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H. F. SMITH

2,318,893

REFRIGERATING APPARATUS

Filed Nov. 22, 1939

2 Sheets-Sheet 1

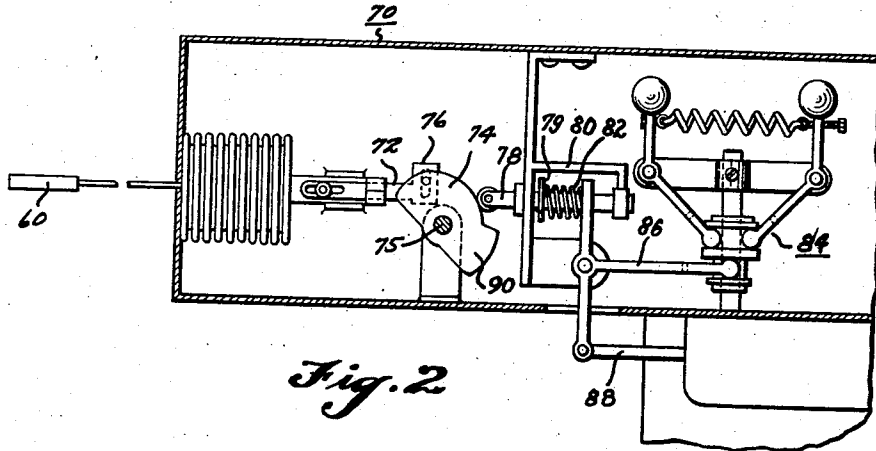


Fig. 2

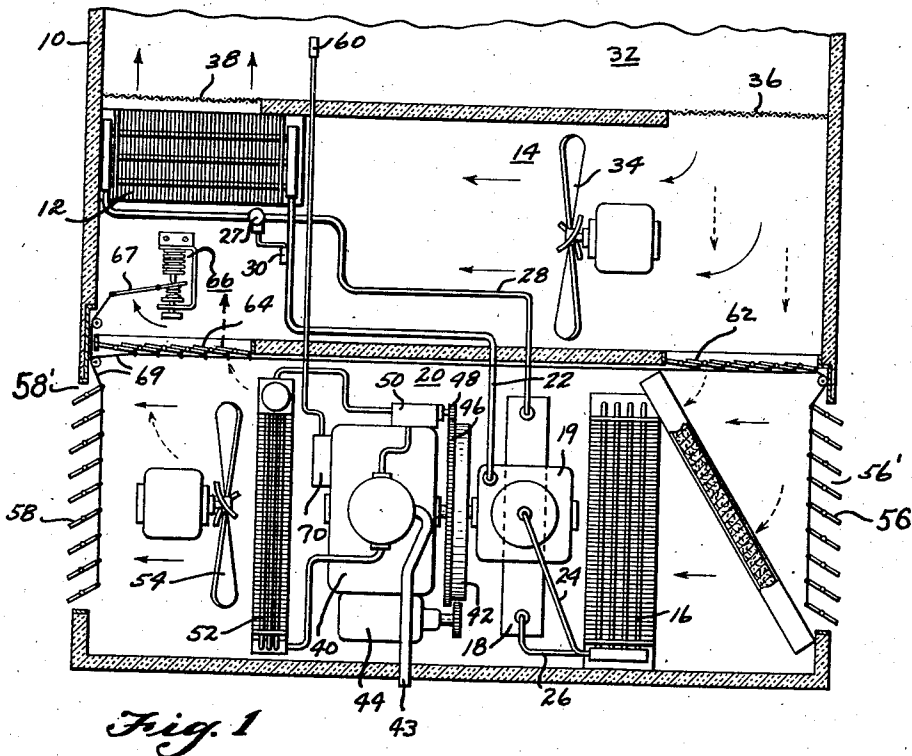


Fig. 1

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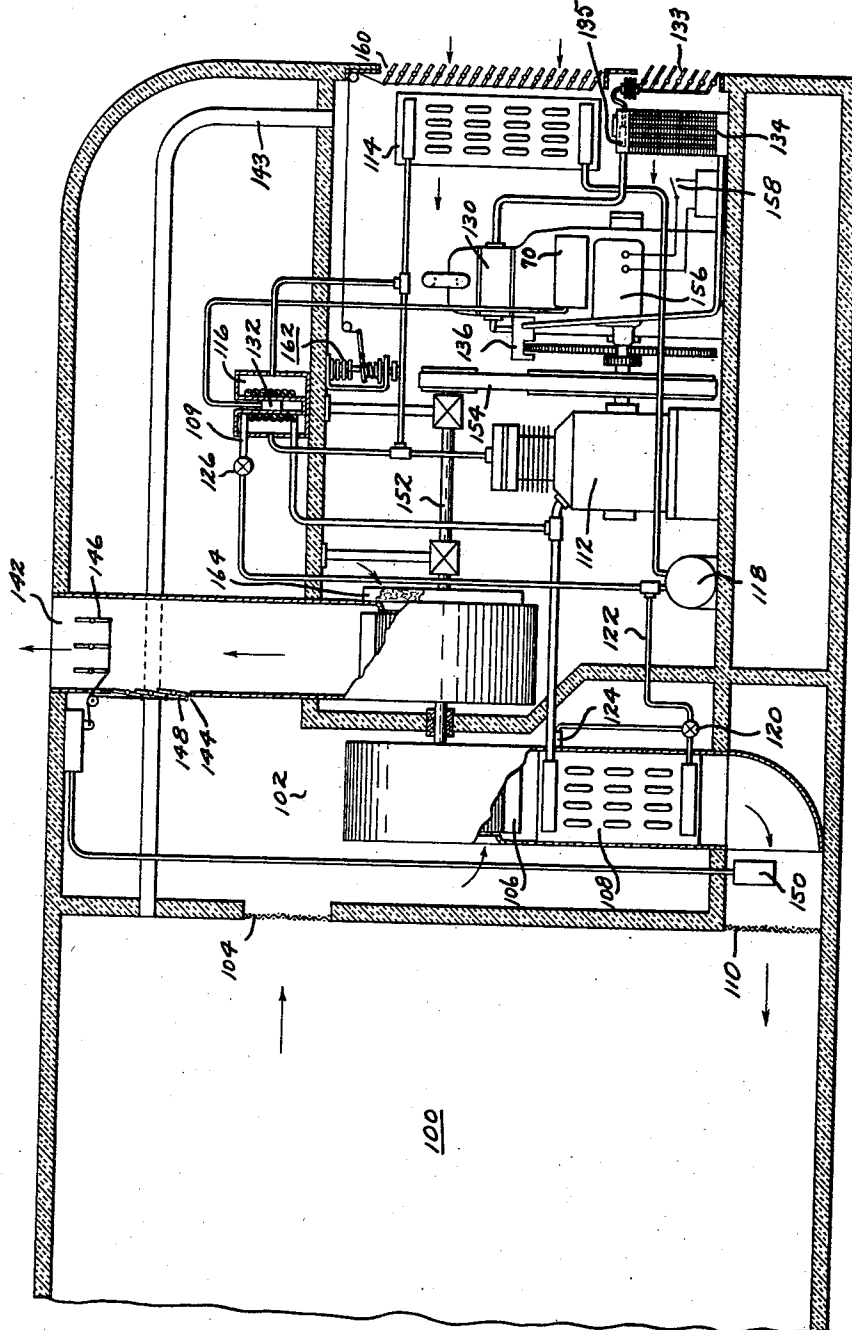


Fig. 3

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UNITED STATES PATENT OFFICE

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REFRIGERATING APPARATUS

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11 Claims. (Cl. 257—3)

This invention relates to refrigeration and more particularly to a refrigerating system for use in railway cars, storage warehouses and the like in which a Diesel engine is used for supplying power for the system.

One object of this invention is to provide an improved control system whereby more uniform temperatures may be maintained.

Another object of this invention is to provide an arrangement in which waste heat from the Diesel engine may be utilized in tempering the air.

Another object of this invention is to provide a Diesel engine operated refrigerating system which is suitable for mounting in a small space such as ordinarily available in a railway car.

