ABSTRACT

Operation of an electric motor driving a refrigerant compressor having forced oil lubrication is controlled by a solenoid operated switch, the solenoid circuit including a thermostatic switch in series with a parallel connected timer switch and oil pressure differential responsive switching means. The timer switch is operated by a relay coil energized by a timing circuit which includes voltage biased switching means having alternate output circuits, one of which includes the relay coil. The switching means is controlled by a capacitor which when charged, causes the timing switching means to change the effective flow of current from one output circuit to the other. In one form of the invention the relay coil is connected in initially energized output circuit of the switching means and is shunted to open the timer switch when the switching means is biased to change energization of the output circuits. The pressure differential responsive switch shunts the timer switch to provide a holding circuit for the solenoid after opening of the timer switch and simultaneously deenergizes the timing circuit.

In another form of the invention, the relay coil is connected in the other output circuit and is not energized for a period determined by charging of the capacitor to a given voltage. In this form the pressure responsive switch does not shunt the timer switch and is effective to deenergize the timer circuit in response to normal oil pressures.

14 Claims, 10 Drawing Figures
CONTROL DEVICE FOR PRESSURE LUBRICATED COMpressORS

BACKGROUND OF THE INVENTION

fails or the control device may be slightly altered and utilized to delay restarting of the compressor after its operation has been interrupted. Safety devices are frequently employed in relatively large capacity refrigerating systems to prevent costly damage to the compressors due to failure of lubrication. Safety control devices heretofore known generally comprise a control circuit for the compressor motor arranged so that the motor energizing circuit is initially closed through a normally closed timer switch. The timer switch may be opened a period after energization of the motor by a thermally responsive element heated by a resistance heater or the like to switch operating temperature. Normally, the heating of the thermal element to its switch operating temperature requires sufficient time for oil circulating pressure to be established in the compressor. The timer switch and its heating element was shunted out of circuit by a second switch operated to close in response to the production of oil pressure and maintain energization of the compressor motor around the opened timer switch.

Safety control devices of the type mentioned have several disadvantages. One disadvantage is that the time required to heat the thermal element to its switch operating temperature will not be constant in the event a variation in oil pressure occurs, thereby affecting the rate of heating of the thermal element. Also, variation in ambient temperature of the thermal element affects the time required for heating the thermal element to its switch opening temperature.

Another disadvantage of the type of oil pressure safety control device mentioned is that should the circuit for heating the thermal element fail for any reason, the timer switch would not be opened. Then, in the event of failure of lubrication pressure, the motor would continue to operate through the timer switch, thereby seriously damaging the compressor.

Another disadvantage found in some prior art oil pressure safety control devices of the type mentioned is that it is necessary to manually reset the timer switch mechanism in the event the switch opens because of failure of lubrication. These reset mechanisms are subjected to corrosion and obstructions of one sort or another which is apt to prevent proper opening of the switch.

It has also been the practice to provide electric motor driven timer devices and control circuits to delay restarting of compressor motors after interruption of current for one reason or another and prevent overloading and locked rotors due to high head pressures. These timer devices are relatively expensive, and are subject to wear and failure.

THE PRESENT INVENTION

The present invention relates to an improved control device for controlling the operation of compressors having pressure lubricating systems. One object of the invention is the provision of a control device which includes an electrically operated timer switch which may be connected in one or the other of two alternate energizing circuits of the output of a voltage biased switching means which is responsive to voltage at one plate of a charging condenser to switch current flow from one of the output circuits to the other after a predetermined charging period of the condenser. When the electrically operated timer switch is connected in one of the two energizing circuits, the control device serves as an oil safety control and when the electrically operated timer switch is connected in the other energizing circuit, the control device serves as a time delay control.

Another object of the invention is the provision of a safety control switch mechanism having a timer operated switch in parallel with the switch responsive to the oil pressure in the lubricating system, the timer switch being operated to closed position by energization of a timer circuit for initiating operation of the compressor motor and which switch is opened after a predetermined time, whereby the timer circuit must be in an operative condition for starting of the compressor.

Another object of the invention is the provision of a safety control switching mechanism of the type mentioned in which the timer switch can be reset following a safety shut-down of the compressor merely by interrupting the power supply to the timer circuit whereby restarting of the compressor can be effected remotely from the control mechanism.

Still another object of the invention is the provision of a safety control switching mechanism of the type mentioned which is unaffected in its timing by substantial variations in line voltages supplied to the timer circuit and is unaffected by changes in ambient temperatures.

The invention further contemplates the provision of a safety control switching mechanism of the type mentioned in which the timing period for opening of the timer switch may be accurately regulated over a relatively wide range of time.

