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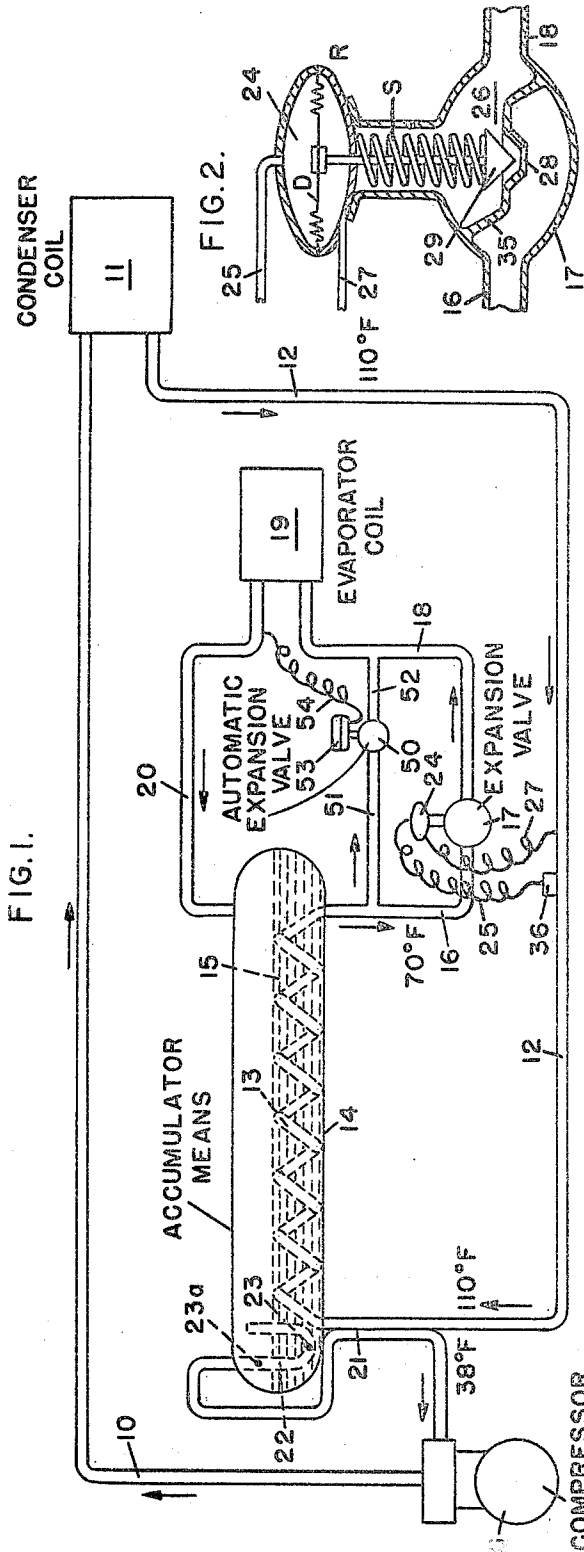
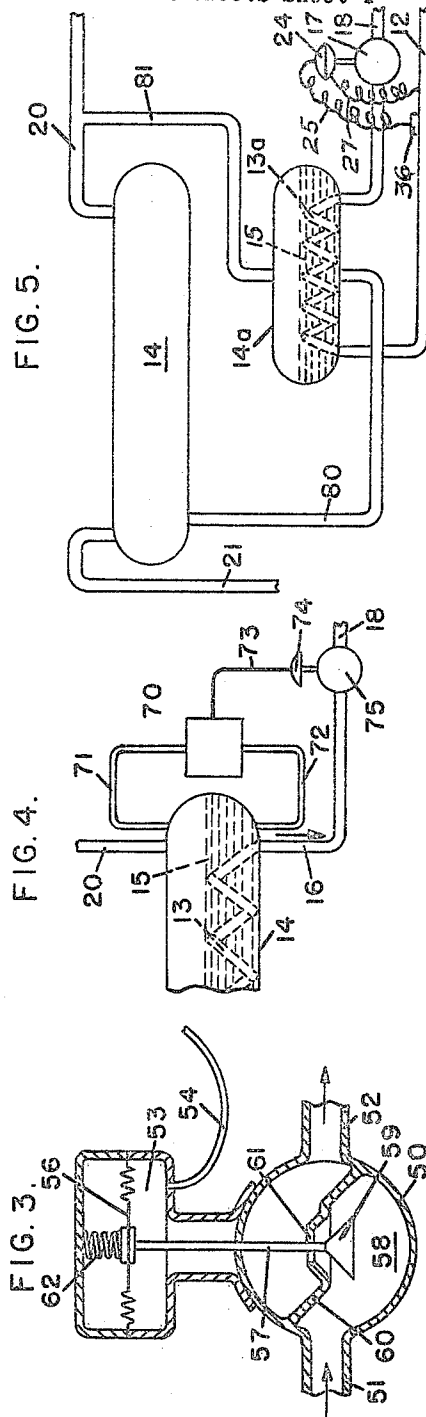
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3,264,837

