April 5, 1960 J. E. WATKINS 2,931,191

REFRIGERATING SYSTEM WITH MEANS TO OBTAIN HIGH LIQUID LINE PRESSURE

Filed March 9, 1956 2 Sheets-Sheet 1

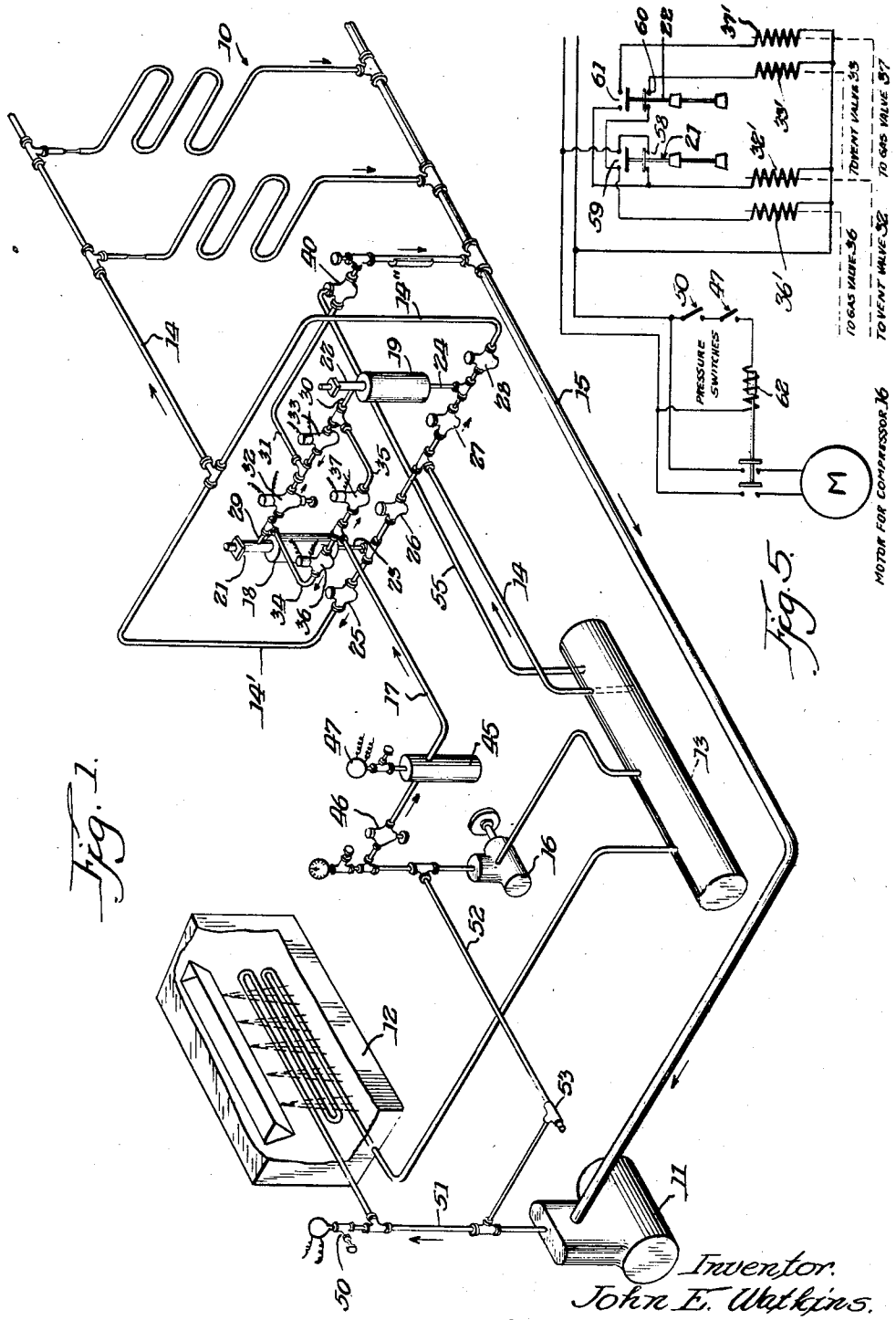


Fig. 1.

Fig. 5.

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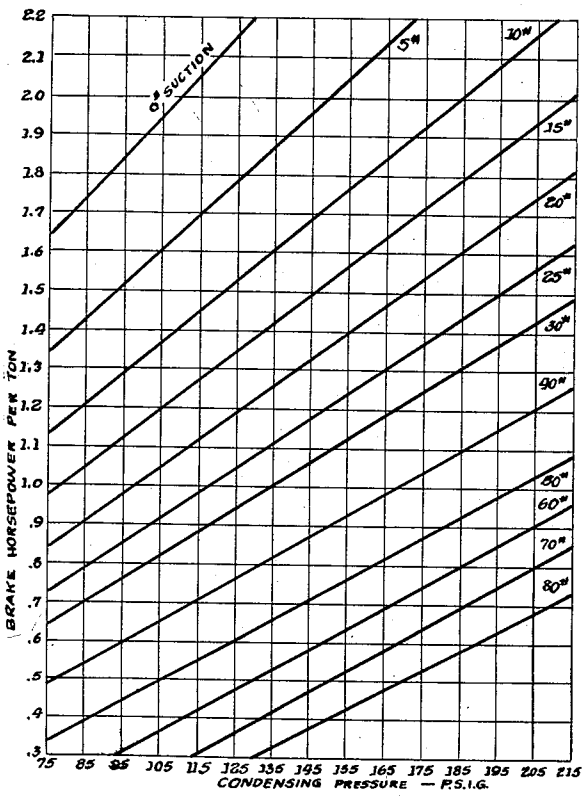


Fig. 2.

