March 24, 1953 V. W. SMITH 2,632,303

HOT GAS DEFROSTING MEANS FOR REFRIGERATING SYSTEMS

Filed Aug. 9, 1949 2 SHEETS—SHEET 1

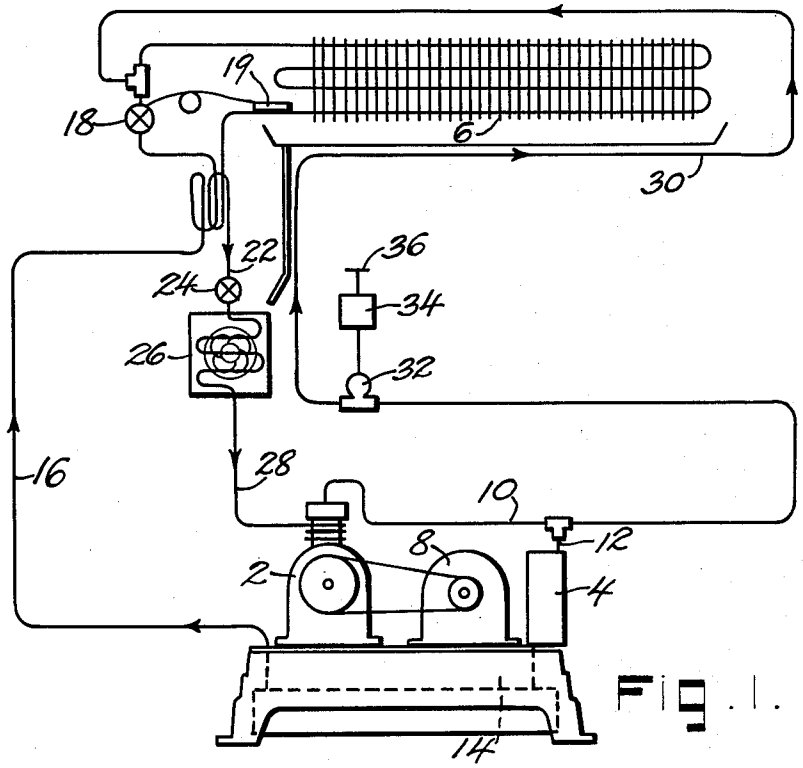


Fig. 1.

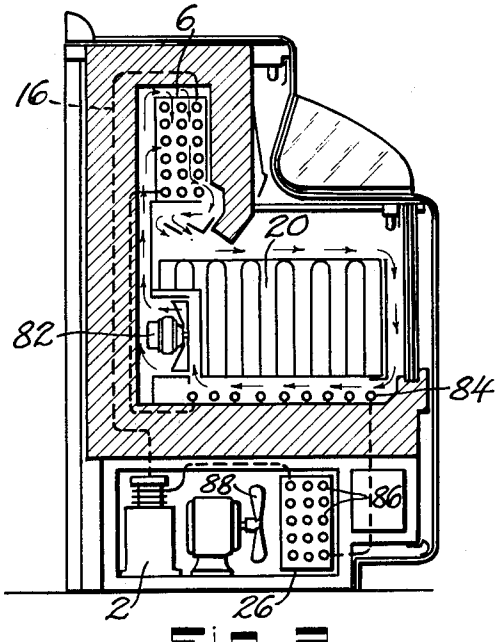


Fig. 2.