REFRIGERATION SYSTEM WITH ACCUMULATOR MEANS

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2 Sheets-Sheet 1



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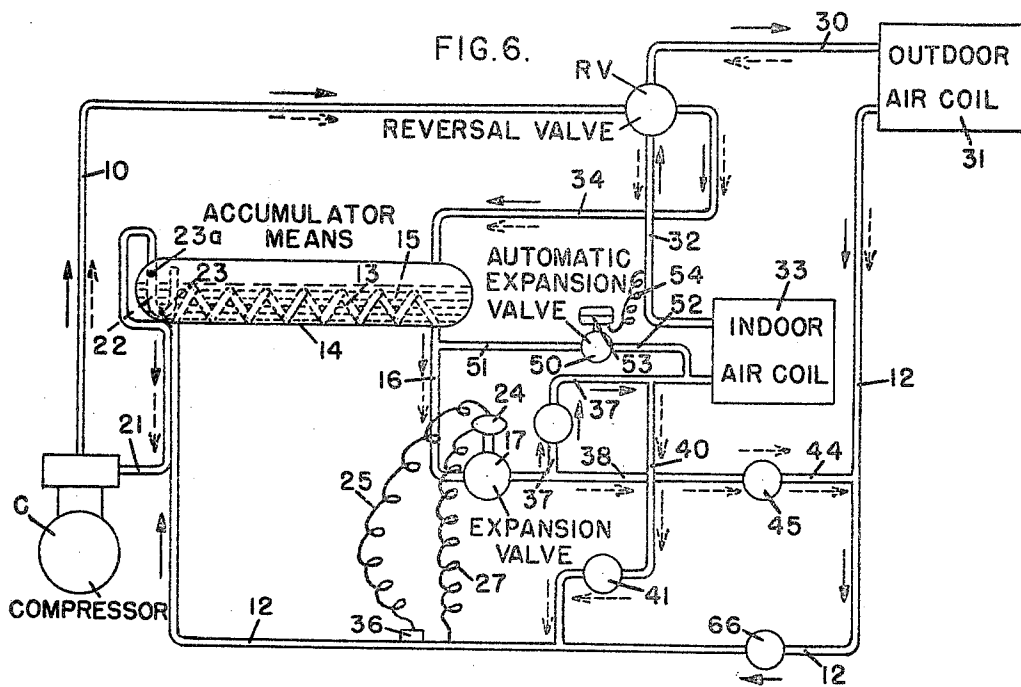
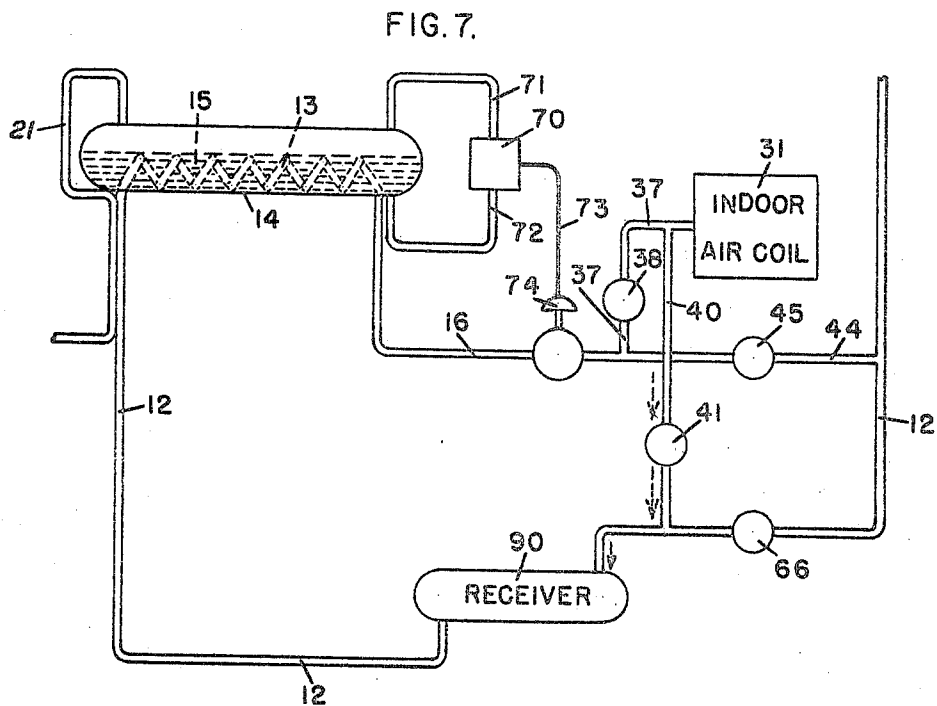
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REFRIGERATION SYSTEM WITH ACCUMULATOR MEANS

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28 Claims. (Cl. 62-117)

This application is a continuation-in-part of my copending application, Serial No. 400,494, filed Sept. 30, 1964, which has been abandoned.

This invention relates to refrigeration systems, and relates more particularly to refrigeration systems used in the conditioning of air.

Thermostatic expansion valves are the most widely used refrigeration controls. They operate to maintain constant degrees of superheat at evaporator outlets. Evaporator coils used with such valves usually have additional surfaces near their outlets for superheating the suction gas. Thus, all of the refrigerant liquid supplied to such evaporator coils is evaporated therein.

In multizone, direct expansion, air conditioning systems, as well as in other systems having varying air flow over evaporator coils, at reduced air flow, refrigerant liquid distribution through the evaporator coils becomes poor so that the usual thermostatic expansion valve cannot operate properly. Another disadvantage of a thermostatic expansion valve is that when used with a condenser coil cooled by outdoor air, at low outdoor temperatures, the condensing pressure is insufficient to operate the expansion valve properly.

This invention continuously supplies more refrigerant liquid to an evaporator at all loads on the latter, than can be evaporated; continuously supplies the unevaporated liquid from the evaporator into a suction line accumulator to maintain a quantity of liquid therein, and continuously evaporates liquid within the accumulator with heat from the high pressure liquid flowing from the condenser to the evaporator, so that refrigerant liquid cannot flow from the accumulator into the associated compressor. The system is charged with a refrigerant charge which is substantially larger than usual, and which, for example, may be 20% larger than usual, with 20% of the refrigerant liquid within the system remaining within the accumulator. Expansion means is used which meters the liquid supplied to the evaporator at the rate at which liquid is evaporated within the evaporator and within the accumulator, so as to maintain the quantity of refrigerant liquid within the accumulator.

An object of this invention is to continuously supply into an evaporator of a refrigeration system, more refrigerant liquid than the evaporator can evaporate, and to continuously evaporate the unevaporated liquid within a suction line accumulator with heat from the high pressure liquid flowing from the condenser to the evaporator, at the rate at which unevaporated refrigerant liquid is supplied from the evaporator into the accumulator.