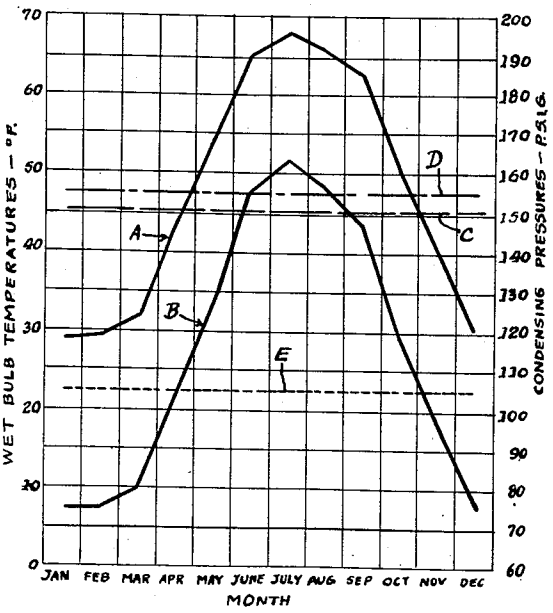
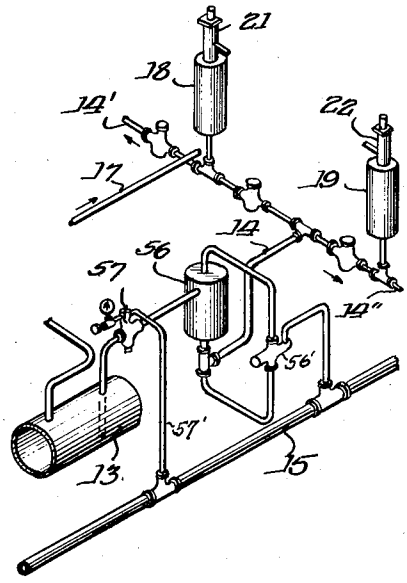


Fig. 3.

Fig. 4.



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REFRIGERATING SYSTEM WITH MEANS TO OBTAIN HIGH LIQUID LINE PRESSURE

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Application March 9, 1956, Serial No. 570,620

14 Claims. (Cl. 62—174)

This invention relates to a refrigerating system, and more particularly a commercial or industrial refrigerating system of the large capacity type having a plant compressor, a condenser into which the compressor discharges which may be either an evaporative condenser or a conventional shell-and-tube condenser, a receiver for storing the refrigerant liquefied in the condenser, and a plurality of plant evaporator coils connected to receive liquid refrigerant from the receiver under high liquid line pressures.

In such refrigerating systems, the liquid line pressure is imposed directly by the plant compressor with its values set by the condenser's capacity. Furthermore, the minimum pressure differential between the high and low sides of the system is predetermined and fixed by the thermal expansion valves and flow valves at the evaporator cooling coils which require considerable pressure drops through their orifices in order to deliver rated capacity. It is the general practice in plants controlled by such instrumentalities, to maintain high liquid line pressures and corresponding high differential pressures between the high and low sides of the system, by maintaining high compressor discharge and high condenser pressures, and to operate the system year around at such high liquid line pressures. With evaporative type condensers where outside air is circulated through the condenser coils, condenser pressures vary in accordance with well known thermo-dynamic principles as determined by the wet bulb temperature of the outside air, generally following seasonal fluctuations in temperature and producing higher condenser pressures during the warmer months and lower condenser pressures during the colder months of the year. During the colder months of the year when condenser pressures would ordinarily fall, the high and required condenser pressures are maintained by stopping fans, shutting off spray pumps and/or restricting spray water supply, thus raising the temperature of the cooling fluid.

It will readily be apparent that refrigerating systems operated in this manner are extremely inefficient. The same may be said for systems employing shell-and-tube type condensers utilizing water circulated through the condenser rather than air for the cooling medium. In such systems, notwithstanding the fact that water temperatures vary substantially between the warmer and the colder months, the general practice again is to increase condenser pressures during periods when the water supplied to the condenser is at colder temperatures, to maintain higher liquid line pressures than would otherwise be produced in the condenser. This may be accomplished by restricting the water supply or by shutting off certain of the banks of the condenser surface during the periods mentioned effectively producing higher condenser pressures.

Greater efficiency has been obtained by setting the control instrumentalities at the evaporator cooling coils for overfeeding at minimum condenser pressures as are experienced during the colder months, and by having the excess of liquid refrigerant produced in the system during

the warmer months and which would normally flood the evaporator coils recirculated through the evaporator coils for cooling purposes. Such a system is disclosed in my Patent No. 2,590,741, issued March 25, 1952.

It is a general object of this invention to provide as did the refrigerating system disclosed in the aforesaid patent, for evaporative cooling with a minimum pressure differential between the high and low sides of the system and maintaining liquid line pressure constant throughout the year regardless of the condensing pressure, but in the present instance by obtaining high liquid line pressure by means separate, apart and distinct from, yet working in conjunction with, the plant compressor.

It is a further object to provide a refrigerating system where condenser pressures are maintained at the lowest possible value as determined by the temperature of the cooling fluid circulating through the condenser, while liquid line pressures are maintained at a relatively high preset value and steady at that value for year round operation regardless of the condensing pressure.

It is a more specific object of this invention to provide a refrigerating system in which condenser pressures are maintained at minimum value as determined by the temperature of the cooling fluid circulated through the condenser, where liquid refrigerant is taken from the receiver at condenser pressure and compressed by pressure imposing means other than the plant compressor to a preset pressure as required by the operating characteristics of the system, and where the liquid refrigerant is then forced at this preset pressure through the liquid line to the evaporator cooling coils.

It is another object of this invention to provide a refrigerating system in which a pressurizing system is incorporated, operative when condenser temperatures and pressures fall, for supplying higher liquid line pressures than will normally be produced by the compressor and condenser when operating at maximum efficiency. Accordingly, it is an object to provide a refrigerating system obtaining maximum efficiency in operation, one that "follows the weather" and allows condenser pressures to rise and fall in accordance with the temperature of the cooling fluid circulated through the condenser, while maintaining a preset normally higher pressure on the entire plant or in the liquid line to the evaporator cooling coils.

Other objects and advantages will become apparent from the following description, taken together with the accompanying drawings wherein:

Figure 1 is a diagrammatic view of a refrigerating system embodying the present invention;

Fig. 2 is a chart illustrating the relation between condenser pressure and brake horsepower for a given compressor;

Fig. 3 is a chart illustrating average annual wet bulb temperatures for a given latitude;

Fig. 4 is a diagrammatic view of a portion of the refrigerating system of Fig. 1 modified to include a flash tank for removing flash gas from the system; and

Fig. 5 is a diagrammatic illustration of a control circuit for certain of the control instrumentalities embodied in the system shown in Fig. 1.