INVENTOR.
VICTOR W. SMITH
BY
Albert Sperry
ATTORNEY

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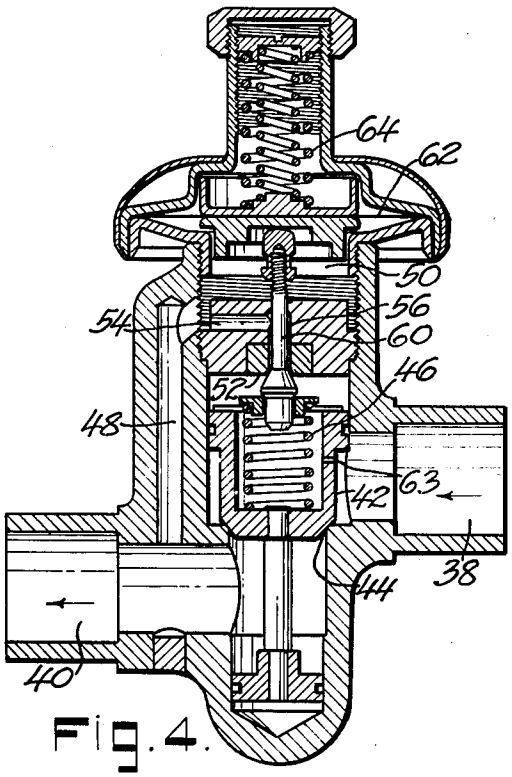


Fig. 4.

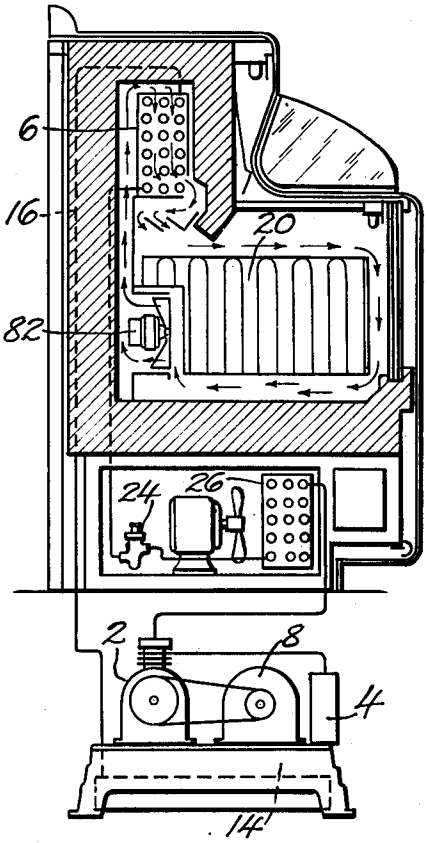


Fig. 3.

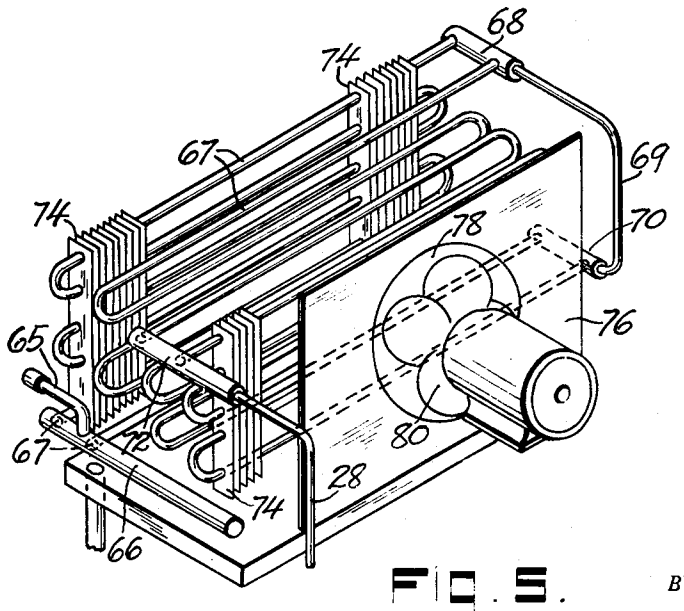


Fig. 5.

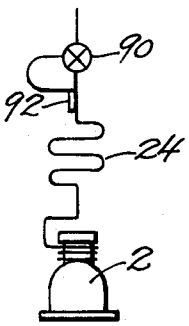


Fig. 6

INVENTOR.
VICTOR W. SMITH
BY Albert Sperry.
ATTORNEY

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UNITED STATES PATENT OFFICE

2,632,303

HOT GAS DEFROSTING MEANS FOR REFRIGERATING SYSTEMS

Victor W. Smith, Trenton, N. J., assignor to C. V. Hill & Company, Inc., Trenton, N. J., a corporation of New Jersey

Application August 9, 1949, Serial No. 109,335

8 Claims. (Cl. 62—3)

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This application is a continuation-in-part of my copending application Serial No. 752,031 filed June 3, 1947, now Patent No. 2,555,161, May 29, 1951.