Another object of this invention is to continuously supply into an evaporator of a refrigeration system, more refrigerant liquid than the evaporator can evaporate; to continuously supply the unevaporated liquid from the evaporator into a suction line accumulator; to continuously evaporate the excess liquid within the accumulator with heat from the high pressure liquid flowing from the condenser to the evaporator, and to control the rate of flow of refrigerant liquid to the evaporator so as to maintain a quantity of refrigerant liquid within the accumulator.

Another object of this invention is to supply an evaporator of a refrigeration system with more refrigerant

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liquid than it can evaporate; to evaporate the excess liquid within a suction line accumulator with heat from the high pressure liquid flowing from the condenser to the evaporator, and to supply refrigerant liquid to the evaporator at the rate at which liquid is evaporated within the evaporator and within the accumulator.

This invention will now be described with reference to the annexed drawings, of which:

FIG. 1 is a diagrammatic view of a nonreversible refrigeration system embodying this invention;

FIG. 2 is an enlarged sectional view of one of the expansion valves shown by FIG. 1;

FIG. 3 is an enlarged section view of the other one of the expansion valves shown by FIG. 1;

FIG. 4 is a diagrammatic view of another expansion valve that can be used with the system of FIG. 1;

FIG. 5 is a diagrammatic view of a suction line accumulator means that can be substituted for the accumulator means shown by FIG. 1;

FIG. 6 is a diagrammatic view of a heat pump embodying this invention, and

FIG. 7 is a diagrammatic fragmentary view showing the expansion valve of FIG. 4 substituted for the expansion valves of FIG. 6, and showing a liquid receiver in the tube connected to the coil within the accumulator.

Description of FIG. 1

A conventional refrigerant compressor C is connected by discharge gas tube 10 to the inlet of condenser coil 11. The outlet of the coil 11 is connected by tube 12 to the inlet of heat exchange coil 13 within a suction line accumulator means 14. The outlet of the coil 13 is connected by tube 16 to the inlet of expansion valve 17, the outlet of which is connected by tube 18 to the inlet of evaporator coil 19. The outlet of the coil 19 is connected by tube 20 to the top of the accumulator means 14 at one end of the latter. A suction gas tube 21 extends through the top of the accumulator means 14 at its other end, and has a U-shaped portion 22 within the accumulator means 14, with an open end near the top of the accumulator means. The tube portion 22 has an oil bleed hole 23 at the center of its bottom, and has an equalizer hole 23a opposite its open end. The tube 21 is connected to the suction side of the compressor C, and has a portion in heat exchange contact with the tube 12. The system contains so large a charge of refrigerant which may, for example be 20 percent larger than usual, so that there is always a quantity of refrigerant liquid, which may have a level 15, within the accumulator means 14, and in which the coil 13 is completely immersed.

The expansion valve 17 supplies refrigerant liquid from the coil 13 into the evaporator coil 19 at the rate at which refrigerant is condensed in the condenser coil 11, which rate is, of course, the rate at which liquid is evaporated within the evaporator 19 and within the accumulator means 14. Preferably, the valve 17 is of the type disclosed in my copending application, Serial No. 324,922, filed November 20, 1963, which has been abandoned.

The valve 17 has a diaphragm chamber 24, the upper portion of which is connected by a capillary tube 25 to a thermal bulb 36 in contact with the tube 12, and the lower portion of which is connected by an equalizer tube 27 to the interior of the tube 12. This expansion valve will be described in detail in the following description of FIG. 2 of the drawings.

Preferably, an automatic expansion valve 50 is shunted across the expansion valve 17, being connected by a tube 51 to the tube 16, and by a tube 52 to the tube 18. The valve 50 has a diaphragm chamber 53, the lower portion of which is connected by an equalizer tube 54 to the tube 20 downstream of the evaporator coil 19. During start-

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up of the compressor C, or unloading of the compressor C, or at very low ambient temperatures, the pressure of the liquid within the tube 12 may be insufficient to cause the valve 17 to open sufficiently, or the valve 17 may not have sufficient capacity at the low pressure condition to supply sufficient liquid to the evaporator coil. To correct for this, the automatic expansion valve 50 opens when the pressure at the downstream side of the evaporator coil is abnormally low, to supply the refrigerant liquid to the evaporator coil 19 which the expansion valve 17 supplies during normal operation. The valve 50 is described in detail in the following description of FIG. 3 of the drawings.

Description of FIG. 2

The diaphragm chamber 24 of the valve 17 has a diaphragm D extending across its center. Below the chamber 24 is a valve chamber 26 having its inlet connected to the tube 16, and its outlet connected to the tube 18. The chamber 26 has a partition 35 extending between its inlet and outlet, and which has a valve opening 28 in its center. A valve piston 29 above the opening 28 is connected by a rod R to the center of the diaphragm D. A coiled spring S extends around the rod R between the bottom of the chamber 24 and the top of the piston 29, and biases the piston 29 towards closed position.

The bulb 36 of the valve 17 contains the same refrigerant that is used in the refrigeration system. An increase in the temperature of the liquid within the tube 12 tends to close the valve 17 so as to back up more liquid within the condenser coil 11 for increasing subcooling of the liquid. Increased liquid pressure within the tube 12 tends to open the valve 17. For an increase in the rate at which refrigerant is condensed in the coil 11, if the valve 17 is not sufficiently open, liquid will back up in the coil 11 until the pressure is increased sufficiently or the temperature is reduced sufficiently to cause the valve 17 to open further. When the condensing rate changes, the valve 17 readjusts accordingly as do all modulating expansion valves, but it meters refrigerant to the evaporator coil 19 at the rate at which the refrigerant is condensed in the condenser coil 11 as does an expansion valve controlled by a high pressure float.

In the system of FIG. 1, the expansion valve 17 maintains 10° F. subcooling of the liquid flowing from the condenser coil 11 at a condensing temperature of 100° F., and is preferred for that reason. However, a conventional expansion valve controlled by a high pressure float could be used, without the subcooling advantage, since it would meter liquid to the evaporator coil at the rate at which refrigerant is condensed in the condenser coil.

