Nov. 26, 1963 D. B. ROBERTS 3,111,815

CONTROLS FOR REFRIGERATION SYSTEMS HAVING AIR COOLED CONDENSERS

Filed April 20, 1962 2 Sheets-Sheet 1

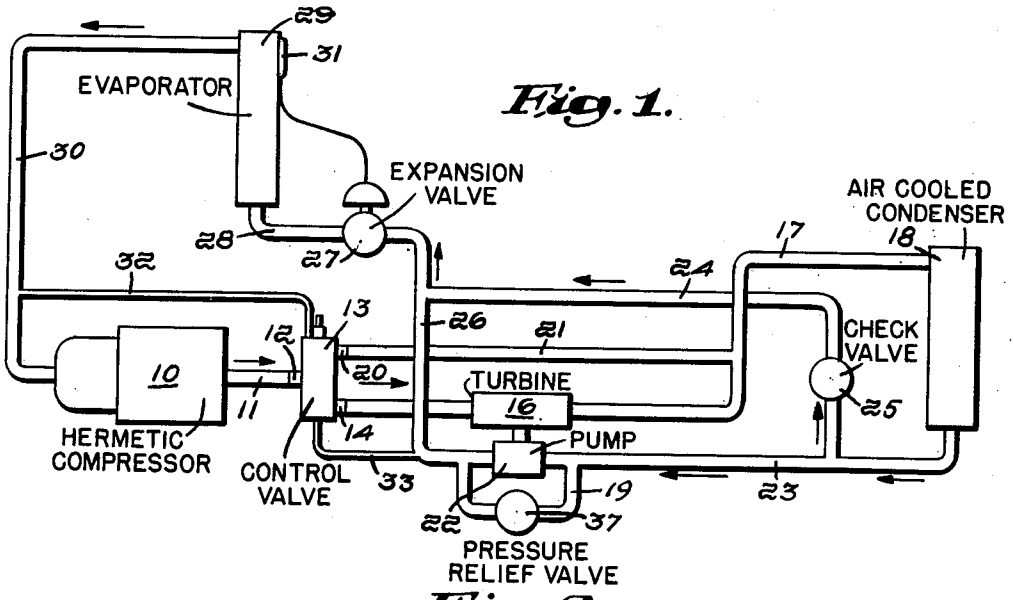

Fig. 1.

Fig. 2.

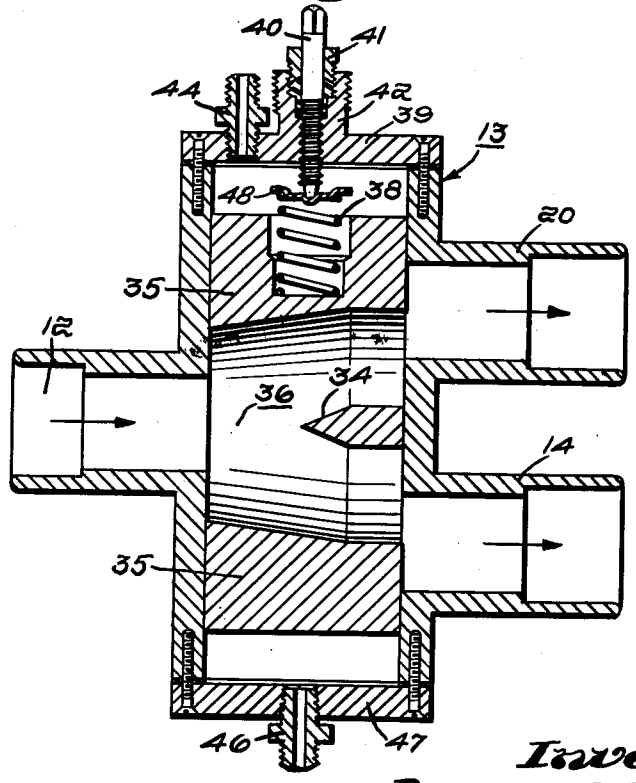

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Fig. 3.