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 plan view with parts broken away showing the general arrangement of the conditioning apparatus;

Fig. 2 is a fragmentary sectional view showing the speed control mechanism; and

Fig. 3 is a sectional elevational view with parts broken away showing a modified arrangement with a modified control system.

In designing a refrigerating system for use in railway cars, warehouses and the like, it is necessary to provide a system which has ample refrigeration capacity for the hottest weather encountered and which is capable of maintaining the temperature within a predetermined range even when the outdoor temperature is colder than the desired indoor temperature. This is especially necessary in freight car installations since it frequently happens that freight cars are used in transporting perishable products from warm climates where cooling alone is necessary to colder climates where at least a small amount of heating is required. In certain climates cooling alone is necessary except for a few cold days during the year when a small amount of heating is required. For purposes of illustration, I have shown these systems applied to a railway car adapted for transporting perishable goods which require uniformly cool temperatures.

Referring to Fig. 1, which is a plan view showing my apparatus mounted in the end compartment of a refrigerated car 10, the refrigerating system comprises an evaporator 12 mounted in a cooling chamber 14, and refrigerant liquefy-

ing apparatus comprising a condenser 16, a receiver 18, and a compressor 19, all mounted in the machine compartment 20. The refrigerant evaporated in the evaporator 12 flows through the vapor line 22 into the compressor 19 which compresses the refrigerant and discharges the compressed refrigerant through the line 24 leading to the condenser 16. Refrigerant condensed by the condenser 16 flows through the line 26 to the liquid refrigerant receiver 18 whence it flows through the line 28 into the evaporator 12. The flow of liquid refrigerant from the receiver 18 to the evaporator 12 is controlled by means of the usual form of thermostatic expansion valve 27 placed in the liquid line 28. This thermostatic expansion valve 27 is provided with a thermostat 30 in thermal exchange with the vapor line 22 so as to automatically throttle the flow of refrigerant to the evaporator in the event that liquid refrigerant spills over into the vapor line 22.

Air from the storage compartment 32 is circulated over the evaporator 12 by means of the fan 34 which withdraws air from the compartment 32 through the opening 36 and discharges the conditioned air into the compartment 32 through the outlet 38. The compressor 19 is driven by the Diesel engine 40 which is provided with the usual flywheel 42 and exhaust pipe 43. A conventional electric starter 44 is provided for starting the Diesel engine. The flywheel 42 is provided with gear teeth 46 which mesh with the pinion 48 of the water circulating pump 50. The pump 50 circulates cooling water for the engine through the engine radiator 52. With the arrangement shown in this modification, the Diesel engine is normally operated continuously while the car is in use, and therefore no special circuit is necessary for automatically starting and stopping the Diesel engine. The starter 44, therefore, may be manually controlled. In order to cause circulation of air over the condenser 16, the compressor 19, the Diesel engine 40 and the engine radiator 52, I have provided a fan 54 which normally draws outside air in through the opening 56' at the one side of the car and discharges the heated air through the opening 58' disposed on the opposite side of the car. The speed of the Diesel engine is controlled by means of a thermostat 60 which, for purposes of illustration, has been shown as mounted in the storage compartment 32. In order to simplify this description, all controls will be referred to as thermostats; however, humidity or effective temperature responsive in-

struments may be substituted therefor. As the temperature in the space 32 increases, the speed of the Diesel engine is caused to increase so as to increase the refrigeration capacity of the refrigerating system. Inasmuch as it sometimes happens that it is necessary to supply heat to the storage compartment rather than cooling the storage compartment, I have provided a set of dampers 62 and 64 which when open permit a portion of the air from the compartment 32 to pass over the condenser 16, the compressor 19, the Diesel engine 46, the radiator 52, evaporator 12, and thence through the outlet 38 leading to the storage compartment.

