June 1, 1943. C. F. HENNEY 2,320,432

REFRIGERATING APPARATUS

Filed Oct. 24, 1939 3 Sheets-Sheet 1

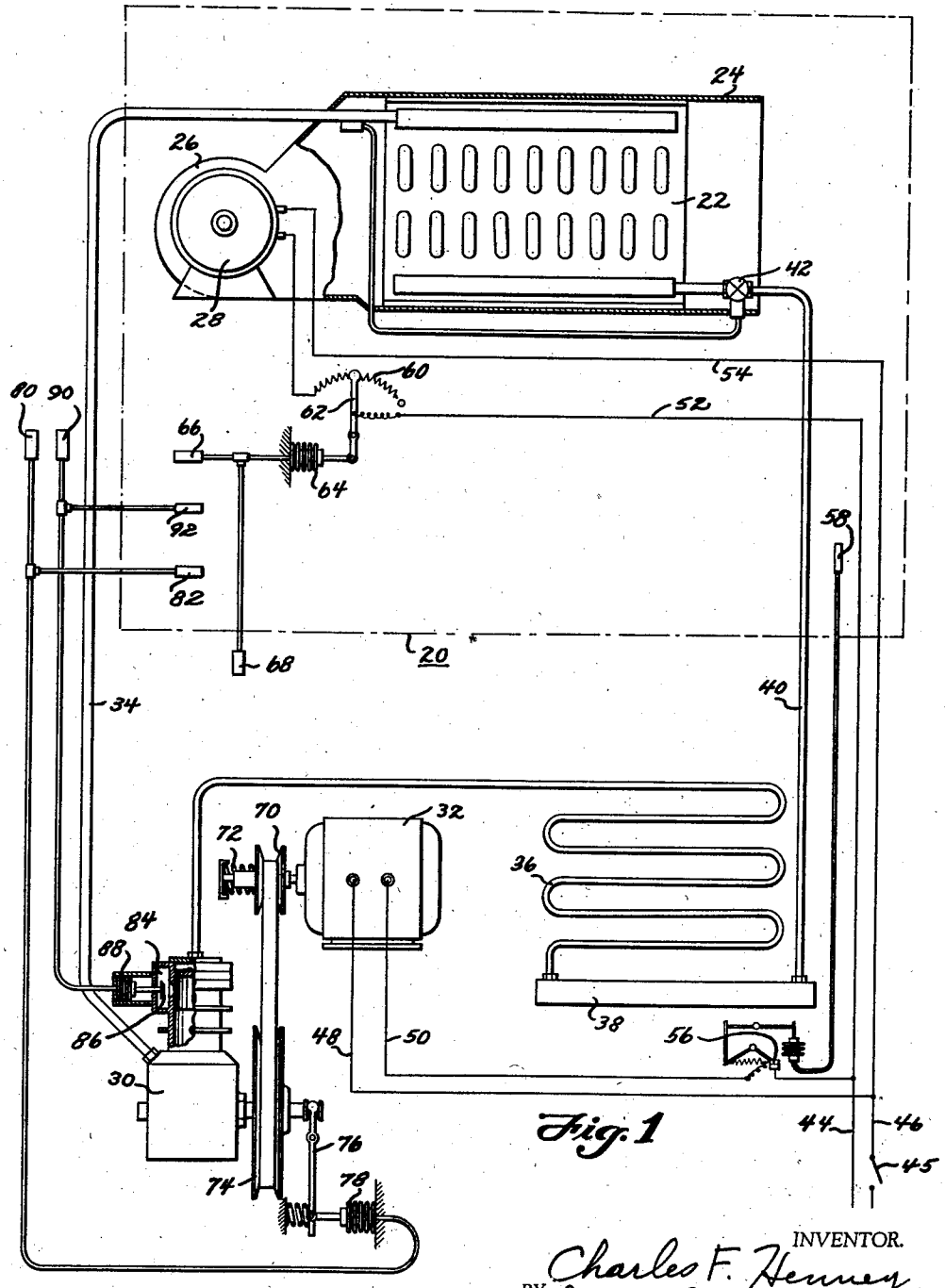


Fig. 1

