

Jan. 25, 1944.

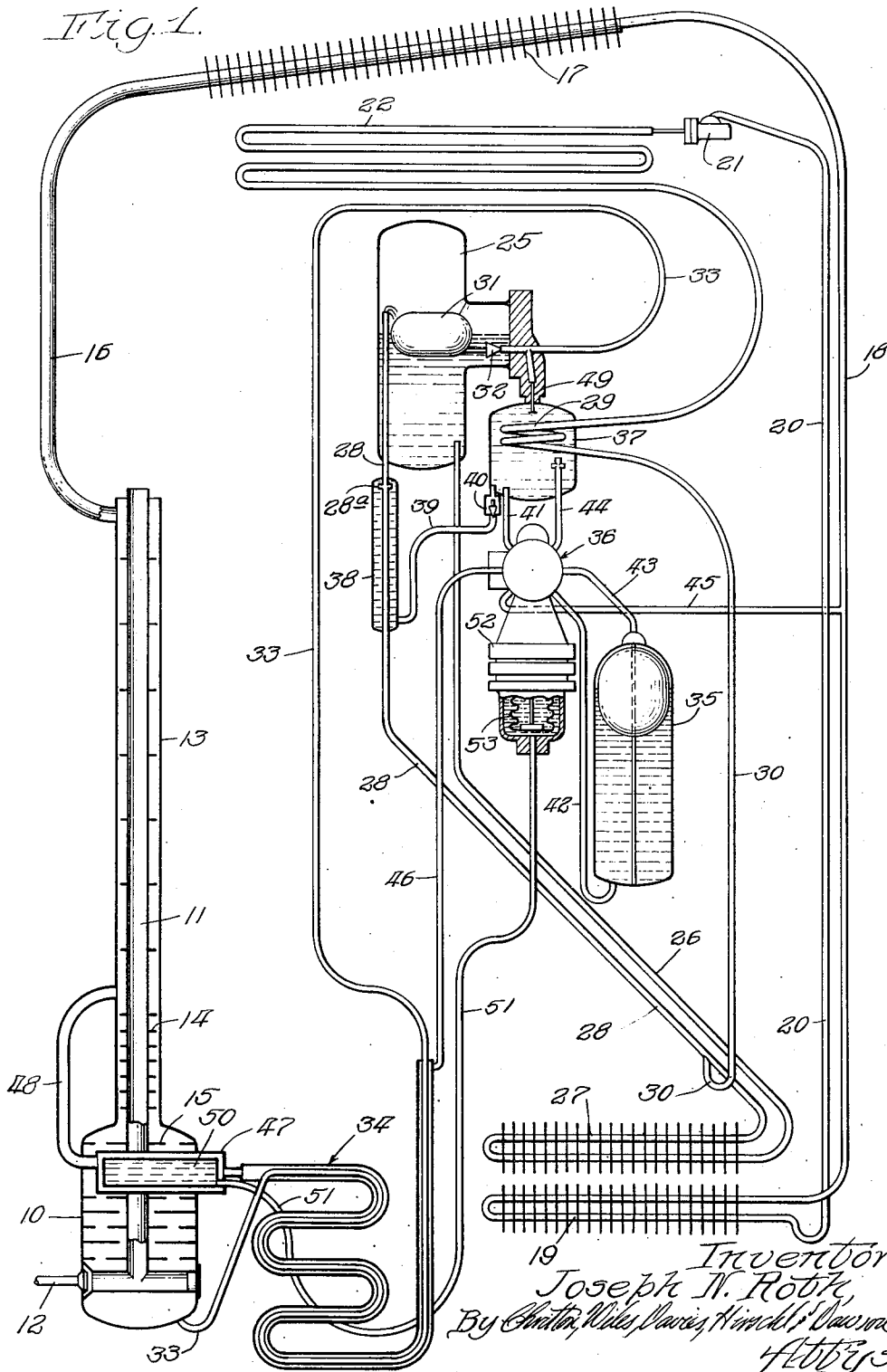
J. N. ROTH

2,339,815

EXPANSION CONTROL

Filed Oct. 17, 1940

2 Sheets-Sheet 1



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EXPANSION CONTROL

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Fig. 2.

