

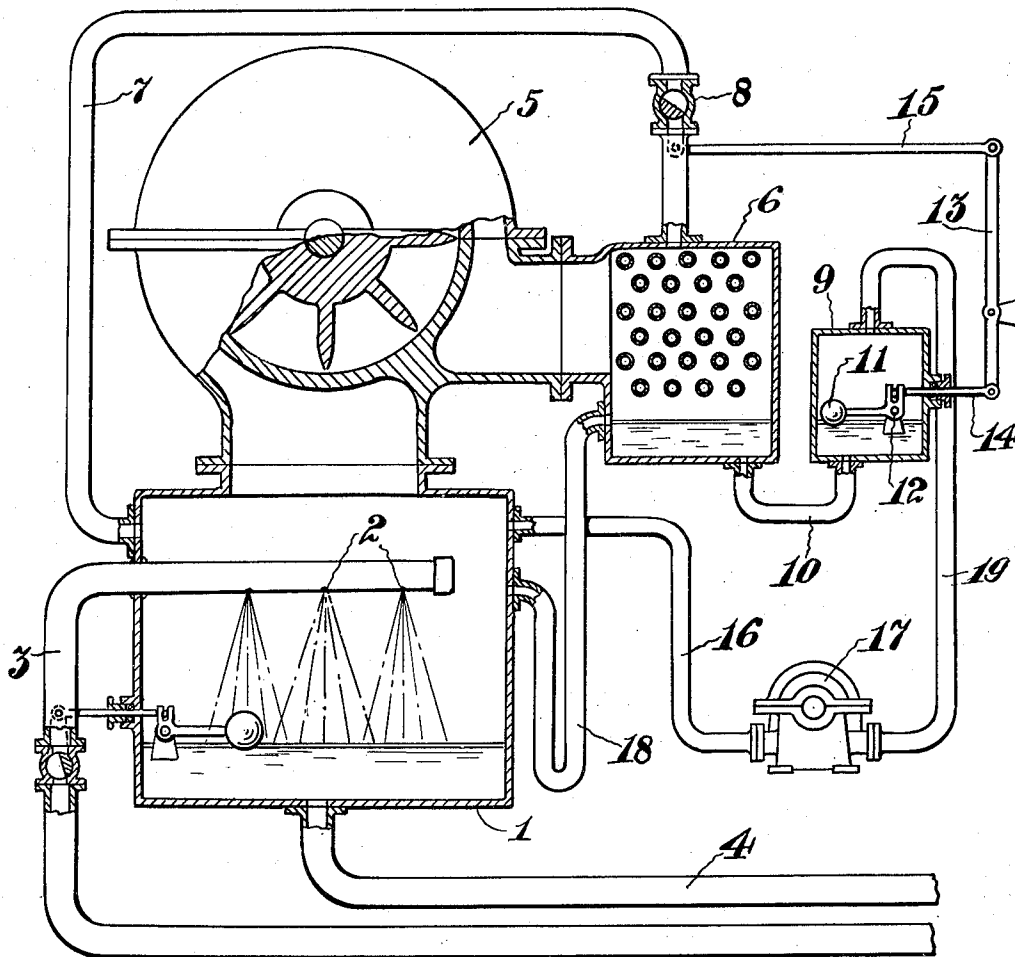
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CONTROLLING APPARATUS FOR REFRIGERATING SYSTEMS

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CONTROLLING APPARATUS FOR REFRIG-
ERATING SYSTEMS

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This invention is an improvement in controlling apparatus, especially for a refrigerating system, to facilitate operation at reduced output.

The invention is adapted for use with a refrigerating system in which a non-volatile refrigerant, such as water, is cooled by vaporizing part thereof, and in which a compressor of the centrifugal type running at constant speed carries off the vapor thus formed. Such a system comprises an evaporator vessel to which the liquid is admitted, a centrifugal compressor for removing the vapor from the evaporator, and a condenser to which the vapor is delivered to be liquefied. As the demand for refrigeration often varies widely in practice, the system must be capable of working without loss of stability at all refrigerating loads.

It is well known that a centrifugal compressor performs well over a considerable part of its load range, but that when the load thereon is considerably diminished, the vapor in the compressor has a characteristic tendency to break back or surge. Surging of the vapor renders the load on the compressor unstable; that is, the volume delivered and the intake and discharge pressures of the compressor fluctuate considerably. Such surging occurs when the compression-ratio of the compressor exceeds a critical value, and when the volume of fluid delivered to the compressor is insufficient to satisfy its volumetric capacity.