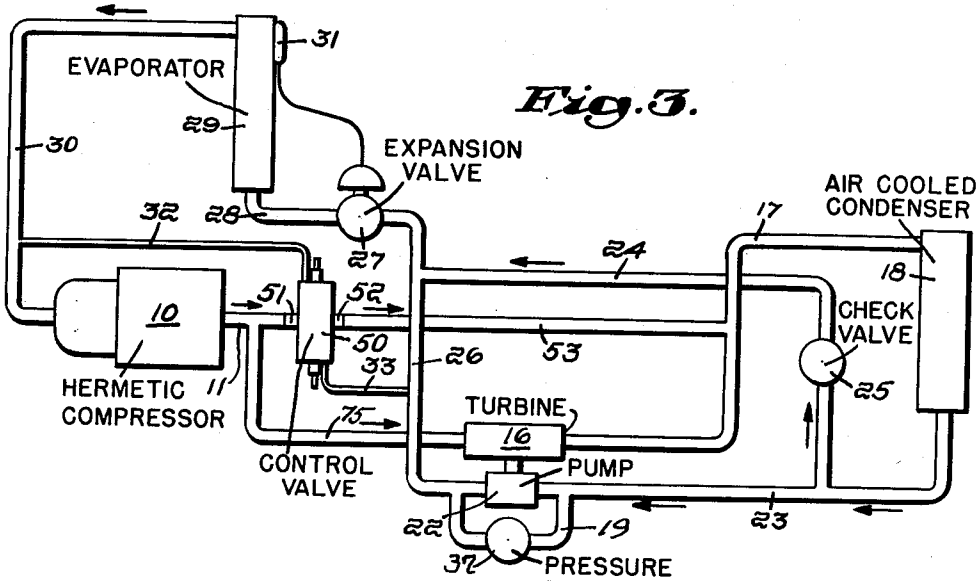
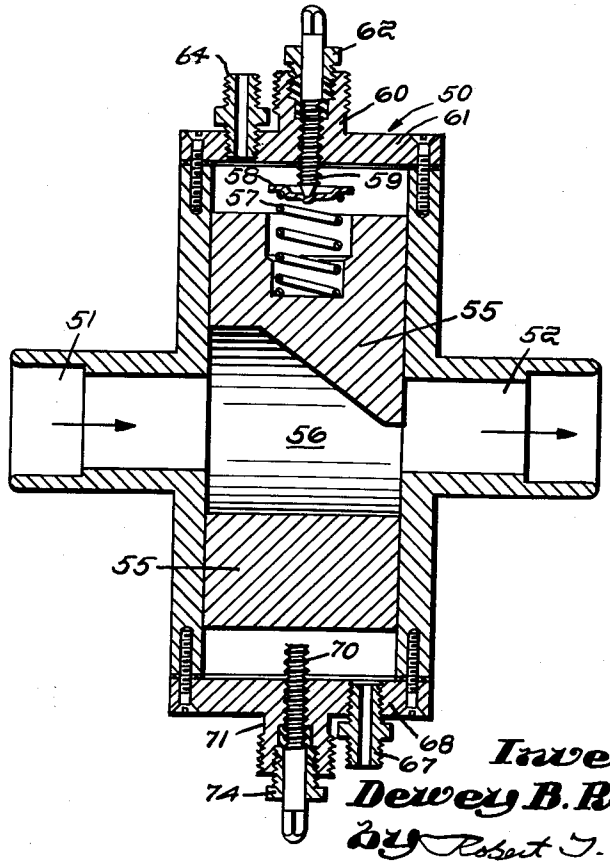


Fig. 4.



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CONTROLS FOR REFRIGERATION SYSTEMS HAVING AIR COOLED CONDENSERS

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This invention relates to controls for refrigeration and air conditioning systems using air cooled condensers.

Due to the lack of sufficient water in many locations to water cool the condensers of refrigeration and air conditioning systems, and due to the cost of water cooling such condensers in those locations where sufficient water is available, air cooled condensers are widely used. In many air conditioning systems for buildings where delicate equipment such as computers is used, their refrigeration systems are operated during cold as well as hot weather. When the condenser of such a system is cooled by outdoor air as is usual, low outdoor temperature may cause such low condensing pressures that there is insufficient refrigerant pressure to properly operate an expansion valve or other expansion means. This problem is well known, and many expedients have been proposed for solving it. Among such expedients have been the starting of a condenser fan, and opening and closing condenser dampers by controls responsive to refrigerant pressure, and the flooding of a condenser to reduce its effective condensing surface for causing an increase in pressure. Such expedients have been inefficient, and have not been satisfactory.