While the invention is susceptible of various modifications, there is shown in the drawings and will herein be described in detail one illustrative form thereof. It is to be understood, however, that it is not thereby intended to limit the invention to the specific form disclosed. On the contrary, it is intended to cover all modifications, alternative constructions, and equivalents falling within the spirit and scope of the invention as expressed in the appended claims.

For purposes of illustration the invention in one aspect has been shown as embodied in a refrigerating system

in which a liquid refrigerant is supplied from a source to a plurality of evaporator cooling coils **10**. The cooling coils, of which there may be more than the number illustrated, ordinarily would be located in different rooms or in different cooling units of the plant, in accordance with conventional practice as embodied in the construction of large capacity commercial type systems.

The source of liquid refrigerant may be of any conventional type and as herein depicted comprises a compressor **11**, and a condenser **12** into which the compressor discharges. A receiver **13** for storing the liquid refrigerant produced in the condenser is provided in this system as in conventional systems, and ordinarily is located in general proximity to the plant compressor **11** and the condenser **12** and is arranged to be drained into a liquid line **14** connected and extending to the remote location where the evaporator cooling coils are found. The suction side of the compressor is connected to a suction line **15** forming the return line from the low pressure side of each of the evaporator cooling coils and thus connecting the plant compressor **11** directly with the evaporator cooling coils.

In carrying out the present invention, to increase operating efficiency of the refrigerating system by allowing condenser pressures to rise and fall in accord with the temperature of the cooling medium circulated through the condenser, in other words, "to follow the weather," liquid line pressures are raised to a preset value which is maintained irrespective of the condenser pressure. In the present instance provision is made in the system for raising the pressure of liquid refrigerant in the liquid line **14**. Furthermore, in keeping with the invention, since the line pressure need only be raised when condenser pressures fall below the preset value, control instrumentalities are incorporated for raising the pressure of the liquid refrigerant effective upon the condenser pressure dropping below the preset value. Accordingly, in the system shown in Figure 1 of the drawings, a pressurizing compressor **16** is included as a part of a pressurizing system for raising liquid line pressures. This is accomplished by taking saturated refrigerant gas from the receiver **13**, raising the pressure of the refrigerant gas to a preset value, and applying the refrigerant gas under the preset pressure by means of a gas line **17** to liquid refrigerant contained in a pair of displacement tanks **18**, **19**, which serve as reservoirs, and for this purpose are connected by a supply line **14** to the receiver for receiving liquid refrigerant. Thus the pressurizing system is used for raising the pressure of the liquid refrigerant in the liquid line to the preset value and for forcing the liquid refrigerant through the liquid line to the evaporator cooling coils.

Referring specifically to Figure 1 again, the liquid line **14** extending to the plurality of evaporator coils, is divided into two branches **14'**, **14''** between the receiver **13** and the coils for connection to the pair of displacement tanks **18**, **19**. These displacement tanks may comprise cylindrical sheet metal tanks of conventional construction, having means shown in the present instance as displacement switches **21**, **22** for regulating the admission of liquid refrigerant into the respective displacement tanks from the receiver **13**.

These displacement switches, which may be "Magnetrol liquid level controls," or may be simple float switches, are used not only for regulating the admission of liquid refrigerant to the tanks, but are also used to regulate the admission to these tanks of refrigerant gas under pressure from the pressurizing compressor **16** for forcing the accumulated liquid into the liquid line to the evaporator cooling coils.

Accordingly, both displacement tanks **18**, **19** are connected by a short segment of supply line **23**, **24** to the respective branches **14'**, **14''** of the liquid line **14**. Furthermore, on both sides of the junction between the supply lines **23**, **24** and the respective branches of the liquid line, check valves **25**, **26** and **27**, **28** are incorporated in order to allow flow from the tanks **18**, **19** into the liquid line **14** to the cooling coils while preventing reverse flow toward the receiver **13**.

For venting the displacement tanks to the suction line **15**, in the construction and arrangement illustrated, vent conduits **29**, **30** are employed, meeting and connected by means of a common vent line **31** directly to the suction line **15** extending to the plant compressor. In the vent conduits **29**, **30** extending respectively to the displacement tanks **18**, **19**, vent valves **32**, **33** are interposed for controlling the venting of the respective displacement tanks.

The displacement tanks **18**, **19** are connected to the gas line **17** by means of these same vent conduits **29**, **30** and also branches **34**, **35** of the gas line **17**. In the branches **34**, **35** of the gas line **17**, gas valves **36**, **37** are interposed for controlling the admission of high pressure gas to the displacement tanks.

The arrangement and construction illustrated enables the supplying of each of the displacement tanks alternately with liquid refrigerant from the receiver and for alternately admitting refrigerant gas under the preset pressure from the gas source. The displacement type or float type switches **21**, **22** are accordingly arranged for controlling the vent valves **32**, **33** and the gas valves **36**, **37**, for alternately opening the respective displacement tanks **18**, **19** to the source of refrigerant gas under the preset pressure or to the suction line to vent the displacement tanks. With the check valves interposed between the respective displacement tanks and the receiver **14**, liquid from the receiver is introduced into each of the displacement tanks alternately while gas is being vented, until high liquid levels are reached when the gas valves **36**, **37** are opened, admitting gas under the preset pressure to force the accumulated liquid into the respective branches of the liquid line through the check valves, which permit drainage from the receiver while preventing reverse flow from the displacement tanks.

