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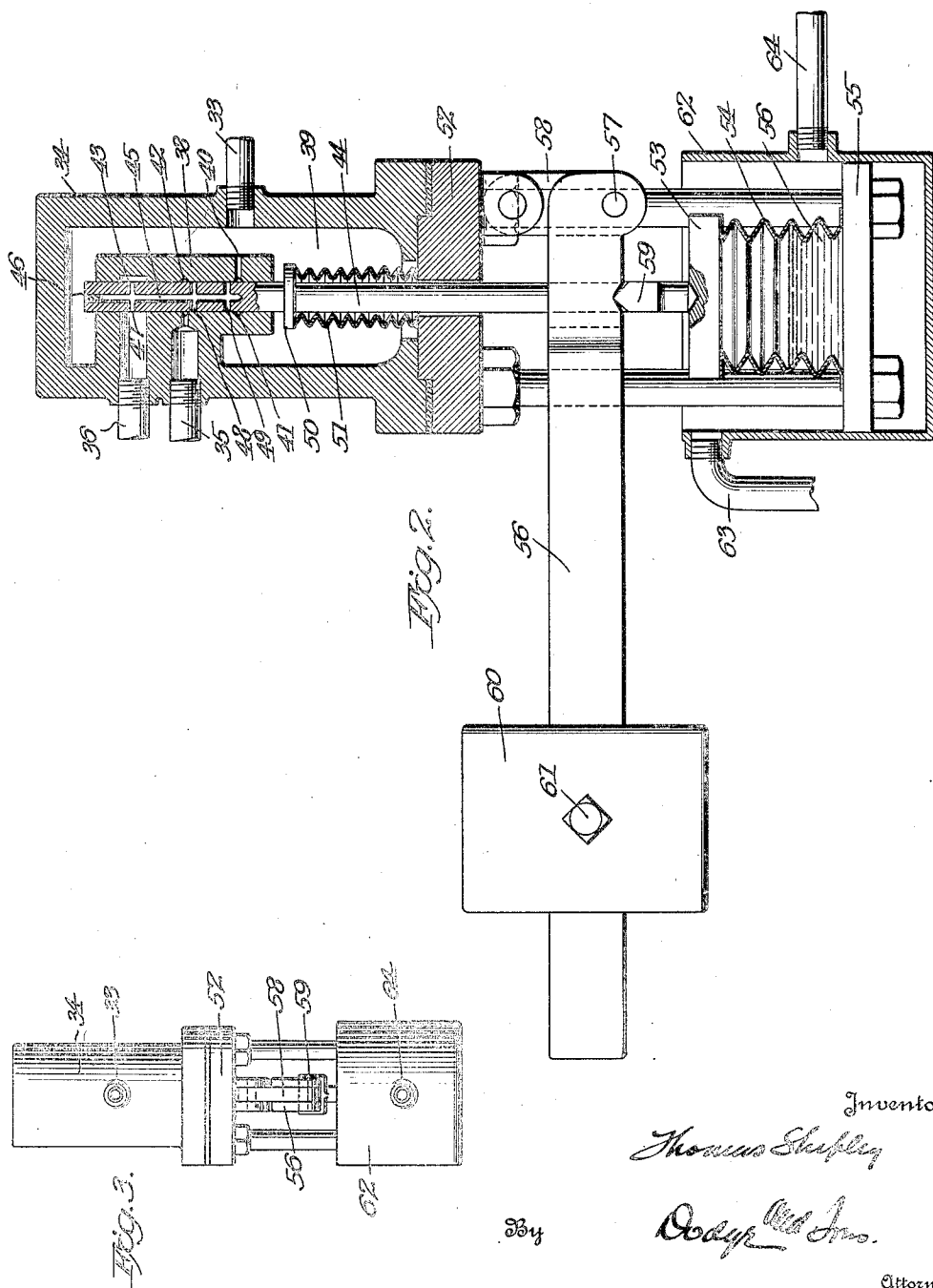
T. SHIPLEY

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REFRIGERATING METHOD AND APPARATUS

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THOMAS SHIPLEY, OF YORK, PENNSYLVANIA, ASSIGNOR, BY MESNE ASSIGNMENTS,
TO YORK ICE MACHINERY CORPORATION, OF YORK, PENNSYLVANIA, A CORPORATION OF DELAWARE.

