ABSTRACT

A refrigerant accumulator in the suction line of a closed refrigeration system, provided with a controllably heated metering tube between the bottom of the accumulator and a downstream point in the suction line, to ensure at least adequate reevaporation of the refrigerant, to eliminate slugging and to return oil to the compressor, particularly during the hot gas defrosting portion of the refrigeration cycle, the heating being effected electrically or by means of hot gas from the compressor.

5 Claims, 9 Drawing Figures
REFRIGERATION SYSTEM WITH SUCTION LINE ACCUMULATOR

Modern positive displacement refrigerant compressor technology has generated designs which provide the maximum in capacity per unit, weight, cost and power. In order to achieve these features the compressors are generally designed for relatively high rotative speeds and high bearing loads. Standard rotative speeds for compressors are now 1,725 and 3,400 revolutions per minute. At these speeds ingestion of liquids of any sort into the compressor chamber can cause instantaneous mechanical failures. Liquid entering the cylinders can stem from two sources; liquid oil can enter the cylinders from foaming of the oil in the compressor crankcase on startup under conditions where liquid refrigerant has condensed or dissolved in the oil during the off-cycle. The other source of liquid is liquid refrigerant in relatively pure form which can return under abnormal conditions through the suction line from the evaporator.

If large quantities of liquid refrigerant enter the compressor, much of the refrigerant will be entrained into the cylinders with the vapor and will cause a condition known as slugging which is accompanied by pouting and knocking sounds and frequently causes instantaneous compressor damage.

If the liquid refrigerant returns to the compressor in small quantities, but over a long period of time, this liquid refrigerant tends to dilute the oil, reducing its lubricity and generating a condition of rapid bearing wear under those designed conditions of high rotative speeds and high bearing loads to which the compressor is ordinarily exposed. To help guard compressors against either immediate or long range damage caused by the return of liquid refrigerant through the suction line to the compressor, more and more compressor manufacturers are presently recommending the use of so-called surge drums or suction accumulators whose purpose is to catch the liquid refrigerant returning in large or small quantities and prevent this potentially harmful liquid refrigerant from reaching the compressor. Because of the new requirements for suction line protection against liquid return to the compressor, many manufacturers have begun listing for sale suction accumulators with various refrigerant holding capacities and various inlet and outlet line sizes supposedly designed to fit a wide range of systems and refrigerant charges.

Manufacturers of accumulators are faced with the problem of providing positive means for the oil, which normally circulates with the refrigerant in refrigeration systems, to be returned to the compressor. If this oil is not returned but is caught or trapped in the suction accumulator, the compressor may run out of oil or the accumulator’s potential for holding liquid refrigerant will be diminished.

According to the present invention, there is provided an external bleeder tube between the accumulator and the suction line together with one or more heaters so positioned, constructed, selected and controlled that liquid refrigerant flowing through the bleeder tube is completely reevaporated before it reaches the suction line.

Practical embodiments of the invention are shown in the accompanying drawings, wherein:

FIG. 1 represents a vertical section of a known type of suction line accumulator;
FIG. 2 represents an elevation of another known type of accumulator, parts being broken away;
FIG. 3 is a diagrammatic view of a refrigerating system embodying the apparatus of the present invention;
FIG. 4 represents a vertical section of a first form of accumulator embodying the invention;
FIG. 5 represents an elevation of a second form of accumulator;
FIG. 6 is a diagrammatic view of a portion of a refrigeration system showing an alternative means for heating the bleed tube;
FIG. 7 is a diagrammatic view of a refrigeration system having means for heating both the bleed tube and the suction line;

FIG. 8 is a diagrammatic view of a portion of a refrigeration system showing the use of a thermostatic control for the bleed tube heater, and
FIG. 9 is a detail diagram showing means for ensuring discriminating functioning of the thermostatic control of FIG. 8.

According to FIG. 1, the accumulator 10 is a vertically disposed cylinder having an inlet 11 from the evaporator, opening at 12 into the upper part of the cylinder, and an outlet 13 leading to the compressor, the outlet being connected to a U-shaped trap 14 open at its free end 15 to receive evaporated refrigerant and provided with a metering orifice or bleed hole 16 adjacent its bottom.

Since the bleed hole is built-in it must be made large enough to return the maximum flow of oil that might be expected. Unfortunately, experience has shown that if the bleed hole is made large enough to return the largest quantities of oil which might be pumped by any compressor, the hole is then so large that excessive amounts of refrigerant are allowed to return to the compressor when the accumulator is partially filled with liquid refrigerant. In addition, laboratory tests and experience have shown that the return of refrigerant and oil flow through the bleed hole is related to the vapor velocity passing through the accumulator. Although this effect would not at first appear to be obvious, the effect was positively determined by quantitative laboratory tests. An investigation of the cause of this increase in refrigerant flow through the bleed hole showed that it is caused by the pressure at the inside of the tube in which the bleed hole is located being much lower than the pressure on the outside. The pressure is lower inside the tube not only by virtue of the frictional pressure drop loss in the outlet tube, but also the much greater pressure reduction caused by the Bernoulli effect, i.e., the higher the fluid velocity, the lower the pressure in that fluid.