The present invention relates to refrigerating systems of the type wherein a compressor, condenser and evaporator are connected in series, and is directed particularly to systems including means for supplying hot refrigerant gas to the evaporator to heat the evaporator for defrosting or other purposes.

The possibility of using hot refrigerant gas from the compressor for defrosting the evaporator has been recognized for over fifty years but systems employing such a principle have never been employed extensively for the reason that the refrigerant is largely condensed to a liquid in the evaporator during the defrosting operation as it gives up heat to melt the ice on the coils and fins of the evaporator. The refrigerant returning to the compressor therefore is largely in the form of liquid which the compressor is not equipped to handle and which causes the compressor to knock and may break valves, stall the motor, or cause other serious injury to the equipment. Moreover, when the condenser and expansion valve are bypassed the refrigerant flows freely from the high side of the compressor, through the evaporator and back to the low side of the compressor. The load is thus reduced so that the compressor races and performs insufficient work on the gaseous refrigerant to raise its temperature enough for effective defrosting.

In an attempt to overcome such practical obstacles to successful application of the principle of hot gas defrosting, restricting valves have been located between the evaporator and compressor to impose a load and reduce the pressure on the intake side of the compressor during defrosting. This prevents racing of the compressor when defrosting but liquid refrigerant still flows past the restricting valve to the compressor, since little or no heat input for vaporization of the condensed refrigerant can take place between the restricting valve and the compressor. Moreover, when the restrictor is itself by-passed during the normal refrigerating operation it is necessary to employ additional valves which complicate the system and often give rise to surging of liquid refrigerant into the compressor when the restrictor is cut in or cut out of the circuit. Furthermore if the restrictor used is responsive to the pressure in the evaporator vigorous surging occurs at the conclusion of the defrosting cycle when the restrictor is rendered inoperative or by-passed and large amounts of liquid refrigerant

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are admitted to the warm evaporator by the regular expansion valve.

Systems also have been proposed wherein heat accumulators and electrical heating elements are provided for vaporizing the condensed refrigerant passing from the evaporator to the compressor. However, when such heat is supplied by accumulators the amount of stored heat available for revaporizing the refrigerant is limited so that when the defrosting operation is prolonged the accumulated heat is expended and the device becomes inoperative. On the other hand when means such as an electrical heating element are used to revaporize the refrigerant the power consumption of the system is prohibitive since the heat input necessary to insure such revaporization must be equal to the heat expended by the gaseous refrigerant when it condenses in defrosting the evaporator.

In accordance with the present invention these objections to prior refrigerating systems are overcome and a system of the compressor-condenser-evaporator type is provided with defrosting means which are efficient and inexpensive to operate and which at the same time impart to the system a wholly new characteristic in that it functions as a stabilizing means which prevents surging of the refrigerant in the lines and prevents over-cooling of the space in which the evaporator is located. These results are preferably attained by employing restricting means and re-evaporating means in combination and continuously maintained in the refrigerating circuit between the evaporator and the compressor. The elements of the combination further are designed and organized so as to insure complete vaporization of refrigerant returning to the evaporator and to eliminate surging, trapping or short circuiting of the refrigerant or entrained oil in by-pass lines or elsewhere in the system.

In accordance with the present invention heat required for re-vaporizing refrigerant condensed during the defrosting operation is derived from a constant and unlimited source of heat supply such as the ambient air. The defrosting operation can then be continued as long as required so as to eliminate all frost from the evaporator. Moreover, when desired heat may be supplied to the evaporator after completion of the defrosting operation and for a further period of time to raise the temperature of the space in which the evaporator is located. In this way the system may be employed as a temperature stabilizing means for maintaining a space at substantially constant and predetermined temperatures under varying conditions of use.

One of the objects of the present invention is to provide a novel type of refrigerating system wherein hot gas defrosting means are employed in combination with a restricting means and a re-evaporator continuously maintained in the refrigerating circuit.

A further object of the invention is to provide a hot gas defrosting system wherein a re-evaporator is provided with an unlimited supply of heat for vaporizing liquid refrigerant returning to the compressor.

