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FEED CONTROL MEANS FOR REFRIGERATION APPARATUS

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My invention is concerned with refrigeration apparatus, relating especially to the control of flow of liquid refrigerant from the condenser to the evaporator in such apparatus.

Broadly, the invention has for its object the provision of control, or "modulation," of the capacity of an air conditioner, or other refrigeration machine, in such manner that temperature conditions within a desired range may be maintained throughout a rather wide range of ambient temperatures which may be encountered during operation of the machine.

While, in its broader aspect, the invention has utility in a wide variety of refrigeration machines, the concepts of the invention are particularly useful as applied to room air conditioners. During operation of such air conditioners, particularly when utilized to condition the air within a bedroom during the cooler hours of the night, reduction in the heat load tends to cause the dry bulb temperature of the air circulating within the room to drop below a desired, predetermined minimum value. Under such conditions it is desirable to control, or to "modulate," the capacity of the machine in such a way as to maintain the desired temperature condition.

It is known that the application of heat to the liquid line which includes the restrictor and interconnects the condenser and the evaporator, tends to result in gasification of liquid flowing in said line, with the result that the effective impedance of the restrictor is increased and the flow of liquid refrigerant into the evaporator is correspondingly retarded. It is with this class of apparatus that my invention is particularly concerned, it being an object of the invention to accomplish this purpose by the use of energy available within the refrigeration system and, more specifically, by controllably effecting heat exchange between the discharge line, which connects the compressor with the condenser, and the said liquid line.

In one aspect of the invention it is an object to initiate such heat exchange in response to reduction in the temperature of air cooled by the evaporator.

More specifically, my invention has as an object the provision of simple, thermodynamically efficient apparatus for effecting such capacity modulation, such apparatus being characterized by the fact that it may if desired be merchandised

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as an accessory and installed by servicemen, in the field, without disturbing the refrigeration circuit.

To the foregoing general ends the invention contemplates the provision of refrigeration apparatus, such for example as air conditioning equipment, including a closed secondary refrigeration circuit having an evaporator portion disposed in heat exchange relation with the discharge line which interconnects the compressor and condenser, and a condenser portion disposed in heat exchange relation with the liquid line which includes the restrictor. In accordance with the invention, flow of refrigerant within the closed secondary circuit takes place under the control of valve means responsive to a reduction in the temperature of the evaporator, or of the air cooled by said evaporator, below a predetermined lower limit.

The manner in which the foregoing and other objects and advantages of the invention may best be achieved will be clearly understood from a consideration of the following description, taken in conjunction with the accompanying drawing, in which:

Figure 1 is a diagrammatic representation of an air conditioning or refrigeration machine embodying the modulating apparatus of my invention; and,

Figures 2 and 3 are fragmentary illustrations of other embodiments of the invention, modified as respects the point at which the condensing portion of the secondary system is disposed in heat exchange relation with the liquid line.

Making more detailed reference to the drawing, there is diagrammatically illustrated in Figure 1 an air conditioning or refrigeration system including an evaporator and a condenser which may be of known, finned coil type, these elements being shown, respectively, at 10 and 11. A compressor 12 is connected with the condenser 11 through the agency of a discharge line 13, a liquid line 14, which includes a strainer 15 and a capillary type restrictor 16, providing for flow of liquid refrigerant from the condenser 11 to the evaporator 10. The refrigeration circuit is completed by a suction conduit 17 through which heat-laden, gaseous refrigerant passes from the evaporator to the compressor. The normal operation of such a system is well known, requiring no descrip-

tion herein except insofar as the operation thereof is modified by the novel heat exchanging means of the invention.

In particular accordance with the invention, and as indicated above, means is provided for controlling the flow of refrigerant through the liquid line from the condenser to the evaporator, by effecting heat exchange between the discharge line 13 and the liquid line 14. This flow controlling means comprises a closed secondary refrigeration circuit, shown at 18, and which circuit includes an evaporator portion 19 disposed in high heat exchange relation with the discharge line 13, and a condenser portion 20 disposed in high heat exchange relation with the liquid line 14. The necessary heat exchange may be ensured by closely associating, as by soldering or the like, the evaporator and condenser portions of the secondary system with the said discharge and liquid lines, it being understood that, if desired, the heat exchange may be effected in other ways familiar to those skilled in the art to which this invention appertains.

While it is preferred to dispose the secondary condenser 20 in heat exchange relation with the liquid line in a region ahead of the entrance point of the capillary restrictor 16, in order that the gas formed in the liquid line may be fully effective in retarding the flow of refrigerant toward the evaporator, it will be evident that variation in location of this heat exchange point may be made without departing from the primary concept of the invention. As illustrated in Figure 2, the secondary condenser may comprise tubing 29a looped or wound about the strainer 15, which arrangement has certain constructional advantages and also results in very efficient transfer of heat from the secondary condenser 20 to the liquid flowing in line 14. Figure 3 illustrates, at 20b, one way in which the secondary condenser may be disposed in heat exchange relation with the capillary tube 16.