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REFRIGERATING APPARATUS

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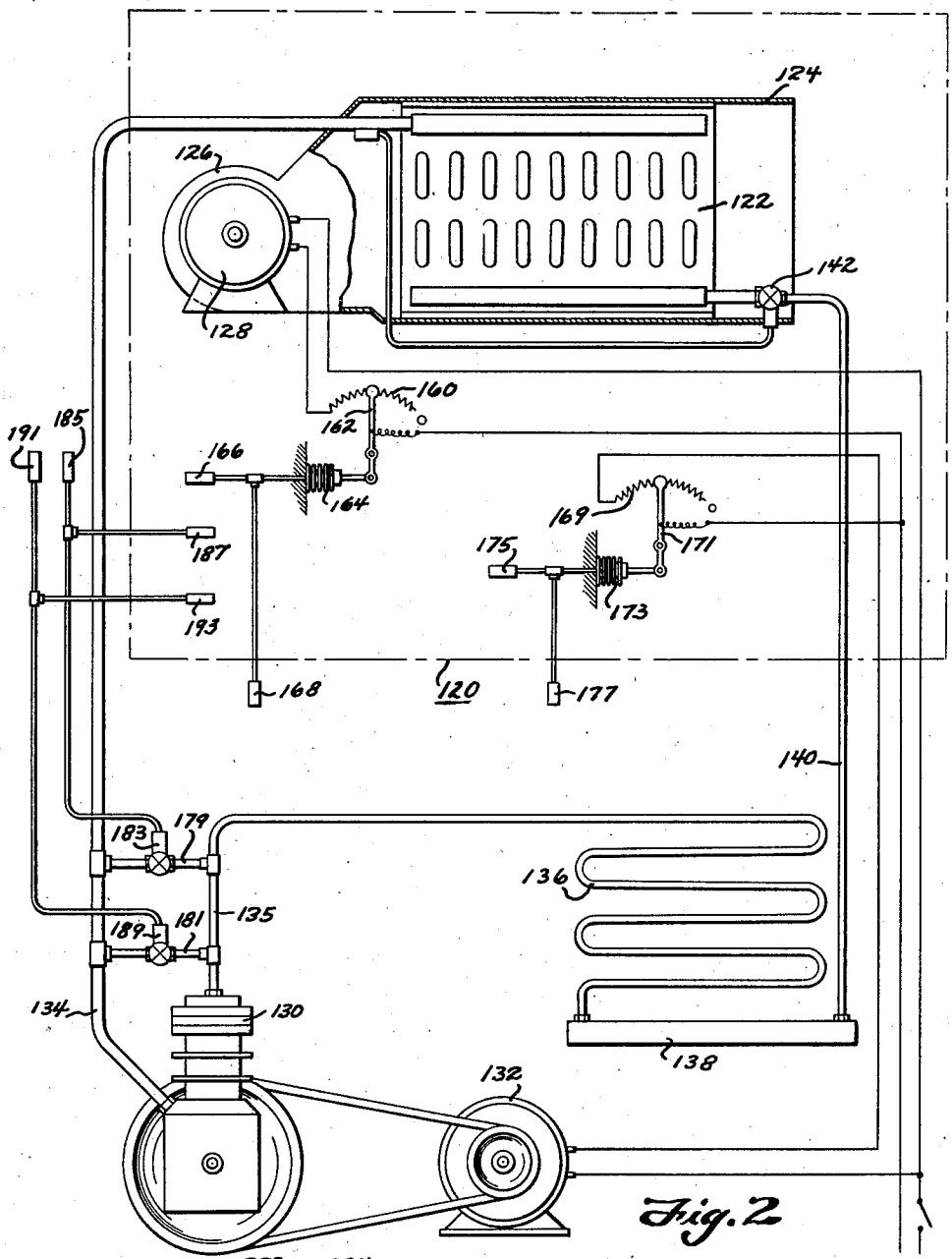