Description of FIG. 3

The automatic expansion valve 50 has a diaphragm 56 extending across the center of its diaphragm chamber 53, with the equalizer tube 54 connected to the chamber 53 below the diaphragm 56. Below the chamber 53 is a valve chamber 58 having its inlet connected to the tube 51, and having its outlet connected to the tube 52. The chamber 58 has a partition 60 extending between its inlet and outlet, and which has a valve opening 61 in its center. A valve piston 59 is on the lower end of a rod 57 below the opening 61. The upper end of the rod 57 is attached to the center of the diaphragm 56. A coiled spring 62 extends between the top of the chamber 53 and the center of the top of the diaphragm 56, and biases the piston 59 towards open position.

A reduction in the pressure of the refrigerant leaving the evaporator coil, below a predetermined pressure, results in a reduction in the pressure below the diaphragm 56, permitting the spring 62 to open the valve 50 for supplying the refrigerant liquid to the evaporator coil that the expansion valve 17 would supply during normal operation.

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The automatic expansion valve 50 has its equalizer tube 54 connected at the downstream side of the evaporator coil instead of being internally equalized. It is preferred that the valve 50 respond to pressure downstream of the evaporator coil 19 since pressure drop within the latter is taken into account, and especially where there is a constriction between the expansion valve and the evaporator coil to which is connected, as in a multiple feed distributor. An automatic expansion valve with an internal equalizer could, however, be used where the pressure drop from the expansion valve to the suction side of the evaporator coil is not high.

Another expansion valve control for overfeeding the evaporator coil so as to maintain a quantity of liquid within the accumulator means, uses an expansion valve which responds to the level of the liquid within the accumulator means, as will be described in the following in the description of FIG. 4 of the drawings.

Description of FIG. 4

A conventional, float-operated, pilot valve 70 is connected by a tube 71 to the top of the accumulator means 14, and by a tube 72 to the bottom of the accumulator means 14, and is connected by a tube 73 to the diaphragm chamber 74 of expansion valve 75. The valve 70 may be a conventional Phillips pilot valve No. 270, and the valve 75 may be a conventional Phillips expansion valve No. 801. The valve 75 could be used instead of the valve 17 of FIG. 1, to maintain a quantity of liquid within the accumulator means. When the liquid level within the accumulator means 14 falls below a predetermined level, the valve 75 opens to supply more liquid to the evaporator coil 19, and vice versa.

FIG. 1 of the drawings shows the heat exchange coil 13 within the accumulator means 14. The accumulator means used could include an auxiliary accumulator means 14a containing a heat exchange coil 13a, as described in detail in the following description of FIG. 5 of the drawings.

Description of FIG. 5

In FIG. 5, the coil 13 is omitted from the accumulator means 14, and a corresponding coil 13a is within an auxiliary accumulator means 14a. Liquid is fed by gravity from the accumulator means 14 through a tube 80 connected to the bottoms of the accumulator means 14 and 14a. The top of the accumulator means 14a is connected by a tube 81 to the tube 20 for supplying gas boiled off from the liquid within the accumulator means 14a into the accumulator means 14. The quantity of the liquid retained within the accumulator means 14 of FIG. 5 is less than that retained within the accumulator means 14 of FIG. 1, since some of the liquid is within the accumulator means 14a of FIG. 5.

Operation of FIGS. 1-5

In the operation of FIG. 1, the compressor C supplies discharge gas through the tube 10 into the condenser coil 11. Liquid from the coil 11 flows through the tube 12, the coil 13, the tube 16, the expansion valve 17 and the tube 18 into the evaporator coil 19. Gas and unevaporated liquid from the coil 19 flow through the tube 20 into the accumulator means 14. Heat from the liquid flowing through the coil 13 evaporates the liquid refrigerant supplied from the coil 19 into the accumulator means 14. Gas separated from the liquid within the accumulator means 14 flows through the suction tube 21 to the suction side of the compressor C. Oil and some liquid refrigerant flow through the bleed hole 23 in the suction gas tube portion 22, into the suction gas tube 21, the liquid refrigerant being boiled by the heat exchange contact between the tubes 12 and 21 so that gas only passes to the suction side of the compressor C.

During shut-downs, the pressure within the accumulator means 14 which might be sufficient to force refrig-

erant liquid from the accumulator means through the tube 21 to the compressor, is equalized through the opening 23a in the suction tube portion 22.

The expansion valve 17 during normal operation, continuously supplies at all loads on the evaporator coil 19, more refrigerant liquid than can be evaporated within the latter, so that unevaporated liquid flows continuously during normal operation, into the accumulator means 14. Heat from the high pressure liquid flowing through the coil 13 continuously evaporates refrigerant liquid within the accumulator means at the rate at which unevaporated liquid is supplied into the latter since the quantity of liquid flowing through the coil 13 is proportional to the quantity of unevaporated liquid flowing from the evaporator coil into the accumulator means.

The rate at which refrigerant is condensed within the condenser coil 11 is the rate at which liquid is evaporated within the evaporator coil 19 plus the rate at which liquid is evaporated within the accumulator means 14. Thus, the volume of liquid supplied by the expansion valve 17 to the evaporator coil is in excess of the volume of liquid evaporated within the latter, so that all of the internal surface of the evaporator coil is thoroughly wetted. The liquid supplied to the evaporator coil is not only sub-cooled by the action of the expansion valve 17, but by the heat exchange contact of the tubes 12 and 21, and additionally by the contact of the coil 13 with the refrigerant liquid within the accumulator means, thus increasing the mass of liquid flowing through the evaporator coil, with corresponding increased heat transfer. Condenser efficiency is increased since the valve 17 keeps the condenser coil 11 adequately drained.

