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REFRIGERATION SYSTEM

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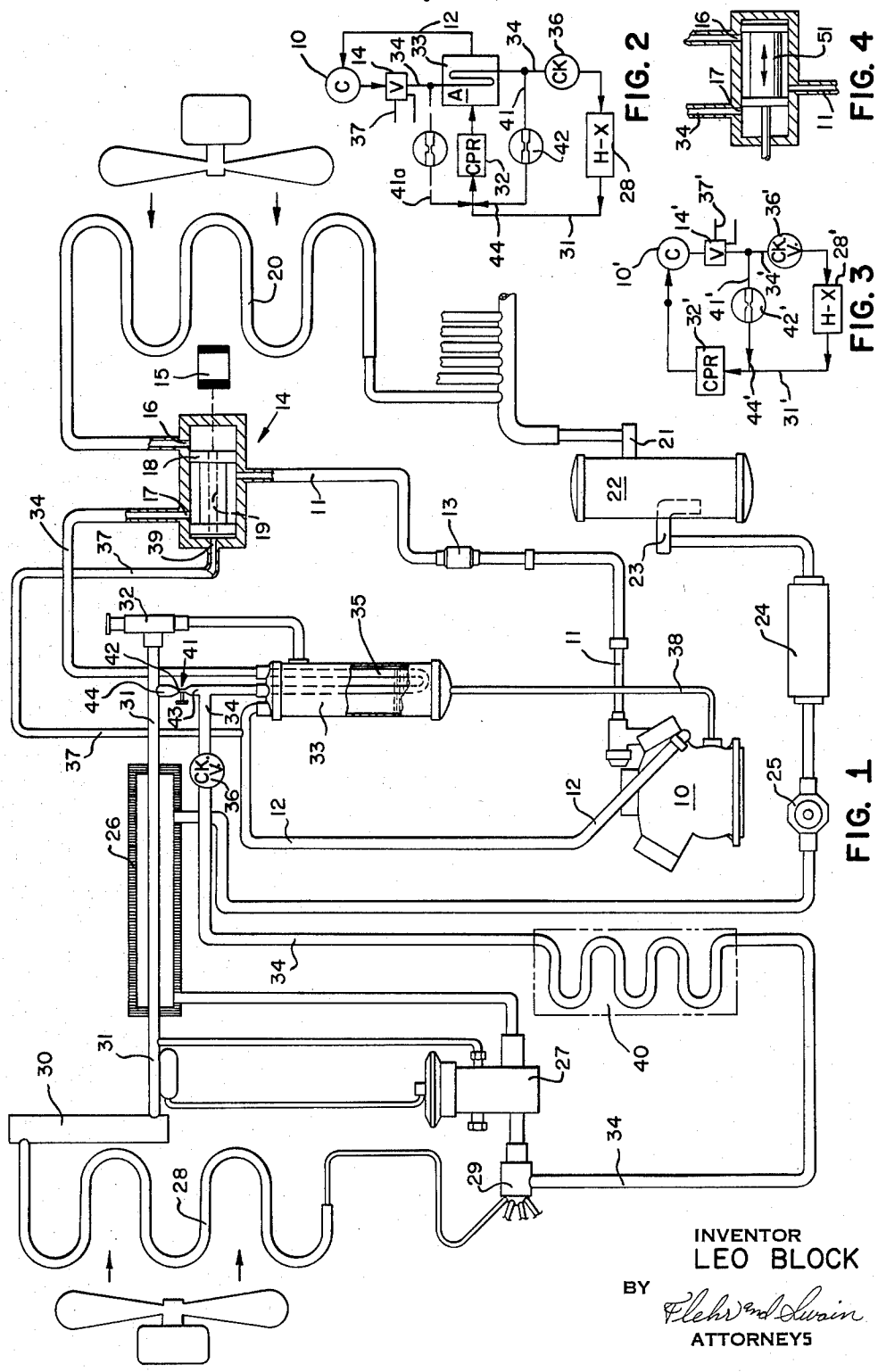

FIG. 1

FIG. 3

FIG. 4

FIG. 2

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REFRIGERATION SYSTEM

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This invention relates to an improved refrigeration system of a type suitable for both cooling and heating.

Refrigeration systems have been devised to effect a combination of both cooling and heating by suitably directing the refrigerant. In one system, during a cooling cycle, refrigerant is supplied from the compressor through the condenser to the receiver. The refrigerant is then metered to the evaporator. The refrigerant passes from the evaporator to the compressor suction by way of a pressure regulator valve and an accumulator. The accumulator serves to trap and evaporate entrained liquid refrigerant to prevent damage to the compressor caused by "liquid slugging."