Fig. 2

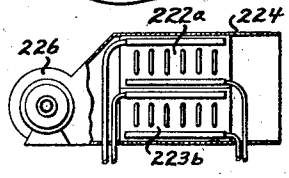


Fig. 3

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REFRIGERATING APPARATUS

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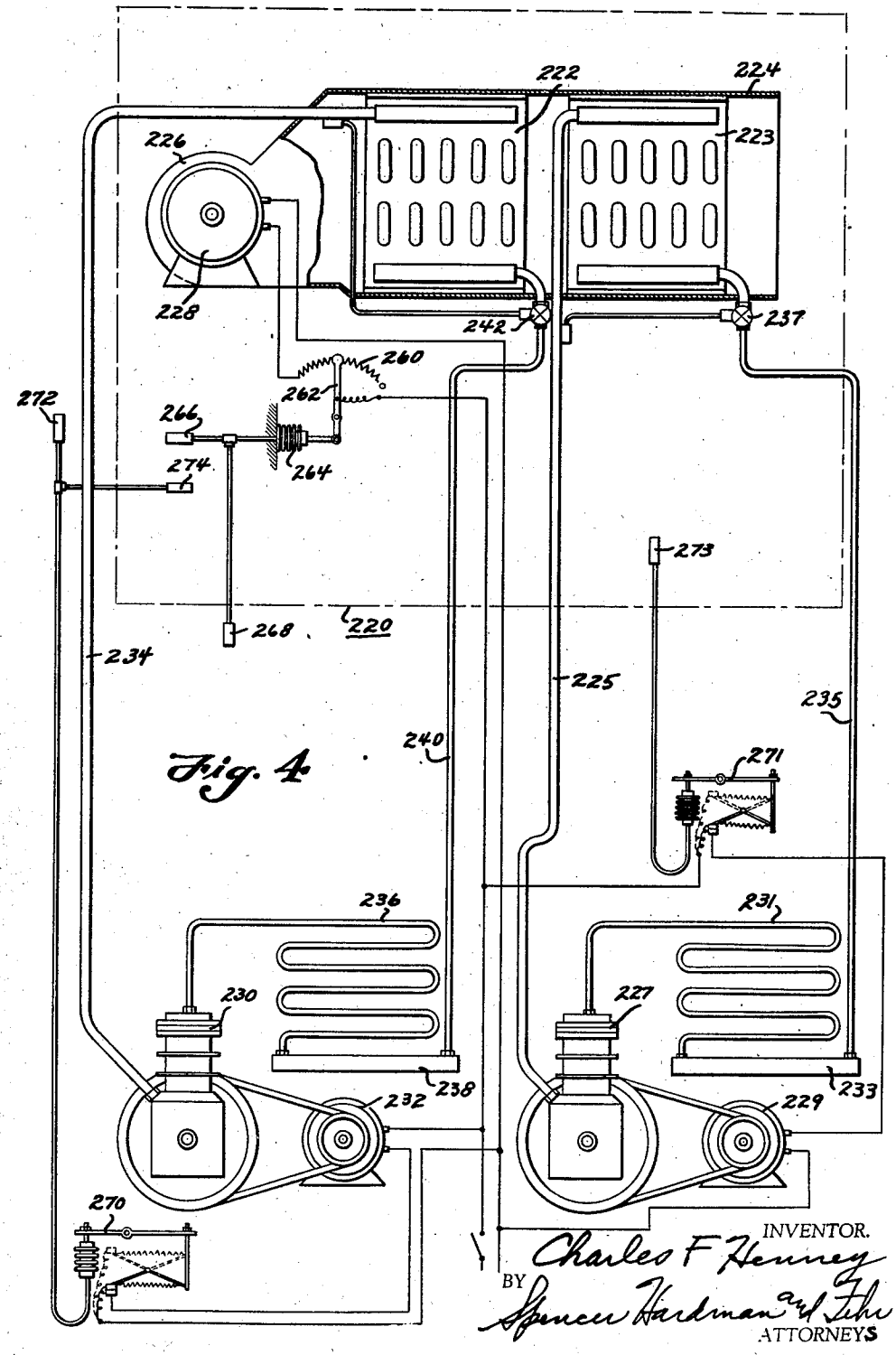


Fig. 4.

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2,320,432

REFRIGERATING APPARATUS

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Application October 24, 1939, Serial No. 301,016

5 Claims. (Cl. 62—6)

This invention relates to refrigerating apparatus and more particularly to air conditioning means and controls for reducing the capacity of the system during light loads.

