United States Patent [19]

Taft et al.

[11] **3,905,202**

[45] **Sept. 16, 1975**

[54] **REFRIGERATION SYSTEM**

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[73] Assignee: **Emhart Corporation,** Hartford, Conn.

[22] Filed: **Jan. 8, 1974**

[21] Appl. No.: **431,757**

[52] **U.S. Cl.** **62/152;** 62/196; 62/510

[51] **Int. Cl.**^{2} **F25D 21/00**

[58] **Field of Search** 62/196, 197, 198, 510, 62/278, 183, 228, 152

[56] **References Cited**

UNITED STATES PATENTS

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3,307,369	3/1967	Harnish	62/510
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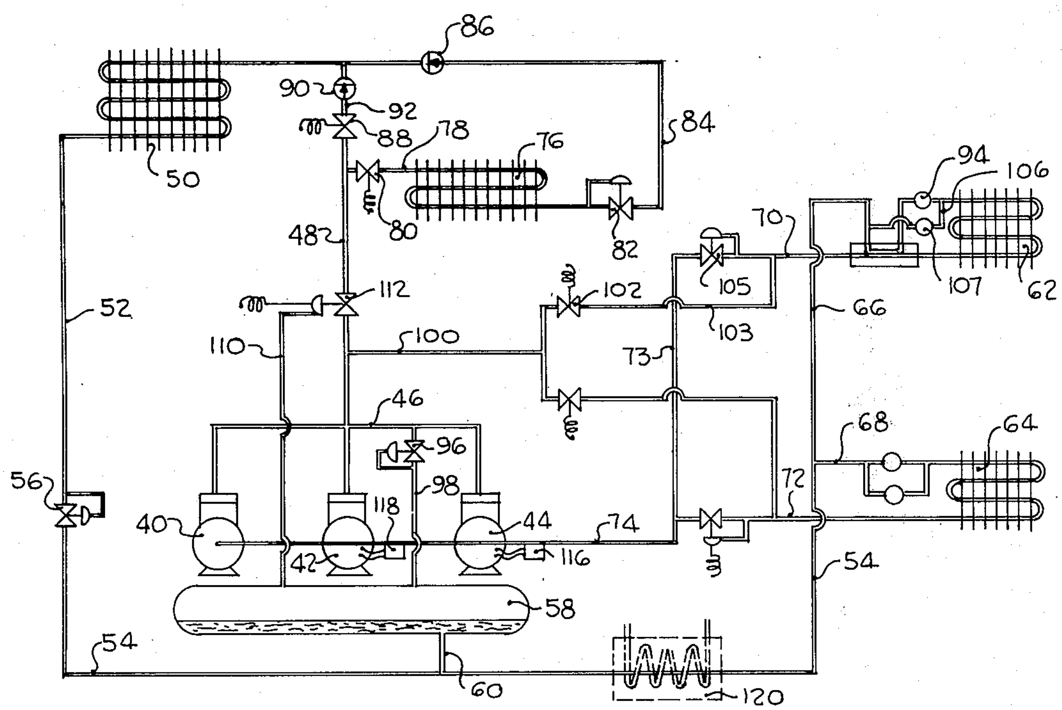
Primary Examiner—William E. Wayner
Attorney, Agent, or Firm—Sperry and Zoda

[57] **ABSTRACT**

A closed cycle refrigeration system comprising one or more compressors, a condenser exposed to ambient temperatures and of sufficient capacity to condense all of the gaseous refrigerant discharged from the compressors, a surge type receiver and one or more evaporators, is arranged so as to assure at least partial flooding of the condenser under normal ambient temperature conditions whereby the liquid refrigerant leaving the condenser is cooled to approximately ambient temperature prior to passage thereof to the evaporators. As a result, a sub-cooler using expanded refrigerant is not generally required and a substantial saving in the power requirements for operating the system is effected. Furthermore, the pressures to which the gaseous and liquid refrigerant are subjected throughout the system are maintained within optimum limits for more efficient and economical operation of the compressors and evaporators. In preferred embodiments of the invention an additional condenser is provided for use in reclaiming heat from the compressed refrigerant in which event the other condenser may function primarily to sub-cool the liquid refrigerant. Hot refrigerant gas from the compressor may also be used for defrosting the evaporators without adversely reducing the pressure at which liquid refrigerant is supplied to those evaporators operating on a refrigerating cycle.