Another object of the invention is to provide a refrigerating system having hot refrigerant defrosting means designed and organized to eliminate surging of refrigerant in the system.

A further object of the invention is to provide a refrigerating system capable of functioning as a temperature stabilizing system.

These and other objects and features of the present invention will appear from the following description thereof in which reference is made to the figures of the accompanying drawings.

In the drawings:

Fig. 1 is a diagrammatic illustration of a typical system embodying the present invention;

Fig. 2 is a vertical sectional view through a typical refrigerated display case embodying the present invention;

Fig. 3 is a vertical sectional view through a refrigerated display case illustrating an alternative embodiment of the present invention;

Fig. 4 is an enlarged sectional view of a constant pressure valve adapted for use in the system illustrated in Figs. 1 and 3;

Fig. 5 is a perspective of a preferred form of re-evaporator employed in the practice of the present invention; and

Fig. 6 is a diagrammatic illustration of an alternative form of restricting valve assembly.

In that form of the invention illustrated in the drawings the refrigerating system embodies a compressor 2, a condenser 4, and an evaporator 6. The compressor is driven by a motor 8. During normal refrigerating operation the refrigerant is passed from the compressor 2 to the condenser 4 through the high pressure line 10 and conduit 12. In the condenser the hot refrigerant gas is cooled and condensed from a vapor to a liquid. The liquid refrigerant passes to a receiver 14 from which it flows to the evaporator 6 through conduit 16 and enters the evaporator through an expansion valve 18 controlled by the temperature responsive bulb 19 located near the outlet from the evaporator. The refrigerant on passing the expansion valve is vaporized in the evaporator drawing heat from air in the chamber 20 in which the evaporator is located. The vaporized refrigerant from the evaporator is thereafter returned to the compressor during the refrigerating cycle through the conduit 22, restrictor 24, re-evaporator 26, and return line 28.

For defrosting purposes the system is provided with a by-pass conduit 30 which serves to conduct hot refrigerating gas from the compressor 2 to the evaporator 6 at a point adjacent but beyond the expansion valve 18. For this purpose the by-pass conduit 30 is connected to the high pressure line 10 between the compressor and the condenser and is provided with a valve 32 which preferably is actuated by means of a solenoid 34 under control of actuating means 36 such as a time clock, thermostat, or other control device. When the actuating means operates to open the valve 32 both the condenser 4 and the expansion valve 18 are by-passed and the hot compressed refrigerant gas flows directly from the compressor 2 to the coils of the evaporator 6. Frost which has accumulated on the coils and fins of the evaporator is then melted rapidly so that the evaporator is defrosted in a very short time. The heat given up by the hot gas in the evaporator causes the refrigerant to condense into a liquid so that liquid refrigerant flows from the evaporator through conduit 22 to the restrictor 24.

The restrictor 24 and re-evaporator 26 are continuously connected in series between the evaporator and compressor. The restrictor is responsive to a condition of the refrigerant passing to the intake side of the compressor such as the pressure or temperature of the returning refrigerant gas.

In practice it is generally preferable to employ a pressure responsive valve which imposes very limited restriction to the flow of refrigerant therethrough under the low pressure conditions of the refrigerating cycle but effectively restricts such flow and acts as an expansion valve under the high pressure conditions of the defrosting cycle. The valve shown in Fig. 4 is of this type and is provided with an inlet port 38, an outlet port 40 and a main valve member 42 loosely fitted within the valve body and urged toward valve seat 44 by spring 46. A suction passage 48 extends from a point adjacent the outlet port 40 to a chamber 50 above a secondary valve seat member 52. A side passage 54 extends from suction passage 48 to the central opening 56 in member 52 wherein a secondary valve member 60 is movable. The latter valve member is held depressed under low pressure conditions of operation by the diaphragm 62 engaged by spring 64. At such times the secondary valve member 60 remains open and suction created at the outlet port of the valve by the intake of the compressor is exerted on the upper surface of the main valve member 42 whereby the valve member is raised against the action of spring 46. In this way the restrictor operates to permit ready flow of refrigerant from the inlet port 38 to the outlet port 40 during the refrigerating cycle.