Inasmuch as the amount of heat given off by the Diesel engine depends in part upon the load placed on the engine, and inasmuch as the load on the Diesel engine is ordinarily the least when the least amount of cooling is required and the outside air is at a low temperature, it is desirable to provide means for conserving on the heat generated by the Diesel engine and, in fact, increasing the heat generated by the Diesel engine under certain conditions when a greater amount of heat is required. In order to increase the amount of heat available for heating the storage compartment, I have provided a thermostat 66 for automatically controlling the dampers 56, 58, 62 and 64. When the temperature of the air passing over the thermostat 66 is not sufficiently warm, the thermostat 66 causes the dampers 56 and 58 to at least partially close and the dampers 62 and 64 to open a corresponding amount. In other words, when it is desirable to add heat to the air in the compartment 32, the dampers 62 and 64 are opened and the dampers 56 and 58 are closed sufficiently to make available additional heat.

The extent of movement of the various dampers will be determined by the temperature of the air surrounding the temperature responsive element 66. The element 66 actuates the dampers through the pivoted lever 67 which operates the damper operating cords 68.

By virtue of the above described arrangement the load on the engine is increased since the circulation of hot air from the engine compartment over the evaporator 12 increases the load on the compressor. By increasing the load on the engine in this manner the temperature of the air delivered to the compartment 32 is increased. This arrangement also prevents frost-up of the evaporator at such times when the air in the compartment 32 is at a low temperature.

It will be observed that a certain amount of intermixing of fresh air and recirculated air will take place when the dampers are moved from the position shown in Fig. 1 to a position intermediate fully open and fully closed position. Some of this fresh air will find its way into the compartment 32 as a result thereof. Consequently, when damper 64 is partly open and damper 56 is only partly closed, the temperature of the outside air will partly determine the temperature of the air circulating over the member 66 and to this extent the temperature of the outdoor air will influence the operation of the refrigerating apparatus.

In Fig. 2 I have shown the engine throttling mechanism 70. As shown therein, variation in temperature at 60 causes reciprocation of the extensible slide member 72 which oscillates the cam 74 by means of the pin and slot connection 76. The cam 74 is mounted to oscillate about the fixed pivot 75. The cam 74 actuates the follower 78 which is slidably mounted on the bracket 80.

The follower 78 is provided with a shoulder element 79 which acts against the spring 82 which when compressed serves to load the centrifugal governor 84 in a well-known manner. The governor controls the engine throttle 88 through the lever arrangement 86. Fig. 2 shows the cam actuator 74 in the position it occupies when the storage space 32 requires little or no refrigeration. As the temperature at the bulb 60 increases indicating need for more refrigeration, the cam 74 is rotated in a clockwise direction with the result that the engine throttle is opened a greater amount so as to speed up the Diesel engine. As the temperature within the compartment recedes the cam element 74 rotates in a counterclockwise direction, thereby serving to slow down the Diesel engine. However, the Diesel engine cannot be slowed down beyond a certain speed; and if by slowing down the engine to this minimum speed too much cooling still takes place, the thermostat 66 will operate the necessary dampers to add heat to the compartment and in the event that this alone is not enough to maintain proper temperatures in the compartment 32 and the temperature drops below a safe level, the cam 74 will be rotated far enough to lift the cam follower 78 onto the high surface 90 which materially increases the speed of the Diesel engine so as to further increase the heat given off by the engine. As the temperature within the compartment 32 increases to a predetermined value at which maximum heating is no longer required, the thermostat 60 will operate the cam 74 so as to slow down the Diesel engine until such time when either more cooling or more heating is required. For purposes of illustration, the thermostat 60 has been shown located in the compartment 32; however, it is within the purview of this invention to place the thermostat 60 in any other location, such as at the discharge side of the evaporator in the compartment 14 or on the outside of the car. Likewise, the thermostatic element 66 may be placed either within the compartment 32, anywhere within the compartment 44 or in the compartment 20, depending upon the effect desired. The preferred arrangement for use in freight cars, however, is the arrangement shown.

In Fig. 3 I have shown, in modified form, air conditioning apparatus in which air from the compartment 100 enters the plenum chamber 102 through the air intake opening 104 and is circulated by the fan 106 over the evaporator 108 and then is returned to the compartment 100 through the discharge opening 110. For purposes of illustration, the air intake has been shown in the upper portion of the car and the conditioned air outlet has been shown as being arranged adjacent the lower portion of the car; however, other well-known air duct arrangements may be used in which the conditioned air, for example, may be discharged into the upper part of the car.