8 Claims, 2 Drawing Figures



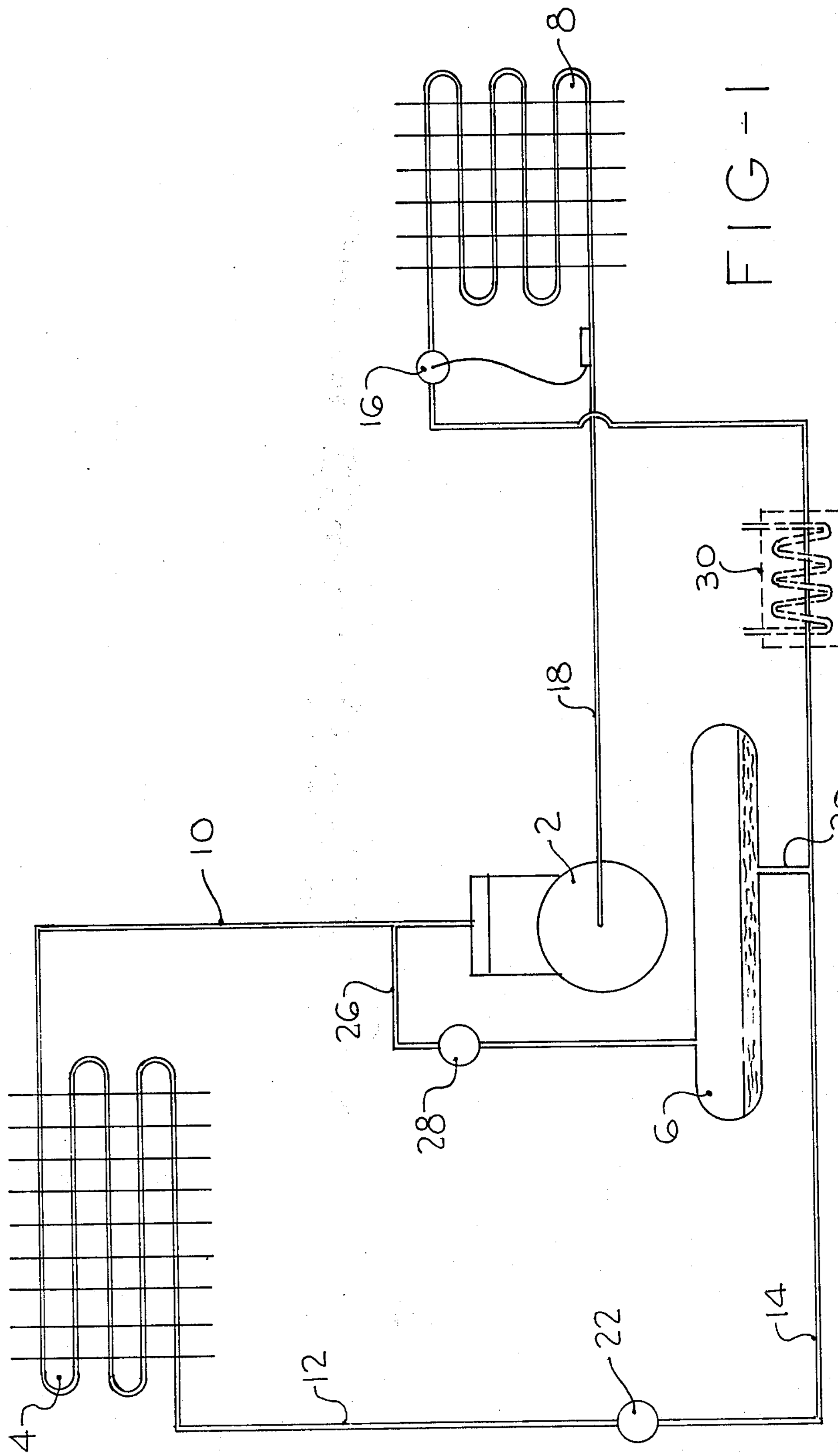


FIG-1

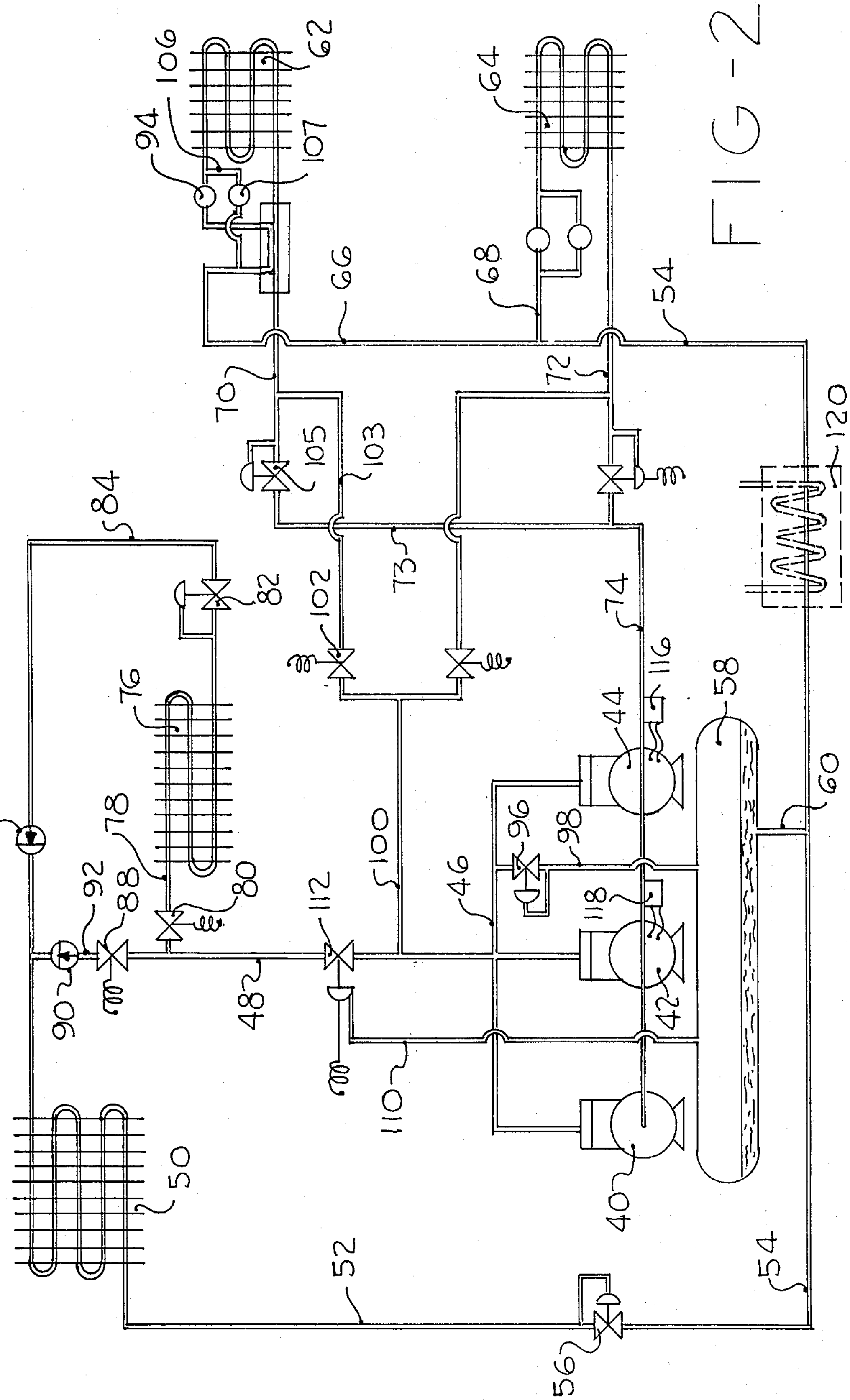

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FIG-2

REFRIGERATION SYSTEM

FIELD OF INVENTION

It has been common practice heretofore to provide refrigeration systems embodying a compressor, a condenser, a receiver and an evaporator, with means for utilizing a part of the heat developed in compressing refrigerant gas to heat areas within the store or enclosure in which the refrigerated equipment is located. In some installations a portion of such heat is also used for defrosting evaporators in the system. Typical constructions of this type are disclosed in U.S. Pat. Nos. **2,555,161; 3,150,498; 3,180,109; 3,358,469;** and **3,427,319.**