While the multiple vent and gas valves may be operated manually, it is contemplated that the use of automatic controls will be desired for automatically raising the pressure of liquid taken from the receiver to the preset value as required by the plant, and forcing the liquid refrigerant through the liquid line to the evaporator cooling coils. For this purpose, the vent valve **32**, **33** and the gas valves **36**, **37** are solenoid operated. As will be seen by reference to the circuit diagram in Fig. 5, solenoids **32'**, **33'** and **36'**, **37'** of the vent and gas valves respectively, are connected in circuit with the float switches **21**, **22** which automatically control the operation of these valves. The control circuit is constructed so that when high liquid levels are reached in the respective displacement tanks, the gas valves **36**, **37** by means of the solenoid actuators **36'** and **37'** are opened to admit gas under the preset pressure from the gas line **17**. During the period when the gas valves **36** and **37** are open, the vent valves **32**, **33** are closed to prevent the escape of gas under pressure from the displacement tanks **18**, **19** respectively. Alternately, when low liquid levels are reached in either of the two displacement tanks **18**, **19** the gas valves **36**, **37** are closed to prevent the admission of refrigerant gas under pressure to the displacement tanks, and the respective vent valves **32**, **33** are opened to vent the tanks to the suction line. Liquid refrigerant is automatically fed into the displacement tanks due to the differential in pressure between the liquid refrigerant stored in the receiver at condenser pressure and the respective displacement tanks.

In order to reduce re-expansion losses a pressure regulator valve **40** is interposed in the vent line **31** between the displacement tanks and the suction line. The function of this valve **40** is to control the venting of the displacement tanks, and thus the pressure therein prior to filling with liquid refrigerant from the receiver **13**.

With a manually operated type valve, the valve 40 is set to allow the respective displacement tanks to vent until a predetermined low pressure is obtained. With an automatically operated valve, the valve 40 may be connected as by a control line 55, to the receiver so as to control the pressure in the displacement tanks to maintain the pressure therein a few pounds below the receiver pressure. The operation of such an automatic valve will be explained in detail below. With a manually operated valve 40 in the system, the setting is determined as follows. This pressure regulator valve 40 is set to allow the respective displacement tanks to vent until a predetermined low pressure is obtained. For a particular system and refrigerant, the minimum condenser (and receiver) pressure that is experienced even in the coldest months of the year may readily be determined. The pressure regulator valve 40 should be set to allow the displacement tanks to vent to a pressure slightly less than this minimum condenser pressure. Accordingly the pressure regulator valve operates to close the vent line 31 upon the attainment of the low and predetermined pressure in the displacement tanks.

In the gas line 17 between the displacement tanks 18, 19 and the pressurizing compressor 16, in the present instance there is interposed a gas receiver 45 for receiving and storing refrigerant gas under the preset pressure as supplied from the pressurizing compressor. For maintaining the preset pressure in the gas receiver 45, a pressure switch 47 may be used, a switch of any conventional construction, arranged to control the operation of the pressurizing compressor, and for that purpose connected in circuit with the compressor motor (not shown), in order to maintain at a steady and uniform value and at the desired preset level the pressure of refrigerant gas in the gas receiver 45. A check valve 46 is used to prevent reverse flow from the gas receiver 45. The gas receiver 45 is employed primarily for maintaining a minimum of surging and short cycling by providing means for storing the compressed gas temporarily on its intermittent or periodic application to the displacement tanks 18, 19.

Also for controlling the operation of the pressurizer compressor 16, a pressure switch 50 may be incorporated in the discharge line 51 from the plant compressor 11. In the present instance, a pressure switch 50 of conventional construction is used, electrically connected to the motor (not shown) driving the pressurizing compressor 16 and set to start the pressurizing compressor when the condenser pressure (or discharge pressure from the plant compressor), falls below the required liquid line pressure. A line 52 is used to supply gas under pressure from the plant compressor to the gas receiver 45. Gas is allowed to pass through the line 52 when the differential between the discharge pressure of the plant compressor and the pressure in the gas receiver exceeds a value as determined by the relief valve 53 which also acts as a check valve to prevent reverse flow of gas.

In the particular system illustrated in Figure 1 of the drawings, the plant compressor operates continuously for maintaining suction pressure in the suction line from the plant, and continuously circulates refrigerant gas from the evaporator cooling coils through the compressor where the gas is compressed and discharged into the condenser where it is liquefied for cooling purposes in the plant.

Referring to Figs. 2 and 3, charts which will be used for illustrating the operation of a refrigerating system including the pressurizing system as hereinbefore described, it will be observed that Fig. 3 includes two similar curves, one of which is curve A using the horizontal coordinant and the left-hand vertical coordinant and illustrating the average wet bulb temperature during the year in the Chicago latitude. Curve B indicates the relationship of average condensing pressures at constant capacity with evaporative condensing, using the right hand vertical coordinant of the chart. The average overall wet bulb temperature during the year is indicated by the dashed horizontal line C while the average noon wet bulb temperature, slightly higher than the average overall wet bulb temperature, is indicated by the horizontal dash-dot line D.

The average overall condenser pressure is indicated by the dotted line E, and is computed from the average condensing pressure curve B which gives values for noon average wet bulb temperatures and thus must be modified, in the present instance by deducting five pounds, in order to obtain the overall average.

With the system illustrated in Figure 1 of the drawings, condenser pressures are allowed to rise and fall in accordance with wet bulb temperatures, limited only by the necessity for shutting off spray water in the event the temperature falls below freezing. The average condenser pressure encountered during the year would be as given in the chart shown in Fig. 3, established at a value of 105 pounds per square inch gauge. Values of pressure hereinafter set forth will be given in terms of p.s.i., designating in all cases gauge pressure.

Turning to the chart shown in Fig. 2, this depicts a family of curves for different suction pressures maintained by a plant compressor of conventional construction, and relates brake horsepower per ton of refrigeration (in this case ammonia) with the condensing pressures. The specific values in this chart were obtained from an 8" x 8" two cylinder V.S.A. compressor operating at 400 r.p.m.

In a refrigerating system using ammonia for the refrigerant, 25 p.s.i. suction pressure might be representative of conventional systems. With an average condenser pressure of 105 p.s.i. as obtained from the chart shown in Fig. 3, the brake horsepower per ton of refrigeration is illustrated by the chart of Fig. 3 to be approximately .92.

To compare, conventional refrigerating systems without the pressurizing system component as illustrated in Figure 1 of the drawings, operating at 25 p.s.i. suction pressure may require a condensing pressure as high as 165 p.s.i. the year around, in order to provide sufficient liquid line pressure for the plant. From the chart shown in Fig. 2, such a conventional refrigerating system operating with an average 165 p.s.i. condenser pressure requires 1.31 brake horsepower per ton of refrigeration.