There is an increase in pressure at the outlet port 40 of the valve as soon as the defrosting cycle starts due to by-passing of expansion valve 18, and direct flow of liquid refrigerant to the evaporator. The pressure at the outlet side of valve 24 then rises whereupon the diaphragm 62 is raised against the action of spring 64 and the secondary valve member 60 then closes under the action of spring 46. Thereafter, the pressure on opposite sides of main valve member 42 is equalized by flow of refrigerant through the small port 63 in the side wall of the main valve member and into the space beneath the valve seat member 52. The valve member then is urged toward open position only by the pressure of refrigerant adjacent inlet port 38 and acting against spring 46. The restrictor then acts as a throttle or expansion valve for limiting the flow of the refrigerant to the re-evaporator and compressor.

In this way an adequate difference in pressure is maintained on oppisite sides of the compressor at all times so as to insure uniformity of operation which maintains a suitable load on the compressor and prevent racing of the motor. At the same time by locating the restrictor 24 close to, and in advance of, the re-evaporator 26 the restrictor acts as an expansion valve during the defrosting cycle. The re-evaporator then oper-

ates as an evaporator, whereas the evaporator 6 then functions as a condenser or heat dissipating means during the defrosting cycle.

The valve 24 further operates to overcome the surging which tends to occur when the refrigerating cycle is first renewed. The evaporator 6 at that time is relatively warm and the bulb 19 at the outlet of the evaporator therefore causes the expansion valve 18 to admit the maximum amount of liquid refrigerant to the evaporator. If restrictor 24 is positively opened or by-passed under such conditions the rapid vaporization of liquid refrigerant in the evaporator will force any liquid remaining in the line directly into the compressor. However, the restrictor of Fig. 4, being responsive to pressure, precludes such surging and limits the flow of refrigerant to the compressor.

Various forms of coils or expansion chambers may be used as the re-evaporator 26 but as shown in Fig. 5 the re-evaporator preferably embodies a pipe 65 extending from restrictor 24 to an inlet header 66. Two coils 67 extend in parallel from inlet header 66 to an upper header 68. A return pipe 69 carries the refrigerant from upper header 68 to a second lower header 70 from which two coils extend in parallel to the outlet header 72 connected to return line 28 leading to the intake or low pressure side of the compressor. The coils of the re-evaporator are provided with the usual fins 74 and are mounted within a casing 76 having openings 78 in opposite sides thereof through which air is circulated. Because of the multiple passages provided for the flow of refrigerant through the re-evaporator the device has a relatively large capacity and offers an extended area for heat exchange without imposing restrictions or back pressure on the system during the normal refrigeration cycle. At the same time a large pressure drop of the refrigerant within the re-evaporator is provided during the defrosting cycle by reason of the restrictor 24 thereby insuring expansion and complete vaporization of the condensed liquid refrigerant passing from the evaporator to the compressor during the defrosting cycle. Thus when operating on the defrosting cycle the evaporator acts as a condenser or heat discharging element whereas the re-evaporator acts as an evaporator or heat absorbing element.

The restrictor 24 and re-evaporator 26 are continuously maintained in the circuit including the evaporator and compressor and therefore the system is very simple in construction and eliminates many of the valves and by-pass conduits used in prior systems employing hot gaseous refrigerant for defrosting purposes. Moreover, by constructing the evaporator so that its capacity and heat exchanging surface equal 20% or more of the capacity and heat exchanging surface of the evaporator or condenser it is found to function as a further surge eliminator during the transition of the system to and from the refrigerating cycle and the defrosting cycle. The re-evaporator then acts as an expansion chamber and receiver which retains all liquid refrigerant passing the restrictor until the refrigerant has vaporized completely. "Slugs" of liquid refrigerant therefore cannot reach the compressor and a continuous and relatively even flow of refrigerant gas returning to the compressor is maintained.