While such systems are generally effective for their intended purposes the power requirements for operating the equipment are relatively high and the over-all efficiency of the systems is correspondingly low. This is particularly true in large installations such as supermarkets wherein there may be a large number of refrigerated fixtures containing evaporators several of which may be operating at the same time and one or more of which may require defrosting while others are operating on a refrigerating cycle. In such systems several compressors may be required for meeting a heavy refrigeration load under some conditions whereas a lesser number of compressors would be adequate at other times. When air cooled condensers are employed in such systems there may be wide variations in the condensing capacity of the condenser with changes in the ambient temperature with resulting variations in the condensing pressure and in the temperature and pressure of the liquid refrigerant supplied to the evaporators. Thus for example, the temperature of the liquid refrigerant leaving the condenser heretofore has generally been in the neighborhood of **80°F** to **100°F**. It is then necessary for a portion of the liquid to be vaporized in the evaporator as "flash gas" in order to reduce its temperature to the operating temperature of the evaporator before any refrigeration effect can be attained by further evaporation thereof. In some cases an evaporative type sub-cooler is provided for reducing the temperature of the liquid refrigerant before it enters the evaporator but such sub-cooling equipment requires the expansion of refrigerant which must be made up by further operation of the compressor and the expenditure of considerable energy.

In those systems of the prior art wherein hot or saturated refrigerant gas is circulated through the evaporators to defrost the same, the pressure at which liquid refrigerant is supplied to those evaporators then operating on a refrigerating cycle is often reduced or fluctuates in a manner which seriously reduces the operating efficiency of the evaporators and their associated expansion valves.

In accordance with the present invention, these and other difficulties and objections are overcome and a system provided whereby the energy required for operation thereof is substantially reduced and the refrigeration efficiency is increased.

These results are preferably attained by providing a condenser which is cooled by ambient air and has sufficient capacity to condense the entire refrigerant output of the compressors under normal temperature conditions and by further varying the effective capacity of the condenser by controlled flooding thereof. At least a portion of the condenser then functions as a sub-cooler to reduce the temperature of the liquid leaving the condenser to approximately the temperature of the ambient atmosphere. When the ambient temperatures are relatively low, say **30°F** or **40°F**, a very substantial saving in power is effected and the need for the sub-coolers heretofore employed is eliminated whereas a substantial but lesser economy is effected at all ambient temperatures below that for which the condensing system is designed for effective operation.

Furthermore, the system includes a surge type receiver together with means for maintaining a controlled pressure in the receiver and in the liquid lines within limits which assure effective and efficient operation of the expansion valves and evaporators to which the refrigerant is supplied. At the same time such pressure is maintained below that at which gaseous refrigerant is supplied to the evaporators during defrosting operations. In this way liquid refrigerant discharged from the evaporators during defrost is readily returned to the liquid line without adverse reduction in the pressure of the refrigerant being supplied to those evaporators operating on a refrigerating cycle.

The system thus provided normally is operated with substantial saving in its energy requirements and is adapted for use in large installations and when the reclaiming of heat for use in a building or enclosure is desired.

THE DRAWINGS

FIG. **1** is a diagrammatic illustration of a simplified refrigeration system embodying the present invention; and

FIG. **2** is a diagrammatic illustration of a more complete refrigeration system embodying the present invention.

In the simplified embodiment of the invention chosen for purposes of illustration in FIG. **1** the refrigeration system comprises a compressor **2**, a condenser **4**, a surge type receiver **6** and an evaporator **8**. Refrigerant gas compressed in the compressor **2** is passed through a discharge line **10** to a condenser **4** exposed to ambient temperature as by being located on the roof of a market or other building in which refrigerated fixtures are used. The condenser **4** is of a size type and design rating such that it has a condensing capacity sufficient to assure condensation of all of the compressed refrigerant gas supplied thereto by the compressor **2** during normal temperature conditions to which it will be subjected. Thus the condenser may be designed to have a higher rated condensing capacity for use in southern latitudes where the average ambient temperatures may be relatively higher than the design rating of the condenser used in systems employed in northern climates where the normal ambient temperature will be substantially lower.