During the heating cycle, high pressure gas is applied by a hot gas line to the evaporator directly from the compressor. Heat of compression provides the main source of heat to the hot gas line. From the evaporator, the hot gases flow through the pressure regulating means, the accumulator, and back into the compressor.

If a large, high rate of flow compressor unit is used in systems of the kind above, the size of the accumulator can become excessive. To enable the accumulator to trap substantially all entrained liquid, it then must have sufficient volume to reduce the velocity of the refrigerant to a point where liquid can drop to the bottom. This problem of size becomes critical, for example, in mobile units. For instance, in trucking systems, the use of even a modest ten ton capacity compressor precludes "packaging" the accumulator compactly with the condensing unit as is not uncommon practice.

One recourse to avoid increasing the size of the accumulator is to reduce refrigerant flow by employing "unloaders." However, unloaders are expensive and complicate the electrical circuitry.

In general, it is an object of the present invention to provide an improved refrigeration system.

It is another object of the invention to provide a refrigeration system additionally capable of heating whereby the size of the accumulator is minimized or even eliminated.

A further object of the invention is to protect the compressor in a heat of compression system against entrained liquid entering the suction side.

A more particular object is to provide means for more effectively vaporizing entrained liquid upstream of the compressor intake.

These and other objects will be pointed out in the following detailed description of the preferred embodiment of the invention and illustrated in the accompanying drawings, in which:

FIGURE 1 schematically shows a heat-cooler refrigeration system according to the invention, conditioned to provide heating (or defrosting);

FIGURE 2 is a simplified schematic diagram of a portion of the system shown in FIGURE 1;

FIGURE 3 is a simplified schematic diagram of another embodiment of the invention; and

FIGURE 4 schematically shows a three-way valve connected to operate the system shown in FIGURE 1.

A refrigeration system suitable for both cooling and heating is shown in FIGURE 1. The refrigeration system, in general, employs a closed circuit including in the following order, a compressor, a condenser, a receiver, expansion valve, evaporator (cooling coils), pressure regulator means and accumulator, the latter being connected to lead back to the compressor (suction side). During the heating cycle, some cooling elements, such as the condenser, are bypassed and refrigerant therein can be withdrawn for circulation through the elements actively serving to provide heating.

To accomplish this withdrawal during heating, controls and connections are conditioned to provide a first fluid path from the discharge side of the compressor to the evaporator while bypassing the condenser. By these controls (which include a four-way valve), a second fluid path is provided which leads from the condenser through the four-way valve and accumulator inlet to the suction side of the compressor. This latter path by-passes the evaporator. Thus, during heating, fluid is withdrawn from the condenser (and also from the receiver) while the compressor discharges hot gas directly to the evaporator via the first path. Means for evaporizing entrained liquid being carried, during heating, toward the compressor intake have been provided. A portion of the hot gas from the first path (hot gas line) is diverted to bypass the evaporator and is injected directly at the inlet side of the pressure regulating means. This diverted hot gas serves to evaporize entrained liquid entering the pressure regulating means during the heating cycle.

In the system as conditioned for cooling, the compressor discharges refrigerant to the condenser and the evaporator leads to the suction side of the compressor. Valve control means are provided to slectively establish either the cooling or heating circuit.

Referring to FIGURE 1 of the drawing, a system is shown (conditioned for heating) and includes a compressor 10 having discharge and suction connections 11 and 12, respectively. Discharge connection 11 leads through a strainer 13 to a four-way valve 14 which can be actuated by a solenoid 15. Valve 14 is provided with two outlet ports 16 and 17. Port 17 leads to a hot gas line 34 described further below. Valve 14 includes a spool 18 having a longitudinal passage 19 extending along its length. Spool 18 is movable between two positions under control of solenoid 15. Port 16 leads to a condenser means 20, only one element of which is shown in the drawing. A fan serves to circulate the air. Another port 39 for a purpose described below, is formed in the end of valve 14 and arranged so that during heating it is connected via passage 19 in spool 18 to port 16.

The outlet side of condenser 20 is coupled to the inlet 21 of a receiver 22. Receiver 22 is provided with an outlet 23 which leads through a dryer 24 and sight glass 25 into a heat exchanger 26. The fluid path then proceeds to an expansion valve means 27. Valve means 27 is of a suitable known design capable of permitting fluid to flow in a direction leading from receiver 22 via outlet connection 23 but serves to block passage of fluid moving in a reverse direction.