REFRIGERATING METHOD AND APPARATUS.

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This invention relates to refrigeration and particularly to a method of and apparatus for maintaining a variable pressure in the condenser in response to variation in condenser temperature. Certain refrigerants, such as carbon dioxide have a relatively low critical temperature and with such refrigerants it is desirable to increase the condenser pressure as the condenser temperature increases, for the reason that at high pressures the heat transfer to the cooling water can be somewhat increased.

The invention is applied to a system of the ordinary compressor, condenser, evaporator circuit type, in which the compressor draws from an evaporator or from a suction trap connected thereto and discharges the compressed refrigerant into a condenser, preferably a water-cooled condenser. From the condenser the refrigerant is delivered back to the suction trap through some back pressure retaining regulating device, such as the familiar float valve, or it may be returned directly to the compressor.

As stated, the invention relates to the regulation of condenser pressure and this regulation is effected by withdrawing refrigerant from the condenser and delivering it into a container or flask at a lower or intermediate pressure, and by returning refrigerant from the flask to the low pressure side of the system, preferably by delivering it to the suction trap. The regulation is effected by a valve which is connected to the condenser, to the evaporator (i. e. to the suction trap), and to the flask. This valve is shiftable between two positions in one of which the evaporator connection is blanked and the condenser is connected with the flask, and in the other of which the condenser connection is blanked and the flask is connected with the evaporator or compressor suction.

This valve is constantly urged toward the first named position by an abutment or motor, subject to the condenser pressure. It is constantly urged in the reverse direction by a thermostatic device responsive to temperature conditions in the condenser, the force exerted by the thermostatic device increasing as the condenser temperature increases. To secure an adjustable effect there is asso-

ciated with the valve a variable loading mechanism consisting in the example illustrated of an adjustable weight.

Particular care has been taken to state above that the thermostatic device is responsive to temperature conditions in the condenser. This phrase is used for the reason that it is not ordinarily convenient to subject the thermostatic device directly to the temperature in the condenser, or at any rate it is usually more convenient to subject it to the temperature of a liquid whose temperature is a function of condenser temperature. Thus, for example, the device may respond to the temperature of the inflowing cooling water which under normal conditions will directly determine the temperature in the condenser, or the device may be subjected to the temperature of the outflowing cooling water or the outflowing refrigerant, which even more closely approximate condenser temperature.

In the various cases recited the adjustments of the thermostatic device would necessarily be somewhat different but the principle of operation of the device would be unchanged. It is immaterial what particular means are used so long as the thermostatic regulating element responds to condenser temperature or to a related temperature in such manner that as condenser temperature rises the thermostatic element will exert an approximately proportionally increasing effect.

There is also illustrated in the drawing a particular form of evaporator in which the liquid refrigerant from the suction trap is constantly circulated through the evaporator coils and back to the trap and in which the rate of circulation is regulated by a bypass valve controlled in response to the heat load on the evaporator coils. For example, in a water cooling device the heat load is a function of the temperature of the water arriving at the evaporator to be cooled.

The use of such a regulating device in combination with the condenser pressure regulating device results in very satisfactory operation, not so readily secured without the automatic regulation of the evaporator.

Fig. 1 is a diagrammatic elevation of a

plant for cooling water to be used in conditioning air and showing the application of the present invention.

Fig. 2 is a vertical axial section of the valve which regulates the condenser pressure.

Fig. 3 is a side elevation thereof, on a reduced scale.

Fig. 4 is a fragmentary view, similar to a portion of Fig. 1, and showing a modification in which the outflowing liquid refrigerant acts on the thermostatic device.