The liquid refrigerant leaving the condenser **4** flows through a drain line **12** to a liquid line **14** by which liquid refrigerant is supplied to one or more evaporators **8**. The liquified refrigerant then passes through an expansion valve **16** for vaporization in the evaporator to refrigerate a fixture of any suitable or preferred type. The expanded and vaporized refrigerant gas leaving the evaporator **8** is returned to the compressor **2** through a return line **18**. The liquid refrigerant receiver **6** communicates with the liquid line **14** by means of a connection **20** whereby a suitable amount of refrigerant may be stored and maintained in the system to assure continued operation thereof.

A modulating pressure responsive valve 22 is located in the drain line 12 leading from the condenser 4 to liquid line 14 and is adjusted to respond to a predetermined pressure so as to maintain the head pressure of the compressor 2 at a desired operating level and sufficiently high to assure at least partial flooding of the condenser at all or at least most ambient temperatures to which the condenser will be subjected.

In accordance with the present invention the pressure to which liquid refrigerant in the receiver 6 and liquid line 14 is subjected is maintained relatively constant and sufficiently high to assure satisfactory and efficient operation of the expansion valve 16 associated with the evaporator 8. For this purpose a pressure control line 26 extends from the discharge line 10 of the compressor 2 to the receiver 6 and is provided with a pressure responsive valve 28 adjusted to respond to a pressure below that which will actuate valve 22 in drain line 12 extending from the condenser to liquid line 14 but high enough to assure effective operation of the expansion valve 16 and evaporator 8.

The system thus provided assures complete condensation of the gaseous refrigerant passing from the compressor 2 to the condenser 4 with at least partial flooding of the condenser at all, or at least most, ambient temperature conditions so that the liquid refrigerant passing from the condenser through drain line 12 to liquid line 14 will be reduced in temperature to approximately ambient temperature. Thus in a typical operation wherein the temperature of the ambient air passed over the condenser is 40°F the liquid refrigerant passing to liquid line 14 will be about 40°F. Under such conditions when using R502 refrigerant, for example, the pressure responsive valve 22 between drain line 12 and liquid line 14 may be adjusted to respond to a pressure of, say, 160 pounds per square inch. This valve will then remain closed until enough liquid refrigerant has backed up in the condenser so as to reduce its effective condensing capacity and increase its condensing pressure and the compressor discharge pressure to about 160 p.s.i. Thereafter, valve 22 will modulate to maintain a constant pressure in the condenser.

The liquid refrigerant accumulated in the flooded portion of the condenser will be cooled during its retention therein to approximately ambient temperature (40°F) and thereafter will pass through the valve 22 from drain line 12 to liquid line 14 at a relatively low temperature. The excess of liquid refrigerant over that immediately required for use in the evaporator or evaporators 8 will pass from the liquid line 14 through connection 20 to the receiver 6 so as to be stored therein for use as required.

In the event the receiver 6 should be so located as to attain the ambient temperature (40°F), the vapor therein, when using R502 refrigerant, will reach saturation at a pressure of about 80 p.s.i. and the pressure of the liquid refrigerant being supplied to the evaporator 8 would only be 80 p.s.i. which is insufficient to assure effective and efficient operation of a typical expansion valve 16 associated therewith. However, in accordance with the present invention the pressure of the liquid refrigerant in receiver 6 and liquid line 14 is maintained and controlled independently of the temperature of the receiver and the refrigerant therein. For this purpose the pressure responsive valve 28 in pressure control line 26 extending from the compressor discharge line 10 to receiver 6 is adjusted to respond to a predetermined pressure, (say 150 p.s.i.) which is somewhat below that which will actuate valve 22 at the condenser outlet. As a result the pressure applied to the liquid refrigerant in the receiver and liquid line 14 will be maintained constant and will not be significantly influenced by the temperature of the refrigerant entering and leaving the receiver. It can instead be maintained sufficiently high to insure efficient operation of the expansion valves and evaporators under all conditions of operation. Moreover, the maintaining of proper and substantially constant pressure on the liquid refrigerant passing to the evaporator will be assured no matter where the receiver may be located and whether it is subjected to low ambient temperature or is positioned in a machine room with compressors and the like where its temperature may be relatively high.

