May 23, 1967 J. R. HARNISH 3,320,763

CONTROLS FOR REFRIGERATION SYSTEMS

Filed Nov. 19, 1965

FIG. 1.

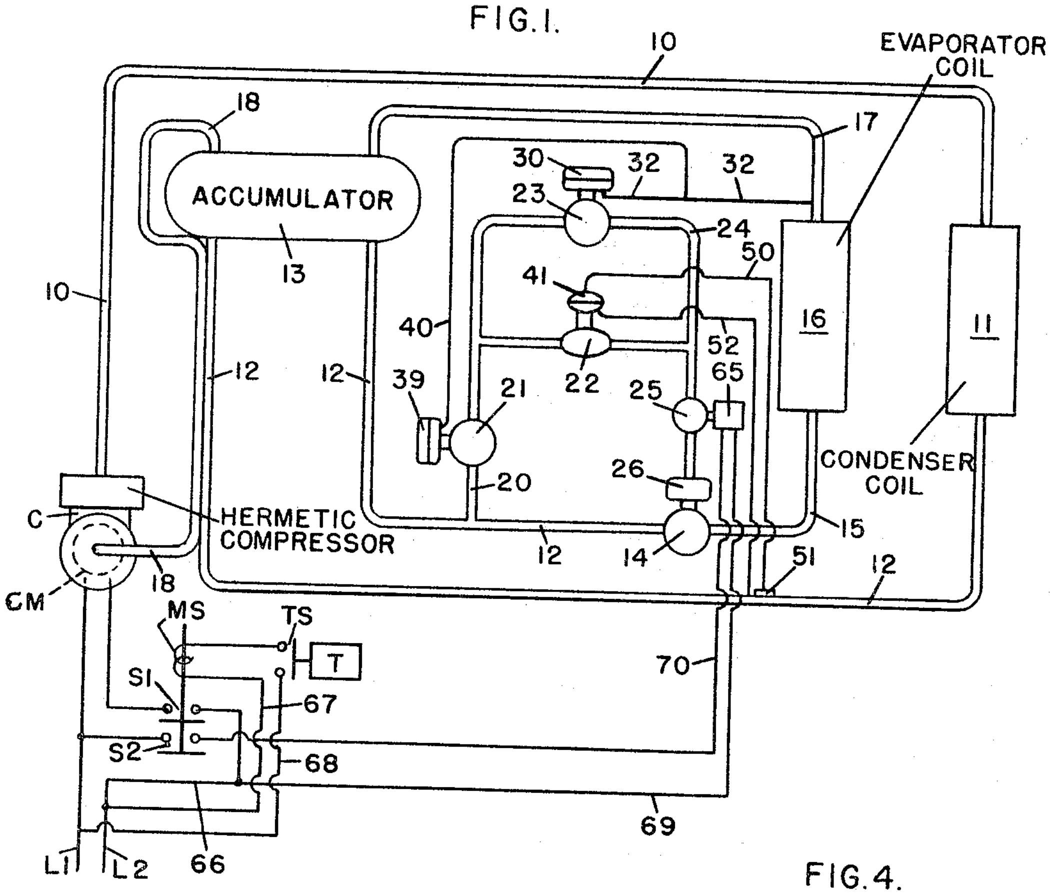


FIG. 2.

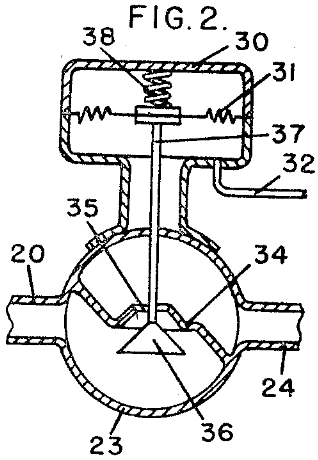


FIG. 3.

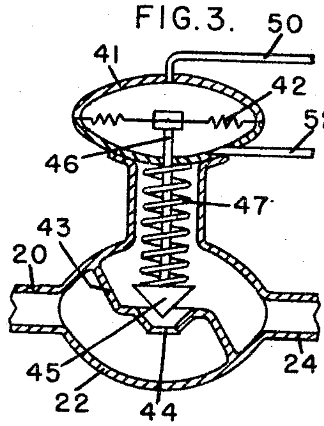
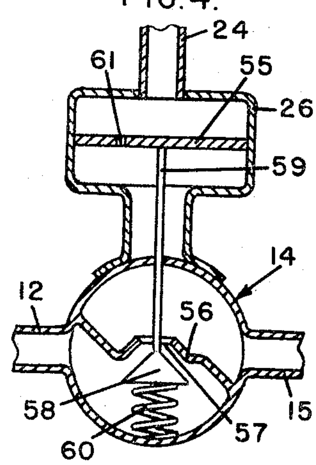


FIG. 4.