A still further object of the invention is the provision of a time delay compressor starting control device in which the delay is controlled by the charging of a condenser, and the circuit for the condenser is discharged when an operating condition of the compressor reaches a normal condition.

Other objects and advantages of the invention will be apparent from the following description of preferred forms of the invention, reference being made to the accompanying drawings wherein:

FIG. 1 is a schematic view of a refrigerating system embodying the invention;

FIG. 2 is a front elevational view of a control device forming a part of the invention;

FIG. 3 is a fragmentary sectional view taken substantially along line 3—3 of FIG. 2 and on a larger scale;

FIG. 4 is a plan view of a circuit board removed from the control device;

FIG. 5 is an end view taken along line 5—5 of the circuit board shown in FIG. 4;

FIG. 6 is a view of the reverse side of the circuit board shown in FIG. 4;

FIG. 7 is a wiring diagram of the control device;

FIG. 8 is a sectional view taken substantially along line 8—8 of FIG. 2;

FIG. 9 is a sectional view taken substantially along line 9—9 of FIG. 2;

FIG. 10 is a wiring diagram of another form of the invention.

A portion of a refrigerating system which may embody both forms of the invention is shown at 10. The refrigerating system is a conventional electric motor driven compressor-condenser-expander type, and because the details of such systems are familiar to those skilled in the art a detailed showing and explanation is unnecessary for an understanding of the invention. The refrigerating system may be for a food storage compartment or for an air cooling system for a room or buildings, for example. The condenser and evaporator are not shown, but it will be understood that the evaporator is utilized for cooling air circulated in the space to be cooled. Suffice to say, the compressor C is driven by an electric motor 11, the operation of which is controlled by a suitable control switch 12, shown as a thermostat switch, so as to maintain a predetermined range of refrigerating temperatures. The thermostat switch 12 is located to respond to the temperature of the air, or other medium, to be cooled by the refrigerating system. The compressor C includes a lubricating oil pump P which is normally operative to force lubricant to the moving parts of the compressor requiring lubrication.

A control device 13 is provided for shutting down the compressor motor in response to a failure of the pump to circulate lubricant at a given pressure differential between the pump discharge and the oil pressure in the lubricating system, whereby preventing damage to the compressor from lack of lubrication. The control device 13 permits short periods of operation of the compressor without the pumping of lubrication in the compressor at the required pressure differential, particularly during initial
The switch 34 is a snap acting double throw type which is well known in the art. The switch includes a movable contact 43, (see FIG. 7) which is adapted to engage one or the other of fixed contacts 44 and 45. The contact 43 is caused to be shifted by a suitable snap mechanism 35 by swinging movement of an actuator arm 46. The contacts and snap mechanism of the switch 34 are enclosed in a casing attached to the board 38 and inside the housing. The actuator arm 46 extends from the casing and housing and is engaged by an actuating lever of an oil pressure responsive mechanism described more fully hereinafter. When a normal oil pressure differential is established between the discharge of the pump P and the interior of the compressor crankcase, the arm 46 is moved to cause contact 43 to engage contact 45. This switching movement establishes a holding circuit for the solenoid 17 around the timer switch 24. When the oil pressure differential is below a safe value, contact 43 engages contact 44.

Referring more particularly to FIG. 7 of the drawings, the timer switch 24 comprises a relay type switch operated by a solenoid coil 47. When the coil 47 is energized the switch is closed and when the coil is deenergized the switch opens. Relay switches of the type described are commercially available. The energization of coil 47 is controlled by the timer circuit described hereinafter.

The circuit board 38 has four flat terminal members 23, 26, 48, 49 attached thereto and these members project through slots in the housing 37 and provide terminal connections with the power supply and the solenoid 17. The relay coil 47 and the timer circuit are energized by a power supply circuit which includes line 1, thermostat switch 12, switch 20, a conductor 50, terminal 49, resistor R1, diode D1, resistor R2, a normally closed reset switch 51 and junction 52. As an alternative source of power a 220v. A.C. supply could be connected with conductor 50 which in turn would be connected to the terminal 48 instead of terminal 49. For such an arrangement a suitable resistor R is interposed between the terminal 48 and diode D1. In either case, the diode D1 provides a pulsating D.C. current which is smoothed and maintained at a given voltage by a voltage regulator comprised of a capacitor C1 and a zener diode D2.