In order to supply the re-evaporator with the necessary heat units for vaporizing the refrigerant a fan 80 is located adjacent one of the

openings 78 in the casing 76. Air at a temperature above the boiling point of the refrigerant is thereby passed over the coils and fins. There is no limit as to the amount of air that can be circulated through the casing and over the coils and fins of the re-evaporator and since the air is constantly renewed and is always at a temperature above the boiling point of any conventional refrigerant used it affords an unlimited supply of heat for transfer to the refrigerant being vaporized. Therefore the defrosting cycle can be continued as long as desired without expense other than the cost of operating the fan 80.

In the illustrations of the present invention embodied in Figs. 2 and 3 the refrigerating and defrosting means are employed for maintaining the desired temperatures in an open top self service refrigerated display case of the type frequently used in the sale of frozen foods. The refrigerated space or chamber is indicated at 20 and air is circulated over the evaporator 6 and through the space 20 by means of the blower 82. The evaporator 6 is located at the rear and above the refrigerated display space 20 and the direction of flow of air within the display space is indicated by the arrows in Fig. 2. Since the temperature of the display space and of the air circulated therethrough and over the coils of the evaporator is maintained below freezing it will be apparent that defrosting of the evaporator normally would not take place without raising the temperature of the air in space 20 above 32° F., the melting point of the frost on the coils. Such a rise in temperature would be ruinous to frozen foods whereas the present invention effects defrosting of the evaporator almost instantly and without material rise in temperature of the air in the refrigerated space 20.

In the construction shown in Fig. 3 the compressor and condenser are located in the basement of the building, and the re-evaporator is housed within the cabinet but in the open base thereof beneath the refrigerated display space 20. Air for supplying heat to the liquid refrigerant in the re-evaporator is therefore drawn from the room in which the display case is located, and since this air circulates freely within the store or room the supply of heat to the re-evaporator from the ambient air is unlimited.

Even when the air circulated over the re-evaporator is drawn from a space refrigerated by the evaporator it is necessarily at a temperature above the boiling point of the refrigerant. Thus as shown in Fig. 2 at least a portion 84 of the re-evaporator coils 86 may be located within the refrigerated space 20 which is cooled by the evaporator 6 during the refrigerating cycle. In such installations the air circulated over the portion 84 of the re-evaporator is cold but still is at a temperature above the boiling point of any conventional refrigerant and therefore is capable of supplying heat to the coils 84 in amounts sufficient to re-vaporize the liquid refrigerant received from the evaporator. Moreover, additional coils 86 of the re-evaporator may be located exteriorly of the refrigerated chamber 20 and supplied with heat from the ambient air by a fan 88 if desired. The coils 84 of the re-evaporator in such installations serve to refrigerate the air within the space 20 while the evaporator 6 is being defrosted and thus compensates for heat losses through the walls of the case and to some extent at least for the sensible heat input to the air adjacent the then heated evaporator 6.

In this way the temperature of the air within

a refrigerated space can be maintained substantially constant even during the defrosting cycle and temperature rise can be reduced or avoided altogether. Moreover, the defrosting cycle can be continued as long as desired or necessary to insure removal of all ice and frost from the coils and fins of the evaporator. In fact the defrosting cycle can be continued indefinitely and used to maintain substantially constant temperatures in an enclosure under special or unusual conditions of operation. Thus during a severe winter or in arctic climates it is sometimes desirable to prevent over-cooling or freezing of articles such as vegetables or eggs, for example, or to avoid long periods for the thawing of refrigerated meats and other products. With the present invention, even though the ambient temperature is well below zero or at any temperature above the boiling point of the refrigerant, the defrosting cycle may be prolonged or made a continuous cycle whereby the re-evaporator operates continuously as an evaporator and the evaporator functions continuously as a heat discharging element over which air may be circulated to produce or maintain a desired and controlled temperature within a chamber. This temperature stabilizing action of the present invention gives to the system an important function not heretofore attainable with prior systems using hot refrigerant gas for defrosting purposes.