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United States Patent Office

3,320,763
Patented May 23, 1967

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3,320,763
CONTROLS FOR REFRIGERATION SYSTEMS

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Filed Nov. 19, 1965, Ser. No. 508,736
9 Claims. (Cl. 62—197)

This invention relates to controls for refrigeration systems.

In my copending application, Ser. No. 447,008, filed Apr. 9, 1965, now Patent No. 3,264,837, there is disclosed a refrigeration system using a sub-cooling control valve as an expansion valve to over-feed an evaporator during normal operation, the sub-cooling control valve being shunted by an automatic expansion valve responsive to the pressure of the refrigerant leaving the evaporator, for preventing the evaporator from becoming starved during abnormal operation when the condensing pressure is insufficient to properly operate the sub-cooling control valve. Such valves are not readily available for relatively large refrigeration systems, and if available, their costs would be relatively high.

A feature of this invention is that a relatively small, sub-cooling control valve operates as a pilot valve to control a relatively large expansion valve during normal operation, with the sub-cooling control valve shunted by a relatively small automatic expansion valve which operates as a pilot valve to control the expansion valve during abnormal operation when the condensing pressure is insufficient to properly operate the sub-cooling control valve.

It is conventional to use a solenoid-operated valve in the high pressure liquid line of a refrigeration system to provide positive liquid shut-off during shut-downs of the system. In a relatively large system, a relatively large shut-off valve is required. Another feature of this invention is that a relatively small, solenoid-operated, liquid shut-off valve is used in the control line of the previously mentioned, relatively large expansion valve.

In a large refrigeration system, the over-load control setting of a compressor motor, and the high pressure cut-out setting, may be critical because of pull-down requirements during warm start-ups when the outdoor ambient temperature is relatively high, and one or both of such controls may turn the compressor motor off. Another feature of this invention is that a relatively small, automatic expansion valve responsive to the evaporator pressure, is located in the control line of the previously mentioned, large expansion valve, and operates to adjust the expansion valve to starve the evaporator for preventing excessive pressures during such warm start-ups.

An object of this invention is to use a relatively small, sub-cooling control valve to control a relatively large expansion valve in a refrigeration system.

Another object of this invention is to use a relatively small, automatic expansion valve to control a relatively large expansion valve in a refrigeration system.

Another object of this invention is to use a relatively small, sub-cooling control valve, shunted by a relatively small, automatic expansion valve, to control a relatively large expansion valve in a refrigeration system.

Another object of this invention is to prevent excessive refrigerant pressures in a refrigeration system during warm start-ups at high outdoor ambient temperatures.

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 an enlarged side section of the automatic expansion valve of FIG. 1;

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FIG. 3 is an enlarged, side section of the sub-cooling control valve of FIG. 1, and

FIG. 4 is an enlarged side section of the main expansion valve of FIG. 1.

A conventional, hermetic, refrigerant compressor C having an enclosed electric motor CM, is connected by discharge gas tube **10** to one end of condenser coil **11**, the other end of which is connected by liquid tube **12**, through a heat exchange coil which is not shown, within accumulator **13**, to the inlet of main expansion valve **14**. The outlet of the valve **14** is connected by tube **15** to one end of evaporator coil **16**, the other end of which is connected by tube **17** to the top of the accumulator **13**. The accumulator **13** is connected by suction gas tube **18** to the suction side of the compressor C. The components in the accumulator **13** are fully disclosed in the previously mentioned application.

The tube **12** is also connected between the accumulator **13** and the expansion valve **14** to tube **20** which is connected through valve **21** to the inlets of sub-cooling control valve **22** and automatic expansion valve **23** operating as pilot valves. The outlets of the valves **22** and **23** are connected by tube **24** through solenoid-operated valve **25** to the top of piston chamber **26** of the main expansion valve **14**.