The refrigerating system comprises a compressor 112 which withdraws evaporated refrigerant from a main evaporator 108 and an auxiliary evaporator 109 and discharges compressed refrigerant to a main condenser 114 and the auxiliary condenser 116. The refrigerant thus condensed flows to the liquid receiver 118 whence liquid refrigerant is supplied to the evaporators 108 and 109. The flow of liquid refrigerant from the receiver 118 to the evaporator 108 is controlled by means of a thermostatic expansion valve 120 located in the liquid line 122. The valve 120 is provided with a thermostatic bulb

124 which throttles the valve 120 at such times when liquid refrigerant reaches the outlet of the evaporator. The flow of refrigerant from the receiver 118 to the evaporator 109 is controlled by means of expansion valve 126 which is set to open only at a pressure somewhat lower than the pressure at which thermostatic expansion valve 120 opens. The valve 126 is normally closed except at such times when the cooling load in the compartment 100 is so low that little or no refrigerant is being evaporated in the evaporator 108 whereby a portion of the liquid refrigerant reaches the bulb 124 at which time the valve 120 tends to close with the result that the suction pressure decreases enough to open the valve 126.

The compressor 112 is driven by the Diesel engine 130, the speed of which is controlled by the thermostatic bulb 132 disposed in thermal exchange with the auxiliary evaporator 109 and the auxiliary condenser 116. The arrangement is such that the Diesel engine operates at a high speed when the temperature at bulb 132 is high, and as the temperature at 132 decreases due to the opening of the valve 126 the speed of the engine will be decreased so as to reduce the amount of refrigeration supplied. The engine is never stopped completely as will be explained hereinafter. With the valve 126 closed the thermostat 132 will be maintained warm by the auxiliary condenser 116, but as refrigerant is supplied to the auxiliary evaporator 109 the temperature at the thermostat 132 is decreased. The thermostat 132 acts on a speed regulator 70 of the type shown in Fig. 2. The Diesel engine 130 is water cooled by means of the radiator 134 and the water circulating pump 136. Outside air is caused to circulate through the machinery compartment by the blower 140. The air which circulates through the machinery compartment normally discharges to the outside of the car through the opening 142 at all times when cooling is required. However, if the temperature in the space 100 drops below the desired value, a portion or all of the heat generated in the machinery compartment is discharged into the plenum chamber 102 through the opening 144. When heated air is discharged into the space 100 the increased pressure in the space 100 causes air from the space 100 to return to the machinery compartment through the vent 143 whereby little heat is lost.

The flow of air through the openings 142 and 144 is controlled by the dampers 146 and 148 respectively, and these dampers in turn are controlled by means of the thermostat 150 which for purposes of illustration has been shown located adjacent the discharge opening 110. By placing the thermostat 150 adjacent the discharge opening 110 the temperature of the air discharged into the compartment 100 is controlled so as to prevent too cold air from being discharged into the compartment 100. The thermostat 150 could be located directly in the compartment itself rather than in the discharge air stream, if desired. The blowers 106 and 140 are both mounted on the jackshaft 152 which is driven by the Diesel engine by means of the belt arrangement 154. The Diesel engine is provided with a starter 156 which is under control of the manual switch 158. As pointed out in connection with the description of the first modification, there are times when the outdoor temperatures are so low that the heat generated by the Diesel engine and the condenser are insufficient to supply the necessary amount of heat required in the compartment 100. In order

to make available a greater amount of heat, I have provided a damper 160 which controls the admission of air from the outside. The damper 160 is controlled by the thermostat 162 mounted directly within the machinery compartment. The thermostat 162 is adjusted to prevent the engine from becoming too cool for efficient operation. Inasmuch as the heated air passing through the machinery compartment is used for heating the compartment 100, I have provided a filter 164 which filters all of the air entering the blower 140.

A damper 133 under control of the water thermostat 135 controls the flow of air over the radiator 134 so as to maintain the engine cooling water at an efficient temperature.