The means employed for controlling operation of the by-pass valve 32 for initiating and terminating the defrosting operation may vary considerably. In practice it has been usual to employ a time clock with electrical circuits for energizing a solenoid to initiate the defrosting operation periodically and to terminate the defrosting operation after a predetermined time. However, as described in the co-pending application of MacMaster, Serial No. 665,912, filed April 20, 1946, the defrosting operation may be initiated by time controlled means and may be terminated by pressure responsive means upon a rise in pressure of the refrigerant gas in the evaporator due to completion of the defrosting operation and subsequent lack of condensation of the refrigerant in the evaporator. When the system is employed as a temperature stabilizing means wherein the evaporator may operate for considerable periods of time as an element for supplying heat to the refrigerated space, the by-pass valve 32 may be controlled by a thermostat or many other suitable means. Thus it will be apparent that the system lends itself to various applications and provides a simplified and smoothly operating system having dual characteristics in that defrosting and temperature control or stabilizing can be effected by suitable control and operation of the by-pass valve 32.

The restrictor 24 used in combination with the reheater also may be varied, and as shown in Fig. 6 a temperature responsive expansion valve 90 may be used and may be controlled by the temperature of the refrigerant passing from the outlet side of valve 90 to the re-evaporator 24. For this purpose a bulb 92 is placed adjacent the line connecting valve 90 to the re-evaporator and supplied with an expanding fluid for actuating the valve. In this construction the flow of relatively warm condensed liquid through valve 90 will cause the valve to close and operate as an expansion valve whereas the flow of expanded and cooled refrigerant gas from the evaporator to valve 90 will serve to hold the valve open to reduce restriction to flow of refrigerant gas to the compressor. Other types of restricting means or valves responsive to the condition of refrigerant on the compressor side of the restricting means may be employed. Similarly the form and type of re-evaporator coils may be varied to adapt the invention to different applications. Other changes also may be made in the construction and arrangement of elements used in the system and in view thereof it should be understood that the particular form of the invention shown in the drawings and herein described are intended to be illustrative only and are not intended to limit the scope of the invention.

I claim:

1. In a refrigerating system having a compressor, a condenser and an evaporator connected by conduit means, together with a controlled by-pass conduit for conducting refrigerant from the compressor to the evaporator so as to by-pass the condenser for defrosting the evaporator, the combination of additional conduit means providing a single passage for return of refrigerant from said evaporator to the compressor, said additional conduit means having a restrictor and a re-evaporator continuously connected in series therein between said evaporator and compressor whereby all of the refrigerant returning to the compressor during both the refrigerating and defrosting cycles of operation is caused to flow through said re-evaporator, said restrictor being responsive to a condition of refrigerant flowing from the evaporator to the compressor to impose relatively limited restriction to such flow during the refrigerating cycle and to function as an expansion valve during the defrosting operation, and means for circulating air at a temperature above the boiling point of the refrigerant in heat exchanging relation with said re-evaporator.

2. In a refrigerating system having a compressor, a condenser and an evaporator connected by conduit means, together with a controlled by-pass conduit for conducting refrigerant from the compressor to the evaporator so as to by-pass the condenser for defrosting the evaporator, the combination of additional conduit means providing a single passage for return of refrigerant from said evaporator to the compressor, said additional conduit means having a restrictor and a re-evaporator continuously connected in series therein between said evaporator and compressor whereby all of the refrigerant returning to the compressor during both the refrigerating and defrosting cycles of operation is caused to flow through said re-evaporator, said restrictor consisting of a valve responsive to pressure adjacent the compressor side thereof to impose relatively little restriction to the flow of refrigerant therethrough during the refrigerating cycle and to function as an expansion valve during the defrosting cycle, and a blower for circulating air at a temperature above the boiling point of the refrigerant in heat exchanging relation with said re-evaporator.

3. In a refrigerating system having a compressor, a condenser and an evaporator connected by conduit means, together with a controlled by-pass conduit for conducting refrigerant from the compressor to the evaporator so as to by-pass the condenser for defrosting the evaporator, the combination of additional conduit means providing a single passage for return of refrigerant from said evaporator to the compressor, said additional conduit means having a restrictor and a re-evaporator continuously connected in series therein between said evaporator and compressor

whereby all of the refrigerant returning to the compressor during both the refrigerating and defrosting cycles of operation is caused to flow through said re-evaporator, said restrictor consisting of a pressure responsive valve including a valve member movable in response to relatively low pressure on the compressor side of the valve to impose relatively slight restriction to the flow of refrigerant through said valve and movable upon an increase in pressure on the compressor side of the valve to impose a relatively greater restriction to flow of refrigerant therethrough, and a blower for circulating air at a temperature above the boiling point of the refrigerant in heat exchanging relation with said re-evaporator.