Air conditioning means employing mechanical refrigeration are designed for properly cooling the enclosure under extreme outside temperatures, for example, 110° F. This amount of cooling is too great for normal temperature conditions and it is therefore customary to cycle the refrigerating system in order to reduce the amount of cooling. Since the cooling unit operates above freezing temperatures and is provided with a fan for circulating the air through the passages in the cooling unit, water condenses and collects upon the cooling unit during the operation of the refrigerating system. However, when the refrigerating system is stopped, the fan continues to operate and blows and evaporates water off the cooling unit, thereby adding to the humidity of the air in the enclosure. This effect is increased and becomes more undesirable as the outside temperature is reduced, since it causes more frequent cycling and higher humidities.

It is therefore an object of my invention to reduce the capacity of the refrigerating system without cycling of the entire refrigerating system to reduce the refrigerant capacity for light loads.

It is another object of my invention to provide suitable automatic controls for controlling the reduction in capacity of a refrigerating system for air conditioning.

It is a more specific object of my invention to provide automatic controls for controlling the reduction of air circulation and heat transfer between the cooling unit and the air in air conditioning.

It is still another object of my invention to provide suitable automatic controls for reducing the speed of refrigerating apparatus for air conditioning.

It is another object of my invention to provide automatic controls for reducing the volumetric efficiency of the compressor of the refrigerating apparatus.

Further objects and advantages of the present invention will be apparent from the following description, reference being had to the accompanying drawings wherein a preferred form of the present invention is clearly shown.

In the drawings:

Fig. 1 is a diagrammatic view illustrating one form of my invention;

Fig. 2 is another diagrammatic view illustrating another form of my invention;

Fig. 3 is a fragmentary view showing a modification of the air circulating and cooling unit of Fig. 4; and

Fig. 4 is another diagrammatic view showing another modified form of my invention.

Briefly, in Fig. 1, I have shown a mechanical refrigerating system having a finned tube evaporator through which air is circulated from the enclosure by an electric fan which has its speed controlled in accordance with inside and outside temperatures substantially in the proportions of 1 to 3. A variable speed drive is provided between the compressor driving motor and the compressor which reduces the speed of the compressor when the outside temperature falls. An expansion chamber controlled by inside and outside temperatures is provided on the compressor for providing a further reduction in compressor capacity. These two means may operate in steps to so that the speed is first reduced and thereafter, to provide a greater reduction in capacity, the capacity chamber is opened. However, any one or any combination of means of any modification disclosed herein may be employed to obtain desired reduction in capacity.

Fig. 2 is provided with a similar cooling unit and electrically controlled fan. In this system, the speed of the compressor driving motor is controlled by a variable resistance in accordance with changes in inside and outside temperature to provide further reduction in capacity. Restricted by-passes controlled by thermostatically controlled valves arranged to operate in steps are also provided.

In Fig. 4, the fan circulates the air through two cooling units which are connected to independent refrigerating systems. These systems are controlled so that they are stopped in steps so that first one system stops and at a lower temperature the second system stops so that the reduction in capacity is in several steps rather than by ordinary cycling. In Fig. 3, the two cooling units are arranged one above the other in the duct to mix the air when the lower unit is rendered inoperative.

Referring now to the drawings and more particularly to Fig. 1, there is shown an enclosure generally designated by the reference character **20** containing a cooling unit **22** of the fin and tube type which is mounted in an air duct **24** which discharges into the enclosure at one end and at the other end is connected to a centrifugal fan **26** which is driven by an electric motor

28. The fan 26 draws air from the enclosure and forces the air through the finned passages in the cooling unit 22, after which the air is discharged through the duct 24 into the enclosure.

The cooling unit 22 is supplied with liquid refrigerant by a liquefying means which includes the compressor 30 driven through pulley and belt means by the electric motor 32. The refrigerant is withdrawn from the cooling unit 22 through the suction conduit 34 by the compressor and pumped into the condenser 36 where the compressed refrigerant is liquefied and collected in the receiver 38. From the receiver 38 the liquid refrigerant is supplied through a liquid supply line 40 under the control of an automatic thermostatic expansion valve 42 to the inlet of the cooling unit 22.