Similarly, because of the relatively high temperature of the superheated gas flowing through the discharge line, it is preferred to dispose the secondary evaporator portion 19 in heat exchange relation with said line. It is possible, however, to obtain a useful effect in accordance with the invention with this heat exchange located at some other point in the system. For example, the temperature of the refrigerant within the first loops of the condenser 11 is appreciably higher than the temperature of the liquid flowing past the condenser portion 20, and it is therefore possible to dispose the evaporator portion 19 in heat exchange relation with said first loops. The important requirement is that the evaporator portion of the secondary system to be so disposed in the apparatus as to be subjected to a temperature materially above the temperature of the liquid flowing through the line 14 and to which liquid the secondary condenser rejects heat.

In each of the embodiments illustrated, flow of refrigerant through the secondary circuit 18 is controlled in accordance with the temperature of air flowing in heat exchange relation with the evaporator 10, and preferably in accordance with the temperature of said air as it flows toward and into contact with said evaporator. A control valve is shown at 21. As illustrated, both sides or legs of the secondary circuit pass through this valve structure, in order to ensure that closing of the valve will result in complete termination of flow within the secondary circuit. However, for most purposes, it may be sufficient to provide

a simpler type of valve disposed in one leg only of the secondary circuit.

To achieve control of the type aforesaid, the apparatus is provided with a temperature-sensitive switch device 22 responsive to the pressure of a vaporizable fluid contained within a feeler bulb 23, the latter being so disposed as to respond to the temperature of the conditioned air as it flows into contact with the evaporator 10. When this temperature has fallen to a predetermined lower value, such for example as 75° F., the switch device 22 is closed, with the result that the valving apparatus 21, which preferably takes the form of a solenoid-actuated valve of a type now well known, is opened, and flow of refrigerant through the secondary circuit is established. While automatic control of the secondary circuit is preferable, the invention also contemplates, in its broader aspect, use of other means such for example as a manually operable valve. Switch means providing independent control of the compressor is illustrated diagrammatically at 24.

When the apparatus is in operation, sufficient reduction in temperature of the air flowing past the evaporator 10, that is, existence of the condition which requires reduction of the cooling capacity of the machine, causes operation of the switch device 22 and consequent opening of the valve 21. There is of course a very substantial temperature difference between the superheated refrigerant passing through the discharge line 13 and the liquid flowing through line 14, and heat available in the warmer refrigerant flowing through the discharge line causes vaporization of the refrigerant contained in the evaporator portion 19 of the secondary circuit. Portion 19 is disposed at a level below that of condenser portion 20, in order that refrigerant condensed in the latter portion may be returned by gravity to the evaporator section. Vaporized secondary refrigerant flows upwardly through the condenser portion 20, where the latent heat of vaporization is given up to the liquid flowing through the line 14, thereby warming said liquid and, concurrently, returning the secondary refrigerant to the liquid state. As indicated above, this transfer of heat results in vaporization of at least a portion of the liquid refrigerant flowing through line 14 toward evaporator 10. Since a given liquid line and restrictor will pass a very small amount of gaseous refrigerant, by weight, as compared with the weight of liquid refrigerant which may pass therethrough, the effective impedance of the restrictor is increased and the amount of liquid refrigerant flowing to the evaporator is correspondingly diminished. This reduction in flow of liquid, in turn, renders the evaporator less effective as a means for cooling the circulating air, and the condition of reduced flow of liquid toward the evaporator is maintained until the air temperature reaches the upper limit of the control range of switch device 22. When the temperature of the circulating air again rises sufficiently, the switch device 22 recloses the valve 21. The air temperature is maintained within a predetermined range by cyclic repetition of the described operation of the secondary system, and the temperature at which said secondary system comes into operation may be readily varied by adjustment of the switch device 22.

From the foregoing description it will be understood that the present invention provides extremely simple and reliable apparatus for modulating the capacity of a refrigeration machine. The apparatus of the invention is particularly

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characterized by high thermodynamic efficiency, and by the fact that the modulating equipment may be repaired or replaced without necessitating a service shut-down of the main system.

I claim:

1. Refrigeration apparatus comprising a series flow circuit having a high pressure side and a low pressure side, and including: compressor, condenser, restrictor and evaporator elements; a first portion of the high pressure side of said circuit, which portion includes said restrictor, having, in normal operation, warm liquid refrigerant flowing therethrough toward said evaporator, and a second portion of the high pressure side of said circuit having flowing therethrough refrigerant at a temperature substantially elevated as respects the temperature of said warm refrigerant; and heat exchange means for controlling the flow of liquid refrigerant from said condenser to said evaporator by effecting partial volatilization of said warm liquid refrigerant, said last means comprising; a closed secondary refrigeration circuit having an evaporator section disposed in heat exchange relation with said second portion and a condenser section disposed in heat exchange relation with said restrictor, and means for controlling the flow of refrigerant through said secondary circuit.