From the foregoing it will be seen that by embodying in a refrigerating system means for raising and maintaining the liquid line pressure at a preset value regardless of the condenser pressure, substantial economies are effected in the power required to operate the plant compressor. The improvement in efficiency over a conventional system with a like rated capacity may be computed at a reduction of 29.8% in required brake horsepower per ton of refrigeration.

This reduction in brake horsepower (B.H.P.) per ton of refrigeration is directly reflected in savings in power costs required to operate the plant compressor.

The pressurizing compressor motor for example, taking a 100-ton plant using ammonia, may be of the order of a two horsepower unit. During periods of low condenser pressure (refer to Fig. 2), for example at suction pressure of 25 p.s.i. and condenser pressure of 75 p.s.i., the total load is 71 B.H.P. With 165 p.s.i. condenser pressure the load is 141 B.H.P., a difference during such periods of 60 B.H.P. The two horsepower pressurizing compressor motor during these periods, in the pressurizing system of this invention effects a savings of 60 B.H.P. for such a plant.

Taking the 100-ton ammonia plant, for purposes of illustration, it may be assumed that in such a plant 40 pounds of liquid ammonia per minute are circulated through the system. Assuming also that the system is to be operated with a liquid line pressure of 165 p.s.i. and an average condenser pressure of 105 p.s.i. it is

thus necessary to raise the pressure of the liquid ammonia an average of 60 p.s.i. The size of compressor motor required to raise 40 pounds of liquid ammonia per minute an average of 60 p.s.i. may be computed as follows:

$$\frac{40\ (\text{pounds}) \times 60\ \text{p.s.i.} \times 3.6}{33{,}000 \times \text{Eff.}} = \frac{.26}{\text{Eff.}}\ \text{H.P.}$$

Taking into account peak load which may be twice the average load, from the above computation it will be seen that a 2 horsepower motor at ordinary efficiency supplies sufficient power to drive the pressurizing compressor at a rate sufficient to increase the liquid ammonia pressure the required average 60 pounds per square inch and has sufficient capacity to operate at twice that load for cold weather operation.

The increase in efficiency over the conventional system of a refrigerating system incorporating the pressurizing component as described hereinbefore, may be increased further by including means operative in connection with the pressure regulating valve **40** included in the vent line **31** between the displacement tanks and the suction line, for maintaining a minimum pressure in the displacement tanks which varies as the receiver pressure. In the system illustrated in Fig. 1 of the drawings, and as described hereinbefore, the pressure regulator valve **40** may be set to allow the displacement tanks to vent to the suction line to reduce the pressure in the tanks to a preset value, the preset value being determined by the minimum receiver pressure which would be experienced during the colder months of operation.

Referring to Fig. 1, it will be seen that provision may be made as shown by the control line **55** for connecting the pressure regulator valve **40** to the receiver **13**, for controlling the pressure regulator valve operation in accordance with the receiver pressure. In this instance the pressure regulator valve **40** may be of conventional construction, embodying a diaphragm connected to the working parts of the valve above which the control line **55** connection to the receiver is made. This may be termed a bleeder connection. Pressure regulator valves of the foregoing type, termed in the art as modulating back pressure valves, and having a spring working to operate against the diaphragm and against the back pressure are of ordinary conventional construction and are readily available. With such an arrangement embodied in the system of Figure 1, the pressure regulator valve **40** is set to maintain a minimum pressure in the displacement tanks **18, 19** which varies as the receiver pressure, and amounting to a predetermined few pounds below the receiver pressure.

During periods of the year when high condenser pressures and thus receiver pressures are experienced, it is unnecessary to have the minimum pressure in the displacement tanks reduced by venting to the same values which would allow the system to operate when low condenser and receiver pressures are experienced, as for example are encountered in the colder months of the year. By including a pressure regulator valve which controls the displacement tank pressure in relation to the receiver pressure, considerable re-expansion losses are eliminated.

In a further aspect of the invention it is contemplated that means may be included for reducing the pressure of the liquid refrigerant obtained from the source in order to remove a portion of the flash gas from the liquid refrigerant prior to repressurizing and feeding to the plant evaporator coils. The pressure reduction to be effected by this means need only be sufficient to remove that quantity of flash gas which would otherwise be produced as an incident to the pressure drop of the liquid refrigerant flowing through the lines from the repressurizing system to the evaporator cooling coils.

In the present instance, as shown in Fig. 4 (where like reference numerals to those included in Figure 1 are used to designate like components), a flash tank **56** may be located in proximity to the receiver **13** and in the liquid line **14** between the receiver and the displacement tanks **18, 19**. Pressure reduction is effected in the present instance by a pressure reducing valve **57** of conventional construction interposed in the line **14** and adapted to be connected by means of a compensating line **57'** to the suction line **15**. A simple expansion valve could also be used in place of the pressure reducing valve, as preferred.

Associated with the flask tank **56** is a level responsive control valve **56'** which may be of any suitable type adapted to maintain a constant liquid lever in the tank. When the level falls the valve opens to vent the flash gas from the tank through a conduit to the suction line **15**. Pressure in the tank is thus reduced causing the pressure regulating valve **57** to admit more liquid refrigerant to the tank.

As shown in Figure 1, with the flash tank or flash chamber **56** included, by means of the pressure reducing valve **57**, liquid refrigerant drained from the receiver **13** may be flashed down to a pressure considerably above suction pressure, but sufficient to remove flash gas which would normally be produced in the lines, fed to the displacement tanks **18, 19** and repressurized in order to obtain a supply of subcooled liquid for feeding to the evaporator cooling coils. The temperature of the liquid refrigerant in the flash tank **56** is below the temperature of the liquid in the receiver **13** as determined by the condenser **12**, and considerably below the saturated tempertaure at the pressure of the refrigerant gas in the displacement tanks. Thus after the liquid has been repressurized it is in the subcooled state. The heat given off during the operation of pressure reduction to produce this low tempertaure of the liquid refrigerant is absorbed in the transformation of a portion of the liquid refrigerant into flash gas.