The electric motor 32 is supplied with electric energy through the common conductors 44 and 46 and the branch conductors 48 and 50 which connect to the common conductors 44 and 46. The electric motor 28 which drives the fan 26 is supplied with electric energy through the common conductors 44 and 46 and through the branch conductors 52 and 54. A switch 45 is provided for deenergizing both motors.

Heretofore, it has been customary to control the refrigerating system by a switch 56 placed in series with one of the branch conductors 50 and controlled by a thermostat bulb 58 in the enclosure 20. It was found, however, that such a system cycled frequently under ordinary conditions producing an undesirable fluctuation in temperature and humidity, and particularly provided undesirably humid conditions within the enclosure. One of the particularly objectionable features of this arrangement was that moisture would condense upon the cooling unit 22 and accumulate during the operating cycle of the system and when the compressor was stopped the fan 26, which would remain in operation, would blow and evaporate the accumulated water and condensation off the cooling unit into the air in the enclosure. This provided an undesirable increase in the humidity in the enclosure and in general provided an average humidity which was higher than comfortable under light load conditions when the outside temperature was much less than the maximum temperature conditions for which the system was designed. For example, it is customary to design a system to provide adequate cooling capacity for an outside temperature of 110° F. whereas normally the temperature is only 80° F. or 90° F. during most of the summer. Therefore, under normal conditions, this frequent cycling took place with the undesirable humidity conditions being produced by such a system.

As a first step in preventing the frequent cycling of the compressor and for reducing the humidity under low temperature conditions, I have provided a means for reducing the speed of the motor 28 and the fan 26 which circulate the air through the finned passages of the cooling unit 22. This reduces the amount of air flowing through the cooling unit and therefore causes a greater reduction in temperature of this air and more moisture condensation so that more moisture is removed from the air by the cooling unit and the humidity condition is thereby avoided. While any of the different forms of speed reduction of an electric motor may be employed, I have shown for purposes of illustration an automatic rheostat including a resistance coil 60 and a tap 62 which is in the form of a lever operated by the bellows 64. The bellows 64 is connected by tubing to a thermostat bulb 66 located inside the enclosure 20 and a thermostat bulb 68 located outside the enclosure 20.

Preferably, these bulbs are each charged with activated charcoal and the system is charged with some suitable non-condensible gas, such as carbon dioxide. Preferably, the amount and effectiveness of the charcoal in the bulb 68 is approximately three times the amount and effectiveness of the charcoal in the bulb 66, since it is desirable that the effective control of the fan 26 be in that proportion to inside and outside temperatures. These bulbs may be ordinary dry bulbs or they may be responsive to effective temperatures or to wet bulb temperature if desired. If the compressor capacity is unchanged, the rheostat 60 may be proportioned to provide a reduction in air circulation through the cooling unit 22 of about 25% or more. However, if means are provided for decreasing the capacity of the compressor as illustrated in Fig. 1, the speed and capacity of the fan may be reduced to provide a reduction in air circulation of as much as 50% or more. As an alternative, the speed and capacity of the fan 26 may be controlled by a humidity device in response to relative or absolute humidity within the enclosure.

In order to provide a reduction in capacity of the compressor 30, I have provided a variable speed drive between the driving motor 32 and the compressor 30. In order to do this, I have employed a V-belt and V-belt type pulleys. The pulley 70 upon the motor 32 has one or both flanges axially movable with the flanges held in engagement with the sides of the belt by a coil spring 72. The large pulley on the compressor 30 is also provided with axially movable flanges 74 which are moved together or apart by a lever mechanism 76 operated by the pressure within the bellows 78. The bellows 78 is connected to a thermostatic bulb 80 located outside the enclosure and to a thermostat bulb 82 located inside the enclosure 20. Preferably, these bulbs are filled with activated charcoal and the system is charged with carbon dioxide. Preferably, the bulb 80 is provided with charcoal having three times the adsorption capacity of the charcoal in the bulb 82 so that changes in the outdoor temperature will have three times as much effect as changes in the inside temperature. Instead of controlling by temperature, a humidity device responsive to relative or absolute humidity within the enclosure may be used to control the speed reduction.

