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REFRIGERATION SYSTEM WITH COMPRESSOR LOADING MEANS

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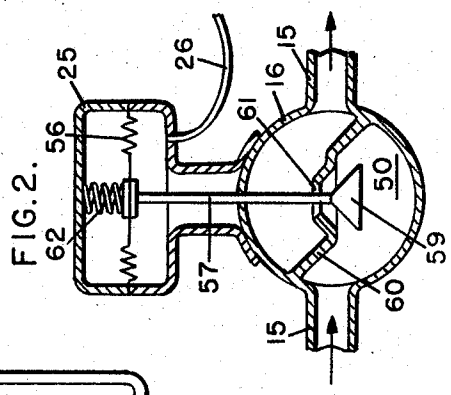


FIG. 2.

FIG. 1.

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REFRIGERATION SYSTEM WITH COMPRESSOR LOADING MEANS

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

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 by such valves to such coils is evaporated therein.

In multi-zone, direct expansion, air conditioning systems, as well as in other systems having varying air flow over air cooling evaporator coils, at a reduced load caused by reduced air flow, refrigerant liquid distribution through an evaporator coil is poor so that the usual thermostatic expansion valve cannot operate properly. In 100% fresh air, direct expansion systems in which the entering air temperature varies with the outdoor ambient, at a reduced load caused by a low air temperature, thermostatic expansion valves cannot operate properly. Another disadvantage of a thermostatic expansion valve is that when a condenser coil is cooled by outdoor air, at low outdoor ambients, the condensing pressure is insufficient to operate the expansion valve properly.

This invention uses an automatic expansion valve, preferably one having an external equalized connected at the downstream end of an evaporator coil so as to respond to refrigerant pressure in the refrigerant leaving the evaporator coil. At certain load conditions, such an automatic expansion valve can overfeed the associated evaporator coil. A suction line accumulator is provided to receive from the evaporator the unevaporated refrigerant liquid, and has a heat exchange coil through which high pressure liquid flows on its way to the expansion valve, with heat from the high pressure liquid evaporating the excess liquid within the accumulator so that no liquid refrigerant is supplied through the suction gas line into the associated compressor, the high pressure liquid being subcooled by this action.

An advantage of such an automatic expansion valve is that it can be designed to flood an evaporator coil under such conditions that the condensing pressure is insufficient to properly operate a thermostatic expansion valve.

Such an automatic expansion valve has an additional advantage when used in 100% fresh air, double duct or multi-zone, direct expansion systems in which the air velocity and/or temperature can vary substantially. In such a system, when a refrigerant compressor is turned off by a load control such as 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. To prevent such cycling, it is usual to operate a compressor continuously, and to use as a load control a refrigerant pressure responsive control which can unload the compressor down to a minimum load point which may be 25% of compressor capacity. A fault of such a control is the load on the evaporator coil may be so low that the compressor may be operating at 10% capacity with the result that the evaporator coil may become iced, and

the compressor may be damaged. So-called "hot gas by-pass systems" have been used to keep the compressor artifically loaded to its minimum load point, but such systems require additional, costly equipment.

In a system embodying this invention, a thermostat is used to unload a compressor down to its minimum load point. If the load decreases below this minimum load point, the temperature of the evaporator coil decreases, the pressure of the refrigerant leaving the evaporator coil decreases, and the automatic expansion valve opens wider to supply more refrigerant liquid into the evaporator coil. If the load is very low, a large amount of liquid is supplied by the automatic expansion valve to the evaporator, emptying the condenser coil. When the condenser coil is empty, gas flows into the heat exchange coil of the accumulator and is condensed therein. The gas condensing in the heat exchange coil boils off liquid within the accumulator, keeping the compressor loaded up to its minimum load point without any additional equipment.

An object of this invention is to use an automatic expansion valve in a refrigeration system having a suction line accumulator, and having a heat exchange coil through which high pressure liquid flows to boil off refrigerant liquid within the accumulator.

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

FIG. 1 is a diagrammatic view of an air conditioning system embodying this invention, and

FIG. 2 is an enlarged section of the automatic expansion valve of FIG. 1.

