July 11, 1939. E. R. WOLFERT 2,165,741

COMPRESSOR UNLOADER

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FIG. 1.

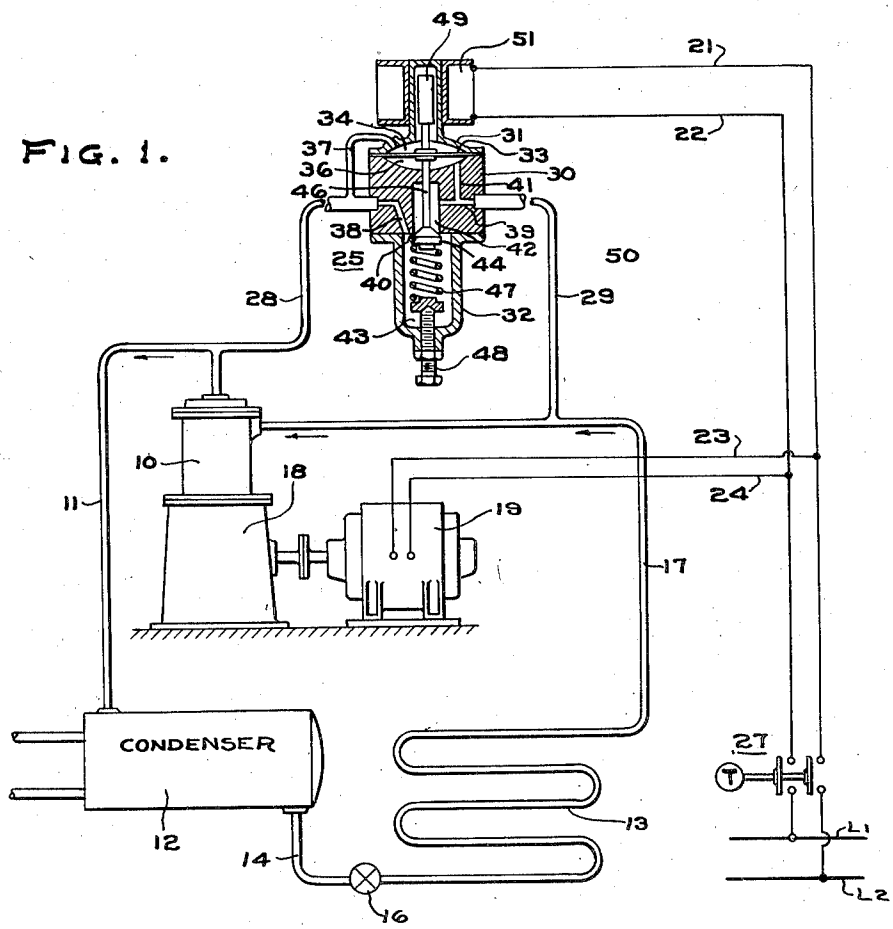
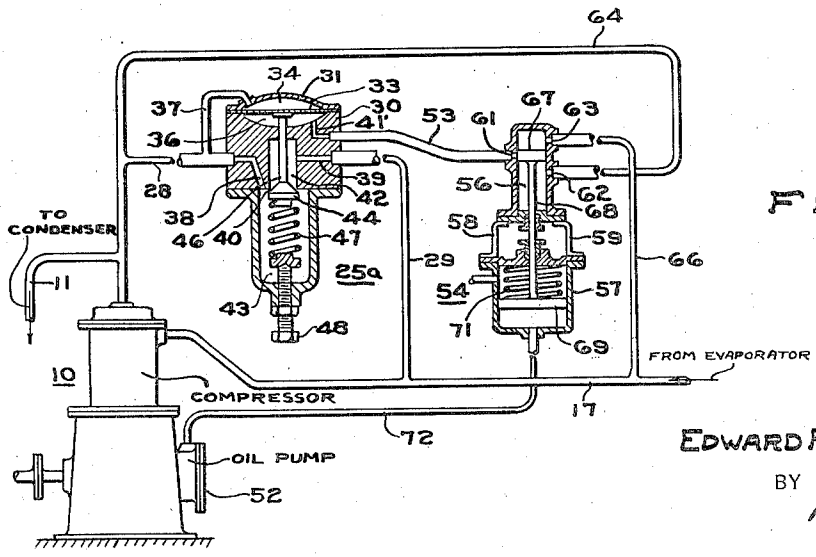



FIG. 2.