One of a group of similar evaporator coils is indicated at 6. These are arranged side by side in the usual manner. 7 is the return main from the air washer. 8 is one of a group of spray pipes fed by the main 7 and arranged to spray water so that it trickles over the coils 6 and is collected in a sump 9, from which it is returned to the spray heads in the air washers, not shown. 10 is a suction trap connected by the suction line 11 to a compressor 12 of any suitable type. The trap 10 is connected at its upper end with a manifold 13 to which the lower end of all the coils 6 are connected. A liquid refrigerant circulating pump 14 draws liquid through connection 15 from the bottom of trap 10 and discharges it through connection 16 to manifold 17 which is connected with the upper ends of all coils 6. A by-pass connection 18 leads from the pipe 16 to the trap 10 and is controlled by a valve 19 which is urged in an opening direction by a spring 20 and which may be forced closed against the action of the spring 20 by pressure acting within metallic bellows 21. Such valves are standard articles of commerce. The interior of the bellows 21 is connected by a liquid filled pipe 22 with a thermostatic cell 23 containing a volatile liquid of suitable character. The expansion of the volatile liquid in response to changes of temperature of the water flowing through the pipe 7 varies the pressure on the liquid in the pipe 22 and consequently varies the pressure within the bellows 21. Thus, if the temperature of the water in main 7 rises, the resulting increase of pressure will tend to close the by-pass valve 19 and increase the circulation of refrigerant through the coils 6. Reduction of temperature of the water in the main 7 has the reverse effect by opening the by-pass and reducing the circulatory rate.

The compressor 12 discharges through a high pressure line 24 into the interior of a condenser 25, indicated as of the shell and tube type, but permissibly of other known types. From this shell liquid line 26 extends to a float controlled feed valve 27 of known type, which delivers refrigerant to the trap 10 in such a way as to maintain a constant level of liquid refrigerant in the trap. float valves of this character are well known, and in the example illustrated the float is mounted in a chamber 28 connected at its

upper end with the trap 10 by a pressure equalizing connection 29 and at its lower end with the trap 10 by a liquid flow connection 30.

The condenser 25 is cooled by water conducted to and from the condenser by pipes 31 and 32. As will be further explained, the connections may be such that water enters by either of these pipes and discharges by the other, as preferred. Leading from a point near the bottom of the condenser 25 is a connection 33 which leads to the housing 34 of the automatic valve. At the opposite side of this housing is a connection 35 which has two branches 35^a and 35^b, the first leading to the top of trap 10 and the second to an auxiliary suction connection on compressor 12. The branches are controlled by stop valves 35^c and 35^d, one or the other of which is closed.

This branched connection is illustrated to establish the general equivalence of a refrigerant-return connection to the trap (evaporator) or directly to the suction of the compressor. Only one connection would ordinarily be open during operation, and in commercial installations either connection alone may be used. The connection 35^b can be used only where conditions are such that there is no danger of liquid refrigerant passing to the compressor.

Above connection 35 is a connection 36 leading from housing 34 to flask 37.

Referring now to Figs. 2 and 3, the structure of the valve mechanism associated with housing 34 will be described.

Mounted axially in the center of the housing 34 is a valve cylinder or piston valve seat, indicated generally by the numeral 38. The connection 33 communicates directly with a chamber 39 within the housing 34 and this space is connected by a passage 40 with an annular port 41 in the interior of the piston valve seat. The connection 35 communicates with an annular groove port 42 spaced from the port 41, and the connection 36 communicates with a much wider annular groove port 43. The valve element consists of the upper end of a rod 44 which is slidable within the seat 38. This rod is formed with a longitudinal port 45 closed at its upper end, as indicated at 46 and having a branch passage 47 which in all positions of the rod 44 is in communication with the port 43. There are also two branch passages 48 and 49. In the upper position of the rod 44 port 48 registers with port 42 while port 41 is blanked. This establishes communication from the flask to the suction trap or compressor suction. In the lower position the port 49 registers with port 41 while port 42 is blanked. This establishes communication from the condenser to the flask and blanks the connection to the suction trap or compressor suction.