This invention provides adequate pressure at an expansion device by boosting the liquid pressure when the pressure difference across the expansion device decreases to the point that it is ineffective. In one embodiment of this invention, a gas turbine driven by discharge gas from a refrigerant compressor, drives a liquid pump which boosts the liquid pressure. The turbine is controlled by a valve which responds to the pressure difference between the liquid and suction lines. When the pressure difference exceeds a predetermined minimum, which may be 120 p.s.i., the control valve permits all of the discharge gas to by-pass the turbine. A liquid by-pass around the pump includes a check valve which is open at this time permitting the liquid to by-pass the pump. When the pressure difference decreases to the predetermined minimum, the combination of suction pressure and spring pressure within the control valve overcomes the liquid pressure within the control valve, and positions a slidable piston within the control valve so as to provide sufficient discharge gas pressure drop across the turbine. The turbine then is in operation, driving the liquid pump to boost the liquid pressure to the desired level, thereby causing the pressures at each end of the control valve to always stay in balance. Any change in discharge or suction pressure will automatically cause the valve piston to reposition for a greater or lesser pressure drop across the turbine. The control valve piston will also change its position as the expansion device opens and closes, thereby always maintaining a constant pressure difference between the liquid and suction lines.

An object of this invention is to maintain a constant pressure difference between the liquid and suction lines of a refrigeration system.

Another object of this invention is to boost liquid pressure within a refrigeration system with a pump driven through a gas turbine by discharge gas, and to control the operation of the turbine so as to maintain a constant pressure between the liquid and suction lines of the system.

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

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

FIG. 2 is a cross-section of the turbine control valve of FIG. 1;

FIG. 3 is a diagrammatic view of another refrigeration system embodying this invention, and

FIG. 4 is a cross-section of the turbine control valve of FIG. 3.

Referring first to FIGS. 1 and 2, a hermetic compressor 10 is connected by discharge tube 11 to inlet port 12 of control valve 13. The valve 13 has one outlet port 14 connected to the inlet of gas turbine 16, the outlet of which is connected by tube 17 to the inlet of air-cooled condenser 18. The valve 13 has another outlet port 20 connected by gas by-pass tube 21 to the tube 17. The turbine 16 drives a liquid pump 22, the inlet of which is connected by tube 23 to the outlet of the condenser 18. Tubing 19 containing a pressure relief valve 37 is connected across the pump 22. The outlet of the pump 22 is connected by tube 26 to expansion valve 27 which is connected by tube 28 to the inlet of the evaporator 29. A pump by-pass tube 24 containing a check valve 25 connects the tube 23 to the tube 26. The outlet of the evaporator 29 is connected by suction tube 30 to the suction side of the compressor 10. The expansion valve 27 is a conventional one controlled by a thermostat 31 responsive to the temperature of the evaporator. The top of the control valve 13 is connected by a tube 32 to the tube 30, and its bottom is connected by a tube 33 to the tube 26.

As shown by FIG. 2, the control valve 13 is cylindrical with its inlet port 12 in one side and its outlet ports 14 and 20 spaced apart in its opposite side. The valve 13 contains a slidable piston 35 in which there is a passage 36 for connecting the inlet port 12 with either or both of the outlet ports 14 and 20, with a rib 34 midway between the outlet end of the passage 36. When the piston is in its lowermost position, its solid upper portion blocks the port 20, and the lower edge of the rib 34 lines up with the top of the port 14. When the piston is in its uppermost position, its solid lower portion blocks the port 14, and the upper edge of the rib 34 lines up with the bottom of the port 20. The top of the piston 35 is recessed to receive the lower portion of a coiled spring 38, the lower end of which touches the piston at the bottom of its recess, and the upper end of which is in contact with the bottom of a disc 48, the top of which is in contact with the lower end of a screw 40 threaded into top wall 39 of the cylinder, and extending through a packing nut 41 threaded in a sleeve 42 formed on the top of the wall 39. The screw 40 is adjustable from exterior of the valve 13 to vary the compression of the spring 38.