The valve **23** has a diaphragm chamber **30** with a diaphragm **31** extending across its center. The interior of the chamber **30** below the diaphragm **31** is connected by capillary tube **32** to the tube **17**. The valve **23** has a partition **34** extending across its interior between its inlet and outlet, with a valve opening **35** therein. A valve piston **36** below the opening **35**, is connected by piston rod **37** to the center of the diaphragm **31**. A coiled spring **38** extends between the center of the top of the diaphragm **31** and the top of the chamber **30**, and biases the piston **36** towards open position.

The valve **21** is similar to the valve **23** except that it is adjusted to close at a different pressure as will be described later, and has a diaphragm chamber **39**, the lower portion of which is connected by a capillary tube **40** to the tube **32**.

The sub-cooling control valve **22** has a diaphragm chamber **41** with a diaphragm **42** extending across its center. It has a partition **43** extending across its interior between its inlet and outlet, with a valve opening **44** therein. A valve piston **45** above the opening **44** is connected by piston rod **46** to the center of the diaphragm **42**. A coiled spring **47** extends around the rod **46** between the bottom of the chamber **41** and the top of the valve piston **45**, and biases the piston **45** towards closed position. The interior of the chamber **41** above the diaphragm **42** is connected by capillary tube **50** to a conventional thermal bulb **51** in heat exchange contact with the tube **12** between the accumulator **13** and the coil **11**. The interior of the chamber **41** below the diaphragm **42** is connected by capillary tube **52** to the interior of the tube **12** adjacent to the bulb **51**.

As shown by FIG. 4, the piston chamber **26** of the main expansion valve **14** has a piston **55** slidable therein. A partition **56** extends across the interior of the valve **14** between its inlet and outlet and has a valve opening **57** therein. A valve piston **58** below the opening **57** is connected by piston rod **59** to the center of the piston **55**. A coiled spring **60** extends between the bottom of the piston **58** and the bottom of the valve **14**, and biases the piston **58** towards closed position. The piston **55** has a pressure equalizing passage **61** extending therethrough.

Referring now to FIG. 1, a solenoid **65** is connected to the valve **25** to open and close the latter. The compressor motor CM is connected to electric supply line L1, and through switch S1 of motor starter MS, and wire **66** to electric supply line L2. The starter MS is connected through switch TS of thermostat T, and wires **67** and **68** to the lines L1 and L2. The solenoid **65** is connected by wire **69** and the wire **66** to the line L2, and is connected by wire **70** and switch S2 of the starter MS to the line L1.

Operation

When the thermostat T calls for cooling, it closes its switch TS which energizes the motor starter MS. The latter closes its switches S1 and S2. The closed switch S1 energizes the compressor motor CM, starting the compressor C. The closed switch S2 energizes the solenoid **65** which opens the valve **25**. The compressor C supplies discharge gas through the tube **10** into the condenser coil **11**. Refrigerant liquid flows from the coil **11** through the tube **12** and the heat exchange coil (not shown) within the accumulator **13**, into the expansion valve **14** which meters refrigerant to the evaporator coil **16**. Gas and unevaporated liquid from the coil **16** flow through the tube **17** into the accumulator **13**. Gas separated from the liquid within the accumulator **13** flows through the suction gas tube **18** to the suction side of the compressor C.

The valve **21** is adjusted to be open during normal operation so as to permit liquid to flow from the tube **12** into the inlets of the pilot valves **22** and **23**. It may be set to start to close when the pressure of the refrigerant leaving the evaporator coil **16** in a system using F–22 refrigerant increases, for example, above 84 p.s.i. as will be described later.

The pilot valve **23** is adjusted to be closed during normal operation when the evaporator pressure is normal, and to open when the evaporator coil **16** is about to become starved as will be described later.