When coupled in a refrigerating system of the kind above-mentioned, the liability of surging of the vapor in the compressor is counteracted to a great degree by changes in the density and volume of the water vapor entering the compressor. But the tendency remains and instability of load will appear when the load is very light.

The chief object of this invention is to obviate entirely the liability of surging of the vapor in the compressor or blower at low loads secured in connection with the removal of water vapor and the transmission thereof to a suitable condenser, thereby assuring smoothness of operation and elimination of all danger of damage to the blower and motor for same.

Another object of the invention is to maintain stable load on the compressor by introducing vapor from the condenser into the inlet side of the compressor and automatically controlling the introduction of said vapor by means acting in accordance with the compression-ratio developed by the compressor.

In the operation of a centrifugal compressor

in a water vapor refrigerating system, the degree of compression increases as the load decreases, that is, the ratio of the discharge pressure to the suction pressure varies inversely as the load thereon and hence, inversely as the load on the system. My invention takes advantage of this condition to keep the by-pass closed over a large range of load, and includes an auxiliary positive displacement compressor which produces a pressure that is higher than that of the centrifugal compressor except at such low loads as will permit surging of the vapor to commence. At such a time the pressure produced by the centrifugal compressor becomes great enough to exceed the pressure produced by the auxiliary device, and at once actuates suitable connections that open the by-pass. Some of the vapor discharged by the compressor is then returned to the intake and all tendency to surge is nullified.

The nature and advantages of the invention are set forth in the drawing and accompanying description which disclose a preferred embodiment of the invention. But while I illustrate in outline a refrigerating system having controlling means according to the invention, the apparatus shown is of course only one embodiment of the principle and various alterations may be made, though not shown herein, such as changes in the form and arrangement of the various parts, within the scope or spirit of the appended claims.

On the drawing the figure shows in outline an apparatus in which the invention is incorporated.

The numeral 1 indicates an evaporator to which a liquid refrigerant, such as water, is admitted in a state of division by way of a spray nozzle 2 connected to an inlet or supply pipe 3. The pressure in the evaporator 1 is low enough to cause some of the water at the inlet temperature thereof to be converted into vapor as it enters. The vaporization extracts heat from the remainder of the water and thus cools off the main body of the liquid. The chilled water is then delivered from the evaporator and conveyed by means of a conduit 4 to a place where a refrigerating effect is desired. As the water is vaporized the vapor is extracted from the evaporator by means of a centrifugal compressor or blower 5. The intake of this blower communicates with the evaporator through a suitable port or passage, and after compression in the blower the vapor is delivered to a condenser 6 where it is liquefied. Both the intake and the outlet of the blower are preferably permanently open and of sub-

stantially fixed cross sectional area, the blower or compressor being of any suitable construction and comprising one or more stages.

The compressor 5 can be rotated by a steam turbine or electric motor with step-up gearing between the driving unit and the compressor so that the compressor will always be revolved at constant high speed regardless of whether the load increases or decreases. The compressor simply floats as it were, on the load as the load varies from full load to part load, and the compressor is to that extent self-regulating. Whenever a drop in load takes place the final temperature of the chilled water also drops and the compressor consumes less power although the speed does not change. When the load diminishes, the pressure of the water vapor in the evaporator falls and there are an accompanying decrease in the density of the water vapor and an increase in the specific volume thereof. At greater load the water vapor is compressed at greater density and lower specific volume, while at low load it is compressed at greater specific volume and less density. At full load or over, the ratio of compression between the discharge pressure of the compressor and the inlet or suction pressure, which is the pressure of the vapor in the evaporator, is relatively small, but this ratio of compression increases steadily as the load falls off. Due to the fact that as the load decreases the pressure within the evaporator decreases and the density and weight of the water vapor formed similarly decrease, the actual volume of vapor delivered to the compressor remains substantially constant in much the same way as it would if an ordinary damper were placed at the inlet of a compressor of this type. The machine thus operates to a large extent as a constant volume blower. The surging point is not apt to be reached at ordinary part loads, but may be arrived at if the load becomes very light.

In the event then that surging of the vapor occurs, as when the refrigerating system is delivering only a small part of its rated output, the load on the compressor becomes unstable and the volume delivered and the inlet and discharge pressures fluctuate considerably. The running of the compressor becomes uneven and some fluctuations in the power supplied to drive the motor also arise. To obviate this at light loads I connect to the condenser 6 and to the evaporator 1 a by-pass pipe 7. This pipe will return part of the water vapor to the evaporator at light load and thus increase the pressure and volume of the water vapor passing into the compressor so that any tendency to surge is eliminated. The by-pass pipe 7 contains a valve 8 which is normally closed, but is automatically opened when the surging point is approached. To control this valve I take advantage of the fact that the ratio of compression of the compressor 5 rises as the load or output decreases and at low load as the surge point is approached it becomes high enough to enable the discharge pressure of the blower 5 to be applied to open the valve 8 and enable some of the vapors in the condenser 6 to return to the evaporator 1.