In order to provide an additional reduction in compressor capacity beyond the limits of a speed reducing device, I provide a capacity chamber 84 which is connected to the compression space of the compressor cylinder by a port which is normally closed by a valve 86 operated by the bellows 88. This bellows is connected to the bulbs 90 and 92. The bulb 90 is located outside the enclosure 20 and contains activated charcoal having an adsorption capacity preferably about three times the activated charcoal contained in the bulb 92 which is located inside the enclosure 20. The bellows 88 and the bulbs 90 and 92 are preferably charged with a gas, such as carbon dioxide, which can be adsorbed and evolved from the charcoal according to changes of temperature. All of these bulbs may be either wet or dry or made responsive to effective temperature or relative or absolute humidity.

When the speed reduction device for the elec-

tric motor 28 is used in connection with the speed reducing means forming a part of the belt drive between the motor 32 and the compressor 30, a speed reduction of as much as 50% may be provided for both the fan motor 28 and the compressor 30. This will greatly reduce the cycling of the compressor 30 under the control of the thermostat 58. It will also prevent the high humidities which have occurred heretofore in the systems as they have been designed. Preferably, the capacity chamber 84 is not used until the maximum amount of speed reduction takes place. Thus, this system should be set so that the valve 86 does not open until the maximum speed reduction has taken place.

In Fig. 2 there is provided a somewhat similar system in which the enclosure 120 is provided with an evaporator 122 located in the duct 124 through which air is circulated by the fan 126 which draws air from the enclosure 120 and forces it through the evaporator 122 after which the cooled air is discharged from the duct 124 in the enclosure 120. As before, the fan is driven by an electric motor 128 which is under the control of a rheostat 160 provided with a tap lever 162 for varying the resistance of the rheostat under the control of the bellows 164 which is connected to the bulbs 166 and 168. The bulb 168 is preferably located outside the enclosure 120 so that it is responsive to outside air temperature while the bulb 166 is mounted within the enclosure 120. As mentioned before, the bulb 163 may contain activated charcoal having an adsorption capacity about three times that of the charcoal provided in the bulb 166. This bulb system is preferably charged with carbon dioxide or some other suitable gas for this purpose.

The evaporator 122 is supplied with liquid refrigerant by liquefying means which includes the compressor 130 driven by an electric motor 132 for withdrawing evaporated refrigerant through the suction conduit 134 and for forwarding the compressed refrigerant to the condenser 136 where the compressed refrigerant liquefies and is collected in the receiver 138. The liquid refrigerant is forwarded to the evaporator 122 through the liquid supply conduit 140 under the control of the thermostatic automatic expansion valve 142.

In order to reduce the capacity of the compressor under light load conditions, I provide a rheostat 169 which is similar to the rheostat 160 and is located in series with the compressor driving motor 132 for reducing the speed of this motor. This rheostat includes a tap lever 171 operated by the bellows 173 under the control of the thermostat bulbs 175 and 177. Each of these bulbs preferably contains activated charcoal and carbon dioxide. The bulb 177 is located outside the enclosure 120 so that it is responsive to outside air temperature and is preferably provided with activated charcoal having three times the adsorption capacity of the charcoal provided in the bulb 175 located within the enclosure 120. The rheostat 169 may also be used for stopping the compressor when the speed of the motor 132 is reduced to a predetermined minimum amount. Preferably, the speed of the motors 128 and 132 are reduced to about 50% to provide a reduction in refrigerating capacity to prevent short cycling of the compressor and to avoid high humidity conditions under light loads.

In order to provide a further reduction in refrigerating capacity, I provide two restricted bypasses 179 and 181 which connect the suction conduit 134 and the conduit 135 connecting the outlet of the compressor and the condenser 136. The by-pass 179 is controlled by valve 183 operated in accordance with the temperatures of the thermostat bulbs 185 and 187 located respectively outside and inside the enclosure 120. These bulbs are charged similarly to the other bulbs in the proportion of about 1 to 3 or some other desired proportion. Likewise, the by-pass 181 is provided with a valve 189 operated in accordance with the temperature of the bulbs 191 and 193 located respectively inside and outside the enclosure and charged in a manner similar to the bulbs 185 and 187. These bulbs may be dry bulbs, wet bulbs, or responsive to effective temperature, or controls responsive to relative or absolute humidity within the enclosure may be used. Preferably, these valves do not open until after substantially the maximum speed reduction of the motor 132 is attained and then first one valve will open to attain further reduction in capacity, after which the other valve will open to attain an additional reduction in capacity. In this way, the capacity of the system is reduced, short cycling is prevented and the humidity can thus be kept within desired limits.