In the example cited above wherein the ambient temperature to which the condenser is subjected is 40°F the condensing pressure and the compressor output pressure will be relatively low and the power expended in operating the system is materially reduced representing a substantial saving in the cost of operation. However, even when the ambient temperature is relatively high, say 90°F, some power savings may be effected. Thus if the ambient temperature is 90°F the condensing temperature will be about 105°F and the condensing pressure and the compressor output pressure will be about 232 p.s.i. when using R502 refrigerant. The liquid refrigerant leaving the condenser will then be about 90°F and be under a pressure above the 160 p.s.i. setting of the pressure responsive valve 22 between drain line 13 and the liquid line 14. The valve 22 will then assume a fully open condition so that liquid refrigerant will pass directly from the condenser to the liquid line without restriction and little or no sub-cooling of the liquid refrigerant will take place. However, the liquid refrigerant in receiver 6 and liquid line 14 will then be under sufficient pressure to assure effective and efficient operation of the evaporator and its expansion valve throughout the refrigeration cycle. The pressure control line 26 and its valve 28 will then be unnecessary and will not function due to the adequate pressure developed in the receiver.

It will thus be apparent that sub-cooling of the refrigerant in the flooded condenser will take place at all times when the ambient temperature is below the temperature for which the system is designed, say 90°F, and at all times when the condensing pressure is below the setting at which the pressure responsive valve 22 will modulate to pass liquid refrigerant from the condenser drain line 12 to the liquid line 14. Accordingly, significant savings in the power expended will be effected during all ambient temperature conditions below that for which the system is designed. Nevertheless, if desired an evaporative sub-cooling element indicated in dotted lines at 30 in FIG. 1 can be provided for use under abnormally high ambient temperature conditions.

In refrigeration systems employed in supermarkets for example, it is advantageous to connect several evaporators or groups of evaporators to a condensing unit. When this is done it is desirable to have some means for controlling the capacity of the condensing unit as the evaporator loads vary due to changing store conditions and variation in the portions of the load on defrost take place. In particular the required capacity of the compressor and condensing unit is reduced when low ambient temperatures increase the liquid sub-cooling which takes place in the condenser thus decreasing the required refrigeration load reflected to the compressors.

Under such conditions a more complete system may be employed as illustrated in FIG. 2. As there shown three compressors **40, 42** and **44** are connected in parallel with a common gas discharge header **46** from which compressed gaseous refrigerant is delivered through discharge line **48** to a condenser **50** positioned to be cooled by ambient air and of sufficient capacity to condense the entire refrigerant discharged from all three compressors. The condenser **50** delivers liquid refrigerant to a drain line **52** and liquid line **54** through pressure responsive valve **56.** The liquid line **54** is connected to a surge type receiver **58** through connection **60** and is connected to the evaporators **62** and **64** through lines **66** and **68** respectively. Refrigerant from the evaporators is returned to the compressors through return lines **70** and **72** and a common return header **74.**

As shown in FIG. 2 at least a portion of the heat produced in compressing the refrigerant may be reclaimed and used to heat an area of the supermarket and for this purpose a heat reclaim coil **76** is connected to the discharge line **48** through a bi-pass line **78** and a thermostatically controlled solenoid valve **80.** A condenser inlet pressure regulating valve **82** is connected in a line **84** extending from reclaim coil **76** to the condenser **50** through a check valve **86** and serves to maintain the desired head pressure in the compressor when the heat reclaim coil **76** is in use. A solenoid valve **88** and check valve **90** are located in the section **92** of the compressor discharge line **48** between the bi-pass line **78** and the condenser **50.** The valve **88** closes when valve **80** is opened so as to assure flow of hot gas in series through heat reclaim coil **76** and condenser **50** when the heat reclaim coil is in use.

As in the form of the invention shown in FIG. 1 the valve **56** is adjusted to assure the desired condensing pressure in condenser **50** and assure at least partial flooding thereof under normal ambient temperature conditions. At the same time a pressure control line **98** having a pressure responsive valve **96** therein extends from discharge header **46** to receiver **58** and establishes the pressure at which the liquid refrigerant in receiver **58** and liquid line **54** will be maintained for delivery to the evaporators **62** and **64.** The adjustment of valve **96** preferably is such that the pressure applied to the receiver and liquid line from gas discharge header **46** will be lower than the discharge pressure of the compressed refrigerant gas delivered to discharge line **48** and condenser **50** so that there will be no danger of reverse flow of refrigerant from the receiver to the condenser.