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## COMPRESSOR UNLOADER

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13 Claims. (Cl. 62—115)

My invention relates to refrigerating apparatus of the compression type and particularly to means for unloading the compressor used with such apparatus.

In refrigerating apparatus of the compression type, the refrigerant compressed in the compressor is discharged at high pressure to a condenser and withdrawn as a vapor at low pressure from an evaporator. The compressor operates intermittently to provide the required refrigeration and it is necessary for the satisfactory operation of the compressor with a motor of minimum size, to reduce the starting load on the compressor in some way until the motor driving the compressor has been brought up to normal operating speed.

Heretofore, one way of reducing the starting load on a compressor has been to equalize the pressures on the high and low sides of the refrigerating system when the compressor is shut down. The objection to this method, when the crankcase is connected to the low side and a refrigerant miscible in oil is used, is that the oil absorbs a greatly increased quantity of refrigerant at the higher pressure obtaining in the low side at such time. The absorption of refrigerant to such extent greatly increases the amount of slugging of the compressor valves upon starting.

Another method of reducing the starting load in connection with compressors of small capacity has been to equalize the pressures at the moment of starting. With larger compressors, however, the equalization is not effected rapidly enough to reduce the starting current of the motor.

In accordance with my invention, the starting load on the compressor is reduced when the compressor stops by partially equalizing the pressures on the high and low sides of the system. The extent to which equalization of the pressures takes place is preferably controlled by the pressure differential between the high and low sides and is such that a pressure low enough to avoid excessive absorption of refrigerant by the lubricating oil is maintained in the low side of the system during the off cycle of the compressor. Thus starting of the compressor is facilitated and slugging of the compressor valves is substantially reduced.

It is, therefore, an object of my invention to provide improved means for reducing the starting load on a compressor used with refrigerating apparatus of the compression type.

It is another object of my invention to reduce the starting load on a compressor in order that a motor of minimum size may be used to drive the compressor.

It is a further object of my invention to reduce the starting load before the compressor starts without excessive absorption of refrigerant by the lubricating oil.

It is still another object of my invention to reduce the starting load on a compressor in such a manner that the amount of refrigerant absorbed by the oil in the crankcase of the compressor will be held to a minimum.

It is a still further object of my invention to prevent slugging of the compressor valves upon starting the compressor by reducing to a minimum the amount of refrigerant absorbed by the oil in the crankcase of the compressor while the compressor is unloaded.

These and other objects are effected by my invention as will be apparent from the following description and claims taken in connection with the accompanying drawings, forming a part of this application, in which:

Fig. 1 shows diagrammatically a refrigerating system embodying one form of my invention; and,

Fig. 2 shows diagrammatically a second form of my invention which may be used with a refrigerating system similar to that shown in Fig. 1.

Referring to Fig. 1 of the drawing for a detailed description of one embodiment of my invention, I show a refrigerating system of the compression type in which refrigerant vapor is compressed in a compressor 10 and is discharged therefrom at a relatively high pressure through a conduit 11 to a condenser 12. The compressed refrigerant is cooled and condensed in the condenser 12 and flows as a liquid to an evaporator 13 through a conduit 14 and an expansion device shown, diagrammatically, at 16. The evaporator 13 is located within the enclosure to be cooled and the refrigerant evaporating in the evaporator 13 passes as a vapor through a conduit 17 to the suction side of the compressor 10, completing the cycle. A reservoir of oil (not shown) is maintained in the crankcase 18, which is connected to the low side, for lubricating the working elements of the compressor 10. A motor 19 provides the motive power for the compressor 10 and operates intermittently in response to the temperature of the enclosure to be cooled. The motor 19 is connected to a suitable source of energy through a series of wires $L_1$ and $L_2$, 21 and 22, and 23 and 24. A thermostatic switch 27, connected in the wires 23 and 24, controls the starting and stopping of the motor in response to predetermined maximum

and minimum temperatures in the enclosure to be cooled.

In order to facilitate starting of the compressor 10 when the enclosure to be cooled demands refrigeration and to keep the size of the motor as small as possible, I have provided means associated with the refrigerating system for reducing the load on the compressor 10 by reducing the pressure differential between the high pressure side and low pressure side of the compressor to a point where easier starting is accomplished and the absorption of vapor refrigerant by the oil in the crankcase 18 is minimized.