Referring first to FIG. 1 of the drawings, a refrigerant compressor C, driven by an electric motor CM, is connected by discharge gas tube **10** to the inlet end of condensor coil **11** which is cooled by outdoor air. The outlet end of the coil **11** is connected by tube **12** to one end of heat exchange coil **13** within suction line accumulator **14**. The other end of the coil **13** is connected by tube **15** containing an automatic expansion valve **16** to the inlet of evaporator coil **17**. The outlet of the coil **17** is connected by tube **18** to the upper portion of the interior of the accumulator **14**. Suction gas tube **20** has a U-shaped portion **21** within the accumulator **14**, with an oil bleed hole **23** in its base, and is connected to the suction side of the compressor C. Portions of the tubes **12** and **20** are in heat exchange contact.

The automatic expansion valve **16** which will be described in detail in connection with FIG. 2, has a diaphragm chamber **25**, the inner portion of which is connected by external equalizer tube **26** to the tube **18** near the outlet of the evaporator coil **17**. A fan **27** driven by an electric motor **28** blows 100% outdoor air over the evaporator coil **17** into the conditioned space.

The compressor C has four cylinders CL1, CL2, CL3 and CL4, having cylinder heads H1, H2, H3 and H4 respectively. The plungers of solenoids S2, S3 and S4 extend into the heads H2, H3 and H4 respectively, to depress the usual suction valve reeds which are not shown, for unloading the cylinders CL2, CL3 and CL4 respectively. When the solenoids are energized, they withdraw their plungers, permitting the suction valve reeds to close during the suction strokes of the respective pistons in the respective cylinders, for loading the respective cylinders.

An outdoor thermostat T1 has a switch **31** connected to electric supply line L2 and to one end of energizing coil **33** of compressor motor starter MS, the other end of which is connected to electric supply line L1. The starter MS has a switch **35** which closes when the coil **33** is energized and connects the motor CM to the supply lines L1 and L2.

A space thermostat T2 responds to the temperature of the air within the conditioned space, and has a plunger 36 pivoted to switch blade 38 between the ends of the latter. The blade 38 is pivoted at one end to fixed support 39, and is curved so as to contact in succession, switch contacts 42, 43 and 44 on increases in temperature. The blade 38 is connected by wire 46 to the line L2. The contact is connected by wire 49 to one end of solenoid S2. The contact 43 is connected by wire 50 to one end of solenoid S3. The contact 44 is connected by wire 51 to one end of solenoid S4. The other ends of the solenoids are connected together and by wire 48 to the supply line L1.

Referring now to FIG. 2 of the drawings, the automatic expansion valve 16 has a diaphragm 56 extending across the center of its diaphragm chamber 25, with the equalizer tube connected to the chamber 25 below the diaphragm 56. Below the chamber 25 is a valve chamber 58 having its inlet and outlet connected to the tube 15. 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 diaphragm chamber 25 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 17, caused by a reduction of the load on the evaporator coil, or caused by a reduction in the condensing pressure, results in a reduction in the pressure below the diaphragm 56, permitting the spring 62 to open the valve 16 further to supply more refrigerant liquid to the evaporator coil.

Operation

When the thermostat T1 calls for cooling, its switch 33 closes, energizing the compressor motor starter MS which closes its switch 35, energizing the compressor motor CM. The solenoids S2, S3 and S4 would be deenergized at this time so that the compressor cylinders CL2, CL3 and CL4 are unloaded, with the compressor cylinder CL1 in operation. If the space temperature increases above the minimum load point on the thermostat T2, the switch blade 38 moves in contact with the switch contact 42, energizing the solenoid S2 which withdraws its plunger to load the cylinder CL2. On a further increase in space temperature, the switch blade 38 moves in contact with the switch contact 43, energizing the solenoid S3 which withdraws its plunger, loading the cylinder CL3. On a further increase in space temperature, the switch blade 38 moves in contact with the switch contact 44, energizing the solenoid S4 which withdraws its plunger, loading the cylinder CL4.