Mounted on the rod 44 is a flange 50. Me-

tallic bellows 51 connects the flange 50 with a head 52 which closes the lower end of the housing 34. Thus the valve rod 44 works in a closed chamber and acts as a piston or plunger urged downward by the pressure within the chamber 39 which is condenser pressure. The lower end of the rod 44 is conical and bears against a thrust block 53 to which is connected the upper end of metallic bellows 54, whose lower end is connected with a head 55. The thrust member 53, bellows 54 and head 55 enclose a variable volume chamber containing a volatile liquid 56, which upon rise of temperature is capable of developing fluid pressure which acts to urge the rod 44 upward. A lever 56 pivoted at 57 to a swinging fulcrum link 58 is seated on the knife edge 59 and acts to transmit the thrust of weight 60 in a downward direction to the rod 44. Weight 60 may be clamped in adjusted positions on the lever 56 by clamping screw 61.

Metallic bellows 54 are enclosed within an open top tank 62 which has an overflow connection 63 and which is fed with a limited amount of water through a pipe 64 connected with the cooling water pipe 31. The rate of flow through the pipe 64 may be regulated by valve 65. If 31 is the supply pipe to the condenser, then the water flowing through the pipe 64 is merely a diverted flow of a portion of the supply cooling water. If 32 is the water supply pipe and 31 is the water discharge pipe, the water flowing through the pipe 64 is merely a diverted portion of the off-flowing cooling water. In the last mentioned case the temperature of the off-flowing water is either the same as condenser pressure or a direct function thereof. In the first case the temperature of the inflowing water is at least approximately proportional to the resulting condenser pressure, assuming a reasonably constant refrigerant load. At any rate there is quite a direct relation between the temperature of cooling water supply and condenser temperature; direct enough to permit a useful regulation to be secured.

It follows that under conditions which would cause a rise of temperature in the condenser 25 the liquid in the bellows 54 would be increased in temperature and would exert an increasing upward thrust on the rod 44, tending to shift the valve to a position in which the flask feeds refrigerant to the system, thus increasing the quantity of refrigerant in circulation and raising the condenser pressure. The condenser pressure increased as a result and acting through the connection 33 opposes the action of the bellows 54 and serves to terminate the feed of refrigerant from the flask when condenser pressure has been increased to the proper amount. Thus the effect of increased temperature, acting in opposition to condenser pressure, and sub-

ject to the modifying effect of the weight 60, is to produce an appropriately increased condenser pressure. In this manner condenser pressure is caused to vary in a particular relation as condenser temperature varies, and the relation is subject to modification.

It is understood, of course, that the nature of the liquid in the bellows 54 is subject to change and that the nature of this liquid or the position of the weight 60, or both, may require change according as the water is fed to the condenser through the connection 31 or the connection 32, for obviously the actual temperature in the tank 62 will be markedly different in the two cases.

Referring now to Fig. 4, a modification is shown in which the temperature of the off-flowing liquid refrigerant directly affects the regulating valve. In this case the condenser is indicated by the numeral 25 and the flask by the numeral 37, as before. The parts 25, 26, 31, 32, 35, 36 and 37 are essentially the same as those heretofore described and are connected with the remaining parts in substantially the same manner as is shown in Fig. 1. Instead of a single connection 33 two connections 71 and 72 are used. The regulating valve housing 73 is provided with two through ports 74 and 75, to both of which the connection 36 leads. The port 74 is connected to the pipe 35 and the port 75 to the pipe 71 which leads to the condenser. The housing 73 is formed with a longitudinal guideway through which the rod 76 slides so as to carry a groove port 77 formed therein in registry with ports 74 and 75 respectively. Condenser pressure delivered through connection 72 to the interior of metallic bellows 78 acts to urge the rod 76 downward. In opposition to this there is a thermostatic motor consisting of metallic bellows 79 which contain a volatile liquid and which are connected to an abutment 80 on the lower end of rod 76. There is a bulb extension 81 on the lower end of the bellows 79 and this projects into a chamber 82 interposed in connection 26 through which refrigerant flows from the condenser to the trap. A lever 83 pivoted at 84 and connected at 85 with the rod 76 carries an adjustable weight 86, which in this instance acts in opposition to condenser pressure.