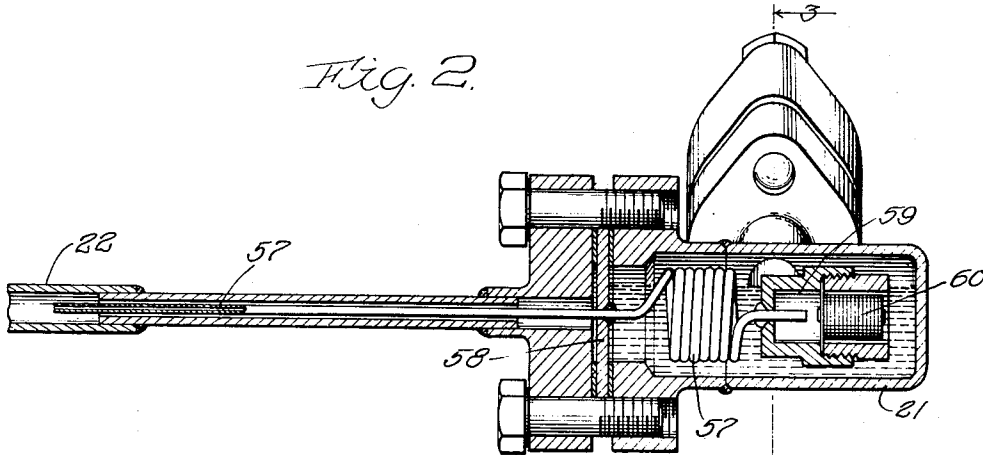


Fig. 3.

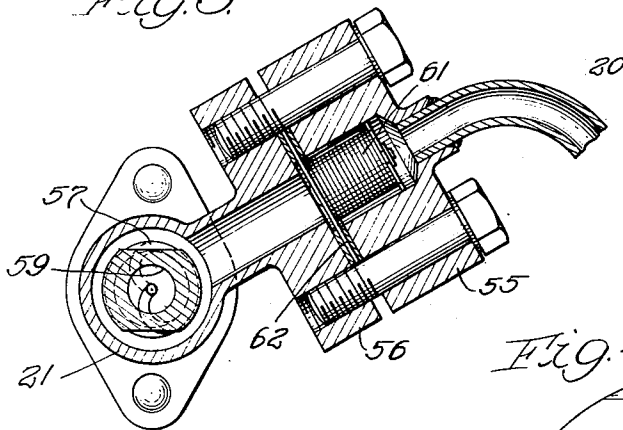


Fig. 6.

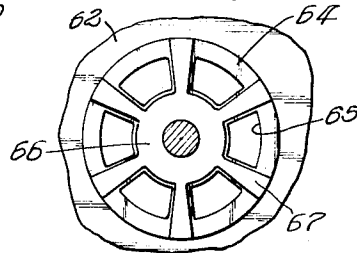


Fig. 4.

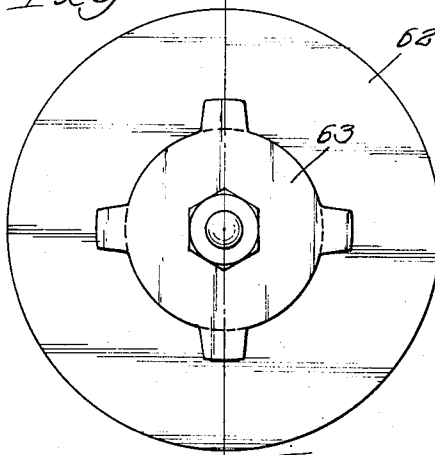
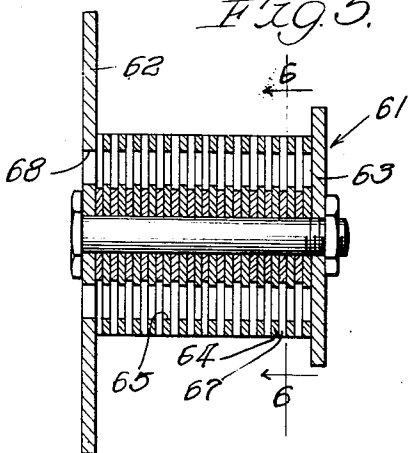


Fig. 5.