In Fig. 4 there is provided another means for providing a reduction in capacity in the form of steps. In this figure, there is provided an enclosure 220 containing a duct 224 through which air is circulated from the enclosure by the centrifugal fan 226 which is driven by an electric motor 228. Refrigerant evaporators 222 and 223 are mounted in series within the duct 224 so that the air drawn from the enclosure 220 will pass through both evaporators 222 and 223, after which it is discharged again in the enclosure. These two evaporating means are connected to separate refrigerating systems, but if desired, they may be connected in multiple or series relation in a single refrigerating system. When connected in multiple, the common suction line may be provided with a valve for maintaining a desired pressure in the evaporators and a shut-off thermostatic valve may be provided in one of the branch liquid lines. A by-pass provided with an automatic expansion valve may then be used between the common liquid line and the compressor inlet.

As shown, the evaporator 223 is connected by a suction conduit 225 to a compressor 227 driven by an electric motor 229. The compressor 227 withdraws evaporated refrigerant from the evaporator 223 through the suction conduit 225 and the compressed refrigerant is liquefied in the condenser 231 and collected in the receiver 233. A liquid supply conduit 235 conducts the liquid refrigerant from the receiver 233 to the inlet of the evaporating means 223 under the control of the thermostatic automatic expansion valve 237.

The evaporator 222 is connected by the suction conduit 234 to the compressor 230 driven by the electric motor 232. This compressor 230 withdraws evaporated refrigerant from the evaporator 222 through the suction conduit 234 and forwards the compressed refrigerant to the condenser 236 where the compressed refrigerant is liquefied and collected in the receiver 238. The liquid in the receiver 238 is conducted through the liquid supply conduit 240 to the inlet of the evaporator 222 under the control of the thermostatic automatic expansion valve 242. While these systems have been described as being of the widely used dry expansion type, other types of refrigerating systems may be used if desired.

In this arrangement, I have again provided a rheostat **260** controlled by the tap lever **262** operated by the bellows **264** under the control of the charcoal filled bulbs **266** and **268** located inside and outside the enclosure for reducing the speed of the motor **228** and the fan **226** as the temperature and the refrigerating load becomes less. This causes a reduction in air-flow through each of the evaporating means **222** and **223** and thereby reduces the load on the compressors and thus permits the operation of the systems at lower back pressures and lower evaporator temperatures which causes more condensation of moisture from the air flowing over the evaporator surface, thus reducing the humidity to a greater extent. The operation of the systems at lower back pressures also reduces their capacity and the cycling of the compressor.

However, in order to provide a further reduction in capacity as the temperature is lowered, the system including the evaporator **223** is stopped when the temperature and the air within the enclosure reaches a certain limit. For this purpose, a snap-acting switch **271** operated in accordance with the temperature thermostat bulb **273** within the enclosure **220** is provided. This bulb **273** and switch **271** may operate in accordance with dry, wet bulb or effective temperature or relative or absolute humidity. This switch is connected in series with the motor **229** which drives the compressor **227**. Thus, by this switch **271**, when the temperature of the air within the enclosure **220** reaches a certain limit, the compressor **227** is stopped, thus stopping evaporation within the evaporator **223**. The other system connected to the evaporator **222** continues its operation after the switch **271** is open. This other system, however, is also provided with a snap acting switch **270** connected in series with the motor **232**. This switch **270** is connected to and operated in accordance with the temperatures of the charcoal and carbon dioxide filled thermostat bulbs **272** and **274** located outside and inside the enclosure **220**. Preferably, the charcoal in the bulb **272** has approximately three times the adsorption capacity of the charcoal in the bulb **274**. All of the bulbs in this system may be either dry bulbs, wet bulbs or effective temperature bulbs so that they may be responsive to temperature or humidity or a combination of temperature and humidity. The switch **270** is so set that it will cycle only at temperatures below the temperature at which switch **271** opens. Thus, at the lower temperatures, the evaporator **222** will cycle after the evaporator **223** becomes inoperative. These cycles will be comparatively long since only a part of the refrigerating capacity is being used. This system is quite efficient since short cycling is prevented and each system operates at substantially its maximum efficiency whenever it is in operation.