It will be observed that condenser pressure acts to destroy connection between the flask and the trap or compressor suction and establish connection between the flask and the condenser, while the thermostatic device, subject directly to condenser temperature, i. e., to the temperature of the off-flowing condensate, acts in the opposite direction, i. e., it tends to interrupt the connection between the flask and the condenser and to establish connection between the flask and the suction side of the system.

The principle of operation of the modified

device is essentially similar to that of the device first described, and the main purpose in illustrating it is to emphasize the fact that the controlling temperature may be condenser temperature or a derivative thereof, and that the organization of the device, such as the arrangement and direction of action of the weight, the nature of the volatile regulating fluid used, and similar details, is subject to variation, according to the conditions met. The essential thing is that the action of the various elements be properly coordinated to bring about the desired result.

The connections 35^a and 35^b both lead to the suction side of the compressor, the only material differences being that with 35^a in use the trap 10 safeguards the compressor against the entrance of liquid refrigerant, and applies such liquid refrigerant to the performance of useful work. Hence in the claims I describe this connection as to the suction side of the compressor in a generic or inclusive sense.

The use of a circulating pump and regulating by-pass in conjunction with an evaporator and trap forms the subject matter of my copending applications Serial Nos. 162,573 and 162,574, and hence is not broadly claimed herein.

What is claimed is,—

1. The method of controlling the pressure on the high pressure side of a thermo-dynamic refrigeration circuit, which comprises alternately feeding and withdrawing refrigerant to and from the circuit to increase and reduce said pressure and automatically controlling said feeding and withdrawal in accordance with condenser temperature, in such manner that an increase in temperature causes an increase in pressure.

2. The method of controlling the pressure on the high pressure side of a thermo-dynamic refrigeration circuit, which comprises alternately feeding and withdrawing refrigerant to and from the circuit to increase and reduce said pressure, and automatically controlling said feeding and withdrawal in accordance with the temperature of a fluid flowing through the condenser, in such manner that an increase in temperature causes an increase in pressure.

3. The method of controlling the pressure on the high pressure side of a thermo-dynamic refrigeration circuit having a low and a high pressure side, which comprises withdrawing a refrigerant from the high pressure side to a reserve at an intermediate pressure to lower the pressure on the high pressure side, and in feeding refrigerant from said reserve to the low pressure side to raise the pressure on the high pressure side, and automatically controlling said feeding and withdrawal in accordance with condenser temperature in such manner that an increase in temperature causes an increase in pressure.

4. The method of controlling the pressure on the high pressure side of a thermo-dynamic refrigeration circuit, which comprises alternately feeding and withdrawing refrigerant to and from the circuit, and controlling said feeding and withdrawal by the conjoint action of condenser pressure and an opposed pressure dependent upon condenser temperature, in such manner that predominance by condenser pressure causes withdrawal and predominance by the temperature-dependent pressure causes feeding.

5. The method of controlling the pressure on the high pressure side of a thermo-dynamic refrigeration circuit, which comprises alternately feeding and withdrawing refrigerant to and from the circuit, and controlling said feeding and withdrawal by the conjoint action of condenser pressure and an opposed pressure dependent upon the temperature of a fluid circulating through the condenser, in such manner that predominance by condenser pressure causes withdrawal and predominance by the temperature-dependent pressure causes feeding.

6. The method of controlling the pressure on the high pressure side of a thermo-dynamic refrigeration circuit having a low and a high pressure side which comprises withdrawing refrigerant from the high pressure side to a reserve at an intermediate pressure, to lower the pressure on the high pressure side, and in feeding refrigerant from said reserve to the low pressure side to raise the pressure on the high pressure side; and controlling said feeding and withdrawal by the conjoint action of condenser pressure and an opposed pressure dependent upon condenser temperature, in such manner that predominance by condenser pressure causes such withdrawal and predominance by the temperature-dependent pressure causes feeding.