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UNITED STATES PATENT OFFICE

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EXPANSION CONTROL

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mesne assignments, to Gibson Refrigerator
Company, Greenville, Mich., a corporation of
Michigan

Application October 17, 1940, Serial No. 361,629

9 Claims. (Cl. 62-5)

This invention relates to expansion control means, and more particularly to means for controlling the delivery of liquefied ammonia from a high-pressure portion of a continuous absorption refrigeration system to the evaporator of such a system.

One feature of this invention is that it provides improved means for controlling delivery of refrigerant from a high-pressure portion to a low-pressure portion of a refrigeration system; another feature of this invention is that it automatically controls the rate of flow of refrigerant to the evaporator in accordance with the rate at which the refrigerant is liquefied in the condenser, which latter rate can be conveniently controlled in accordance with refrigeration requirements; another feature of this invention is that it is particularly adapted for use with a refrigerant having a high latent heat, as ammonia, and in a continuous refrigeration system; as a continuous absorption refrigerator; another feature of this invention is that complete control of the delivery of refrigerant to the evaporator is had without the use of any moving parts, as in the conventional float-controlled expansion valve; yet another feature of this invention is that the rate of flow of refrigerant through a capillary tube can be retarded more than would be the case if such refrigerant passed through entirely in liquid form, and this retarding effect can be varied in accordance with conditions in the refrigeration system; other features and advantages of this invention will be apparent from the following specification and the drawings, in which:

Figure 1 is a schematic or diagrammatic showing of a system employing this invention as embodied in a domestic continuous absorption refrigerator; Figure 2 is a detail view, principally in vertical section, of the expansion control arrangement; Figure 3 is a transverse sectional view along the line 3-3 of Figure 2; Figure 4 is an end elevation of a filter element; Figure 5 is a sectional view along the line 5-5 of Figure 4; and Figure 6 is a view along the line 6-6 of Figure 5.

In the particular embodiment of my invention described herewith, the system in general comprises a still adapted to have a mixture of refrigerant and absorbent, as ammonia and water, boiled therein by the application of heat; a condenser connected by a vapor conduit to the still to liquefy the refrigerant vapor delivered thereby; an evaporator or cooling unit in which the liquefied refrigerant is permitted to vaporize, the

evaporator having restricted connection with the condenser; an absorber in which the gas from the evaporator is reabsorbed in liquid; and means for effecting flow of weak liquor from the bottom of the still to the absorber and flow of rich liquor from the bottom of the absorber to the still. This latter means includes a transfer chamber intermediate the absorber and the still and a valve arrangement whereby the chamber is selectively connected to the absorber or to the still.

Referring more particularly to a specific system schematically or diagrammatically illustrated in Figure 1, the still 10 is adapted to contain a mixture of water and ammonia. A flue 11 is provided within the still and heat delivered thereto by the combustion of gas or some other fuel delivered by the burner 12. An analyzer tower 13, in the form of a long cylindrical tubing enclosing the flue 11, rises from the upper part of the still, which is a vertical cylindrical vessel. Both the analyzer tower and the still are provided with baffle plates, as 14 and 15, these plates serving to stratify the liquid in the still and to improve the efficiency of the apparatus.

