the heating circuit. Refrigerant is discharged from the heat exchanger **47** to the float control mechanism **60** by line **61**, and a line **62** extends to the waste heat condenser **30**.

Heating demand is sensed by a temperature responsive device **63** attached to the line **54** through which the heating medium leaves the heat exchanger **47**. The sensor **63** is connected by a line **65** to an actuator **67** which operates a flow control means, such as a diffuser valve **70**, to control the passage of refrigerant vapor from the third stage of the compressor to the heat exchanger **47**. The diffuser valve **70** is moved between open and closed positions in proportion to the heat load imposed on the tube bundle **50** as determined by the sensor **63**. The refrigerant vapor line **27** includes a flow control valve **75** which, in the absence of a heating load of predetermined value on heat exchanger **47**, is in open position to provide the flow of refrigerant vapor from the second compressor stage **11** to the waste heat condenser **30** to reject the heat of compression and the latent heat of the refrigerant.

The apparatus also includes a line **76** extending from the discharge of the first stage of the compressor to the waste heat condenser **30**, and a line **77** extending from the waste heat condenser **30** to the inlet of the compressor. A flow control valve **78** is connected in the line **76**, and a similar valve **79** is connected in line **77**. The valves **78,79** are closed until the heating load on the exchanger **47** reaches a predetermined value.

If the sensor **63** senses a temperature of the water in the tube bundle **50**, indicating the existence of a heating requirement for the outer or peripheral portion of the building, the diffuser valve **70** will be moved toward open position for the flow of refrigerant vapor through the line **45**. As the diffuser valve **70** of the third compressor stage moves to a wider open position and the pressure in the heating condenser falls as it supplies heat to the water leaving at **54**, the pressure between stages **2** and **3** of the compressor falls to the point at which all of the flow discharging from the second state passes on to the third stage, and no refrigerant vapor flow travels through line **27** to the condenser **30**. However, a given water chilling load imposed on the cooler **17** is satisfied by the flow of liquid refrigerant through line **37**, metering valve **40**, and line **41**. Under this situation, the condenser **30** is being supplied with refrigerant from heat exchanger **47** through lines **61,62**.

The line **62** terminates in a supply header **80** arranged in the waste heat condenser **30** and is effective to disperse the refrigerant on the tube bundle **31**, whereby the condenser **30** serves as a flash economizer to provide an adequate supply of

refrigerant vapor to the last compressor stage to handle a high heating load.

If the hot water heating load demand further increases, the diffuser sleeve valve **70** opens still further, whereupon the refrigerant from line **62** that is wetting the tube bundle **31** in condenser **30** by being sprayed on the tube bundle boils, thereby drawing heat from the cooling tower water line **33,35**. Refrigerant vapor accordingly passes from the waste heat condenser **30** in reverse flow as indicated by the arrow **81** through the then open valve **75** to be compressed and again condensed in the heat exchanger **47**. Under these operating conditions, a heating to cooling ratio of approximately 1.2 to 1 may be obtained.

However, if there is still further reduction in the outside air temperature, with increase in heat load demand, and accordingly a reduction in the temperature of cooling tower water supplied to waste heat condenser **30**, the pressure in the waste heat condenser **30** may drop below the suction pressure intermediate the second and third compressor stages with reduction of available refrigerant vapor flow from the condenser **30** to the inlet of the third compressor stage. Means is provided for sensing the pressure in the waste heat condenser **30**. Inasmuch as condenser pressure and temperature are substantially synonomous, the condenser pressure may be determined by a temperature sensor **93** attached to the incoming water line **33**. The sensor **93** is of a conventional type having contacts operable sequentially according to the sensed temperature. The output of the sensor **93** is passed to the valves **75,78,79** through cable **95** in which there is connected a relay or switching device **96** controlled by the sensor **63** through line **97**.