The speed of the engine 112 could be controlled in the same manner in which the speed of the engine 40 is controlled, if desired, in which case the evaporator 109 and condenser 116 would be omitted. With either arrangement the engine is intended to operate continuously even though the correct temperature exists in the conditioned space.

It is apparent, therefore, that I have provided a system which is capable of maintaining proper conditions within the conditioned space irrespective of outside temperatures.

From the above described arrangement it is apparent that the torque control is had by the use of a centrifugal governor driven by the engine which by its action varies the amount of fuel injected at each stroke to correspond to the torque load. This keeps the engine turning at constant speed while the torque, or resistance to turning, changes from zero to maximum. The speed of the engine is controlled by changing the load on the centrifugal governor. The loading on the governor in turn is controlled by a thermostat responsive to the refrigeration requirements.

Referring to the arrangement shown in Fig. 3, for example, at high temperatures the centrifugal governor will be loaded to its high speed and the expansion valve 120 will be wide open. The engine will, consequently, come to full speed and the fans will force a full flow of air through the evaporator as well as through the condenser. As the temperature within the space 100 begins to decrease, the low side pressure will decrease somewhat and the expansion valve bulb 124 will restrict the flow of liquid refrigerant to keep the evaporator properly filled with liquid in the well-known manner but by virtue of the large volume of warmer air over the evaporator 108 the low side pressure will remain relatively high, thereby causing the engine to operate at full speed. As the temperature in the space 100 decreases still further, the air returning to the evaporator will be still cooler and will cause less refrigerant to evaporate. Gradually, the low side pressure will start to fall and the sensitive pressure relay 126 will begin to remove loading from the centrifugal governor, thereby slowing down the engine. When the amount of heat removed by the refrigerator equals the heat leaking into the space 100 the speed of the engine will become steady and uniform refrigeration will result. Inasmuch as the engine will not operate below a predetermined minimum speed, heat must be added via the dampers 148 in the event that the temperature of the air passing over thermostat 150 drops below a predetermined value. At minimum speed of the engine very little heating would normally be available, so whenever heating is required at

least a portion of the heated air must be over the evaporator before its being discharged into the compartment 100 so as to further load the engine.

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. In combination, a main evaporator, an auxiliary evaporator, a main condenser, an auxiliary condenser in thermal exchange relationship with said auxiliary evaporator, a compressor, refrigerant flow connections whereby said compressor is adapted to withdraw refrigerant vapor from said evaporators and discharge the compressed refrigerant into said condensers, a prime mover for operating said compressor, a thermostat in thermal exchange relationship with said auxiliary evaporator, and means operated by said thermostat controlling the speed of said prime mover.

2. In combination, a main evaporator, an auxiliary evaporator, a main condenser, an auxiliary condenser in thermal exchange relationship with said auxiliary evaporator, a compressor, refrigerant flow connections whereby said compressor is adapted to withdraw refrigerant vapor from said evaporators and discharge the compressed refrigerant into said condensers, a prime mover for operating said compressor, a thermostat in thermal exchange relationship with said auxiliary evaporator, means operated by said thermostat controlling the speed of said prime mover, a first pressure responsive valve controlling the flow of refrigerant to said main evaporator, and a second pressure responsive valve controlling the flow of refrigerant to said auxiliary evaporator, one of said valves being set to operate at a lower pressure than the other valve.

3. In combination, an evaporator, refrigerant liquefying apparatus for supplying liquid refrigerant to said evaporator comprising a compressor, a condenser, and an internal combustion engine for operating said compressor, means for circulating air to be conditioned for an enclosure in thermal exchange with a portion of said liquefying apparatus, means for simultaneously circulating air to be conditioned for said enclosure in thermal exchange with said evaporator, and means responsive to a predetermined low temperature for increasing the amount of liquid refrigerant supplied to said evaporator.

4. In combination, an evaporator, refrigerant liquefying apparatus for supplying liquid refrigerant to said evaporator comprising a compressor, a condenser, and an internal combustion engine for operating said compressor, means for circulating air to be conditioned for an enclosure in thermal exchange with said internal combustion engine and said condenser, means for simultaneously circulating air to be conditioned for said enclosure in thermal exchange with said evaporator, and means responsive to a predetermined low temperature for increasing the amount of liquid refrigerant supplied to said evaporator.