During normal operation, the sub-cooling control valve **22** adjust the expansion valve **14** to meter refrigerant to the evaporator coil **16** at the rate at which refrigerant is condensed in the condenser coil **11** while maintaining, for example, 10° F. subcooling at a condensing temperature of 100° F. An increase in the temperature of the liquid in the tube **12** at the bulb **51**, acts through the bulb **51**, the capillary tube **50** and the diaphragm **42** of the valve **22**, to adjust the piston **45** of the valve **22** towards closed position, reducing the liquid pressure above the piston **55** of the valve **14**, and causing the valve piston **58** of the valve **14** to move towards closed position so as to back up more liquid within the condenser coil **11**, for increasing the sub-cooling of the liquid. Increased liquid pressure in the tube **12** where the capillary tube **52** is connected to the latter, acts through the tube **52** and the diaphragm **42** to adjust the valve piston **45** of the valve **22** towards open position, increasing the liquid pressure above the piston **55** of the valve **14**, and causing the valve piston **58** of the valve **14** to move towards open position. For an increase in the rate at which refrigerant is condensed in the coil **11**, if the valve **14** is not sufficiently open, liquid in the coil **11** will back up until the pressure is increased sufficiently or the temperature is reduced sufficiently to cause the valve **22** to adjust the valve **14** towards open position, and vice versa. When the condensing rate changes, the valve **22** readjusts the valve **14** accordingly, but the latter meters refrigerant to the evaporator coil **16** at the rate at which refrigerant is condensed in the condenser coil **11**. The valve **14** continuously overfeeds the evaportor coil **16** as disclosed in the previously mentioned application.

During abnormal conditions, such as at very low outambient temperatures or other conditions resulting in abnormally low condensing pressures, the liquid subcooling at the bulb **51** may be insufficient for the valve **22** to adjust the expansion valve **14** sufficiently open to prevent the evaporator coil **16** from becoming starved. At such times, the pilot valve **23** responds through the capillary tube **32** to the resulting reduced pressure of the refrigerant within the tube **17** at the outlet of the evaporator coil **16**, the reduced pressure below the diaphragm **31** of the valve **23**, permitting the spring **38** to move the piston **36** to open position, supplying liquid above the piston **55** of the valve **14** to cause the valve piston **58** of the valve **14** to open sufficiently to provide sufficient refrjgerant to the evaporator coil **16** to prevent it from becoming starved.

The bleed passage **61** in the piston **55** of the valve **14** permits pressure in the chamber above the piston **55** to equalize the evaporator pressure when the valve **22** or the valve **23** moves towards closed position, by flowing through the passage **61** and the interior of the valve **14** into its outlet, thus permitting the spring **60** to move the valve piston **58** of the valve **14** towards closed position.

On start-ups of the system, when the latter is a water chilling system, at an outdoor temperature of, say 105° F., the chilled water temperature may be 90° F. or even higher. This means that the compressor has to operate at very high suction pressures, and correspondingly high discharge pressures until the water has been chilled down to a temperature below 55° F. The condenser would be sized to operate at an outdoor air temperature of about 115° F., but only when the temperature of the chilled water leaving the chiller is at, say, 50° F. Consequently, warm start-ups during high outdoor ambient temperatures, may result in the compressor motor being tripped out by an overload control or by a high pressure cut-out. The valve **21** prevents this. When the evaporator pressure increases above 84 p.s.i., this pressure transmitted by the capillary tube **40** to the interior of the diaphragm chamber **39** of the valve **21**, causes the valve **21** to throttle towards closed position, decreasing the quantity of liquid supplied to the pilot valve **22** or **23** whichever is operating, and causing the valve **14** to throttle towards closed position to starve the evaporator, thus preventing excessively high refrigerant pressures and compressor motor overload.

When the thermostat T is satisfied, it opens its switch TS, deenergizing the motor starter MS which opens its switch S1, stopping the compressor motor CM. At the same time, the switch S2 of the starter MS opens, deenergizing the solenoid **65** which closes the valve **25** in the control tube **24** of the expansion valve **14**, shutting off the supply of liquid to the piston chamber **26** of the valve **14** so that the spring **60** closes the valve piston **58** of the valve **14**, providing positive shut off when the system is turned off.

Since the valves **21**, **22**, **23** and **25** are in the liquid supply to the piston chamber **26** of the expansion valve **14**, they can be relatively small valves, for example, three ton valves for controlling a one hundred ton valve **14**.

While the invention has been disclosed as embodied in a non-reversible system having condenser and evaporator coils, it may be used in heat pumps, and in systems in which the evaporators are water or other liquid chillers, and/or in which the condensers are liquid cooled.