In a ten ton system embodying this invention, with the system overcharged by 20% so that 20% of the liquid within the system remains within the accumulator means, at a maximum load, thirty pounds per minute of liquid would be supplied to the evaporator coil, but only twenty pounds per minute of gas would flow from the evaporator coil into the accumulator means. The other ten pounds per minute of refrigerant flowing from the evaporator into the accumulator means would be liquid, the heat exchange coil within the accumulator means converting this liquid to gas so that there would be thirty pounds per minute of gas flowing to the compressor. At half load, fifteen pounds per minute of liquid would be supplied to the evaporator coil, with ten pounds of gas and five pounds of liquid per minute flowing from the evaporator into the accumulator means, and fifteen pounds per minute of gas flowing from the accumulator means to the compressor. The internal surface of the evaporator coil is thoroughly wetted at all loads. Since no superheat is provided at the evaporator coil 19, the heat transfer is further increased.

During start-up of the compressor, or unloading of the compressor, or at very low ambient temperatures, the pressure of the liquid within the tube 12 may be insufficient to cause the valve 17 to open sufficiently, or the valve 17 may not have sufficient capacity at the low pressure condition, to feed the evaporator coil sufficiently. At such times, the automatic expansion valve 50 responding to the resulting drop in pressure in the refrigerant leaving the evaporator coil, opens to supply the evaporator coil with sufficient refrigerant liquid to prevent it from becoming starved.

The automatic expansion valve 50 has an additional advantage when used in 100% fresh air, double-duct or multizone, direct expansion, air conditioning systems in which the air velocity and or temperature varies substantially. In such a system, when an associated refrigerant compressor is turned off by a thermostat or a refrigerant pressure control, the temperature or the refrigerant pressure may quickly rise and cause the compressor to be restarted, causing frequent cycling of the latter. Using the automatic expansion valve 50, when the air flow over an evaporator coil of such a system decreases and reduces

the load on the evaporator coil to the point that the pressure of the refrigerant leaving the evaporator coil decreases sufficiently to cause the valve 50 to open, the latter supplies liquid to the evaporator coil. If the load is very low, a large amount of liquid is supplied to the evaporator coil, emptying the condenser coil. When the condenser coil is empty, gas flows into the accumulator means 14 and is condensed therein, with the condensed liquid supplied through the valve 50 into the evaporator coil. The gas condensing in the coil 13 within the accumulator means boils off liquid within the accumulator means, keeping the compressor loaded up to its minimum load point so that it will not cycle.

As previously mentioned, the system of FIG. 1 could be modified to use the expansion valve 75 shown by FIG. 4, to replace the valves 17 and 50 of FIG. 1. Referring now to FIG. 4, a decrease in the liquid level within the accumulator means 14 caused by insufficient liquid flow from the evaporator coil 19 into the accumulator means 14, would cause the pilot valve 70 to adjust the expansion valve 75 to open wider to admit more liquid into the evaporator coil. An increase in the liquid level within the accumulator means 14 caused by too much liquid flowing from the evaporator coil, would cause the pilot valve 70 to adjust the expansion valve 75 towards closed position. This expansion valve does not have the subcooling control feature of the expansion valve 17.

In the modification of FIG. 1 shown by FIG. 5, the coil 13 is omitted from the accumulator means, and a corresponding coil 13a is within an auxiliary accumulator means 14a which is filled by gravity flow from the accumulator means 14. Liquid is evaporated within the accumulator means 14a at the rate at which liquid flows from the evaporator coil into the accumulator means 14, gas flowing from the accumulator means 14a into the accumulator means 14 for return to the compressor. Liquid from the condenser 11 flows through the coil 13a to the expansion valve 75.

Description of FIG. 6

Those components of FIG. 6 which are similar to corresponding components of FIG. 1 are given the same reference characters. Compressor C is connected by discharge gas tube 10 to a conventional four-way reversal valve means RV, which is connected by tube 30 to outdoor air coil 31; is connected by tube 32 to indoor air coil 33, and is connected by tube 34 to accumulator means 14. The outdoor air coil 31 is connected by tube 12 containing a check-valve 66 to the inlet of heat exchange coil 13 immersed in liquid within the accumulator means 14. The outlet of the coil 13 is connected by tube 16 to the inlet of expansion valve 17, and by tube 51 to the inlet of automatic expansion valve 50. The outlet of the expansion valve 17 is connected by tube 37 containing a check-valve 38 to one side of the indoor air coil 33, and by tube 44 containing a check-valve 45, and by a portion of the tube 12 to one side of the outdoor air coil 31. The tube 37 between where it is connected to the indoor air coil 33 and the check-valve 38 is connected by tube 40 containing check-valve 41 to the tube 12 between the check-valve 66 and the inlet of the coil 13. The outlet of the expansion valve 50 is connected to the tube 37 between where it connects with the indoor air coil 33 and the check-valve 38.

The expansion valve 17, the details of which are shown by FIG. 2, has a diaphragm chamber 24, the upper portion of which is connected by capillary tube 25 to thermal bulb 36 in contact with the tube 12, and the upper portion of which is connected by capillary tube 27 to the interior of the tube 12. The automatic expansion valve 50 has a diaphragm chamber 53, the lower portion of which is connected by capillary tube 54 to the interior of the tube 32. The valve 50 is shown in detail by FIG. 3.

Suction gas tube 21 is connected to the suction side of the compressor C, and extends through the top of the

accumulator means 14, with a U-shaped portion 22 within the accumulator means 14. An oil bleed hole 23 is in the center of the bottom of the tube portion 22, and a relief opening 23a is in the tube portion 22 above liquid level 15 in the accumulator means 14, between the bleed hole 23 and where the tube portion 22 joins the suction gas tube 21.

Description of FIG. 7

FIG. 7 shows how the heat pump of FIG. 6 can be modified to use an expansion valve 75 controlled by a float operated pilot valve 70 to maintain a predetermined liquid level within the accumulator means 14. The top of the valve 70 is connected by a tube 71 to the top of the accumulator means 14, and its bottom is connected by a tube 72 to the bottom of the accumulator means 14. The valve 70 is connected by a tube 73 to the top of diaphragm chamber 74 of the valve 75. Connected in the tube 12 between the check-valve 66 and the inlet of the coil 13 is a liquid receiver 90 which can be omitted at a slight sacrifice in system performance, the excess refrigerant liquid in such case, during air heating operation, being stored within the coil operating as a condenser.