All constructions of suction accumulators observed to this date are affected by this problem which means that the rate of refrigerant flow from the body of liquid accumulated in the accumulator into the suction line is not a constant but a variable.

An effort by the present applicant to solve this problem is shown in FIG. 2, wherein the horizontally disposed accumulator 17, having an inlet 18 and outlet 19 (corresponding to inlet 11 and outlet 13-15 in FIG. 1) is provided with an external bleeder tube 20, running from a point 21 at the bottom of the accumulator to a point 22 in the suction line 23. This external bleeder tube 20 is so designed and constructed that it can be removed and exchanged for a bleeder of a different diameter.

In addition, the easily serviceable design means that the bleed tube can be more closely sized to the actual requirements without any concern that dirt might plug the bleed tube and permanently destroy the usefulness of the accumulator.

Instead of the bleeder having to be made sufficiently large for the worst situation, the bleeder can be made with an internal bore which exactly matches the system requirement. Even if an error is made in initially sizing the bleeder its replaceability makes a size adjustment an easy matter.

Even though the development of the suction accumulator with external and replaceable bleed tube constituted a tremendous advancement over the best previously available accumulators, and although the application of this accumulator has been satisfactory, all these accumulators had certain application limitations. All accumulators had, generally, to be installed so that a relatively long run of suction line existed between the outlet of the accumulator and the compressor inlet. In addition, the suction line had to be exposed to an ambient 32° F. or higher. The purpose of requiring this length of suction line maintained at a relatively high ambient was to insure that even the limited amount of liquid refrigerant that flowed through the calibrated bleeder tube into the suction line under conditions when floodback into the accumulator occurred, was completely evaporated to dryness so that no liquid refrigerant at all entered the compressor. Under the conditions where the accumulator was placed very close to the compressor and/or where a very short suction line was employed, or the suction line was exposed to cold winter
bients, for example —10°F or —20°F. Reevaporation of even the small amount of liquid refrigerant bled through the bleed tube could not occur and this liquid refrigerant entered the compressor causing oil dilution and excessive bearing wear leading to early compressor failure.

In order to make sure that no liquid returns to the compressor, even where the suction line is short and cold as, for instance, where the accumulator is mounted directly on the compressor chassis, either of two solutions can be employed. A first possible solution is the provision of a heat exchanger in the suction line between the accumulator outlet and the compressor using, for instance, the heat available from the hot gas leaving the compressor discharge to warm the suction vapor leaving the accumulator and evaporate the liquid mixed with that vapor. This system has the drawback that the normally cold suction vapor is heated not only when the ambient surrounding the system is low, as in the winter, but also when the weather is very hot. Then the suction heat exchanger aggravates potential compressor overheating and reduces compressor capacity by warming the suction vapor entering the compressor which makes the vapor less dense and allows the compressor to pump less with each rotation of its crankshaft.

As illustrated in FIG. 3, a refrigeration system in which the present invention may be embodied includes the evaporator 30 supplied with liquid refrigerant from the condenser 31 and receiver 32 under the control of the expansion valve 33. The compressor 34 supplies gaseous refrigerant under compression through the line 35 to the condenser, during refrigeration, or through the hot gas defrosting line 36, controlled by solenoid valve 37, directly to the evaporator 30 during defrosting. The accumulator 38 is similar to that shown in FIG. 2, receiving refrigerant from the evaporator through the line 39 and having an outlet 40 opening into the upper part of the accumulator and connecting with the suction line 41 to the compressor. An external bleeder tube 42, similar to tube 20, leads from the bottom of the accumulator to the suction line and there is also provided, according to the invention, a heater 43 so positioned and controlled that liquid refrigerant flowing through the bleed tube is completely reevaporated before it reaches the suction line. This construction has the advantage that even strong heating of the bleed tube will have essentially no effect on the temperature of the vapor entering the compressor. The heater therefore becomes discriminating in that it only heats liquid refrigerant or perhaps oil leaving the accumulator into the bleed tube but does not exert any heating effect on the suction vapor traversing the accumulator itself.