In the embodiment of my invention shown in Fig. 1, I provide a by-pass connection between the discharge side of the compressor 10 and the suction side or crankcase 18, which under certain conditions of operation provides a communicating passage between the high pressure and low pressure sides of the compressor 10. The by-pass connection comprises a spring biased and electrically operated valve 25 which is connected to the discharge conduit 11 through a conduit 28 and with the suction conduit 17 through a conduit 29. The valve 25 comprises a body portion 30, a top cover portion 31, and a bottom cover portion 32 all of which are assembled as a unit. A diaphragm 33 is secured in position between the top cover portion 31 and the body portion 30 and serves to divide the space therebetween into a chamber 34 and a chamber 36. The chamber 34 communicates with the conduit 28 through a conduit 37, thereby subjecting the upper side of the diaphragm 33 to the pressure of the gas on the discharge side of the system. The chamber 36 communicates with the conduit 29 through passages 38 and 41 formed in the body portion 30, thereby filling the chamber 36 with gas from the low side of the system and subjecting the lower side of the diaphragm to the pressure of the gas in the low side of the system. As shown in Fig. 1, a chamber 42 communicating with the passage 39 and opening into a chamber 43, at 40, is provided in the body portion 30. The chamber 43 is formed by the bottom cover portion 32 and the body portion 30 and communicates with the discharge side of the system through a passage 38. Thus gas from the high side of the system will flow through the opening at 40 into the low side of the system unless some means is provided to close this opening when such a flow is not desired. I provide for this purpose a pin valve 44 which is connected to the diaphragm 33 through a push rod 46 and is held in alignment with the opening 40 by a spring 47, the force of which may be adjusted by a screw 48. Thus the opening and closing of the pin valve 44 will depend upon the pressure differential existing between the high and low sides of the system and the force exerted by the spring 47 in valve closing direction. In accordance with my invention, therefore, when using a refrigerant, such as dichlorodifluoromethane, also known as "Freon-12", in the refrigerating system, I adjusted the spring 47 to exert a pressure, as for example 40 lbs. per sq. in., in a valve closing direction so that when the pressure differential between the high and low sides of the system is, for example, 40 lbs. per sq. in., the forces in valve closing direction will balance the force in valve opening direction, and when the pressure differential is slightly less than the pressure exerted by the spring 47, the valve 44 will close and will remain closed until the pressure differential has been increased to an amount greater than the force exerted by the spring 47. Thus it is apparent that the compressor can be partially unloaded and a predetermined pressure differential maintained during the off cycle of the compressor by simply adjusting the force exerted by the spring 47 to close the valve when the predetermined pressure differential is reached between the high and low sides of the system.

In order to avoid flow of gas from the high side to the low side of the system through the by-pass connection during the on cycle of the compressor, a solenoid 51 is provided to maintain the pin valve 44 in closed position during the operation of the refrigerating system. The solenoid 51 is energized simultaneously with the motor 19 through the wires 21 and 22, and exerts a force which draws an armature 49, which is connected to an extension of the push rod 46, upwardly, thereby closing the opening at 40 and shutting off the flow of gas between the high and low sides of the system.

*Fig. 1.—Operation*

The operation of the refrigerating system embodying the first form of my invention is as follows: Assuming that the enclosure to be cooled demands refrigeration and the switch 27 has closed to energize the motor 19, refrigerant vapor is compressed in the compressor 10 and is discharged at a high pressure to the condenser 12. The compressed refrigerant is cooled and condensed in the condenser 12 and passes as a liquid to the evaporator 13 through a conduit 14 and an expansion valve, shown diagrammatically at 16. The refrigerant in the evaporator 13 absorbs heat from the enclosure to be cooled and passes as a vapor to the suction side of the compressor 10. As has been explained, hereinbefore, the pin valve 44 is maintained in the closed position during the operation of the refrigerating system and there is no flow of high pressure gas through the by-pass connection to the low side of the system. As is apparent from the drawing, the upper side of the diaphragm 33 is subjected to the pressure of the gas in the high side of the system while the under side of the diaphragm 33 is subjected to the pressure in the low side of the system. There is, therefore, a relatively high pressure differential between the high and low sides of the system during the operation of the refrigerating system which, except for the force exerted by the solenoid 51, would overcome the force exerted by the spring 47 in valve closing direction and cause the pin valve 44 to move out of the opening 40 and permit the flow of gas from the high to the low side of the system.