Means for cooling or heating a commodity space of a refrigerated truck, meat locker, or the like, includes a heat exchange unit 28 serving during the cooling operation, as an evaporator unit and during the heating cycle as a condenser. Unit 28 is located downstream of expansion valve 27. Unit 28 includes inlet and outlet headers 29, 30, respectively. Outlet header 30 passes fluids via line 31 through heat exchanger 26 to a valve 32. Valve 32 regulates pressure at the compressor suction 12. Valve 32 may, for example, be set on the order of 20–30 p.s.i. to ensure that the pressure is low enough to prevent overloading of the compresser prime mover.

A suction accumulator unit 33 is interposed between valve 32 and the suction side 12 of compressor 10. Unit 33 serves to receive and trap any liquid which may be entrained in the low pressure gas moving from heat exchange unit 28. During the heating cycle, accumula-

tor unit 33 and heat exchange loops therein serve to function as an evaporator means.

Means have been provided for operating the above described closed circuit system whereby heat exchange unit 28 is additionally utilized to heat the commodity space, or for defrosting the cooling coils. Thus, a fluid path is established comprising a hot gas line 34. Line 34 forms a direct connection from port 17 to the upstream side of heat exchange unit 28 at header 29. Line 34 includes one or more loops forming a heat exchange portion 35 disposed in heat exchange relation with respect to accumulator unit 33. If desired, line 34 can be formed with a number of fins instead of the loops shown.

Means for more effectively vaporizing entrained liquid upstream of the compressor suction comprise means for diverting a portion of the hot gas from line 34 for direct injection immediately upstream of the pressure regulating means. This diverting means includes a cross connection 41 having a constricting orifice 42 therein. Cross connection 41 is disposed to bypass heat exchange unit 28. Accordingly, cross connection 41 is preferably connected at one end 43 downstream of accumulator unit 33. The other end 44 is connected immediately upstream of pressure regulating means 32.

Line 34 further includes a check valve 36 to oriented to pass fluid coming from port 17 and to prevent movement of fluid in a reverse direction. A drip pan 40 can be included in hot gas line 34 between inlet header 29 and accumulator unit 33.

Another fluid path is arranged to form a direct bleed line connection from condenser 20 to the suction side 12 of compressor 10. Thus, a small diameter line 37 leads from port 39 of valve 14 to the suction side of compressor 10. Line 37 can be disposed to discharge into the upper region of accumulator unit 33 so as to provide a liquid trap which guards against slugging the compressor, or it can be coupled directly into suction connection 12 as shown. An oil drain 38 for accumulator unit 33 leads to compressor 10.

Operation of the system is as follows: A cooling operation is effected by conditioning solenoid 15 to move spool 18 to the right-hand position. Thus, discharge connection 11 leads to port 16 and line 37 connects to port 17. Although compressor suction is sensed at port 39, fluid is not withdrawn from line 34 into compressor 10 due to the location of check valve 36. Compressor 10 discharges high pressure gas into condenser 20.

In the condenser, the refrigerant is condensed into a liquid. This high pressure liquid then flows to receiver 22 and then ultimately to expansion valve 27 where the pressure of the liquid refrigerant is reduced. Low pressure liquid then enters unit 28 (serving as an evaporator). The liquid in unit 28 absorbs heat from the circulating surrounding air. The absorbed heat causes the low pressure liquid to boil and form a low pressure gas or vapor. The vapor is conducted through pressure regulating valve 32, suction accumulator 33 and then enters compressor 10.

During cooling, any liquid refrigerant or oil entering accumulator unit 33 which may have become entrained in the low pressure gas, will drop to the bottom. Thus, compressor 10 is protected against liquid slugging. The entrapped liquid in accumulator unit 33 eventually boils off to form a vapor while the oil will gradually drain to compressor 10 through line 38.

When a heating operation is called for, valve 14 is operated to make the connections illustrated in FIGURE 1. Compressor discharge is connected to port 17. Line 37 is coupled to port 16 to connect the suction side of compressor 10 directly to condenser 20.

Suction is thus applied to condenser 20 as well as to receiver 22, whereby refrigerant is drained from the inactive units of the system and circulated through the elements active in the heating cycle.