Such an accumulator, with heated bleed tube, can be mounted at or near the compressor, will allow free return of oil which is trapped in the accumulator, and yet effects the complete evaporation of liquid refrigerant traversing the oil flow passage without any heating effect on the suction vapor entering the compressor. This system can be used for defrosting of evaporators even when the accumulator, compressor, and other high side components are located in ambient as low as 0°F or —10°F. An additional improvement in accumulator design is a modification, shown in FIG. 4, which at least partially offsets the variation in refrigerant flow through the bleeder which occurs with various vapor velocities. This improvement constitutes extending the outlet of the bleed tube 44 into the outlet tube 45 and bending the outlet tube, as indicated at 46, upwards so that a pilot tube effect is generated. With this construction the impact pressure of the vapor on the end of the bleed tube opposes the increased pressure difference which higher vapor velocities generate.

An additional refinement in the design of the bleed tube involves the application of heat in such a way as to significantly decrease the rate of flow which occurs through the bleed tube even when the bleed tube is of a large diameter. FIGS. 3 and 4 show the basic bleed tube arrangement of this invention which pitches uniformly from the bottom of the accumulator to the outlet tube with or without the pilot effect. FIG. 5 shows the bleed tube 47 modified in the form of a trap 48. Heat is applied at 49 on the downward flowing side of the trap and separately at 50 on the upward flowing side of the trap. The application of heat on the downward flowing side of the trap generates bubbles whose buoyancy tends to offset the pressure differential generated by the vapor flow and by the head of liquid in the accumulator. By the correct application of the heat at this point the flow of liquid refrigerant in the bleed tube can be adjusted as required so that the heater 50 on the outward upflowing leg of the bleed tube can completely evaporate the liquid refrigerant which succeeds in traversing the downflowing leg. Together the division of heat between the downflowing leg and the upflowing leg constitutes means for externally changing the effective flow capacity of the bleed tube without actually modifying its internal construction or diameter.

The bubbling of the refrigerant in the trap is comparable to the "vapor lock" effect obtainable in any small tube, including the tube 44 in FIG. 4. When liquid refrigerant moves through a relatively small tube in the form of a solid column of liquid under a given head the flow of that liquid is sharply impeded when the stream is heated and thereby assumes the quality of a mixture of vapor bubbles plus liquid. This impeding is caused by vapor bubbles in a refrigerant liquid stream moving in a small bore tube is called "vapor lock," and when an adequate amount of heat is applied to the metering tube it could practically cut off most of the flow of liquid through it. While the application of heat to the metering tube creates the condition called "vapor lock" in a refrigerant liquid stream, the application of heat to the metering tube while oil is moving through it during normal operation has practically a zero effect on the flow of the oil returning to the compressor during normal operation except that the oil becomes warmer and correspondingly less viscous.

Heating of the bleeder tube, as described above, is of particular importance during defrosting, when some of the refrigerant from the evaporator is most likely to be liquid in form. However, the heaters 43, 49, 50 may be kept on continuously, if desired, in order to avoid the necessity for providing special controls. A suitable setting can be determined for any given installation and adjustments, if any, may then be on a seasonal basis. During normal operation of the system, for refrigeration, with little or no liquid entering the accumulator, the heating of the small amounts of vapor passing through the bleeder tube has a negligible effect on the refrigerant gas flowing to the compressor, but whenever any liquid does enter the accumulator—during defrosting or for any reason during refrigeration—it is rendered harmless by the use of this invention.

As a practical alternative, heat from the compressor discharge may be used to ensure vaporizing temperatures in the bleed tube. FIG. 6 shows an arrangement in which the accumulator 51 has an outlet 52 communicating with the suction line 53 to the compressor 54. The bleed tube 55 (similar to the tubes 42 or 44) is heated by close association with the line 56 through which flows a portion of the hot gas which is bypassed around a throttling device 58 in the discharge line 57. The line 56 and tube 55 may be strapped or soldered together to ensure heat transfer contact. All parts of the suction line normally tend, with varying degrees of effectiveness, to vaporize liquid refrigerant passing therethrough. If the distance from the evaporator to the compressor or from the accumulator to the evaporator is short, there would be more need for heat in the bleed tube and/or in the suction line than there would if such distances were longer. Since the discharge line carries much more heat than is needed for ensuring complete vaporization in the suction line, the line 56 in FIG. 6 may be relatively small and the throttling device 58 may be either a hand valve, for adjustment as required, or an orifice of selected size, to ensure an adequate diversion of hot gas through the line 56, while permitting most of said gas to follow its normal course to the condenser.