7. The combination of an evaporator; a condenser; a compressor connected to draw volatile refrigerant from the evaporator and deliver it under pressure into the condenser; means for delivering refrigerant from the condenser to the evaporator; a flask; a valve device connected with said flask and condenser and with the suction side of said compressor and shiftable between two positions, in the first of which the condenser is connected with the flask and the connection to the suction of the compressor is blanked, and in the second of which the flask is connected with the suction of the compressor and the condenser connection is blanked; a motor subject to condenser pressure urging said valve toward the first named position; and a thermostatic motor urging said valve toward the second named position with a force which varies according to condenser temperature.

8. The combination of an evaporator; a condenser; a compressor connected to draw

volatile refrigerant from the evaporator and deliver it under pressure into the condenser; means for delivering refrigerant from the condenser to the evaporator; a flask; a valve device connected with said flask, evaporator and condenser and shiftable between two positions, in the first of which the condenser is connected with the flask and the evaporator connection is blanked, and in the second of which the flask is connected with the evaporator and the condenser connection is blanked; a motor subject to condenser pressure urging said valve toward the first named position; and a thermostatic motor urging said valve toward the second named position with a force which varies according to condenser temperature.

9. The combination of an evaporator; a condenser; a compressor connected to draw volatile refrigerant from the evaporator and deliver it under pressure into the condenser; means for delivering refrigerant from the condenser to the evaporator; a flask; a valve device connected with said flask and condenser and with the suction side of said compressor and shiftable between two positions, in the first of which the condenser is connected with the flask and the connection to the suction of the compressor is blanked, and in the second of which the flask is connected with the suction of the compressor and the condenser connection is blanked; a motor subject to condenser pressure urging said valve toward the first named position; a thermostatic motor operating upon increase in temperature to urge said valve toward the second named position with increased force; and means for passing a fluid which circulates through the condenser in heat conducting relation with said thermostatic motor.

10. The combination of an evaporator; a condenser; a compressor connected to draw volatile refrigerant from the evaporator and deliver it under pressure into the condenser; means for delivering refrigerant from the condenser to the evaporator at a rate independent of condenser pressure; a flask; a valve device connected with said flask, evaporator and condenser and shiftable between two positions, in the first of which the condenser is connected with the flask and the evaporator connection is blanked, and in the second of which the flask is connected with the evaporator and the condenser connection is blanked; a motor subject to condenser pressure urging said valve toward the first named position; and a thermostatic motor device responsive to condenser temperature and urging said valve toward the second named position with a force which varies according to condenser temperature.

11. The combination of an evaporator; a condenser; a compressor connected to draw volatile refrigerant from the evaporator and deliver it under pressure into the condenser;

means for delivering refrigerant from the condenser to the evaporator; a flask; a valve device connected with said flask, evaporator and condenser and shiftable between two positions, in the first of which the condenser is connected with the flask and the evaporator connection is blanked, and in the second of which the flask is connected with the evaporator and the condenser connection is blanked; a motor subject to condenser pressure urging said valve toward the first named position; and a thermostatic motor including a movable abutment and a confined volume of volatile liquid acting thereon arranged to be affected by condenser temperature and connected to urge said valve toward the second-named position by the vapor pressure of said liquid.

12. The combination of an evaporator; a condenser; a compressor connected to draw volatile refrigerant from the evaporator and deliver it under pressure into the condenser; means for delivering refrigerant from the condenser to the evaporator; a flask; a valve device connected with said flask, evaporator and condenser and shiftable between two positions, in the first of which the condenser is connected with the flask and the evaporator connection is blanked, and in the second of which the flask is connected with the evaporator and the condenser connection is blanked; a motor subject to condenser pressure urging said valve toward the first named position; a thermostatic motor including a movable abutment and a confined volume of volatile liquid acting thereon and arranged to urge said valve toward the second named position upon an increase of temperature; and means for passing a liquid circulating through said condenser in heat conducting relation with said volatile liquid.

13. The combination of an evaporator; a condenser; a compressor connected to draw volatile refrigerant from the evaporator and deliver it under pressure into the condenser; means for delivering refrigerant from the condenser to the evaporator; a flask; a valve device connected with said flask, evaporator and condenser and shiftable between two positions, in the first of which the condenser is connected with the flask and the evaporator connection is blanked, and in the second of which the flask is connected with the evaporator and the condenser connection is blanked; a motor subject to condenser pressure urging said valve toward the first named position; a thermostatic motor device responsive to condenser temperature and urging said valve toward the second named position with a force which varies according to condenser temperature; and an adjustable loading mechanism for said valve device.