A fitting 44 screwed into the top wall 39 of the valve 13 connects a suction pressure chamber between the top of the piston 35 and the wall 39, with the suction gas tube 32. A fitting 46 screwed into bottom wall 47 of the valve 13, connects a liquid pressure chamber between the bottom of the piston 35 and the bottom wall 47, with the liquid tube 33.

In the normal operation of FIGS. 1 and 2, when the outdoor temperature is not low enough to lower the condensing pressure to the point where the expansion valve 27 is ineffective, the check valve 25 will be open and the liquid pressure supplied through the tubes 24, 26 and 33 to the bottom of the piston 35 of the valve 13 will be greater than that of the suction gas pressure and the pressure of the spring 38 at the top of the piston, so that the piston will move up to close the outlet port 14 connected to the turbine 16, and to open the outlet port 20 connected to the turbine by-pass tube 21. The turbine 16

and the pump 22 do not, therefore, operate. Liquid flows from the bottom of the condenser 18 through the pump by-pass tube 24, check valve 25 and the tube 26 to the expansion valve 27.

When the outdoor temperature decreases to a point where the condensing pressure is too low for the expansion valve 27 to operate properly, the suction pressure and the pressure of the spring 38 on top of the piston 35 will be greater than the liquid pressure on the bottom of the piston 35, so that the latter will move down to cover the outlet port 20 connected to the turbine by-pass tube 21, and to open the outlet port 14 connected to the turbine 16. The turbine 16 operates the pump 22 to boost the liquid pressure, the liquid flow being from the bottom of the condenser 18, through the tube 23, the pump 22 and the tube 26 to the expansion valve. The pump 22 at this time exerts a higher pressure in the tube 24 than in the tube 23, causing the check valve 25 to close. The relief valve 37 functions as a safety device to by-pass liquid from the tube 26 through the tube 19 to the tube 23 in the event of a malfunction of the turbine control valve 13. The check valve 23 could be built into the pump 22.

The pressures at each end of the control valve piston are equal since any unbalance due to any change in discharge pressure or suction pressure will automatically reposition the piston for a greater or less pressure drop across the turbine 16. The piston of the control valve will also vary its position as the expansion valve moves towards open or closed position, thereby always maintaining a desired constant pressure difference between the liquid and suction lines.

Adjustment of the spring pressure varying screw 40 permits the control valve to be adjusted to maintain different desired pressure drops across the expansion valves. The spring 38 can be changed for one having different characteristics as may be required where the evaporator is located at different levels.

The embodiment of the invention shown by FIGS. 3 and 4 is generally similar to that shown by FIGS. 1 and 2 and differs therefrom only by having a different control valve construction, and having different connections to the control valve. The components of FIG. 3 which are similar to corresponding ones of FIG. 1 are given the same reference characters.

Control valve 50 of FIGS. 3 and 4, has an inlet port 51 connected to the discharge pipe 11, and has a single outlet port 52 aligned with the port 51, and connected to turbine by-pass tube 53. The valve 50 has a piston 55 with a passage 56 extending therethrough. The piston 55 has a recess in its head with a spring 57 therein similar to the recess and spring 38 respectively, of FIG. 2; has a disc 58 on top of the spring 57, and an adjusting screw 59 threaded in sleeve 60 on top wall 61 of the valve 50 and extending through a packing nut 62. A fitting 64 connects the suction gas chamber between the top of the piston 55 and the valve top wall 61 with suction gas tube 32. Fitting 67 threaded into bottom wall 68 of the valve 50 connects the liquid chamber between the bottom of the piston 55 and the valve bottom wall 68 to the liquid tube 33.

The valve 50 has an adjustable screw 70 threaded into sleeve 71 on the bottom of the valve bottom wall 68, and extending through a packing nut 74, the inner end of which acts as an adjustable stop for the bottom of the piston 55 for preventing possible damage to the turbine on start up as might occur if all of the discharge gas was supplied to the turbine. The screw 70 prevents the outlet port 52 connected to the turbine by-pass from being fully closed by down movement of the piston 55.