After withdrawing refrigerant from the inactive units,

the heating circuit can best be understood by referring to the simplified diagram in FIGURE 2. Like reference numerals have been retained comparable to those in FIGURE 1.

Gases heated by compression are discharged from compressor 10, through valve 14 and passed directly along hot gas line 34. Heat transfer is effected in accumulator unit 33. The bulk of the hot gases then continues along line 34, through check valve 36, to enter heat exchange unit 28 at the upstream end. The hot gas condenses to a liquid due to relatively cool air circulating over unit 28. At least part of the gas leaves unit 28 as a high pressure liquid in line 31. Pressure regulating valve 32 serves to throttle this liquid to a low pressure and allows it to enter suction accumulator unit 33. This reduction in pressure results in some of the hot liquid flashing into a vapor.

If a limited portion of the hot gas is diverted from line 34 and passed directly to the inlet side of valve 32, entrained liquid will be more readily vaporized. It has been observed that this injection of hot gas tends to agitate the liquid so that intermittent slugs of liquid will not occur. Thus, hot gas and liquid enters valve 32 as a homogenized mixture rather than alternately flowing gas and liquid. Liquids are, therefore, much less likely to be carried into the compressor. As the mixture passes through valve 32 the pressure is reduced, causing additional flashing of liquid into vapor. The mixture then enters accumulator unit 33 where any remaining liquid collects at the bottom to be vaporized by heat exchange with hot gas line 34.

By diverting a portion of the stream from hot gas line 34, it might be expected that the heating capacity of the system may be slightly reduced, as all the refrigerant does not flow through heat exchange unit 28. It has been observed, however, that this is not necessarily so. At extremely low ambient temperatures, where the size of the suction accumulator is marginal, and the liquid refrigerant is not thoroughly separated from the vapor returning to the compressor, an actual reduction in heating capacity takes place because liquid that is admitted to the compressor cannot be compressed and thus cannot absorb heat of compression energy. In other words, although a rugged, well-built compressor can tolerate a small amount of liquid slugging, the amount of heat transfer to the liquid-vapor mixture is less than would be transferred to an all-vapor refrigerant. This, of course, is caused by the incompressability of liquid. By diverting a portion of the hot gas, the liquid subdivides so thoroughly that it is readily vaporized prior to compression. In this manner, the refrigerant (now all vapor) can absorb a greater amount of heat from the compressor, and the net heating capacity of the system is increased, notwithstanding the diversion.

In addition, the increased efficiency in vaporizing entrained liquids permits the size of accumulator unit 33 to be quite compact and in some cases entirely eliminated, depending upon the demands of the system. Such an arrangement is shown in FIGURE 3.

It is to be understood that with compressors of different capacity, accumulators of different size, and with systems for different applications, the preferred proportion of hot gas to be diverted will vary. Mainly, this will be a function of the amount of heat that is to be given off by heat exchange unit 28, and the ambient temperature in which the compressor must operate. Accordingly, constricting orifice 42 can be more convenient if adjustable as by employing a needle valve 45 or the like, as shown in FIGURE 1. Furthermore, in certain applications, it may be desirable to locate cross-connection 41 in a position as shown in FIGURE 2 by the dashed lines and designated 41*a*. In this position line 41 will, of course, be diverting hot gases from hot gas line 34 prior to transfer of heat therefrom to liquids in accumulator unit 33.

The rate of heat transfer from line 34 to the collected

liquid in accuumulator unit 33 can be considered "self-compensating." Thus, as the liquid level increases at the bottom of the accumulator, a greater amount of heat is transferred from the hot gas phase to the liquid phase. As the liquid is boiled off, the level thereof drops and the rate of heat transfer is commensurately reduced.

If, during heating (or defrosting), it is not desired to withdraw refrigerant from the cooling portion of the above circuit, the system shown in FIGURE 1 can be arranged to omit check valve 36 and valve 14 replaced by a three-way valve 50, connected as shown in FIGURE 4. Rightward positioning of spool 51 forms a fluid path which couples discharge connection 11 to port 16 while closing off hot gas line 34. In its left-hand position, spool 51 closes off port 16 and provides a path between connection 11 and port 17, thereby permitting compressor discharge to flow into hot gas line 34. Of course, in this system while the refrigerant is not drained from the inactive elements, the other advantages as previously noted are retained.