14. The combination of an evaporator; a condenser; a compressor connected to draw

volatile refrigerant from the evaporator and deliver it under pressure into the condenser; means for delivering refrigerant from the condenser to the evaporator; a flask; a valve device connected with said flask and condenser and with the suction side of said compressor and shiftable between two positions, in the first of which the condenser is connected with the flask and the connection to the compressor suction is blanked, and in the second of which the flask is connected with said suction connection and the condenser connection is blanked; a motor subject to condenser pressure urging said valve toward the first named position; a thermostatic motor device responsive to condenser temperature and urging said valve toward the second named position with a force which varies according to condenser temperature; and an adjustable loading mechanism for said valve device.

15. The combination of an evaporator; a condenser; a compressor connected to draw volatile refrigerant from the evaporator and deliver it under pressure into the condenser; means for delivering refrigerant from the condenser to the evaporator; a flask; a valve device connected with said flask and condenser and with the suction side of said compressor and shiftable between two positions, in the first of which the condenser is connected with the flask and the connection to the compressor suction is blanked and in the second of which the flask is connected with said suction connection and the condenser connection is blanked; a motor subject to condenser pressure urging said valve toward the first named position; a thermostatic motor device arranged to urge said valve toward the second named position with a force which increases with temperature; means for passing a liquid circulating through said condenser in heat exchanging relation with said thermostatic motor; and an adjustable loading mechanism for said valve device.

16. The combination of an evaporator; a condenser; a compressor connected to draw volatile refrigerant from the evaporator and deliver it under pressure into the condenser; means for delivering refrigerant from the condenser to the evaporator; a flask; a valve device connected with said flask, evaporator and condenser and shiftable between two positions, in the first of which the condenser is connected with the flask and the evaporator connection is blanked, and in the second of which the flask is connected with the evaporator and the condenser connection is blanked; a motor subject to condenser pressure urging said valve toward the first named position; a thermostatic motor including a movable abutment and a confined volume of volatile liquid acting thereon arranged to be affected by condenser temperature and connected to

urge said valve toward the second-named position by the vapor pressure of said liquid; and an adjustable loading mechanism for said valve device.

17. The combination of an evaporator; a suction trap; connections establishing a closed circuit through said evaporator and trap; a pump for circulating refrigerant through said circuit; regulating means controlling said circulation; means for passing a medium to be cooled in contact with said evaporator; thermostatic means subject to the temperature of said medium and controlling said regulating means; a compressor connected to draw refrigerant vapor from said trap; a condenser into which said compressor discharges; a flask; a valve device connected with said flask and condenser and with the suction side of said compressor, and shiftable between two positions, in the first of which the condenser is connected with the flask and said suction connection is blanked, and in the second of which the flask is connected with the suction of the compressor and the condenser connection is blanked; means subject to condenser pressure urging said valve device toward the first named position; and a thermostatic motor device responsive to condenser temperature and urging said valve toward the second named position with a force which varies according to condenser temperature.

18. The combination of an evaporator; a suction trap; connections establishing a closed circuit through said evaporator and trap; a pump for circulating refrigerant through said circuit; regulating means controlling said circulation; means for passing a medium to be cooled in contact with said evaporator; thermostatic means subject to the temperature of said medium and controlling said regulating means; a compressor connected to draw refrigerant vapor from said trap; a condenser into which said compressor discharges; a flask; a valve device connected with said flask, trap and condenser and shiftable between two positions, in the first of which the condenser is connected with the flask and the trap connection is blanked, and in the second of which the flask is connected with the trap and the condenser connection is blanked; means subject to condenser pressure urging said valve device toward the first named position; a thermostatic motor device responsive to condenser temperature and urging said valve toward the second named position with a force which varies according to condenser temperature; and an adjustable loading mechanism for said valve device.

In testimony whereof I have signed my name to this specification.

THOMAS SHIPLEY.