The inlet of the turbine 16 instead of being connected to an outlet port in the control valve 50 is connected directly to the discharge gas tube 11 by a discharge gas tube 75.

The embodiment of FIGS. 3 and 4 operates similar to that of FIGS. 1 and 2, the only difference being that the central valve 50 only opens a by-pass around the turbine when its piston 55 is moved upwardly, and does not at the same time close off the supply of discharge gas to the turbine as in the operation of FIGS. 1 and 2. The resistance to flow through the turbine is sufficient to cause all of the discharge gas to flow through the by-pass tube 53 of FIG. 3 when the valve piston 55 of the valve 50 opens its outlet port 52.

What is claimed is:

1. In a refrigeration system having a compressor, an air cooled condenser, an expansion device, and an evaporator connected in series in the order named in a refrigeration circuit, the combination of a liquid pump connected in said circuit between said condenser and said device for pumping liquid from said condenser to said device, means including a check valve forming a by-pass around said pump for flowing liquid from said condenser to said device when said pump is not operating, a gas turbine connected in said circuit between said compressor and said condenser and connected to said pump to drive said pump, means forming a second by-pass around said turbine, and means included in said second by-pass and including means responsive when said check valve is closed, to the difference between the suction pressure at said compressor and the liquid pressure at said expansion device for increasing the flow of gas through said second by-pass when said difference exceeds a predetermined minimum and for decreasing the flow of gas through said second by-pass when said difference is at or is less than said minimum.

2. In a refrigeration system having a compressor, an air cooled condenser, an expansion device, and an evaporator connector in series in the order named in a refrigeration circuit, the combination of a liquid pump connected in said circuit between said condenser and said device for pumping liquid from said condenser to said device, means including a check valve forming a by-pass around said pump for flowing liquid from said condenser to said device when said pump is not operating, a gas turbine connected in said circuit between said compressor and said condenser and connected to said pump to drive said pump, means forming a second by-pass around said turbine, means included in said second by-pass and including means responsive to the difference between the suction pressure at said compressor and the liquid pressure at said expansion device for increasing the flow of gas through said second by-pass when said difference exceeds a predetermined minimum and for decreasing the flow of gas through said second by-pass when said difference is at or is less than said minimum, and means including a pressure relief valve connected around said pump.

3. In a refrigeration system having a compressor, an air cooled condenser, an expansion device, and an evaporator connected in series in the order named in a refrigeration circuit, the combination of a liquid pump connected in said circuit between said condenser and said device for pumping liquid from said condenser to said device, means including a check valve forming a by-pass around said pump for flowing liquid from said condenser to said device when said pump is not operating, a gas turbine connected in said circuit between said compressor and said condenser and connected to said pump to drive said pump, means forming a second by-pass around said turbine, and means included in said second by-pass and included in the connection of said turbine to said compressor and including means responsive to the difference between the suction pressure at said compressor and the liquid pressure at said expansion device for increasing the flow of gas through said second by-pass and decreasing the flow of gas through said turbine and increasing the flow of gas through said turbine when said difference exceeds a predetermined minimum, and for decreasing the flow through said second by-pass and increasing the flow

of gas through said turbine when said difference is at or is less than said minimum.

4. In a refrigeration system having a compressor, an air-cooled condenser, an expansion device, and an evaporator connected in series in the order named in a refrigeration circuit, the combination of a liquid pump connected in said circuit between said condenser and said device for pumping liquid from said condenser to said device, means including a check valve forming a by-pass around said pump for flowing liquid from said condenser to said device when said pump is not operating, a gas turbine connected in said circuit between said compressor and said condenser and connected to said pump to drive said pump, means forming a second by-pass around said turbine, means included in said second by-pass and included in the connection of said turbine to said compressor and including means responsive to the difference between the suction pressure at said compressor and the liquid pressure at said expansion device for increasing the flow of gas through said turbine when said difference exceeds a predetermined minimum, and for decreasing the flow of gas through said second by-pass and increasing the flow of gas through said turbine when said difference is at or is less than said minimum, and means including a pressure relief valve connected around said pump.