The contacts of the relay **96** are open when the sensor **63** does not sense the presence of a heating demand above a predetermined value. In this situation, the valve **75** as previously stated is in open position; and the valves **78,79** are closed. Upon sensor **63** sensing a heating load demand above the predetermined value, the valves **75,78,79** are placed under the control of the sensor **93**. The arrangement is such that when the pressure within waste heat condenser **30** drops below the suction pressure between stages **2** and **3** of the compressor, the sensor **93** actuates the valve **75** to closed position and the valve **78** to open position. This results in a flow of refrigerant vapor from the condenser **30** through line **76** to the inlet of the second compressor stage impeller **11**. Accordingly, the increase in heating load is readily satisfied by the lift obtained from the second and third stages of the compressor. In like manner, with still further reduction in outside temperature, with a proportionately greater heating load placed on the heat exchanger **47**, and with a further reduction of pressure in condenser **30**, valve **78** is closed and valve **79** in line **77** is opened.

In the absence of any heating load, the diffuser volume control valve **70** does not close entirely tight as will be understood by those familiar with centrifugal compressor operation. To prevent over-pressurizing the heat exchanger **47** during extended periods when there is no heating demand load, the float valve mechanism **60** may be shunted by a branch line **100** in which an orifice **101** is connected. The orifice **101** is dimensioned to pass a sufficient flow of refrigerant from the heat exchanger to the condenser **30** to prevent the buildup of an undesirably high pressure in the heat exchanger and overheating of the last compressor stage.

With valves **75, 78** closed and valve **79** in line **77** open, all stages of the compressor now impart lift to the refrigerant vapor through line **45** which is significantly greater in volume than that supplied by line **20**, whereby the system is capable of producing a heating to cooling ratio of approximately 1.8 to 1.

The apparatus arrangement of the system embodying our invention renders it particularly suitable for installation in smaller building units where internal zone cooling loads are much smaller than the heating requirements in the spring and fall seasons.

We claim:

1. Apparatus for simultaneously satisfying heating and cooling demands in a building comprising a multistage compressor, a waste heat condenser, and a cooling load evaporator connected to form a circuit including a refrigerant vapor line extending between each stage of said compressor, other than the last stage thereof, and said waste heat condenser, a first liquid refrigerant passage including flow metering means extending from said waste heat condenser to said evaporator, cooling capacity control means regulating the flow of refrigerant vapor from said evaporator to the inlet of said compressor in accordance with the cooling load demand imposed on said apparatus, a heat exchanger, a refrigerant vapor passage extending from the discharge of the last stage of said compressor to said heat exchanger, means for circulating water to be heated for satisfying a heating load demand in heat exchanging relation to the refrigerant in said heat exchanger, a second liquid refrigerant passage including flow metering means extending from said heat exchanger to said waste heat condenser, refrigerant flow control means for regulating the flow of refrigerant vapor from said last stage to said heat exchanger according to the heating load demand imposed on said heat exchanger, a flow control valve in each of said refrigerant vapor lines, one of said valves being opened in the absence of a heating load imposed on said heat exchanger and the others of said valves being closed, flow control valve operating means associated with said waste heat condenser and operable upon the presence of a heating load on said heat exchanger to selectively open and close said flow control valves in said refrigerant vapor lines according to the pressure in said waste heat condenser.

2. Apparatus as set forth in claim **1** wherein said waste heat condenser includes a tube bundle containing a cooling medium, a refrigerant spray means connected to said second liquid refrigerant passage means and operable to spray the liquid refrigerant on said tube bundle.

3. Apparatus as set forth in claim **1** wherein said waste heat condenser includes a tube bundle containing a cooling medium, said flow control valve operating means including a temperature sensor responsive to the temperature of said cooling medium in said tube bundle.

4. Apparatus as set forth in claim **1** wherein said refrigerant flow control means for regulating the flow of refrigerant vapor from said last compressor stage includes a temperature sensor responsive to the temperature of the circulating water in said heat exchanger.

5. Apparatus as set forth in claim **1** wherein said flow control means for regulating the flow of refrigerant vapor from said last compressor stage includes a temperature sensor responsive to the temperature of the circulating water leaving said heat exchanger.

6. Apparatus as set forth in claim **1** wherein said refrigerant flow control means for regulating the flow of refrigerant from said last compressor stage includes a diffuser valve operable to vary the flow of refrigerant from said last compressor stage, and a temperature sensor responsive to the temperature of said circulating water in said heat exchanger for operating said diffuser valve.

7. Apparatus as set forth in claim **1** wherein said one flow control valve opened in the absence of a heating load imposed on said heat exchanger being in the refrigerant vapor line extending from next to the last stage of said compressor to said waste heat condenser.

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