4. In a refrigerating system having a compressor, a condenser and an evaporator connected by conduit means, together with a controlled by-pass conduit for conducting refrigerant from the compressor to the evaporator so as to by-pass the condenser for defrosting the evaporator, the combination of additional conduit means providing a single passage for return of refrigerant from said evaporator to the compressor, said additional conduit means having a restrictor and a re-evaporator continuously connected in series therein between said evaporator and compressor whereby all of the refrigerant returning to the compressor during both the refrigerating and defrosting cycles of operation is caused to flow through said re-evaporator, said re-evaporator presenting a cross sectional area for the flow of refrigerant exceeding the cross sectional area of the conduit means in advance thereof, and means for circulating air at a temperature above the boiling point of the refrigerant in heat exchanging relation with said re-evaporator.

5. In a refrigerating system having a compressor, a condenser and an evaporator connected in a closed circuit by conduit means, together with a controlled by-pass conduit for conducting refrigerant from the compressor to the evaporator for defrosting the evaporator, the combination of a restrictor and a re-evaporator connected in series and continuously included in said circuit between the evaporator and the compressor whereby all of the refrigerant returning to the compressor during both the refrigerating and defrosting cycles of operation is caused to flow through said re-evaporator, said evaporator being located within a space to be refrigerated, at least a portion of said re-evaporator being located in heat exchanging relation with air in said space, and means for circulating air at a temperature above the boiling point of the refrigerant in heat exchanging relation with said re-evaporator.

6. In a refrigerating system having a compressor, a condensor and an evaporator connected in a closed circuit by conduit means, together with a controlled by-pass conduit for conducting refrigerant from the compressor to the evaporator for defrosting the evaporator, the combination of a restrictor and a re-evaporator connected in series and continuously included in said circuit between the evaporator and the compressor whereby all of the refrigerant returning to the compressor during both the refrigerating and defrosting cycles of operation is caused to flow through said re-evaporator, said evaporator being located within a space to be refrigerated, at least a portion of said re-evaporator being located in heat exchanging relation with air in said space, and means for circulating air from said space in heat exchanging relation with said portion of said re-evaporator.

7. In a refrigerating system having a compressor, a condenser and an evaporator connected in a closed circuit by conduit means, together with a controlled by-pass conduit for conducting refrigerant from the compressor to the evaporator for defrosting the evaporator, the combination of a restrictor and a re-evaporator connected in series and continuously included in said circuit between the evaporator and the compressor whereby all of the refrigerant returning to the compressor during both the refrigerating and defrosting cycles of operation is caused to flow through said re-evaporator, said evaporator being located within a space to be refrigerated and said re-evaporator being located on the exterior of said space, means for circulating air from the exterior of said space over said re-evaporator, there being only three valves in said conduits, namely an expansion valve in said conduit means between the condenser and the evaporator, a by-pass valve in said by-pass conduit, and a pressure responsive valve functioning as the restrictor during the defrosting cycle and rendered relatively inactive by a reduction in pressure of refrigerant passing to the compressor during the refrigerating cycle.

8. In a refrigerating system having a compressor, a condenser and an evaporator connected by conduit means, together with a controlled by-pass conduit for conducting refrigerant from the compressor to the evaporator so as to by-pass the condenser for defrosting the evaporator, the combination of additional conduit means providing a single passage for return of refrigerant from said evaporator to the compressor, said additional conduit means having a restrictor and a re-evaporator continuously connected in series therein between said evaporator and compressor whereby all of the refrigerant returning to the compressor during both the refrigerating and defrosting cycles of operation is caused to flow through said re-evaporator, said re-evaporator including an inlet header and an outlet header with a plurality of coils extending in parallel relation from said inlet header to said outlet header, and means for circulating air at a temperature above the boiling point of the refrigerant in heat exchanging relation with said re-evaporator.

VICTOR W. SMITH.

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