The energizing circuit for the relay coil 47 includes junction 52, resistor R3, transformer Q1, coil 47, junction 53, contacts 43,44 of switch 34, terminal 26 and conductor 27. The base of the transistor Q1 controlled by a timer circuit is comprised of junction 52, a field effect transistor (FET) Q2, junction 54, a potentiometer R4 and junction 53. The base of the FET Q2 is connected with a junction 55 of a charging circuit for a condenser C1, which charging circuit includes junction 52, resistor R5, condenser C2, and the potentiometer R4. When a potential is initially applied to the junction 52, the voltages at junctions 54, 55 are relatively low due to the charging capacity of C2 and as a result, Q1 is turned on to supply an operating current flow to the relay coil 47 which closes switch 24. When C2 has been charged to a given level, the voltage at junction 55 turns on Q2 which causes an increase in voltage at junction 55, thus turning off Q1 and effectively deenergizing the circuit. The length of time required for charging C2 to the level mentioned depends upon the setting of the potentiometer R4. Preferably, the values of the capacitor C2, and resistors R4,R5 are such that the charging time may range from 10 to 240 seconds, depending upon the setting of the potentiometer R4. The resistance of the potentiometer R4 can be varied by rotating a shaft 56. The shaft projects through an opening in the board 38 and is slotted to receive a screwdriver for rotation. The adjustment is made prior to assembly of the board 38 into the housing 37.

The transistor Q1 is latched off by a transistor Q3 having its base connected with the emitter of Q1 through a resistor R6 and its collector connected with the collector of Q1. The emitter of Q3 is connected with junction 53 through a resistor R7.

When the current supply for the coil 47 and the timer circuit is interrupted, the condenser C2 will immediately discharge through FET Q2 to a substantial degree and thereby
The piston 71 is comprised of a permanent magnet, the flux of which cooperates with the flux of magnets carried on the operating lever 70 to cause the lever to move according to movements of the piston. Opposite ends of the cylinder 72 are connected with the interior of the compressor crankcase and the discharge side of the oil pump P. The piston is spring biased towards one end of the cylinder 72 and responds to a differential pressure in opposite ends of the cylinder to move against the spring and operate the actuator lever 70.

Referring to the construction details of the pressure differential mechanism which are best seen in FIG. 8, the cylinder 72 comprises a tubular member of non-magnetic material having fittings 74 and 75 suitably secured in opposite ends. The inner end portion of the fitting 74 has a neck 76 which projects well into the cylinder. The neck 76 forms a support for a coil spring 77 which urges the piston 71 towards the fitting 75. The inner end of the neck forms a stop to limit the travel of the piston to the left, as viewed in FIG. 8. The outer end 80 of the fitting 74 is threaded to receive a coupling 81 by which the fitting is connected with a tube 82 leading to the crankcase of the compressor C. The fitting 74 has an axial bore 83 which forms a fluid path from the interior of the cylinder to the tube 82.

The fitting 75 has a stub portion 84 which extends into the cylinder 72 and the end thereof forms a seat against which the piston is urged by the spring 77. The outer end of the fitting 75 is threaded to receive a coupling 85 by which the fitting is connected with a tube 86 leading to the discharge side of the pump P. The fitting 75 has an axial bore 87 which connects the tube 86 with the interior of the cylinder 72.

The cylinder 72 is supported by the flanges of the frame 36. The flanges have aligned openings which receive the central portions of the fittings 74, 75, as shown. The fitting 75 has a collar 90 which abuts the frame flange 41 about the edge of the opening receiving the fitting. The fitting 74 has a threaded portion on which a nut 91 is threaded and which engages the portion of the frame flange 40 about the opening through which the fitting extends.

It will be seen that when the compressor is operating normally, the oil discharge from the pump P will enter the bore 87 and overcome the force of the spring 77 and move the piston to the neck 76. The piston 71 has a relatively loose fit with the cylinder walls and oil passes therethrough. Furthermore, the oil conduits 82, 86 are of appreciable diameter so that the change in oil pressure differential is quickly reflected by movement of the piston. This movement of the piston swings the lever 70 counterclockwise about its pivot, as viewed in FIG. 2, and shifts the arm 46 to actuate the switch 34. When the oil pressure is low or the pressure differential between the crankcase and the discharge is too low to circulate the lubricating oil and maintain the piston on the neck 76 the spring 77 moves the piston to the stub 84. This shifts the lever 70 counterclockwise about its pivot. The arm 46 is normally biased to follow counterclockwise movement of the lever 70 to operate the switch 34 to break the circuit to solenoid 17. It will be appreciated that the tension of the spring 77 determines the differential in pressure at which the piston is operated.