What is claimed is:

1. In a refrigeration system having a compressor, a condenser, an expansion valve and an evaporator connected in series in a refrigeration circuit; a pilot valve having an inlet connected to said circuit between said condenser and said expansion valve to receive refrigerant liquid from said circuit, said pilot valve having an outlet, said pilot valve having means including means responsive to the pressure and the temperature of the refrigerant liquid leaving said condenser for opening and closing said pilot valve, said expansion valve having a chamber connected to said outlet of said pilot valve for receiving refrigerant liquid from said pilot valve when said pilot valve is open, and means including means responsive to the pressure of the liquid entering said chamber for adjusting said expansion valve towards open position on an increase in the pressure of the liquid entering said chamber and for adjusting said expansion valve towards closed position on a decrease in the pressure of the liquid entering said chamber.

2. The invention claimed in claim **1** in which there is provided a second pilot valve having an inlet connected to said inlet of said first mentioned pilot valve and having an outlet connected to said outlet of said first mentioned pilot valve, and in which said second pilot valve has means including means responsive to the pressure of the refrigerant at said evaporator for opening said second pilot valve on a decrease in the pressure of the refrigerant at said evaporator and for closing said second pilot valve on an increase in the pressure of the refrigerant at said evaporator.

3. The invention claimed in claim **2** in which a liquid tube connects said inlets of said pilot valves to said circuit, in which a second liquid tube connects said outlets of said pilot valves to said chamber, and in which a third pilot valve is connected in one of said tubes, said third valve having means including means responsive to the pressure of the refrigerant at said evaporator for opening said third valve on a decrease in the pressure of the refrigerant at said evaporator and for closing said third valve on an increase in the pressure of the refrigerant at said evaporator.

4. The invention claimed in claim **3** in which means is provided for starting and stopping said compressor, in which a shut-off valve is connected in one of said tubes, and in which means is provided for closing said shut-off valve when said compressor is stopped and for opening said shut-off valve when said compressor is started.

5. The invention claimed in claim **1** in which a liquid tube connects said inlet of said pilot valve to said circuit, in which a second liquid tube connects said outlet of said pilot valve to said chamber, and in which a second pilot valve is connected in one of said tubes, said second pilot valve having means including means responsive to the pressure of the refrigerant at said evaporator for opening said second pilot valve on a decrease in the pressure of the refrigerant at said evaporator and for closing said second pilot valve on an increase in the pressure of the refrigerant at said evaporator.

6. The invention claimed in claim **5** in which means is provided for starting and stopping said compressor, in which a shut-off valve is connected in one of said tubes, and in which means is provided for closing said shut-off valve when said compressor is stopped and for opening said shut-off valve when said compressor is started.

7. The invention claimed in claim **1** in which means is provided for starting and stopping said compressor, in which a liquid tube connects said inlet of said pilot valve to said circuit, in which a second liquid tube connects said outlet of said pilot valve to said chamber, in which a liquid shut-off valve is connected in one of said tubes, and in which means is provided for closing said shut-off valve when said compressor is stopped and for opening said shut-off valve when said compressor is started.

8. In a refrigeration system having a compressor, a condenser, an expansion valve and an evaporator connected in series in a refrigeration circuit; a pilot valve having an inlet connected to said circuit between said condenser and said expansion valve to receive refrigerant liquid from said circuit, said pilot valve having an outlet, said pilot valve having means including means responsive to the pressure of the refrigerant at said evaporator for opening said pilot valve on a decrease in the pressure of the refrigerant at said evaporator and for closing said pilot valve on an increase in the pressure of the refrigerant at said evaporator, said expansion valve having a chamber connected to said outlet of said pilot valve for receiving refrigerant liquid from said pilot valve when said pilot valve is open, and means including means responsive to the pressure of the liquid entering said chamber for adjusting said expansion valve towards open position on an increase in the pressure of the liquid entering said chamber and for adjusting said expansion valve towards closed position on a decrease in the pressure of the liquid entering said chamber.

9. The invention claimed in claim **8** in which means is provided for starting and stopping said compressor, in which a liquid tube connects said inlet of said pilot valve to said circuit, in which a second liquid tube connects said outlet of said pilot valve to said chamber, in which a liquid shut-off valve is connected in one of said tubes, and in which means is provided for closing said shut-off valve when said compressor is stopped and for opening said shut-off valve when said compressor is started.

References Cited by the Examiner

UNITED STATES PATENTS

2,571,625	10/1951	Seldon	62—225
3,023,591	3/1962	Tilney	62—210 X

MEYER PERLIN, *Primary Examiner.*