Rich ammonia vapors boiled off the liquor in the still pass upwardly through the analyzer tower 13 and then through the pipe connection 16 to the rectifier 17, a finned inclined tube at the top of the system. From there the ammonia vapors, any entrained water vapor having been removed by the rectifier, pass down through the connection 18 to a condenser 19 at the lower end of the apparatus. This condenser comprises one or more loops of piping, finned to increase the heat radiation. The ammonia vapor is here condensed into liquid ammonia, and then elevated by the vapor pressure behind it through the connection 20 to the receiver 21.

The amount of ammonia boiled off and liquefied is a function of the concentration of the liquor in the still and of the amount of heat supplied to it, so that if the concentration of liquor is kept relatively constant the rate of delivery of liquid ammonia to the receiver 21 will be practically a direct function of the amount of heat supplied to the still. The amount of fuel delivered to the burner 12, and thus the amount of heat supplied and the rate of delivery of liquid ammonia to the receiver, can be regulated in any desired manner, as by a valve (not here shown) actuated in conventional manner by a thermostat in the cooling chamber of the refrigerator.

Liquid ammonia passes from the receiver 21 to the dry evaporator 22, preferably comprising sev-

eral coils of piping, through the restriction interposed by control means which will hereafter be described in more detail. The control arrangement is such that, as more liquid ammonia is delivered to the receiver, flow from the receiver to the evaporator is increased to maintain the level of liquid in the receiver within certain desired limits.

Absorbing apparatus is provided in the form of an upper chamber or vessel 25 having extending downwardly therefrom a cooling and absorption loop. This loop is formed by a pipe 26 extending down from the bottom of the absorber vessel; the absorber cooling coil 27, finned for better heat radiation; and the upwardly extending pipe or leg 28, terminating in the vessel 25 slightly above the level of absorption liquid therein.

Expanded ammonia vapor from the evaporator 22 first passes through a small loop or coil 29, the purpose of which will be hereinafter explained, then through the pipe 30 into the rising leg 28 of the absorber loop, near the lower part thereof. The incoming vapor creates bubbles in the leg 28 of the absorber loop which provide a liquid lift or pump insuring circulation of absorption liquid through the loop. Inasmuch as the liquid in this rising leg is at all times the weakest liquor in the absorber, and cool as a result of passing through the coil 27, all absorption takes place in the pipe 28 under normal conditions, the liquid flowing out of the top of this pipe being quite rich.

The level of liquid in the absorber vessel 25 is maintained by a float 31 and valve 32 controlling delivery of weak liquor from the still. The pipe 33 leads from the lower end of the still (where the liquor is weakest) through a heat exchanger 34 and then on up to open into the absorber, the flow into the absorber being controlled by the valve 32, which opens whenever the level of liquid in the vessel 25 drops below a desired point.

The means for returning rich liquor from the absorber to the still comprises as its principal parts a transfer chamber 35, a valve assembly 36, a pressure chamber 37 and associated operative interconnections. A flow connection is provided from the leg 28 of the absorber loop, out of the short open-ended cross tube 28^a, through the jacket 38, pipe 39, and check valve 40, into the pressure chamber 37. When the valves are set in a certain position a flow path is provided from the pressure chamber, and thus from the absorber, through the pipe 41, the valve mechanism, and the pipe 42 to the bottom of the transfer chamber 35, any vapor therein being vented through the pipe 43 and the pipe 44 (interconnected by the valve assembly) into the pressure chamber.

When the valve device is actuated, in accordance with a condition of the system, to move the valves to another position, the pipe 43 is connected to the pipe 45 which is open to high pressure vapor in the pipe 18; and the pipe 42 is connected to the pipe 46, connected through the heat exchanger 34 to a jacket 47 around a thermostat bulb in the still, and then through a pipe 48 into the analyzer tower. The transfer chamber and connecting pipes now being at high pressure, the rich liquor therein flows into the analyzer tower and thence to the still until the valves are again moved to the position first described above.