If the refrigeration system includes provision for hot gas defrosting, the hot gas line can be routed adjacent to the suction line, as shown in FIG. 7, where the accumulator 59 with
inlet 60, outlet 61 and bleed tube 62 is associated with hot gas lines for heating both the bleed tube and the suction line 63. The compressor discharge line 64 includes a portion 65 in heat transfer contact with the bleed tube 62 (as in FIG. 6) while the hot gas defrost line 66, controlled by solenoid valve 67, is similarly in heat exchange relation to the suction line 63 throughout a sufficient length of said outlet line from the accumulator, to evaporate liquid returning during defrost. This supplementary heating would provide a safety factor in case of excess liquid return from the evaporator to the accumulator, above the vaporizing capacity of the metering tube. Such heating of the suction line would not have the harmful effects of continuous heating, mentioned above, since the heating takes place only during defrosting and the suction line is not heated during normal refrigeration.

Where electric heaters are used they may be arranged to turn on when the compressor starts and to turn off when the compressor stops, as by means of a relay indicated conventionally at 70, in FIG. 3, associated with the compressor motor circuit. If consumption of electric power must be controlled carefully a thermostat may be provided on the suction line near the compressor inlet to turn on the heater or heaters when the suction line becomes cold, implying the presence of liquid refrigerant. This would mean that electric heaters might remain deenergized for long periods of time, for instance, during warm weather when the accumulator, bleed tube and suction line cooperate inherently to perform their reevaporating function. In colder weather, however, when the ambient around the suction line is such that liquid flowing through the bleed tube is not reevaporated, the heater would be turned on.

In FIG. 8 is shown a portion of a system similar to that of FIG. 3 but having thermostat 71, with bulb 72 adjacent suction line 73 arranged to open and close the switch 74 in the circuit of heater 75 (corresponding to heater 43).

The use of a thermostat detecting only the suction line temperature, as a means for ascertaining the presence or absence of liquid, is not always reliable since liquid refrigerant at a temperature higher than the thermostat setting could, under certain circumstances, be present and could return to the compressor without detection by the thermostat. As an added refinement, to eliminate the possibility just mentioned, a small cartridge heater 76 (FIG. 9) may be added to the suction line 77 adjacent the thermostat bulb 78, or to said bulb itself, in order to ensure that the thermostat will react only to the presence of liquid, assuming a setting higher than the temperature of any returning liquid. The cooling ability of liquid refrigerant is about 100 times better than that of vapor refrigerant. With liquid refrigerant in the suction line the bulb of the thermostat is effectively cooled despite the presence of the small heater 76, tripping the thermostat and energizing the relatively high voltage heater on the bleed tube. If there is only cold vapor in the line, its cooling effectiveness is insufficient to overcome the heating of the bulb by the heater 76 and the bleed tube heater is not energized. The arrangement just described constitutes a positive means for detecting the presence of liquid refrigerant in the suction line without putting a sensor directly in the flow stream.

What is claimed is:

1. A refrigeration system comprising a compressor, a condenser, an evaporator, and a refrigerant accumulator connected in a closed circuit by lines which includes a suction line from the accumulator to the compressor and a discharge line from the compressor to the condenser, and a restricted passage extending from the lower portion of the accumulator to a point in the suction line spaced downstream from the accumulator, said restricted passage being constituted by a bleed tube one end of which extends into the suction line and is provided with an opening facing upstream, and means for applying heat to said restricted passage.

2. A refrigeration system comprising in a closed circuit, a compressor, a condenser, an expansion valve, an evaporator, an accumulator including a tank, an inlet, an outlet provided with an extension located below the tank, a conduit residing wholly beneath said tank and mechanically coupled to the bottom of the tank and said extension, one end of said conduit extending into said outlet and being provided with an opening facing upstream, an electric heater thermally connected to said conduit, and a suction line connecting said extension to the compressor inlet.

3. A refrigeration system comprising in a closed circuit, a compressor, a condenser, an expansion valve, an evaporator, an accumulator including a tank, an inlet, an outlet provided with an extension located below the tank, a conduit residing wholly beneath said tank and mechanically coupled to the bottom of the tank and said extension, a suction line connecting said extension to the compressor inlet, said conduit having a trap portion provided with a downward flow side and an upward flow side, a heating means comprising a first electric heater adjacent to the downward flow side, a second electric heater adjacent to the upward flow side, and means for controlling at least one of said heaters.

4. A refrigeration system comprising in a closed circuit, a compressor, a condenser, an expansion valve, an evaporator, an accumulator including a tank, an inlet, an outlet provided with an extension located below the tank, a conduit residing wholly beneath said tank and mechanically coupled to the bottom of the tank and said extension, an electric heater thermally connected to said conduit, a thermostat in the circuit of said electric heater, said thermostat having a sensing element responsive to changes in temperature, said sensing element being in thermal contact with said suction line.

5. A refrigeration system according to claim 4 and which includes a heater coating with said sensing element.