The advantages to be gained by including the pressure reducing means as just before described, may be more graphically explained by comparing the operation of the system as illustrated in Fig. 4, with a conventional system including a flash tank, and with a system like that disclosed in Fig. 1 of the aforementioned Patent No. 2,590,741, issued March 25, 1952.

With the present system, the pressure regulator valve **57** may be set to reduce the pressure of the liquid refrigerant to a predetermined pressure, some substantial value above the maximum suction pressure experienced in the normal operation of the system. By means of the pressurizing compressor **16** and the displacement tanks **18, 19** and associated controls, the liquid refrigerant at this low pressure, and at the corresponding low temperature is then subjected to the preset pressure of substantially 165 p.s.i. and fed to the cooling coils. No flash gas is produced in the liquid lines extending to the expansion valves and evaporation cooling coils, and a solid supply of liquid refrigerant is produced for cooling purposes.

In a conventional system including a flash chamber and having expansion valves at the evaporator cooling coils sized for substantial pressure drops, liquid refrigerant taken from the receiver at condenser pressure is reduced in pressure for removing a portion of the flash gas from the liquid. In such a system the liquid is fed at flash tank pressure to the evaporator cooling coils. Flash gas, therefore, is produced in the line as an incident to the pressure drop therein. This flash gas deleteriously affects the efficiency of operation of the various valves in the system.

In a system like that shown in the aforementioned Watkins Patent No. 2,590,741, issued March 25, 1952, the flash tank pressure is employed for feeding the liquid refrigerant to the evaporator cooling coils. Thus flash gas is produced in these lines affecting unfavorably the operation of the system. With a pressurizing system, as described hereinbefore, to provide subcooled liquid for

supplying to the evaporator cooling coils, this flash gas may be removed prior to introducing the liquid refrigerant into the liquid line for feeding to the cooling coils.

As described hereinbefore, provision is made for automatically controlling the admission of liquid refrigerant alternately to the displacement tanks and for alternately admitting refrigerant gas under the preset pressure from the pressurizing compressor, for applying said pressure to the liquid accumulated in the displacement tanks and for forcing the liquid into the feed line to the plant. For purposes of completeness of description, an exemplary control circuit is shown in Fig. 5, illustrating the electrical connections between the float or displacement switches 21, 22, the vent valves 32, 33 and the gas valves 36, 37 included in the pressurizing system. In this exemplary control circuit, initial closure of switch 21 controlling the admission of liquid refrigerant and the admission of refrigerant gas under the preset pressure to displacement tank 18, operates upon low liquid levels being reached in the tank to close the gas valve 36 by opening contacts 59 and de-energizing the solenoid 36' of the gas valve. Simultaneously contacts 58 are closed, energizing the solenoid 32' of the vent valve 32. The displacement tank 18 is accordingly vented to the suction line 15 through vent line 31, and automatically the pressure therein is reduced either to preset minimum pressure by the pressure regulator valve 40, or to a pressure a few pounds per square inch less than the pressure in receiver 13. By reason of the differential in pressure between the receiver 13 and the tank 18, liquid refrigerant is drained from the receiver and introduced in the bottom of the said tank. Upon the liquid level in the tank reaching the high level, the float switch 21 operates to reverse the arrangement, closing the vent valve 32 by de-energizing the solenoid 32' thereof, and opening the gas line valve 36 by making the circuit to the solenoid 36' of the valve, and thus allowing refrigerant gas under the preset pressure to be admitted into the displacement tank 18 to apply the preset pressure to the accumulated liquid therein and to force the liquid into the branch 14' of the liquid line and thence into the liquid line 14 itself. Reverse flow of the liquid is prevented by check valve 26 connected in the branch 14' of the liquid line and between the displacement tank 18 and the receiver 13.

The float switch 22 controlling the admission of liquid refrigerant and refrigerant gas under preset pressure to displacement tank 19, operates in a similar manner. Thus when the low liquid level is reached, the switch 22 by means of contacts 60 closes the circuit to the vent valve solenoid 33', opening the vent valve and venting the tank, the solenoid 37' of the corresponding gas valve during this period being de-energized and the valve being closed. When the tank is filled, the arrangement is reversed, the solenoid 37' energized and the gas valve opened to admit high pressure gas to the tank, and the solenoid 33' de-energized and the vent valve 33 closed.

It will also be noted that the circuit to the switch 22 controlling the displacement tank 19 is arranged across the contacts 58, 59 operated by the float or displacement valve 21 in the other tank 18. The arrangement is such that the contacts 59 must be closed to energize the solenoid 33, and open the corresponding vent valve. These contacts are closed only when the liquid in the tank 18 is at a high level and the switch 21 is in its raised position. Similarly, to energize the solenoid 37' and open the gas valve 37, the contacts 58 must be closed, these contacts being closed only when the tank 18 is empty.

With the control illustrated as exemplary, the displacement tank 18 controlled by the displacement or float switch 21 provides the primary source of liquid refrigerant under pressure for the liquid line, the tank 19 being employed to supply liquid refrigerant under the required pressure only during refill of the tank 18.

The control circuit illustrated in Fig. 5 also shows an exemplary arrangement for the pressure switches 47 and 50 controlling the operation of the motor driving the compressor 16. In the present instance, to energize this motor winding and start the motor both switches are required to close; the switches are connected in series. As mentioned above, the discharge pressure of the plant compressor 12 upon falling below the preset pressure established for the liquid refrigerant in the line to the cooling coils, actuates to close the switch 50. Upon the pressure in the gas receiver 45 falling below the said pressure, the switch 47 closes, as shown in Fig. 5, energizing the relay 62 to close the motor circuit and thus start the motor.

I claim as my invention:

1. A refrigerating system, comprising, a compressor, a condenser into which said compressor discharges for producing liquid refrigerant and arranged to receive cooling fluid the temperature of which varies circulated through it, a cooling coil, and a liquid refrigerant circulating circuit connecting said coil to the condenser and compressor including a liquid line for conveying the refrigerant to the coil from the condenser, the feeding of liquid refrigerant through the system requiring a liquid line pressure determined by the pressure drop through the system, which pressure is normally supplied by the pressure in the condenser, and a pressurizing system connected in said liquid line, said pressurizing system including means connected to the line for receiving liquid refrigerant at the line pressure, and means associated with said receiving means for applying pressure to the liquid refrigerant to raise its pressure, and control means for operating said pressurizing system when condenser temperatures and pressures fall for raising the pressure of liquid refrigerant in the line above the pressure in the condenser to the pressure required to feed the liquid refrigerant through the system so as to obtain maximum operating efficiency by allowing condenser pressures to rise and fall in accordance with the temperature of the cooling fluid circulated through the condenser.