To utilize the discharge pressure of the compressor 5 in this way and make it otherwise ineffective, I provide a container 9 and connect the container at the bottom through a trap forming pipe 10 with the bottom of the condenser 6. In the container 9 is a float 11 carried by a bell-crank lever mounted on a pivot 12. This lever is joined by a rod or link 13 to one end of an out-

side lever 14 the other end of which is pinned to a link 15 connected to an outside arm on the rotary valve 3. As the vapor delivered by blower 5 is condensed it collects at the bottom of the condenser 6 and flows through the pipe 10 and into the container 9. The top of the container 9 is connected by a pipe 19 to the discharge port of a small positive displacement compressor or pump 17, either of the rotary or reciprocating type. The intake port of this compressor 17 is connected by a pipe 16 to the evaporator. The compressor 17, preferably running at a constant speed, withdraws a small portion of vapor from the evaporator and discharges it into the container 9. Most of the condensing of this vapor will occur in the container 9, and the pressure in the container will depend on a number of factors: the speed of the pump 17, the capacity of pump 17 and pipes 16 and 19, the volume of the chamber 9 (which acts as an expansion chamber), and the rate of condensation in the chamber 9 which is dependent upon the surface area of the liquid therein. By proper design and control of these factors I am enabled to control the pressure in the container at will. Suffice it to say at the present that the pressure produced in the container 9 will be considerably higher than the condenser pressure at all normal loads but, as the load approaches the critical minimum at which surging will occur, the container pressure will decrease much more rapidly than does the condenser pressure and the liquid level in the container will rise. The float 11 will normally be held in such a position that it will be out of the water in the container 9 and thereby hold the valve 8 in closed position. However, as the load falls, the rising liquid level in the container will at the desired moment engage the float 11 and cause the valve 8 to open. The pressure in the evaporator will then increase or at least be prevented from falling below the critical minimum, and an equilibrium will be established between evaporator, condenser and container pressures, and the position of the valve 8 will be determined accordingly. Thus the purpose of the pump 17 is to produce a pressure which will be dependent among other things upon the pressure in the evaporator but which will exceed the condenser pressure at normal loads and which will be approximately the same as condenser pressure at the loads when surging is likely to occur.

In operation, when normal load is being experienced the volume and weight of vapor delivered by the pump 17, although considerably less than that of the blower 5, will be sufficiently great to build up a pressure in the container 9 considerably in excess of the pressure in the condenser 6. The water in the container is then depressed until equilibrium between the condenser and container pressures is attained. Vapor at such normal loads may even blow through the pipe 10 and into the condenser 6 but such action is not detrimental. When the load decreases however, the pump 17 being a constant volume pump delivers ever decreasing weights of vapor, and such decreased weight of vapor is more easily and more quickly condensed in the container 9. The pressure therein inevitably decreases because of this fact and because of the fact that the actual compression produced in the pump 17 is much less than before. The liquid rises in the container and, with proper design, engages the float 11 to cause the valve 8 to open just shortly before the low load occurs

at which the load on the blower 5 becomes unstable.

The small motor driven compressor 17 is built for a compression ratio giving a compression slightly less than the peak of compression reached by the compressor 5 when the load becomes very light, and the container 9 is correctly proportioned to produce the proper expansion and condensing action of the vapor delivered thereto. Thus the discharge pressure of the compressor 5 can become greater than the discharge pressure of the compressor 17 and cause the level of the liquid in the container 9 to rise and the valve 8 to open when it is needed. At all other times the discharge pressure of the blower 5 is rendered ineffective by the high pressure produced by the pump 17.

The bottom of the condenser can be connected to the upper part of the evaporator 1 through a U-shaped pipe 18, so that the liquefied water vapor can be returned to the evaporator 1. This pipe acts as a trap because some water will always be in the bend thereof and communication cannot be directly established between the condenser and the evaporator 1. The small volume of vapor withdrawn from the evaporator 1 by the pump 17 in general condenses in the container 9, but as the water is drawn out of the condenser through the pipe 18 as fast as it reaches the height of the entrance to this pipe, the level of the condensate in the condenser remains virtually constant and hence there is no risk of the water rising too high in the condenser 6. Since the condensate level in the container 9 corresponds to the difference in pressure between the container 9 and the condenser 6, it cannot rise greatly above the condensate level in the condenser and thus there is no danger of flooding the container.