5. In a refrigeration system having a compressor, an air cooled condenser, an expansion device, an evaporator, and tubing connecting the outlet of said device to the inlet of said evaporator and the outlet of said evaporator to the suction side of said compressor, the combination of a liquid pump having its inlet connected to the outlet of said condenser and having its outlet connected to the inlet of said device, means including a check valve forming a by-pass around said pump for supplying liquid from said condenser to said device when said pump is not operating, a control valve having an inlet connected to the discharge side of said compressor, and having an outlet, a gas turbine connected to said discharge side of said compressor and having its outlet connected to the inlet of said condenser, by-pass tubing connected to said outlet of said control valve and to said inlet of said condenser, said turbine being connected to said pump to drive said pump, a piston slidable in said control valve and having a passage for passing gas from said valve inlet to said valve outlet, means including a tube connecting said suction side of said compressor to the interior of said control valve at one end of said piston, and means including a tube connecting said inlet of said device to the interior of said control valve at the opposite end of said piston.

6. In a refrigeration system having a compressor, an air-cooled condenser, an expansion device, an evaporator, and tubing connecting the outlet of said device to the inlet of said evaporator and the outlet of said evaporator to the suction side of said compressor, the combination of a liquid pump having its inlet connected to the outlet of said condenser and having its outlet connected to the inlet of said device, means including a check valve forming a by-pass around said pump for supplying liquid from said condenser to said device when said pump is not operating, a control valve having an inlet connected to the discharge side of said compressor, and having an outlet, a gas turbine connected to said discharge side of said compressor and having its outlet connected to the inlet of said condenser, by-pass tubing connected to said outlet of said control valve and to said inlet of said condenser, said turbine being connected to said pump to drive said pump, a piston slidable in said control valve and having

a passage for passing gas from said control valve inlet to said control valve outlet, means including a tube connecting said suction side of said compressor to the interior of said control valve at one end of said piston, means including a tube connecting said inlet of said device to the interior of said control valve at the opposite end of said piston, and means including a pressure relief valve connected around said pump.

7. In a refrigeration system having a compressor, an air cooled condenser, an expansion device, an evaporator, and tubing connecting the outlet of said device to the inlet of said evaporator, and the outlet of said evaporator to the suction side of said compressor, the combination of a liquid pump having its inlet connected to the outlet of said condenser, and having its outlet connected to the inlet of said device, means including a check valve forming a by-pass around said pump for flowing liquid from said condenser to said device when said pump is not operating, a control valve having an inlet connected to the discharge side of said compressor and having spaced-apart, first and second outlets, a gas turbine having its inlet connected to said first outlet and having its outlet connected to the inlet of said condenser, a second by-pass tube connected to said second outlet and to said inlet of said condenser, a piston slidable in said control valve and having a passage for connecting said valve inlet with either or with portions of both of said first and second outlets, means including a tube connecting said suction side of said compressor into the interior of said control valve at one end of said piston, and means including a tube connecting said inlet of said device to the interior of said control valve at the opposite end of said piston.

8. In a refrigeration system having a compressor, an air cooled condenser, an expansion device, an evaporator, and tubing connecting the outlet of said device to the inlet of said evaporator, and the outlet of said evaporator to the suction side of said compressor, the combination of a liquid pump having its inlet connected to the outlet of said condenser, and having its outlet connected to the inlet of said device, means including a check valve forming a by-pass around said pump for flowing liquid from said condenser to said device when said pump is not operating, a control valve having an inlet connected to the discharge side of said compressor and having spaced-apart, first and second outlets, a gas turbine having its inlet connected to said first outlet and having its outlet connected to the inlet of said condenser, a second by-pass tube connected to said second outlet and to said inlet of said condenser, a piston slidable in said control valve and having a passage for connecting said valve inlet with either or with portions of both of said first and second outlets, means including a tube connecting said suction side of said compressor into the interior of said control valve at one end of said piston, means including a tube connecting said inlet of said device to the interior of said control valve at the opposite end of said piston, and means including a pressure relief valve connected around said pump.

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