2. In a refrigerating system, the combination comprising, a receiver for storing liquid refrigerant under pressure, the pressure in said receiver varying over a substantial range, a cooling coil, a liquid line for conveying liquid refrigerant to said cooling coil from said receiver, the feeding of liquid refrigerant through the system requiring a liquid line pressure determined by the pressure drop through the system, the system being arranged so that the receiver pressure is normally above said required pressure, and means in said liquid line for raising the pressure of the liquid therein to the pressure required to feed the liquid refrigerant through the system when the receiver pressure drops below said required pressure, said last-named means including a reservoir connected to the line for receiving liquid, and pressure applying means associated with said reservoir for raising the pressure of the liquid refrigerant therein sufficiently to overcome said pressure drop to pump the refrigerant from the reservoir through the liquid line to the cooling coil.

3. A refrigerating system having, in combination, a compressor, a condenser into which said compressor discharges, a receiver for storing the refrigerant liquefied in said condenser, an evaporator cooling coil, a refrigerant circulating circuit including a liquid line for conveying liquid refrigerant from said receiver, a pressurizing system connected in said liquid line for feeding liquid refrigerant from the receiver to the cooling coil, the feeding of liquid refrigerant requiring a pressure in the liquid line which pressure is dependent upon the pressure drop through the system, and a return line connecting the cooling coil to the compressor, said pressurizing system including a reservoir for liquid refrigerant having a connection to the line, pressure reducing means in said last-named connection reducing the pressure of the liquid refrigerant to a pressure below the pressure required to feed the liquid, a source of gas under pressure, and a connection between said source and said reservoir for sup-

plying gas under pressure to the liquid in the reservoir and raising the pressure of the said liquid to the required pressure.

4. A refrigerating system having, in combination, a compressor, a condenser into which said compressor discharges and arranged to have cooling fluid the temperature of which varies circulated about the condenser coils, a receiver for storing the refrigerant liquefied in said condenser, and a liquid refrigerant circulating circuit connected to said condenser including a liquid line receiving liquid from said receiver, a return line connected to said compressor, and a cooling coil connected across said lines, the feeding of liquid refrigerant through the circuit requiring a liquid line pressure dependent upon the pressure drop through the circuit, and means connected in the liquid line for pressurizing the liquid in said liquid line when the same drops below said pressure, said pressurizing means including a pair of tanks connected alternately to the receiver for filling with liquid refrigerant and the line for supplying said liquid refrigerant to the cooling coil, and means connected to the receiver for alternately applying pressure to the liquid refrigerant in the tanks.

5. In a refrigerating system, a source of liquid refrigerant under pressure including a receiver, a pair of tanks connected to said receiver by conduit means so as to be alternately filled with liquid refrigerant, pressure reducing means between said receiver and said tanks for flashing down the pressure of liquid refrigerant supplied to the tanks below said receiver pressure, a cooling coil, a liquid line connecting said coil with said tanks, a source of refrigerant gas under pressure higher than the pressure of the liquid refrigerant in said tanks, said source including the receiver, and means for connecting said source of refrigerant gas to the tanks for raising the pressure of the liquid refrigerant in each of the tanks when the latter are filled to the pressure of the source, so as to provide pressure for feeding the liquid refrigerant through said liquid line to the cooling coil.

6. In a refrigerating system having a condenser for the liquid refrigerant, said condenser being arranged to have cooling fluid the temperature of which varies circulated through it, a reservoir connected to receive liquid refrigerant from the condenser and providing means for storing said liquid refrigerant, an evaporator cooling coil, and a liquid line for feeding liquid refrigerant from said reservoir to said coil, the feeding of liquid refrigerant requiring a pressure in the liquid line determined by the pressure drop through the system, the combination comprising, means connected to said reservoir for applying pressure to the liquid refrigerant therein, and control means responsive to the pressure in the condenser for causing said pressure applying means to operate when the pressure drops below the required liquid line pressure, so as to maintain the pressure of said liquid refrigerant in said reservoir and in the liquid line irrespective of the condenser pressure as determined by the temperature of the cooling fluid.

7. A refrigerating system having, in combination, a compressor, a condenser into which said compressor discharges and arranged to receive cooling fluid the temperature of which varies circulated about the condenser coils, a receiver for storing the refrigerant liquefied in said condenser, a liquid line receiving liquid refrigerant from said receiver, a return line connected with said compressor, a cooling coil connected across said lines, the feeding of liquid refrigerant requiring a given pressure in the liquid line determined by the pressure drop through the system, means for applying pressure to the liquid in the liquid line, and control means responsive to the condenser pressure for operating said last-named means so as to maintain the liquid line pressure at a value sufficient to overcome said pressure drop irrespective of variations in the condenser pressure, and effective when cooling fluid temperatures and corresponding condenser pressures fall below a predetermined value.

8. In a refrigerating system having a source of liquid refrigerant and refrigerant gas under pressure including a compressor, a condenser, and a receiver connected to said condenser for storing said liquid refrigerant and refrigerant gas under pressure; an evaporator cooling coil; and a liquid refrigerant circuit including a liquid line connecting said receiver to said coil, the combination comprising, a reservoir connected in said liquid line, pressure reducing means between said receiver and reservoir for flashing down the pressure of liquid refrigerant supplied to the latter, and means connected to said source for applying compressed refrigerant gas to said reservoir and raising the pressure of said liquid refrigerant so as to provide pressure for forcing the liquid refrigerant through said liquid line to the cooling coil.