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 heat exchange coil 13 within the accumulator 14, the tube 15 and the automatic expansion valve 16 into the evaporator coil 17. Gas and any unevaporated refrigerant liquid from the coil 17 flows through the tube 18 into the accumulator 14. The refrigerant liquid entering the accumulator is evaporated by heat from the high pressure liquid flowing through the coil 13, the liquid flowing through the latter being subcooled by this action. Gas separated from the liquid within the accumulator flows through the suction gas tube 20 to the suction side of the compressor C. Oil enters the bleed hole 23 and is supplied with the suction gas to the suction side of the compressor. Any refrigerant liquid entering the oil bleed hole 23 is evaporated by heat from the high pressure liquid flowing through that portion of the tube 12 which is in contact with a portion of the tube 20, the high pressure liquid being further subcooled by this action.

When the temperature within the conditioned space decreases to the minimum load point, the compressor cylinders CL2, CL3 and CL4 are unloaded, with the compressor C continuing in operation at its 25% capacity, minimum load point, assuming that the temperature of the outdoor air has not decreased to the point that the thermostat T1 would deenergize the compressor. With the compressor continuing in operation, the temperature within the conditioned space may decrease to the point that corresponds to 10% compressor capacity. If this happens, the resulting decrease in the temperature of the evaporator coil 17 results in a corresponding decrease in the pressure of the refrigerant leaving the evaporator coil, causing the expansion valve 16 to open wider to supply more liquid to the evaporator coil, draining the condenser coil 11. Gas then flows from the condenser coil 11 through the coil 13 within the accumulator 14, being condensed within the coil 13 and supplied as liquid through the valve 16 to the evaporator coil, refrigerant liquid within the accumulator being evaporated by this action. Thus, an artificial load of 15% capacity can be added to the 10% capacity load under which the compressor is operating, bringing the compressor load to its minimum 25% load point, preventing icing of the evaporator coil and possible damage to the compressor.

At low outdoor ambients which would cause the condensing pressure to decrease below the pressure at which a thermostatic expansion valve would operate properly, the automatic expansion valve 16 would respond to the decrease pressure at the outlet end of the evaporator coil, and would open sufficiently to prevent the evaporator coil from becoming starved. The valve 16 can be sized and adjusted to operate at the lowest outdoor temperature expected to be encountered.

While a 100% outdoor air, direct expansion, air cooling system with an air cooling evaporator coil, has been described and illustrated, this invention is applicable to double duct and multi-zone systems, and to systems in which refrigeration is used to chill water which is circulated through air cooling coils. Also, while the control responsive to the load on the evaporator coil has been described and illustrated as a space thermostat, where water is chilled as in a shell-and-tube type chiller, the load control could be a thermostat responsive to the temperature of the water flowing from the air cooling coils into the chiller.

What is claimed is:

1. A cooling system comprising a refrigerant compressor, a condenser, a heat exchange coil, and automatic expansion valve, an evaporator and an accumulator connected in the order named in a refrigeration circuit, said coil being arranged to heat liquid within said accumulator, said compressor having first and second cylinders, and having means including a solenoid for loading and unloading said second cylinder, an electric circuit for energizing said solenoid, means for cooling a fluid with said evaporator, a thermostat responsive to the temperature of said fluid, said thermostat having a switch in said circuit, an electric motor for driving said compressor, a control switch independent of said thermostat, and an electric circuit including said control switch for energizing said motor.

2. A cooling system as claimed in claim 1 in which means including responsive to the pressure of the refrigerant flowing from said evaporator into said accumulator is provided for adjusting said expansion valve towards open position on a decrease in pressure and towards closed position on an increase in pressure.

3. A cooling system as claimed in claim 2 in which said control switch is a switch of an outdoor thermostat.

4. A cooling system as claimed in claim 1 in which said control switch is a switch of an outdoor thermostat.

5. A cooling system as claimed in claim 1 in which said evaporator is an air cooling coil, and in which said

thermostat is responsive to the temperature of the air cooled by said air cooling coil.

6. A cooling system as claimed in claim 5 in which means including means responsive to the pressure of the refrigerant flowing from said evaporator into said accumulator is provided for adjusting said expansion valve towards open position on a decrease in pressure and towards closed position on an increase in pressure.

7. A cooling system as claimed in claim 6 in which said control switch is a switch of an outdoor thermostat.

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