When the interconnection between the pressure chamber and the transfer chamber is again provided there is, of course, a rush of high pressure vapor through the pipe 43 and 44 to the chamber 37. The check valve 40, however, pre-

vents these vapors from getting back into the low pressure side of the system; and the liquid in the chamber 37, cooled by the coil 29, rapidly absorbs the vapor, assisted in this respect by a fine stream of weak liquor bled into the chamber 37 through the conduit 49 branching from the weak liquor pipe 33. The rapid absorption of rich ammonia vapor causes the pressure in the chambers 35 and 37 to drop below the pressure in the absorber 25 for a brief time, so that there is a positive pressure-driven flow of rich liquor from the absorber to completely refill the chambers 35 and 37. When these are completely filled with liquid the weak liquor entering through the branch pipe 49 immediately starts to raise the pressure therein, the check valve 40 closing; and shortly the chambers 35 and 37 will again stand at high pressure. There is thus only a brief interval during which the valves in the assembly 36 must withstand the full difference of pressure between the high and low sides of the system.

Actuation of the valve means in the valve assembly 36 is accomplished by a thermostat bulb 50 in the jacket 47 connected by a liquid actuating leg 51 to a chamber in the bottom of the valve housing 52. Liquid refrigerant in the pipe 46, open at all times to still pressure, generates a certain pressure within the Sylphon bellows 53; whereas the pressure of the actuating liquid in the thermostat bulb 50 (preferably a predetermined ammonia-water concentration) is effective against the exterior of the Sylphon 53. The valve arrangement preferably includes a snap-action mechanism, so that when the pressure of the thermostat liquid exceeds the still pressure by a certain amount the bellows, and thus the valves moved by it, move to upper position; and when the bulb pressure has dropped a certain amount below the still pressure the bellows and valves move down to the other position. These two alternate positions effect the connections heretofore described.

While the continuous absorption refrigeration system hereabove described contains a number of inventions and improvements over other known systems, these will not be described in more detail here, this present application being particularly directed to improved means for controlling delivery of refrigerant from the high side to the low side or evaporator of the system. Other improvements in the system are the subject matter of my earlier filed joint and several copending applications, more particularly applications Serial No. 296,995, filed September 28, 1939, Serial No. 298,110, filed October 5, 1939, Serial No. 314,704, filed January 19, 1940, Serial No. 319,541, filed February 17, 1940, Serial No. 326,292, filed March 27, 1940, and Serial No. 352,328, filed August 12, 1940, and other later filed copending applications. The operation of the various other parts of the system will not, therefore, be described in further detail here; but the remainder of this specification will be directed to a description of the improved expansion control apparatus, more particularly as embodied in the apparatus shown in Figures 2 to 6.

Referring now more particularly to these latter figures, it will be seen that the receiver 21 is in general a cylindrical vessel with its axis horizontal; and that the pipe 20, delivering liquefied refrigerant from the condenser 19, opens into a wall of the receiver near its upper part. For convenience of assembly and repair the pipe 20 is not welded directly to the wall of the receiver

21, but to a plate 55; and this is bolted to a flange 56, as may be best seen in Figure 3. It is important that the communication of the pipe 20 with the receiver 21 be near its upper part, since in the operation of my improved control it is desirable to maintain a quantity of liquified refrigerant in the receiver at all times; yet it is desired to permit communication of the space above this liquid with refrigerant vapor at condenser temperature and pressure, so that no liquid trap should be provided in this part of the apparatus. In normal operation of a system of this kind refrigerant vapor partially liquefies in the condenser 19, and slugs of liquid ammonia are pushed up the pipe 20 by the vapor. With the arrangement here shown it is intended to have some liquid refrigerant at all times in the receiver 21; and some refrigerant vapor, at condenser pressure and approximately at condenser temperature, in the receiver above this liquid.