I claim:

1. In a closed circuit refrigeration system including compressor means having suction and discharge connections, condenser means arranged to receive fluid under pressure from said discharge connection, evaporator means disposed downstream of said condenser means, expansion means immediately upstream of said evaporator means, pressure regulating means disposed downstream of said evaporator means for regulating fluid pressure at said suction connection to the compressor, flow path control means for selectively heating said evaporator means, said flow path control means forming a first fluid path for passing hot gases from said discharge connection to said evaporator and by-passing said condenser and forming a second fluid path from said condenser to said suction connection and by-passing said evaporator to withdraw fluid from said condenser and receiver during discharge of compressed fluid into said evaporator to heat same, and means for vaporizing entrained liquid moving from said evaporator means to said suction connection to protect said compressor comprising means for injecting compressor-heated gas immediately upstream of said pressure regulating means.

2. In a closed circuit refrigeration system including compressor means having suction and discharge connections, condenser means served by said discharge connection, receiver means in fluid communication with said condenser means, said receiver means having inlet and outlet connections, expansion valve means for passing and expanding fluid moving via said outlet connection in a direction leading from said receiver means and serving to block passage of fluid moving in a reverse direction, first heat exchange means disposed downstream of said expansion valve means, pressure regulating means disposed downstream of said first heat exchange means for regulating fluid pressure at said suction connection to the compressor, and second heat exchange means interposed between said pressure regulating means and said suction connection, flow path control means for heating said first heat exchange means, said flow path control means comprising means forming a first fluid path from said discharge connection to said first heat exchange means and by-passing said condenser means and forming a second fluid path from said condenser means to said suction connection and by-passing said first heat exchange means to withdraw fluid from said condenser means during discharge of compressed fluid into said first heat exchange means to heat same, and means for diverting a portion of the fluid moving in said first fluid path for direct injection immediately upstream of said pressure regulating means.

3. A closed circuit refrigeration system including compressor means having suction and discharge connections, condenser means served by said discharge connection, first heat exchange means disposed downstream of said condenser means, fluid expansion means interposed in fluid

communication between said condenser means and said first heat exchange means, pressure regulating means disposed downstream of said first heat exchange means for regulating fluid pressure at said suction connection of said compressor, and second heat exchange means interposed between said pressure regulating means and said suction connection, heating system means comprising means forming a first fluid path from said discharge connection to said first heat exchange means and by-passing said condenser means, means forming a second fluid path from said condenser means to said suction connection and by-passing said first heat exchange means to withdraw fluid from said condenser means during discharge of compressed fluid into said first heat exchange means, and means for vaporizing entrained liquid moving from said first heat exchange means to said suction connection, said vaporizing means comprising a cross connection including a constricting orifice disposed to divert a portion of the hot gases moving, during heating, along said first fluid path and inject same immediately upstream of said pressure regulating means.

4. In a refrigeration system having means for heating a refrigerated space, a heating circuit comprising a compressor having suction and discharge connections, fluid accumulator means, a heat exchange unit disposed to heat said space, said unit having inlet and outlet connections, a hot gas line disposed between said discharge connection and said inlet connection, said hot gas line passing in heat exchange relation via said accumulator means and serving to heat fluids entrapped therein, means forming a first fluid path from said heat exchange unit to said accumulator means to transfer fluid thereto, said path including pressure regulator means, a second fluid path from said accumulator means to said suction connection, and means for vaporizing entrained liquid entering said accumulator means comprising a constricting cross connection disposed to divert a portion of the gas in said hot gas line to bypass said heat exchange unit, and further arranged to inject said diverted hot gas directly from said hot gas line to said first path immediately upstream of said pressure regulating means.

5. A refrigeration system as defined in claim 4 wherein said constricting cross connection includes a constricting orifice.

6. In a refrigeration system adapted to cool a refrigerated space and having a heat exchange unit for cooling said space and selectively serving as means for heating said space, said heating means including a heating circuit comprising a compressor having suction and discharge connections, said heat exchange unit having inlet and outlet connections, a hot gas line disposed between said discharge connection and said inlet connection, said hot gas line forming a sufficiently direct connection between the discharge connection and said inlet to supply sufficiently heated gas to said inlet to provide heating of said heat exchange unit, means forming a fluid path from said heat exchange unit to said suction connection to transfer fluid thereto, said path including a pressure regulating means serving to provide a pressure drop thereacross, and a constricted cross connection disposed to divert a portion of the gas in said hot gas line to bypass said heat exchange unit and further arranged to inject the diverted hot gas directly from said hot gas line to said fluid path immediately upstream of said pressure regulating means.

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