When the temperature of the enclosure to be cooled has reached the lower limit for which the thermostat associated with switch 27 is set, the motor 19 will be deenergized and the solenoid 51 will be no longer operative to maintain the pin valve 44 in the closed position. The pressure differential existing in the system will be sufficient to overcome the force exerted by the spring 47 and the pin valve 44 will move downwardly out of the opening 40 and allow gas to pass from the high side to the low side of the system. This flow of gas will continue until the pressure differential has been reduced to a predetermined value, for example, slightly less than 40 lbs. per sq. in., at which the adsorption of refrigerant, such as "Freon 12", by the lubricating oil is at a sufficiently low value. The upward biasing force of the spring 47 when the valve 44 is in the closed position will balance the force in valve-opening direction when the pressure differential is, for

example, 40 lbs. per sq. in. The pin valve will be maintained in the closed position by the spring 47 when the compressor is stopped and by the force exerted by the solenoid 51 when the compressor is operating. Thus during the off cycle of the compressor 10, the load on the compressor has been sufficiently reduced to place the compressor in immediate condition for starting while, at the same time, sufficient pressure differental between the high and low sides of the system has been retained to minimize absorption of vapor refrigerant by the lubricating oil in the crankcase 18.

*Fig. 2*

In the embodiment shown in Fig. 2, partial unloading of the compressor, when it is shut down, is effected in the same manner as in Fig. 1, namely, in response to the pressure differential between the high and low sides. This embodiment differs, however, in that closing of the valve in the by-pass connection during operation of the compressor is effected by equalizing the pressures on opposite sides of the pressure-responsive diaphragm 33 in response to pressure developed by the lubricating oil pump of the compressor. The refrigerating system is the same as that of Fig. 1.

This embodiment includes a valve 25*a* which is similar to the valve 25 of Fig. 1 except that the solenoid 51 and the armature 49 are omitted, and the chamber 36 is not connected to the passage 42, but is connected through a passage 41' and a conduit 53 to a pilot valve 54.

Like reference numerals will therefore be used to designate similar parts in both embodiments and the description of the refrigerating system and the valve 25 already given in connection with Fig. 1 will suffice for the second embodiment.

The pilot valve 54, which is used to control the operation of the valve 25*a*, comprises a gas chamber 56 and an oil chamber 57 which are held in spaced relation with each other by brackets 58 and 59. The gas chamber 56 is provided with an outlet port 61 opening into the conduit 53 and two inlet ports 62 and 63. The inlet port 62 communicates with the conduit 28 through a conduit 64, thereby providing a passage for the flow of gas at discharge pressure into the chamber 56. The inlet port 63 communicates with the conduit 17 through a conduit 66 and a passage is thereby provided for gas at suction pressure into the chcamber 56. The high pressure gas and the low pressure gas in the chamber 56 are separated from each other by a slide valve 67 which is operated from the oil chamber 57 to set up communication between the outlet port 61 and the inlet port 62 when the compressor 10 is operating and between the inlet port 63 and the outlet port 61 when the compressor is stopped. Thus when the compressor 10 is operating, both sides of the diaphragm 33 are subjected to discharge pressure and when the compressor is not operating, the upper side of the diaphragm 33 is subjected to discharge pressure while the bottom side of the diaphragm is subjected to the pressure of the gas in the low side of the system. The slide valve 67 is connected to one end of a rod 68 which extends out of the gas chamber 56 and into the oil chamber 57 through suitably sealed openings. A piston 69 in the oil chamber is attached to the other end of the rod 68 so that any movement of the piston 69 will produce a like movement of the slide valve 67. A spring 71 disposed in the oil chamber 57 is arranged to oppose the upward movement of the piston 69, when the piston is actuated by oil pressure developed by the oil pump 52 and supplied to the oil chamber 57 through a conduit 72.

*Fig, 2.—Operation*

When the compressor 10 is operating, oil pressure developed by the pump 52 will actuate the piston 69 and will cause the slide valve 67 to move upwardly to place the outlet port 61 in communication with the inlet port 62. Gas from the high side of the system will flow into the chamber 36 to subject the lower side of the diaphragm 33 to discharge pressure. Since the upper side of the diaphragm 33 is also subjected to discharge pressure, the pressure differential will be zero and the biasing force of the spring 47 will maintain the pin valve 44 in closed position in the opening 40. The pin valve 44 will be maintained in the closed position just as long as the compressor 40 is operating and oil pressure is developed by the pump 52.