Referring now more particularly to Figure 2, it will be seen that a capillary tube 57 provides connection between the receiver 21 and the evaporator pipes 22. This capillary tube is welded or otherwise sealed in an opening in a plate 58 separating the receiver from the evaporator; a small portion of the capillary tube 57 extends straight out from this plate to open into the evaporator pipe 22, but the major part of the capillary tube is coiled up within the receiver 21. The arrangement for connecting the capillary tube to the evaporator tubing is the subject matter of my copending application Serial No. 501,936, filed September 11, 1943. The other or righthand end of the capillary tube does not open directly into the main receiver chamber, but into a small auxiliary chamber 59 separated from the main receiver chamber by filter means 60. This filter is similar in arrangement and operation to another filter 61 which is in the connection between the pipe 20 and the receiver 21.

Referring now more particularly to Figures 4, 5 and 6, it will be seen that each of these filters comprises a main end plate 62 and a smaller end plate 63. These two end plates are separated by a plurality of washers or filter elements, these being of two types and stacked alternately; and the whole assembly is held together by a bolt. The bolt preferably has a polygonal shank, as for example hexagonal, and the washers are provided with similar holes so that when they are stacked upon the bolt shank they are nonrotatable thereon. As may be best seen in Figures 5 and 6, one of these types of washers, here identified as 64, is a disc provided with six regularly spaced openings or holes 65. The other type of washer, here identified as 66, is a spider with legs 67 projecting out between the openings in the other washer. The end plate 62 is provided with openings, as 68, aligned with the openings 65 in the one set of washers.

These washers are stamped out of sheet metal, as sheet steel, and are only a few thousandths of an inch thick, always being of lesser thickness than the internal diameter of the capillary tube with which they are to be used. Liquid passing from the pipe 20 into the receiver 21, for example, surrounds the circumference of this filter arrangement and flows in edgewise between the elements 64, thereafter flowing down through the registering openings 65 and out through the openings 68 in the end plate 62 into the receiver. By this arrangement a broad filter area is provided, yet particles even remotely approaching the size of the internal diameter of the capillary

tube are prevented from reaching it and clogging it.

Returning now more particularly to the arrangement shown in Figure 2, it will be seen that a substantial part of the coiled portion of the capillary tube 57 is immersed in liquid refrigerant, but a part of its top is exposed to the warm refrigerant vapor. When liquid refrigerant enters a capillary tube its restriction to flow causes a pressure drop through the tube, so that as the liquid flows therethrough its pressure at any given point decreases as it approaches the evaporator pipes. Under these conditions, because of the reduction in pressure, liquid refrigerant in the capillary tube is colder than that in the receiver 21, its temperature progressively decreasing as it approaches the end plate 58. Under these conditions the exposed part of the coil acts as a condenser, part of the warm refrigerant vapor in contact with it giving up its heat and turning into liquid. This heat passes through the walls of the capillary tube and in turn causes a change of state of the liquid refrigerant therein, vaporizing or gasifying a part of it. Change of state retards flow of refrigerant through the capillary, since the change not only creates back pressure in the tube, but also results in a much greater volume of fluid therein, the gaseous refrigerant occupying several times the space of the liquid refrigerant.

As the level of the liquid refrigerant in the receiver falls, more area of the coil portion of the capillary tube 57 is exposed to the refrigerant vapor, and more gasification of liquid refrigerant in the tube takes place, thus providing more retardation of refrigerant flow therethrough. Similarly, if the level of liquid in the receiver 21 rises by reason of delivery of liquid thereto faster than it is passing through the capillary tube, there is less coil to be exposed to refrigerant vapor, and less retarding effect on refrigerant flow. Practically all heat input to the capillary tube comes from condensing action where it is in contact with refrigerant vapor, the heat conduction of the liquid refrigerant being rather poor. It will thus be seen that if the receiver fills until the coils are completely submerged the refrigerant will pass through the capillary tube substantially entirely in liquid state, so that there will be a greatly increased flow of refrigerant.