In using the system illustrated in FIG. 2 it will, of course, be apparent that any number of evaporators required for use in the system may be connected in this manner to the liquid line **54** and sufficient liquid refrigerant should be contained in the receiver **58** to assure delivery of liquid refrigerant to the liquid line **54** through connection **60** when the demands of the evaporator exceeds the supply of liquid refrigerant received from the condenser **50** at any period of operation.

In order to defrost the evaporators when ice or frost has accumulated thereon, hot gas from the compressors may be delivered through the hot gas header **46** and branch hot gas line **100** to whichever evaporators require defrosting. Thus when evaporator **62** is to be defrosted solenoid valve **102** in branch **103** of hot gas line **100** is opened to deliver hot refrigerant gas to the line **70** whereas valve **105** in return line **73** is closed. The hot gas then flows through evaporator **62** in a direction reverse to that in which the expanding gas flows during the refrigerating operation whereby the temperature of the coils and fins of the evaporator is raised to defrost the same whereas the hot gas is cooled and at least partially condensed to a liquid. The resulting condensate then flows through bi-pass line **106** and check valve **107** about the expansion valve **94** and returns through line **66** to the liquid line **54.**

The liquid refrigerant resulting from the defrosting of the evaporator **62** is thus made available for use in refrigerating evaporator **64** and other evaporators employed in the system and to supplement the supply of liquid refrigerant being passed to such other evaporators. Such flow of the liquid refrigerant from defrosting evaporator **62** to liquid line **54** will take place by reason of the fact that the pressure applied to the liquid refrigerant in receiver **58** and liquid line **54** by pressure control line **98** and valve **96** is maintained below the pressure of the hot refrigerant gas supplied to the defrosting evaporators from branch hot gas line **100.**

There may be some instances, when several evaporators are being defrosted at the same time, wherein the demand for hot gas from the compressor will be so great as to reduce the pressure thereof in the hot gas header **46** and hot gas line **100.** In that event the pressure applied to the liquid refrigerant in the receiver **58** and liquid line **54** through valve **96** and pressure control line **98** may fall below that which will assure proper operation of the expansion valves associated with the evaporators. In order to avoid this possibility a receiver pressure sensing line **110** is connected to the receiver **58** and extends to a diaphragm actuated regulating valve **112** located in the compressor discharge lines **48** at a point beyond the branch hot gas line **100.** The regulating valve **112** is normally open but is operable to restrict flow of gas from the compressor through discharge line **48** in the event the pressure in the discharge line should fall below the desired liquid line pressure. In that event valve **112** will tend to close and modulate so as to increase the compressor head pressure and the pressure applied to the liquid refrigerant in the receiver and liquid lines through pressure control line **98** and pressure responsive valve **96.** In this way an adequate and predetermined difference in pressure between the hot gas being used for defrosting purposes and the liquid refrigerant being supplied to the evaporators is assured under all conditions of operation of the system.

When the ambient temperature to which the condenser **50** is subjected is relatively high all three compressors **40, 42** and **44** may be required to meet the demand for refrigerant by the numerous evaporators which may be employed in the system. However, when the ambient temperature adjacent the condenser **50** is moderate or normal, the temperature of the sub-cooled liquid being supplied to the liquid line **54** and receiver **58** will be reduced and the discharge pressure of the condenser will be similarly reduced. Under such conditions only two of the compressors such as compressors **40** and **42** may be required to satisfy the refrigerating load with the result that the third compressor such as compressor **44** can be cycled off. For this purpose an element **116** responsive to the compressor suction pressure may be provided to terminate operation of compressor **44** as the refrigeration load is reduced. As a result the energy input which would otherwise be required to drive the compressor **44** is saved, and substantial economies effected in the power demands of the system.