When the compressor 10 stops and oil pressure is no longer developed by the pump 52, the spring 71 will cause the piston 69 to move downwardly. The slide valve 67 will move below the outlet port 61 thereby cutting off communication between the high pressure side of the system and the chamber 36. The outlet port 61 and the inlet port 63 will be brought into communication with each other and gas from the low side of the system will flow into the chamber 36 to subject the under side of the diaphragm 33 to suction pressure. The upper side of the diaphragm is still subjected to discharge pressure with the result that the pressure differential is relatively high and is sufficient to overcome the biasing force provided by the spring 47. The pin valve 44 will therefore open and compressed refrigerant will flow from the high pressure side to the low pressure side of the system through the by-pass connection. This flow of compressed refrigerant will continue until the pressure differential has been reduced to a predetermined value, as for example, 40 pounds per sq. in.

In reducing the pressure differential, the pressure on the low side is increased only a limited amount in order that the absorption of refrigerant, such as "Freon-12" will not be excessive. With the pressure differential 40 pounds per sq. in., the biasing force of the spring 47 will urge the pin valve 44 upwardly to close the opening 40, thereby stopping the flow of high pressure gas to the low side of the system. The pin valve 44 will be maintained in the closed position while the compressor 10 is stopped. As long as the presure differential is less than the biasing force of the spring 47, as has already been explained, the pin valve 44 will also remain in the closed position when the compressor 10 is operating as there is no valve opening force opposing the biasing force of the spring 47. Thus when the compressor 10 is stopped, the starting load on the compressor is reduced and, at the same time, sufficient pressure differential has been retained in the system in order that the absorption of refrigerant by the lubricating oil will not be excessive.

It will be apparent from the foregoing that I have provided means for partially unloading a compressor by which starting of the compressor is facilitated, the absorption of refrigerant by the lubricating oil is minimized, and slugging of the compressor valves is substantially reduced.

While I have shown my invention in several

forms, it will be obvious to those skilled in the art that it is not so limited, but is susceptible of various other changes and modifications without departing from the spirit thereof, and I desire, therefore, that only such limitations shall be placed thereupon as are imposed by the prior art or as are specifically set forth in the appended claims.

What I claim is:

1. In refrigerating apparatus, the combination of an intermittently operated compressor having a high pressure side and a low pressure side, means for reducing the pressure on the high pressure side of said compressor when said compressor is stopped and means for rendering said first means inactive in response to a predetermined minimum pressure differential between the high pressure side and low pressure side of said compressor.

2. In refrigerating apparatus, the combination of an intermittently operated compressor, a condenser connected to the high pressure side of said compressor, an evaporator connected to the low pressure side of said compressor, means for admitting compressed refrigerant from the high pressure side of said compressor to the low pressure side thereof during the off-cycle of said compressor and means responsive to the pressures on the high and low sides of said compressor for stopping the flow of compressed refrigerant to the low side of said compressor when a predetermined minimum pressure differential exists between said high and low side.

3. In refrigerating apparatus, the combination of an intermittently operated compressor, a condenser connected to the high pressure side of said compressor, an evaporator connected to the low pressure side of said compressor, a by-pass connection between the high pressure side and the low pressure side of said compressor, a valve in said by-pass connection, means for opening said valve to admit compressed refrigerant from the high pressure side to the low pressure side of said compressor when said compressor stops and means for closing said valve when a predetermined minimum pressure differential exists between said high pressure side and said low pressure side.

4. In refrigerating apparatus, a refrigerant circulating system including an evaporator, a condenser and an intermittently operated compressor, a connection between the high pressure side of said compressor and the low pressure side thereof, a valve in said connection, means for maintaining said valve closed when said compressor is operating and means operable automatically when said compressor is stopped for opening said valve in response to a pressure differential between the high and low sides of said compressor above a predetermined value and for closing said valve in response to a pressure differential below said predetermined value.

5. In refrigerating apparatus, a refrigerant circulatory system including an evaporator, a condenser and an intermittently operated compressor, a connection between the high pressure side of said compressor and the low pressure side thereof, a valve in said connection, means for maintaining said valve closed when said compressor is operating, and automatically operable means for opening said valve when said compressor stops to reduce the pressure on the high pressure side of said system and for closing said valve when the pressure differential between the high pressure and low pressure side of said system has been reduced to a predetermined value.