5. In combination, an evaporator, refrigerant liquefying apparatus for supplying liquid refrigerant to said evaporator comprising a compressor, a condenser, and an internal combustion engine for operating said compressor, means for circulating air to be conditioned for an enclosure in thermal exchange with a portion of said liquefying apparatus, means for simultaneously circulating air to be conditioned for said enclosure in

thermal exchange with said evaporator, means responsive to a predetermined low temperature for increasing the amount of liquid refrigerant supplied to said evaporator, and means for varying the amount of air to be conditioned which is circulated in thermal exchange with said portion of said liquefying apparatus.

6. Air conditioning apparatus comprising in combination, an evaporator, refrigerant liquefying apparatus including a compressor, a condenser, and a prime mover for said compressor, refrigerant flow connections between said evaporator, compressor and condenser, means for circulating air to be conditioned for an enclosure in thermal exchange with said evaporator, means for circulating outside air in thermal exchange with a portion of said liquefying apparatus, first temperature responsive means controlling the operation of said prime mover, second temperature responsive means controlling the flow of outside air over said liquefying apparatus, means for circulating at least a portion of the air circulating over said liquefying apparatus into thermal exchange with said evaporator and thereafter into said enclosure, and means responsive to the temperature of the conditioned air for controlling said last named means.

7. Air conditioning apparatus comprising in combination, a volatile refrigerant evaporator, refrigerant liquefying means for supplying refrigerant to said evaporator; said refrigerant liquefying means comprising a compressor and an internal combustion engine for operating said compressor; heat dissipating means; means for transferring heat from said internal combustion engine to said heat dissipating means; and means for flowing air to be conditioned into thermal exchange relationship with said heat dissipating means so as to heat said air and thereafter into thermal exchange relationship with said evaporator so as to recool said air.

8. Air conditioning apparatus comprising in combination, a volatile refrigerant evaporator, refrigerant liquefying means for supplying refrigerant to said evaporator; said refrigerant liquefying means comprising a compressor and an internal combustion engine for operating said compressor; heat dissipating means; means for transferring heat from said internal combustion engine to said heat dissipating means; means for flowing air to be conditioned into thermal exchange relationship with said heat dissipating means so as to heat said air and thereafter into thermal exchange relationship with said evaporator so as to recool said air; and means for increasing the flow of refrigerant to said evaporator in response to an increase in the heating requirements whereby the load on said internal combustion engine is increased.

9. Air conditioning apparatus comprising in combination, an evaporator, refrigerant liquefying apparatus including a compressor, a condenser, and a prime mover for said compressor, refrigerant flow connections between said evaporator, compressor and condenser, means for circulating air to be conditioned for an enclosure in thermal exchange with said evaporator, means for circulating outside air in thermal exchange with a portion of said liquefying apparatus, first temperature responsive means controlling the operation of said prime mover, second temperature responsive means controlling the flow of outside air over said liquefying apparatus, and means for circulating at least a portion of the air circulating over said liquefying apparatus into thermal ex-

change with said evaporator and thereafter into said enclosure.

10. In combination, an evaporator, refrigerant liquefying apparatus for supplying liquid refrigerant to said evaporator, means for circulating air to be conditioned for an enclosure in thermal exchange with a portion of said liquefying apparatus, means for simultaneously circulating air to be conditioned for said enclosure in thermal exchange with said evaporator, and means responsive to a predetermined low temperature for increasing the amount of liquid refrigerant supplied to said evaporator.

11. Apparatus for either heating or cooling air for an enclosure comprising in combination, an

evaporator, refrigerant liquefying apparatus comprising a compressor, a condenser, and an internal combustion engine for operating said compressor, refrigerant flow connections between said evaporator, compressor and condenser, means for circulating air from said enclosure in thermal exchange with at least a portion of said refrigerant liquefying apparatus and said evaporator in series, means for by-passing said refrigerant liquefying apparatus with at least a portion of said air, and means for flowing outside air in thermal exchange with said portion of refrigerant liquefying apparatus and for discharging said last named air to the outside.

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