This automatic variation of heat input to the liquid within the capillary tube, with its consequent variation of the retarding effect on the flow of refrigerant through the capillary tube, has proved very important, particularly in continuous absorption refrigeration systems. Heretofore it has been necessary to use a float-actuated expansion valve, yet the rate of refrigerant flow was so small and the pressures so high that there was great wire drawing and frequent failure of the expansion valve arrangement. The refrigeration art has heretofore thought it impossible to use a capillary tube to accomplish refrigerant control under such conditions. In the first place, any attempts to use a capillary tube without the provision of some retarding means beyond its ordinary restriction to flow would require the use of such a fine tube as to be impracticable; and secondly, the rate of refrigeration in continuous absorption systems is controlled by varying the amount of fuel burned, so that some means would have to be provided for enabling greatly increased flow of refrigerant when the fuel input was high, and a greatly retarded flow

of refrigerant to the evaporator when the burner was turned very low.

Turning first to the problem of the size of a capillary tube required if used in the ordinary way in which it is used in electric refrigerators, it will be seen that the restriction of the capillary tube would have to be in the neighborhood of twenty times as great as that imposed by a capillary used in a conventional electric refrigerator. In the first place, the latent heat of ammonia is so much greater than that of Freon, the common commercial refrigerant used in electrical systems, that it requires about four cubic feet of Freon to equal to refrigerating effect of one cubic foot of ammonia. Moreover, the electric refrigerator is designed to pass a higher quantity of refrigerant than is necessary to hold the food chamber at a desired temperature, so that it may run intermittently and yet maintain an average evaporator temperature, for example, of twelve degrees. Since the average electric refrigerator is so designed as to need to run only one-third to one-half the time, we can assume that it is designed to pass to the evaporator about two and one-half times the amount of refrigerant which should be delivered in a continuous machine. Moreover, where a capillary tube is used as a control means, the rate of flow of refrigerant through the tube is a function of the pressure differential between the high and low sides of the refrigeration system; and the average pressure differential between the high and low sides of a continuous absorption machine is about twice that between the high and low sides of an electrically driven compressor type machine. In a 95° F. room, for example, the condensing pressure of ammonia may be 181 pounds per square inch, with an evaporator pressure of eighteen pounds, a differential of 163 pounds; whereas the condensing pressure of Freon may be 108 pounds as against an evaporator pressure of 16 pounds, a differential of 92 pounds.

All of these differences are cumulative, so that the latent heat ratio of four to one, the rate of flow ratio of two and one-half to one, and the pressure differential ratio of about two to one should all be multiplied. It is thus apparent that a capillary tube to be used to control delivery of ammonia to the evaporator in a continuous absorption refrigerator should have about twenty times the restrictive effect of a capillary tube controlling delivery of Freon to the evaporator of an electric refrigerator. While formulae have not as yet been developed for the relations, it is known that lengthening a capillary tube, or reducing its internal diameter, increases its restrictive effect on fluid flow. In an electric refrigerator manufactured and sold by the company by which I am employed proper restrictive effect for Freon is obtained by the use of six feet of capillary tube having an internal diameter of .032 inch. In order to greatly increase the restrictive effect in an attempt to control delivery of ammonia to the evaporator of a continuous absorption refrigerator, I tried ten feet of capillary tube having an internal diameter of .0065 inch, and found it impracticable. In the first place, it did not provide sufficient restrictive effect to the flow of refrigerant, blowing through at high room temperature; and in the second place, it was so undesirably small in internal diameter that it plugged up with only small globules or droplets of oil.

By employing the improved arrangement which I have described above, supplying heat to the refrigerator through the capillary tube and caus-

ing a change of state of some of it while it is in the tube, I find that sufficient restrictive effect is obtained by the use of three and one-third feet of capillary tube having an internal diameter of .012 inch, about 35 inches of this tube being coiled up in the receiver. Moreover, the variation in heat input to the tube with variation of liquid level in the receiver causes the rate of delivery of refrigerant through the capillary tube to the evaporator to conform exactly to the rate of delivery of liquified refrigerant to the receiver; and this automatic compensating action properly controls delivery through exceedingly wide ranges of heat input to the generator, and through wide ranges of temperature in the room in which a domestic refrigerator embodying this invention operates.