Air cooling operation of FIGS. 6 and 7

Referring first to the air cooling operation of FIG. 6, the solid-line arrows show the direction of refrigerant flow during normal operation when the automatic expansion valve 50 is closed. The compressor C supplies discharge gas through the tube 10, the reversal valve RV and the tube 30 into the outdoor air coil 31 operating as a condenser. Liquid from the coil 31 flows through the tube 12, the check-valve 66, the coil 13, the tube 16, the expansion valve 17, the tube 37 and the check-valve 38 into the indoor air coil 33 operating as an evaporator. Gas and unevaporated liquid from the coil 33 flow through the tube 32, the valve means RV and the tube 34 into the accumulator means 14. The high pressure liquid flowing through the coil 13 heats and evaporates within the accumulator means 14, the unevaporated liquid from the coil 33 at the rate at which it flows into the accumulator means. Gas flows from the accumulator means 14 through the suction gas tube 21 as described in the foregoing in connection with FIG. 1. Oil and some refrigerant liquid flow from the accumulator means through the oil bleed hole 23, which refrigerant liquid is evaporated within the tube 21 where it contacts the tube 12 through which high pressure liquid flows, such liquid being subcooled by this heat exchange.

The expansion valve 17 meters liquid to the indoor air coil 33 at the rate at which refrigerant is condensed in the outdoor coil 31, to continuously, during normal operation, at all loads on the coil 33, to supply more liquid to the latter than can be evaporated therein so that unevaporated liquid flows continuously into the accumulator means to maintain a quantity of refrigerant liquid therein.

The heat pump of FIG. 6 is overcharged with refrigerant as described in connection with FIG. 1, so that there is more refrigerant than is necessary to meet the requirements of the indoor and outdoor air coils, with refrigerant liquid stored within the accumulator means. Heat from the liquid flowing through the coil 13 evaporates the unevaporated liquid flowing from the coil 33 at the rate at which such liquid flows into the accumulator means, so that the quantity of liquid within the accumulator means remains substantially constant although there will be rises and falls in its level during load changes. The liquid flowing through the coil 13 is subcooled.

The automatic expansion valve 50 operates as described in the foregoing in connection with FIG. 1, to feed the indoor air coil 33 at such times, during abnormal operation, that the valve 17 is unable to prevent the coil 33 from becoming starved.

In the modification of FIG. 6, shown by FIG. 7, the expansion valve 75 is adjusted by the pilot valve 70 which responds to changes in the level of the liquid within the

accumulator means. On a decrease in the liquid level, the valve 75 opens to supply more liquid to the indoor air coil 33 so that more unevaporated liquid can flow from the latter into the accumulator means to raise the level of the liquid therein. On an increase in the liquid level, the valve 75 is adjusted by the pilot valve 70 to supply less liquid to the coil 33 so that less unevaporated liquid flows from the latter into the accumulator means. Liquid from the coil 31 flows through the tube 12, the check-valve 66 and the receiver 90 into the coil 13.

Air heating operation of FIGS. 6 and 7

Referring first to FIG. 6, the dashed line arrows show the direction of refrigerant flow during heating operation. The compressor C supplies discharge gas through the tube 10, the reversal valve means RV and the tube 32 into the indoor air coil 33 operating as a condenser. Liquid from the coil 33 flows through the tubes 37 and 40, the check-valve 41, the tube 12, the coil 13, the tube 16, the expansion valve 17, the tube 44, the check-valve 45 and the tube 12 where the latter extends above the tube 44, into the outdoor coil 31 operating as an evaporator. Gas and unevaporated liquid from the coil 31 flow through the tube 30, the reversal valve means RV and the tube 34 into the accumulator means 14. Heat from the liquid flowing through the coil 13 evaporates the unevaporated liquid flowing from the coil 31 into the accumulator means. The automatic expansion valve 50 is closed during heating operation, since high pressure gas enters its equalizer tube 54.

In the modification of FIG. 6 shown by FIG. 7, the expansion valve 75 operates in the same manner as described in the foregoing in connection with the cooling operation of FIG. 7, except that the valve 75 feeds the outdoor coil 31 instead of the indoor coil 33, and since, as is well known, a smaller charge of refrigerant is required during heating operation of a heat pump than during cooling operation, the excess liquid is stored in the receiver 90.

When the usual control which is not shown, which responds to the formation of frost on the outdoor coil 31 during heating operation, acts to shift the heat pump from heating operation to cooling operation so that the outdoor coil 31 can operate as a condenser to melt the frost, little pressure differential is available across the expansion valve 17 so that it cannot supply sufficient liquid to the indoor coil operating as an evaporator at this time, to prevent the latter from becoming starved. The expansion valve 50 opens at such a time, and supplies liquid in parallel with the valve 17 which may be open or closed, to the indoor coil 31.

The accumulator means of FIG. 5 could be used in the heat pump of FIG. 6 and FIG. 7.

Among the advantages of this invention, control is not affected by varying flow across an evaporator coil; the evaporator coil does not require superheating surface; the entire inner surface of the evaporator coil is wetted without danger of liquid carry-over to the compressor; the increased liquid flow increases heat transfer; excess liquid is supplied to the evaporator coil without a liquid pump; the compressor head pressure is automatically controlled, and a condenser coil can be used more effectively at low ambient temperatures. When used in a heat pump, there are the additional advantages that a single expansion valve can be used; there is less pressure drop through a reversal valve and its return line; the indoor air coil when used as a condenser for indoor air heating, is more effective at low outdoor temperatures, and there is no refrigerant liquid flow into the compressor to dilute its lubricant at the instant of reversal of the reversal valve when the coil that has been operating as a condenser is connected through the compressor with the coil that has been operating as an evaporator.

While the invention has been illustrated and described as using indoor air and outdoor air coils, shell-and-tube

type heat exchangers through which a liquid such as water is circulated, could be used.