This construction has the effect of so greatly extending the range of load stability for the compressor 5 that the risk of instability of load at even light loads is entirely nullified. Surging of the vapor is thus prevented entirely and the system can be operated at any point in its range from the lightest load to overload with perfect safety to the compressor and its motor and all of the driving parts connected to same.

I claim:

1. The combination with an evaporator having a plurality of evacuators therefor, one or more of said evacuators developing a ratio of compression variable with the load on the evacuators, of means acting in accordance with the discharge pressures of said evacuators to stabilize the load on the evacuators as said ratio of compression approaches a critical value.

2. The combination with an evaporator having a plurality of evacuators for removing vapor therefrom, of means subjected to the discharge pressures of all said evacuators and acting at low evacuator loads to stabilize the pressure in the evaporator.

3. The combination with an evaporator having a plurality of evacuators for removing vapor therefrom, of means subjected to the discharge pressures of said evacuators and acting in accordance with said pressures and as the load on the evacuators drops to maintain the pressure in the evaporator above a certain critical minimum.

4. The combination of an evaporator and evacuator means for the evaporator, a compressor for withdrawing a portion of vapor from the evaporator, and means acting in accordance with the difference in the discharge pressures of said evacuator means and said compressor to main-

tain the pressure in the evaporator above a certain critical minimum and thereby stabilize the load on the evacuator means.

5. The combination of an evaporator and means for evacuating the evaporator, a condenser to receive the discharge of said means, a compressor for withdrawing a portion of vapor from the evaporator, and means subjected to the pressure in the condenser and the discharge pressure of said compressor and acting in accordance with said pressures to control the pressure in the evaporator.

6. The combination of an evaporator and means for evacuating the evaporator, a by-pass around said evacuating means, a compressor for withdrawing a portion of vapor from the evaporator, and means acting in accordance with the discharge pressures of said evacuating means and said compressor to control said by-pass.

7. The combination of an evaporator and means for evacuating the evaporator, a by-pass around said evacuating means, a condenser to which the evacuating means discharges, a compressor for withdrawing a portion of vapor from the evaporator, and means acting in accordance with the pressure in the condenser and the discharge pressure of said compressor to open said by-pass as the load on said evacuating means drops.

8. The combination of an evaporator and evacuating means therefor, a by-pass around the evacuating means, a condenser to receive the discharge of the evacuating means, a compressor for withdrawing a portion of the vapor from the evaporator, and means acting in accordance with the difference between the discharge pressure of the compressor and the pressure in the condenser to control said by-pass and thereby control the pressure in the evaporator.

9. The combination of an evaporator and a compressor for removing vapor therefrom, said compressor having a compression ratio which varies inversely as the load thereon, a condenser to which the compressor discharges, a by-pass around the compressor, a positive displacement pump for withdrawing a portion of vapor from the evaporator, a container to which the pump delivers, a conduit between the condenser and the container, and means in the container acting in accordance with the difference in the pressure in the condenser and the discharge pressure of the pump to control said by-pass.

10. The combination of an evaporator and a centrifugal compressor for removing vapor therefrom, means connected to be actuated by a force corresponding to the compressor discharge pressure to maintain the pressure in the evaporator above a certain critical minimum and thereby maintain stable load on the compressor, and means for rendering said force ineffective except when said pressure approaches said minimum.

11. The combination of an evaporator and a centrifugal compressor for removing vapor therefrom, a by-pass around the compressor, means connected to be actuated by a force corresponding to the compressor discharge pressure to control said by-pass and thereby control the pressure in the evaporator, and means for rendering said force ineffective except when the pressure in the evaporator approaches a certain critical minimum.

12. The combination of an evaporator and a compressor for removing vapor therefrom, said compressor having a compression-ratio which varies inversely as the load thereon, a positive dis-

placement pump for removing a portion of the vapor from the evaporator, the pump discharge pressure being normally greater than the compressor discharge pressure, and means subjected 5 to said discharge pressures and acting to effect an increase in the pressure in the evaporator when said compressor discharge pressure becomes greater than said pump discharge pressure thereby maintaining said evaporator pressure above 10 a certain critical minimum.

13. The method of stabilizing the load on a centrifugal compressor which consists in opposing a force corresponding to the compressor discharge pressure with a normally greater force, reducing the said forces disproportionately as the 5 load drops, and effecting an increase of the compressor intake pressure when the difference in said opposed forces approaches a certain critical value.

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