In Fig. 3, I have shown a modified arrangement of the two evaporators in the duct **224**. In this arrangement, the evaporator **222***a* is placed above the evaporator **223***b*. In this figure, the evaporator **222***a* corresponds to the evaporator **222** and is connected to a similar refrigerating system while the evaporator **223***b* corresponds to the evaporator **223** and is connected to a similar refrigerating system. Thus, in this arrangement, when the air is circulated through the duct **224** by the fan **226**, the air will flow through the evaporators **222***a* and **223***b* in parallel. When both evaporators are in operation, the effect will be substantially the same as in Fig. 4. However, when evaporator **223***b* becomes inoperative, the air will pass through its passages without being materially cooled. This air, therefore, will be relatively warm and will tend to rise. However, the air passing through the evaporator **222***a* will be cooled and will tend to fall. Thus, after passing through the evaporators, the air will tend to mix because the upper air will be cooled and will tend to fall and the lower air will be warm and will tend to rise. This arrangement has the further advantage in that a greater amount of dehumidification will be performed, since only one-half the air passes through the evaporator **222***a* and, therefore, this air will be cooled to a greater extent than in the arrangement shown in Fig. 4.

While the form of embodiment of the invention as herein disclosed constitutes a preferred form, it is to be understood that other forms might be adopted, all coming within the scope of the claims which follow.

What is claimed is as follows:

1. Refrigerating apparatus for an enclosure to be cooled and dehumidified comprising in combination, an evaporator, a condenser, a compressor, refrigerant flow connections between said evaporator compressor and condenser, fan means for flowing air over said evaporator, means responsive to the dry bulb temperature in said enclosure for varying the flow of air over said evaporator, and means responsive to the dry bulb temperature of the air for passing a portion of the refrigerant directly from the high side of said compressor to the low side of said compressor.

2. Refrigerating apparatus for an enclosure to be cooled and dehumidified comprising in combination, evaporator means, condenser means, compressor means, refrigerant flow connections between said evaporator means, condenser means and compressor means, means for flowing air to be conditioned in thermal exchange with said evaporator means, means influenced by the outside air temperature for reducing the rate of cooling of the air by said evaporator as the outside air temperature decreases, means for by-passing a portion of the refrigerant discharged by said compressor means directly to the intake of the compressor, and means responsive to the inside air temperature controlling the flow of refrigerant through said by-pass.

3. In combination, evaporator means, condenser means, a compressor, refrigerant flow connections between said evaporator means, condenser means and said compressor, means for flowing air to be conditioned in thermal exchange with said evaporator means so as to cool and dehumidify said air, means for varying the amount of air cooled and dehumidified by said evaporator means, means for varying the effective output per stroke of said compressor, and means for varying the speed of said compressor, said last named means including means responsive to the outdoor air temperature.

4. Refrigerating apparatus for an enclosure to be cooled and dehumidified comprising in combination, evaporator means, condenser means, a compressor, refrigerant flow connections between said evaporator means, compressor and condenser means, fan means for flowing air to be cooled and dehumidified in thermal exchange with said evaporator means so as to cool and dehumidify the air, means for decreasing the rate of cooling of said air by said evaporator means as the outside air temperature decreases, and means responsive to the temperature of the air in said enclosure for passing a portion of the refrigerant

directly from the high side of said compressor to the low side of said compressor.

5. Refrigerating apparatus for an enclosure to be cooled and dehumidified comprising in combination, evaporator means, condenser means, a compressor, refrigerant flow connections between said evaporator means, compressor and condenser means, fan means for flowing air to be cooled and dehumidified in thermal exchange with said evaporator means so as to cool and dehumidify the air, means for decreasing the rate of cooling of said air by said evaporator means as the outside air temperature decreases, means responsive to the temperature of the air in said enclosure for passing a portion of the refrigerant directly from the high side of said compressor to the low side of said compressor, and means for varying the speed of said compressor.

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