What is claimed, is:

1. The method of operating a refrigeration system containing a compressor, a condenser, a heat exchange coil, an expansion valve, an evaporator, and suction line accumulator means connected in series in the order named, which comprises overcharging said system with refrigerant so that there is more refrigerant than is necessary to satisfy the requirements of said condenser and evaporator, and that there is always a quantity of refrigerant liquid within said accumulator means; continuously evaporating liquid within said accumulator means with heat from the high pressure liquid flowing through said coil, and adjusting said expansion valve at all loads on said evaporator to continuously overfeed said evaporator with refrigerant liquid at such a rate that unevaporated liquid flows continuously from said evaporator into said accumulator means at substantially the rate at which liquid is evaporated within said accumulator means.

2. The method of operating a refrigeration system containing a compressor, a condenser, a heat exchange coil, an expansion valve, an evaporator, and suction line accumulator means connected in series in the order named, which comprises overcharging said system with refrigerant so that there is more refrigerant than is necessary to satisfy the requirements of said condenser and evaporator, and that there is always a quantity of refrigerant liquid within said accumulator means; adjusting said expansion valve at all loads on said evaporator to continuously supply more refrigerant liquid into said evaporator than can be evaporated therein so that unevaporated refrigerant liquid flows continuously from said evaporator into said accumulator means, and continuously evaporating liquid within said accumulator means with heat from the high pressure liquid flowing through said coil at substantially the rate at which said unevaporated liquid flows into said accumulator means.

3. The method of operating a refrigeration system containing a compressor, a condenser, a heat exchange coil, an expansion valve, an evaporator, and suction line accumulator means connected in series in the order named, which comprises overcharging said system with refrigerant so that there is more refrigerant than is necessary to satisfy the requirements of said condenser and evaporator, and that there is always a quantity of refrigerant liquid within said accumulator means; continuously evaporating liquid within said accumulator means with heat from the high pressure liquid flowing through said coil, and adjusting said expansion valve in response to the pressure and temperature of the liquid flowing from said condenser to said coil to maintain a predetermined amount of subcooling of the liquid flowing from said condenser into said coil.

4. A refrigeration system comprising a compressor, a condenser, a heat exchange coil, an expansion valve, an evaporator, and suction line accumulator means connected in series in the order named, the refrigerant charge in said system being so much larger than is necessary to satisfy the requirements of said condenser and said evaporator that there is always a quantity of refrigerant liquid within said accumulator means, said coil being arranged to evaporate liquid within said accumulator means with heat from the high pressure liquid flowing through said coil, and means for adjusting said expansion valve to continuously overfeed said evaporator at all loads on said evaporator during normal operation of said system, with refrigerant liquid at the rate at which liquid is evaporated within said evaporator and within said accumulator means, so that unevaporated liquid flows continuously from said evaporator into said accumulator means at substantially the rate at which liquid is evaporated within said accumulator means.

5. A refrigeration system as claimed in claim 4 in which said means for adjusting said expansion valve re-

sponds to changes in the level of liquid within said accumulator means.

6. A refrigeration system as claimed in claim 4 in which said means for adjusting said expansion valve responds to the temperature and the pressure of the liquid flowing from said condenser into said coil.

7. A refrigeration system as claimed in claim 6 in which an automatic expansion valve is connected across said expansion valve.

8. A refrigeration system as claimed in claim 7 in which said automatic expansion valve responds to the pressure of the refrigerant at the downstream side of said evaporator.

9. A refrigeration system as claimed in claim 4 in which said system includes a first tube connecting said coil to said condenser; includes a suction gas tube connecting said accumulator means to said compressor; in which said suction tube has a U-shaped portion within said accumulator means with an oil bleed hole in the bottom of said U-shaped portion, and in which portions of said tubes are in heat exchange contact for evaporating the refrigerant liquid that flows through said bleed hole into said suction gas tube.

10. A refrigeration system as claimed in claim 9 in which said means for adjusting said expansion valve responds to the temperature and the pressure of the liquid flowing from said condenser to said coil.

11. A refrigeration system as claimed in claim 10 in which an automatic expansion valve is connected across said expansion valve.

12. A refrigeration system as claimed in claim 11 in which said automatic expansion valve responds to the pressure of the refrigerant at the downstream side of said evaporator.

13. A heat pump comprising a refrigerant compressor; an outdoor heat exchanger; an indoor heat exchanger; a heat exchange coil; an expansion valve; suction line accumulator means; means when indoor coiling is required, for routing discharge gas from said compressor to said outdoor exchanger to operate said outdoor exchanger as a condenser, for routing liquid from said outdoor exchanger through said coil and said valve to said indoor exchanger to operate said indoor exchanger as an evaporator, for routing gas and unevaporated liquid from said indoor exchanger into said accumulator means, and for routing gas from said accumulator means to the suction side of said compressor, and when indoor heating is required, for routing discharge gas from said compressor to said indoor exchanger to operate said indoor exchanger as a condenser, for routing liquid from said indoor exchanger through said coil and valve to said outdoor exchanger to operate said outdoor exchanger as an evaporator, for routing gas and unevaporated liquid from said outdoor exchanger into said accumulator means, and for routing gas from said accumulator means to said suction side of said compressor; the refrigerant charge in said heat pump being so much larger than is necessary to suit the requirements of said exchangers that there is always a quantity of refrigerant liquid within said accumulator means; said coil being arranged to evaporate liquid within said accumulator means with heat from the high pressure liquid flowing through said coil; and means for adjusting said expansion valve to continuously overfeed during normal operation, the one of said exchangers that is operating as an evaporator at all loads on the latter, with refrigerant liquid from said coil at substantially the rate at which liquid is evaporated within the one of said exchangers that is operating as an evaporator and within said accumulator means, so that unevaporated refrigerant liquid flows continuously from the one of said exchangers that is operating as an evaporator into said accumulator at substantially the rate at which liquid is evaporated within said accumulator means by heat from said coil.