Furthermore, when low ambient temperatures are encountered so that substantial sub-cooling of the liquid refrigerant is effected, the defrosting of one or a number of evaporators will further reduce the demand for liquid refrigerant whereas the hot gas required for the defrosting operation may be supplied by a single compressor with the result that the compressors **42** and **44** may both be cycled off while the single compressor **40** satisfies the refrigerant and defrosting requirements. For this purpose the element **118** connected to compressor **42** is provided and designed to respond to a further reduction in the compressor inlet pressure to terminate operation of compressor **42**. In this way still further reduction in the power required to operate the refrigerating system is effected.

It will thus be apparent that the system of FIG. **2** can be operated when employing only a single compressor during those periods when the condenser **50** is exposed to low ambient temperatures whereas only two compressors may be required during most normal operation and the third compressor will only be called into use during such times as the ambient temperature is abnormally high. The reduction in the power requirements of the system is thereby accomplished by utilizing the condenser **50** to effect a sub-cooling of the liquid refrigerant during all normal periods of operation and significant reduction in the energy requirements of the system is effected. Nevertheless, even when abnormally high ambient temperature conditions are encountered and it is necessary to resort to the use of an evaporative type sub-cooling device **120**, the system will operate effectively and the advantages afforded by maintaining a constant liquid line pressure during defrosting operations are attained.

While typical embodiments of the present invention have been shown in the drawing and described above it will be apparent that the invention is capable of many other modifications and changes without departing from the spirit and principal of the invention. In view thereof it should be understood that the forms of the invention specifically disclosed herein are intended to be illustrative only and are not intended to limit the scope of the invention.

We claim:

1. A refrigerating system comprising a compressor having a discharge line and an intake line, a condenser connected to the discharge line of said compressor, a receiver for receiving condensed refrigerant from said condenser, a plurality of evaporators each provided with an expansion valve, a liquid line extending from said receiver to each of said expansion valves and evaporators, a return line extending from said evaporators to the intake line of the compressor, means for selectively defrosting said evaporators by the use of hot refrigerant gas from the discharge line of the compressor, a line extending from the discharge line of the compressor to said receiver and having a pressure reducing valve therein operable to maintain the pressure in said receiver and liquid line lower than the pressure in the discharge line of the compressor, and means operable during defrost and responsive to a reduction in pressure in the receiver forincreasing the pressure in the discharge line of the compressor.

2. A refrigerating system as defined in claim **1** wherein said means for maintaining liquid refrigerant in the receiver and liquid line under substantially constant pressure includes a line extending from said compressor discharge line to said receiver and has a valve therein responsive to a pressure below that which will actuate said pressure responsive valve in said liquid line.

3. A refrigerating system as defined in claim **1** wherein a heat reclaiming coil is provided together with means for selectively connecting said heat reclaiming coil in series with said condenser.

4. A refrigeration system as defined in claim **1** wherein means are provided for delivering gaseous refrigerant to each of said evaporators at a pressure exceeding the liquid line pressure for defrosting said evaporator.

5. A refrigerating system as defined in claim **1** wherein there are a plurality of compressors and a plurality of evaporators, the compressor capacity being in excess of that required to satisfy the refrigerant load of said evaporators under low ambient temperature conditions and means are provided for rendering at least one of said compressors inoperative under low ambient temperature conditions.

6. A refrigerating system as defined in claim **4** wherein there are a plurality of evaporators which may be defrosted by the delivery of gaseous refrigerant thereto, means for sensing the pressure of the refrigerant in the receiver, and valve means responsive to the operation of said sensing means operable to maintain the pressure at which refrigerant is discharged from the compressor above the pressure applied to liquid refrigerant in said liquid line.

7. A refrigerating system as defined in claim **5** wherein said means for rendering at least one of said compressors inoperative is responsive to the pressure of refrigerant gas in a suction line leading from said evaporators to said compressors.

8. A refrigerating system as defined in claim **7** wherein said sensing means is operable to control the pressure at which gaseous refrigerant is discharged from said compressor and a pressure sensing line extends from said receiver to said sensing means to actuate the same.

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UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 3,905,202

DATED : Sept. 16, 1975

INVENTOR(S) : Donald L. Taft, Victor W. Smith, Neal P. Schumacher

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

In the first line of Claim 8, change "7" to -- 6 --.

Signed and Sealed this

Ninth **Day of** *May 1978*

[SEAL]

Attest:

RUTH C. MASON
Attesting Officer

LUTRELLE F. PARKER
Acting Commissioner of Patents and Trademarks