9. In a refrigerating system the combination comprising, a compressor, a condenser into which said compressor discharges and arranged to have cooling fluid the temperature of which varies circulated about the condenser coils, said condenser and compressor constituting a source of liquid refrigerant under pressure, an evaporator cooling coil, a liquid line for feeding liquid refrigerant from said source to said cooling coil, the feeding of liquid refrigerant requiring a given liquid line pressure determined by the pressure drop through the system, a reservoir in said liquid line, pressure reducing means between said condenser and reservoir for flashing down the pressure of liquid refrigerant supplied to the latter, and means for raising the pressure of the liquid refrigerant in the reservoir to a value sufficient to overcome the pressure drop and which is maintained irrespective of the condenser pressure as determined by the temperature of the cooling fluid, so as to provide pressure for feeding the liquid refrigerant to the cooling coil.

10. In a refrigerating system, the combination comprising, a receiver for storing liquid refrigerant under pressure, a cooling coil, a liquid line for feeding liquid refrigerant to said cooling coil from said receiver, said liquid line having a pair of branch lines therein, a pair of displacement tanks, one of said tanks being interposed in each of said branch lines, a source of refrigerant gas under a preset pressure, gas lines connecting said displacement tanks and said source of refrigerant gas, valves in said liquid and gas lines for controlling the flow of liquid and gas respectively, and means for operating said valves for filling each of said displacement tanks alternately with liquid refrigerant from the receiver and refrigerant gas from the gas source, and for admitting liquid refrigerant alternately from each of said tanks to the liquid line connected to the cooling coils whereby to force the liquid refrigerant in said tanks at said preset pressure into said liquid line and to the cooling coils.

11. In a refrigerating system, the combination comprising, a source of liquid refrigerant under pressure, a pair of reservoirs for storing said liquid refrigerant, conduits connecting said source and said reservoirs, a cooling coil, a liquid line for feeding liquid refrigerant to said coil from said reservoirs, a source of refrigerant gas under pre-set pressure normally higher than the pressure of the liquid refrigerant in said reservoirs, a gas line for supplying gas from said source of refrigerant gas to said reservoirs for placing the liquid refrigerant stored therein under the pre-set pressure, valves for regulating the supply of liquid refrigerant and refrigerant gas to said reservoirs and for admitting liquid refrigerant to the liquid line from said reservoirs, and means for controlling said valves for supplying each of said reservoirs alternately with refrigerant gas and liquid refrigerant from the respective sources thereof whereby to fill the reservoirs with liquid refrigerant from the source thereof and to raise the pressure of the liquid refrigerant stored in said reservoirs to the pre-set pressure, and for admitting liquid refrigerant at the pre-set pressure to the liquid line alternately from each of said reservoirs to feed the cooling coil.

12. A refrigerating system comprising, in combination, a compressor, a condenser into which said compressor discharges and arranged to receive cooling fluid the temperature of which varies circulated through it, a receiver connected to said condenser for storing the refrigerant liquefied in said condenser, a pressure reducing valve and flash chamber receiving liquid refrigerant from the receiver for reducing the pressure of the liquid refrigerant below the receiver pressure and removing flash gas therefrom, the liquid in said flash chamber being sub-cooled, and a liquid refrigerant circuit including a liquid line connected to the flash chamber, an evaporator cooling coil connected to the liquid line, and a return line connecting the cooling coil to the compressor, the feeding of liquid refrigerant through the circuit requiring a liquid line pressure determined by the pressure drop through the system, and means for pressurizing the sub-cooled liquid refrigerant obtained from the flash chamber and fed through the liquid line to the cooling coil, to a pressure sufficient to overcome said pressure drop, which latter pressure is maintained irrespective of variations in the condenser pressure, so that condenser pressures are allowed to rise and fall in accordance with the temperature of the cooling fluid circulated through the condenser.

13. In a refrigerating system, the combination comprising, an evaporator cooling coil, a source of liquid refrigerant under pressure, a pair of reservoirs for storing said liquid refrigerant, supply conduits connecting said source and said reservoirs, a source of refrigerant gas under pre-set pressure normally higher than the pressure of the liquid refrigerant obtained from the source thereof, gas supply conduits connecting said source of refrigerant gas and said reservoirs, vent lines connected to the reservoirs, a pressure regulator connected to said vent lines, said pressure regulator being effective to regulate the venting of said reservoirs to obtain a vented pressure in said reservoirs a predetermined relatively small amount below the pressure of the liquid refrigerant obtained from said source to allow filling the reservoirs with liquid refrigerant from the source thereof, a liquid line connecting said evaporator cooling coil with said reservoirs for feeding liquid refrigerant obtained alternately from each of said reservoirs to said cooling coil, valves in said liquid and gas supply conduits and vent and liquid lines, and means for controlling the said valves for alternately filling the reservoirs with liquid refrigerant placing the liquid refrigerant therein under the pre-set pressure of the gas and admitting liquid refrigerant at said pre-set pressure alternately from each of said reservoirs into the liquid line for feeding to the cooling coil.

14. In a refrigerating system, the combination comprising a source of liquid refrigerant including a compressor and a condenser through which cooling fluid is circulated the temperature of which varies, the discharge pressure of the compressor being variable in accordance with the temperature of the cooling fluid circulated through the condenser, a receiver connected to the condenser, a tank for liquid refrigerant connected to the receiver, a liquid line receiving liquid refrigerant from said tank, the feeding of liquid refrigerant requiring a given pressure in the liquid line determined by the pressure drop through the system, means between the receiver and tank for reducing the pressure of liquid refrigerant obtained from said receiver and supplied to the tank by flashing down the liquid refrigerant to a sub-cooled state, and means for maintaining the sub-cooled liquid refrigerant in said tank at a predetermined pressure sufficient to overcome said pressure drop irrespective of the compressor discharge pressure.

References Cited in the file of this patent

UNITED STATES PATENTS

1,944,472	Sloan et al.	Jan. 23, 1934
2,188,350	Holmes	Jan. 30, 1940
2,277,647	Jones	Mar. 24, 1942
2,589,859	Phillips	Mar. 18, 1952
2,590,741	Watkins	Mar. 25, 1952
2,621,051	Kramer	Dec. 9, 1952
2,685,780	Zearfoss	Aug. 10, 1954
2,705,404	Malutich	Apr. 5, 1955
2,740,263	Kritzer	Apr. 3, 1956
2,778,195	Christensen	Jan. 22, 1957