6. In refrigerating apparatus, a refrigerant circulatory system including an evaporator, a condenser and an intermittently operated compressor, a connection between the high pressure side of said compressor and the low pressure side thereof, a valve in said connection, magnetic means for maintaining said valve in closed position when said compressor is operating and pressure responsive means for opening said valve when said compressor stops to admit refrigerant from the high pressure side of said compressor to the low pressure side thereof and for closing said valve when said high pressure has been reduced and said low pressure increased sufficiently to obtain a predetermined pressure differential therebetween.

7. In refrigerating apparatus, a refrigerant circulating system including an evaporator, a condenser and a compressor, a motor for driving the compressor, a connection between the high pressure side of said compressor and the low pressure side thereof, a valve in said connection, magnetic means for maintaining said valve in a closed position when said compressor is operating, pressure responsive means for opening said valve when said compressor stops to reduce the pressure on the high side of said system and to increase the pressure on the low side of said system and for closing said valve when a predetermined pressure differential exists between said high pressure side and said low pressure side and temperature responsive means for effecting the operation of said motor and said magnetic means.

8. In refrigerating apparatus, a refrigerant circulatory system, including an evaporator, a condenser and an intermittently operated compressor, a lubricant pump actuated by said compressor, a by-pass connection between the high pressure side of said compressor and the low pressure side thereof, a valve in said connection, means responsive to the pressures on the high and low pressure sides of said compressor for actuating said valve and a pilot valve actuated by oil supplied by said oil pump for controlling the operation of said pressure responsive means.

9. In refrigerating apparatus, a refrigerant circulating system including an evaporator, a condenser and an intermittently operated compressor, a lubricant pump actuated by said compressor, a by-pass connection between the high pressure side of said compressor and the low pressure side thereof, a valve in said connection, pressure responsive means for operating said valve, and a pilot valve actuated by oil from said lubricant pump for controlling the operation of said pressure responsive means, said pressure responsive means being effective to maintain said first valve in a closed position when said compressor is operating.

10. In refrigerating apparatus, a refrigerant circulating system including an evaporator, a condenser and an intermittently operated compressor, an oil pump actuated by said compressor, a by-pass connection between the high pressure side of said compressor and the low pressure side thereof, a valve in said by-pass connection, pressure responsive means for operating said valve and a pilot valve responsive to the oil pressure produced by said oil pump for controlling the operation of said pressure responsive means, said pressure responsive means being effective when said compressor is operating to maintain

said first valve in a closed position and when said compressor stops to open said first valve to admit compressed refrigerant to the low pressure side of said system and to close said first valve when the pressure differential between the high side of said compressor and the low pressure side thereof has reached a predetermined value.

11. In refrigerating apparatus, a refrigerant circulating system including an evaporator, a condenser and a compressor, a motor for driving said compressor, an oil pump actuated by said compressor, a by-pass connection between the high pressure side of said compressor and the low pressure side thereof, a valve in said by-pass connection, a spring for biasing said valve in valve-closing direction, a pressure-responsive element subjected, when the compressor is stopped, in valve-opening direction to the pressure of the gas on the high side of the system and in valve-closing direction to the pressure of the gas in the low side of the system and means responsive to pressure developed by the oil pump for equalizing the pressure on said pressure-responsive element whereby said valve is closed by said spring when said compressor is operating.

12. In refrigerating apparatus, a refrigerant circulating system including an evaporator, a condenser and a compressor, a motor for driving said compressor, an oil pump attached to said compressor and actuated thereby, a by-pass connection between the high pressure side of said compressor and the low pressure side thereof, a valve in said by-pass connection, pressure responsive means for opening and closing said valve, said pressure responsive means including a diaphragm, one side of which is subjected to the pressure on the high pressure side of said compressor, and a pilot valve responsive to oil pressure developed by said pump for controlling the operation of said pressure responsive means, said pilot valve being effective when said compressor is operating to subject the other side of said diaphragm to the pressure on the high pressure side of said compressor to maintain said valve in a closed position, and when said compressor is not operating to subject the other side of said diaphragm to the pressure on the low pressure side of said compressor to open said valve, said pressure responsive element closing said valve in response to a predetermined low pressure differential when said compressor is stopped.

13. In refrigerating apparatus, a refrigerant circulatory system including a condenser, an evaporator and a compressor, a motor for driving said compressor, a by-pass connection between the high and low pressure side of said compressor, a valve in said by-pass connection, means for automatically maintaining said valve in closed position when said compressor is operating and means responsive to the pressure on the low side of said system for opening and closing said valve when said compressor is not operating.

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