While I have shown and described certain embodiments of my invention, it is to be understood that it is capable of many modifications. Changes, therefore, in the construction and arrangement may be made without departing from the spirit and scope of the invention as disclosed in the appended claims.

I claim:

1. Apparatus of the character described for controlling delivery of liquefied ammonia from a high pressure portion to a low pressure portion of a continuous absorption refrigeration system, including: a receiving chamber in the high pressure portion; a capillary tube connecting the chamber to the low pressure portion to deliver refrigerant thereto, the major portion of the capillary tube lying within the chamber and being adapted to be at least partly immersed in liquid refrigerant therein, the construction and arrangement being such that the immersion varies with the amount of liquid in the chamber and the part not immersed is in contact with warm refrigerant vapor.

2. Apparatus of the character described for controlling delivery of liquefied ammonia from a high pressure portion to a low pressure portion of a continuous absorption refrigeration system, including: a receiving chamber in the high pressure portion in communication with the condensing portion of the system through an opening in the wall of the chamber near its top; a capillary tube connecting the chamber to the low pressure portion to deliver refrigerant thereto, the major portion of the capillary tube being coiled within the chamber and being adapted to be at least partly immersed in liquid refrigerant therein, the construction and arrangement being such that the immersion varies with the amount of liquid in the chamber and the part not immersed is in contact with warm refrigerant vapor, whereby flow of refrigerant through the tube is automatically accelerated if the refrigerant is being delivered to the chamber more rapidly than it is passing through the tube.

3. Apparatus of the character claimed in claim 2, including a filter for preventing blocking of the capillary tube.

4. A method for retarding flow of refrigerant through a capillary tube providing insufficient restriction to flow of liquid refrigerant, comprising exposing part of said tube to gaseous refrigerant to deliver heat to said tube and gasify part of the liquid refrigerant therein during its passage therethrough, varying the amount of said tube exposed to said gaseous refrigerant in accordance with the amount of additional retardation so desired, and delivering the refrigerant at a discharge point located substantially out of

heat exchange relation with the part of said tube exposed to said gaseous refrigerant.

5. Apparatus of the character described for controlling delivery of refrigerant from a high pressure portion to a low pressure portion of a refrigeration system, including: a capillary tube through which the refrigerant flows; a receiving chamber in the high pressure portion into which one end of the tube opens; and means for delivering refrigerant to said chamber, the construction and arrangement being such that liquid and vapor separate in the chamber and heat is supplied to the tube from the vapor to gasify at least part of the liquid refrigerant therein and the amount of heat supplied is increased when said rate of flow exceeds the rate of delivery to said chamber and decreased when said rate of flow is less than the rate of delivery to the chamber, the tube extending to a discharge end located substantially out of heat exchange relation with the chamber.

6. Apparatus of the character described for controlling delivery of refrigerant from a high pressure portion to a low pressure portion of a refrigeration system, including: a capillary tube through which the refrigerant flows; a receiving chamber into which one end of the tube opens;

and means for delivering liquid refrigerant and warm refrigerant vapor to the chamber, a substantial portion of the tube lying within the chamber and adapted to be at least partly immersed in liquid refrigerant therein, the construction and arrangement being such that the liquid and vapor separate in the chamber so that the immersion varies with the amount of liquid in the chamber and the part not immersed is in contact with the warm vapor to receive heat sufficient to gasify at least part of the liquid refrigerant therein, the other end of the tube being located substantially out of heat exchange relation with the chamber.

7. Apparatus of the character claimed in claim 5, wherein the refrigeration system is of the continuous absorption type and the refrigerant is ammonia.

8. Apparatus of the character claimed in claim 5, including a filter for preventing blocking of the capillary tube.

9. Apparatus of the character claimed in claim 6, wherein the refrigeration system is of the continuous absorption type and the refrigerant is ammonia.

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