14. A heat pump as claimed in claim 13 in which said means for adjusting said expansion valve is responsive to

the temperature and the pressure of the liquid flowing from the one of said exchangers that is operating as a condenser into said coil.

15. A heat pump as claimed in claim 14 in which an automatic expansion valve is connected across said expansion valve.

16. A heat pump as claimed in claim 15 in which said automatic expansion valve responds to the pressure of the refrigerant leaving said indoor exchanger when the latter is operating as an evaporator.

17. A heat pump as claimed in claim 13 in which an automatic expansion valve is connected across said expansion valve.

18. A heat pump as claimed in claim 17 in which said automatic expansion valve responds to the pressure of the refrigerant leaving said indoor exchanger when the latter is operating as an evaporator.

19. A heat pump as claimed in claim 13 in which said means for adjusting said expansion valve responds to changes in the level of liquid within said accumulator means.

20. A heat pump as claimed in claim 13 in which there is a first tube connecting said coil to the one of said exchangers that is operating as a condenser; in which there is a suction gas tube connecting said accumulator means to said compressor; in which said suction gas tube has a U-shaped portion within said accumulator means, with an oil bleed hole in the bottom of said U-shaped portion; and in which portions of said tubes are in heat exchange contact for evaporating the refrigerant liquid that flows through said oil bleed hole into said suction gas tube.

21. A heat pump comprising a refrigerant compressor; an outdoor heat exchanger; an indoor heat exchanger; an accumulator means; an expansion valve; a heat exchange coil within said accumulator means; means when cooling is required, for routing discharge gas from said compressor to said outdoor exchanger to operate said outdoor exchanger as a condenser, for routing condensed refrigerant from said outdoor exchanger through said heat exchange coil and said valve to said indoor heat exchanger to operate the latter as an evaporator, for routing gas and unevaporated refrigerant liquid from said indoor exchanger into said accumulator means, and routing gas from said accumulator means to said compressor, and when heating is required, for routing discharge gas from said compressor to said indoor exchanger to operate the latter as a condenser, for routing condensed refrigerant from said indoor exchanger through said heat exchange coil and said valve to said outdoor exchanger to operate the latter as an evaporator, for routing gas and unevaporated refrigerant liquid from said outdoor exchanger into said accumulator means, and for routing gas from said accumulator means to said compressor; the refrigerant charge in said heat pump being so much larger than is necessary to suit the requirements of said exchangers that there is always a quantity of refrigerant liquid within said accumulator means in contact with said heat exchange coil, and means for adjusting said expansion valve to deliver refrigerant from said heat exchange coil to the one of said exchangers that is operating as an evaporator to continuously overfeed the latter at all loads on said heat pump during normal operation of the latter at the rate at which liquid is evaporated within the one of said exchangers that is operating as an evaporator and within said accumulator means, so that unevaporated refrigerant liquid flows continuously from the one of said exchangers that is operating as an evaporator into said accumulator means at substantially the rate at which refrigerant liquid is evaporated within said accumulator means.

22. A heat pump is claimed in claim 21 in which an automatic expansion valve is connected across said expansion valve.

23. A heat pump as claimed in claim 21 in which said means for adjusting said valve responds to the temperature and pressure of the liquid flowing from the one of said exchangers that is operating as a condenser into said coil.

24. A heat pump as claimed in claim 23 in which an automatic expansion valve is connected across said expansion valve, and in which means responsive to the pressure of the refrigerant flowing from said indoor exchanger is provided for adjusting said automatic expansion valve.

25. A heat pump comprising a refrigerant compressor; refrigerant reversal means; a discharge gas tube connecting said compressor to said means; an outdoor heat exchanger; a second tube connecting said means to said exchanger; an indoor heat exchanger; a third tube connecting said means to said indoor exchanger; accumulator means; a fourth tube connecting said reversal means to said accumulator means; a suction gas tube connecting said accumulator means to said compressor; a heat exchange coil within said accumulator means; a fifth tube connecting said outdoor exchanger to said heat exchange coil, said fifth tube containing a first check-valve; an expansion valve; a sixth tube connecting said heat exchange coil to said expansion valve; a seventh tube connecting said expansion valve to said indoor exchanger, said seventh tube containing a second check-valve; an eighth tube connecting said indoor exchanger to said fifth tube between said first check-valve and said heat exchange coil, said eighth tube containing a third check-valve; a ninth tube connecting said expansion valve to said fifth tube between said first check-valve and said outdoor exchanger, said ninth tube containing a fourth check-valve; said reversal means in cooling position routing discharge gas from said discharge gas tube through said third tube into said outdoor exchanger to operate said outdoor exchanger as a condenser, and routing gas and unevaporated refrigerant from said indoor exchanger operating as an evaporator through said third and fourth tubes into said accumulator means, said reversal means in heating position routing discharge gas from said discharge tube through said third tube into said indoor exchanger to operate the latter as a condenser, and routing gas and unevaporated refrigerant from said outdoor exchanger operating as an evaporator through said second and fourth tubes into said accumulator means; the refrigerant charge in said heat pump being so large, and the rate at which refrigerant is circulated in said heat pump being so much larger than the rate at which refrigerant liquid can be evaporated within the one of said exchangers that is operating as an evaporator that unevaporated liquid flows into said accumulator means so as to maintain a quantity of liquid within said accumulator means in contact with said heat exchange coil, and means for adjusting said expansion valve to deliver refrigerant from said heat exchange coil to the one of said exchangers that is operating as an evaporator at the rate at which refrigerant is condensed within the one of said exchangers that is operating as a condenser.

26. A heat pump as claimed in claim 25 in which an automatic expansion valve is connected across said expansion valve, and in which means responsive to the pressure of the refrigerant flowing from said indoor exchanger is provided for adjusting said automatic expansion valve.

27. A heat pump as claimed in claim 25 in which said means for adjusting said expansion valve responds to the temperature and the pressure of the liquid flowing from the one of said exchangers that is operating as a condenser into said heat exchange coil.

28. A heat pump as claimed in claim 27 in which an automatic expansion valve is connected across said expansion valve.

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