2. Refrigeration apparatus comprising a series flow circuit having a high pressure side and a low pressure side, and including: compressor, condenser, strainer, restrictor and evaporator elements; a first portion of the high pressure side of said circuit, which portion includes said strainer, having, in normal operation, warm liquid refrigerant flowing therethrough toward said evaporator, and a second portion of the high pressure side of said circuit having flowing therethrough refrigerant at a temperature substantially elevated as respects the temperature of said warm refrigerant; and heat exchange means for controlling the flow of liquid refrigerant from said condenser to said evaporator by effecting partial volatilization of said warm liquid refrigerant, said last means comprising; a closed secondary refrigeration circuit having an evaporator section disposed in heat exchange relation with said second portion and a condenser section disposed in heat exchange relation with said strainer, and means for controlling the flow of refrigerant through said secondary circuit.

3. Refrigeration apparatus comprising a series flow circuit having a high pressure side and a low pressure side, and including: compressor, condenser, restrictor and evaporator elements; a first portion of the high pressure side of said circuit having, in normal operation, warm liquid refrigerant flowing therethrough toward said evaporator, and a second portion of the high pressure side of said circuit having flowing therethrough refrigerant at a temperature substantially elevated as respects the temperature of said warm refrigerant; and heat exchange means for controlling the flow of liquid refrigerant from said condenser to said evaporator by effecting partial volatilization of said warm liquid refrigerant, said last means comprising; a closed secondary refrigeration circuit having an evaporator section disposed in heat exchange relation with said second portion and a condenser section disposed in heat exchange relation with said first portion, and means responsive to the temperature of air cooled by the evaporator to control the flow of refrigerant within said secondary circuit.

4. Refrigeration apparatus comprising a series

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flow circuit having a high pressure side and a low pressure side, and including: compressor, condenser, restrictor and evaporator elements; a first portion of the high pressure side of said circuit having, in normal operation, warm liquid refrigerant flowing therethrough toward said evaporator, and a second portion of the high pressure side of said circuit having flowing therethrough refrigerant at a temperature substantially elevated as respects the temperature of said warm refrigerant; heat exchange means for controlling the flow of liquid refrigerant from said condenser to said evaporator by effecting partial volatilization of said warm liquid refrigerant, said last means comprising a closed secondary refrigeration circuit having an evaporator section disposed in heat exchange relation with said second portion and a condenser section disposed in heat exchange relation with said first portion; and means including a valve disposed in said secondary circuit and operative to control the flow of secondary refrigerant therethrough.

5. Apparatus in accordance with claim 4, and further including temperature-responsive means for actuating said valve.

6. Refrigeration apparatus, comprising: compressor, condenser, and evaporator elements; suction and feed conduit means connecting said elements in series flow circuit, said feed conduit means comprising a discharge line portion interconnecting said compressor and said condenser and a liquid line portion which includes a restrictor and through which liquid derived from said condenser flows toward and into said evaporator; and heat exchange means for controlling the flow of liquid refrigerant from said condenser to said evaporator by effecting partial volatilization of said liquid refrigerant, said last means comprising a closed secondary refrigeration circuit having an evaporator section disposed in heat exchange relation with said discharge line portion and a condenser section disposed in heat exchange relation with said liquid line portion.

7. Refrigeration apparatus, comprising: compressor, condenser, and evaporator elements; suction and feed conduit means connecting said elements in series flow circuit, said feed conduit means comprising a discharge line portion interconnecting said compressor and said condenser and a liquid line portion which includes a restrictor and through which liquid derived from said condenser flows toward and into said evaporator; and heat exchange means for controlling the flow of liquid refrigerant from said condenser to said evaporator by effecting partial volatilization of said liquid refrigerant, said last means comprising a closed secondary refrigeration circuit having an evaporator section disposed in heat exchange relation with said discharge line portion and a condenser section disposed in heat exchange relation with said liquid line portion, between said condenser and said restrictor.

8. Refrigeration apparatus, comprising: compressor, condenser, and evaporator elements; suction and feed conduit means connecting said elements in series flow circuit, said feed conduit means comprising a discharge line portion interconnecting said compressor and said condenser and a liquid line portion which includes a restrictor and through which liquid derived from said condenser flows toward and into said evaporator; heat exchange means for controlling the flow of liquid refrigerant from said condenser to said evaporator by effecting partial volatilization of said liquid refrigerant, said last means com-

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prising a closed secondary refrigeration circuit having an evaporator section disposed in heat exchange relation with said discharge line portion and a condenser section disposed in heat exchange relation with said liquid line portion; and means including a valve disposed in said secondary circuit and operative to control the flow of secondary refrigerant therethrough.

9. Apparatus in accordance with claim 6, and further including means responsive to the temperature of air cooled by said evaporator to control the flow of refrigerant within said secondary circuit.

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10. Apparatus in accordance with claim 6, and further including a valve disposed in said secondary circuit and temperature-responsive means for actuating said valve to control the flow of refrigerant through said secondary circuit.

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