The lever 70 has a U-shaped portion which includes a yoke 100 and two legs 101, 102. The legs are pivoted on a pivot pin 103, one end of which is attached to the main wall of the frame 36 in an operating therethrough. The legs 100, 101 straddle the cylinder 72 and carry a pair of magnets 104 and 105. The magnets 104, 105 are preferably of a ceramic type and are arranged with north and south poles of the magnetic piston 71. This causes the magnets 104, 105 to follow the piston and swing the lever 70 about the pivot pin 103. The yoke 100 of the lever 70 has a turned lug portion 106 having an opening into which an adjusting screw 107 is threaded. One end of the screw 107 is positioned to engage the adjusting portion 46 of the switch 34. The arm 46 is inherently biased to retain engagement with the screw 107. By turning the screw 107 one direction or the other, the pressure differential at which the piston 71 operates the switch 34 can be more or less varied.
SUMMARY OF OPERATION

When the thermostatic switch 12 closes in response to a demand for refrigeration the circuit for the compressor motor is closed by energization of the solenoid 47 and closure of switch 24 as described. After the compressor has operated for a given number of seconds, determined by the setting of the potentiometer R7, switch 24 is opened by the shutting of the relay solenoid 47 by the timer circuit. If, during the predetermined period of operation a normal pressure differential is developed between the outlet of pump P and the interior of the compressor crankcase, switch 34 is shifted to establish the contactor circuit through the contacts 43,45. This operation of the double throw switch 34 interrupts the current supply to the timer circuit and that circuit is reset by the discharge of the capacitor C2. When the thermostatic switch 12 is satisfied, the circuit for the solenoid 17 is opened and the compressor motor is stopped.

Should lubrication pressure fail during operation of the refrigerating system switch 24 shifts contact 45 from contact 45 to contact 44. Upon the closing of the contact 43 on contact 44 the timer circuit and the solenoid 47 are reenergized, causing switch 24 to be reclosed. The switch 24 is maintained closed for the time period described after which the switch is reopened. If normal lubrication pressure has been re-established, the compressor will be maintained in operation through contact 45 of the switch 34. On the other hand if oil pressure has not been re-established the timer circuit will function to prevent effective energization of the solenoid 47 for the switch 24.

After repairs or adjustments have been made to restore normal oil pressure in the compressor, the compressor motor can be restarted merely by momentarily interrupting the power to the timer circuit. This may be effected by momentarily opening either of the switches 20 or 51, whichever is most convenient. This action causes immediate discharge of the capacitor C2 as described, and upon re-establishment of current the timing cycle is initiated.

The timer circuit disclosed is exceptionally accurate in timing irrespective of wide variations in ambient temperatures and is not subject to voltage variations. The pressure differential responsive switch actuating mechanism disclosed is particularly suitable in that the piston 71 acts rapidly in response to changes in pressure differentials. Furthermore, because the piston normally rests against the stop formed by the inner end of the cylinder there is no movement of the piston and its associated parts during normal operation of the refrigerating system although fluctuations in pressure differential will occur.

In certain relatively larger refrigeration and air conditioning systems, oil pressures must develop relatively rapidly. In such cases the control device can be set to shut down the motor in a sufficiently short time to also protect overheating of the motor due to a locked rotor.

SECOND FORM OF INVENTION

By slight alteration of the circuit, the control device 13 can be utilized to provide a time delay between shut down of the compressor motor 11 and restarting. This is desirable to permit more or less equalization of pressures in the refrigerating system before restarting the compressor.

Referring to FIG. 10, the control device 13 is shown altered to provide time delay in restarting the compressor motor. Like parts of the device have the same reference characters as the parts shown and described relative to FIG. 1. It will be observed that the relay 47 and the resistor R7 are connected in alternate output circuits of the switching means comprised of the transistors Q1,Q3. In FIG. 10, the relay coil 47 is connected in the output circuit comprising the emitter of Q3 and the resistor R7 connected with the emitter of Q1. Thus, when the thermostat 12 calls for refrigeration, the timer circuit is energized and the initial output circuit is through resistor R7 rather than coil 47. Consequently, the contactor coil 17 is not energized until capacitor C2 becomes charged to a point in which the transistor Q3 becomes conductive. At that time coil 47 is energized and closes the motor controller contactor switch 24.

The connection of the oil pressure responsive switch 34 in the control circuitry is altered as shown by the effectiveness of contact 45 so that when contact 43 shifts from contact 44 to contact 45, the timer circuit is broken and the capacitor C2 discharges; however, contacts 43,45 are ineffective to shunt switch 24. When the oil pressure differential falls, due to termination of operation of the compressor, the timer circuit is re-energized by closure of contacts 43,44.

In either form of the invention, should there be a malfunction in the timer circuit which destroys the current supply through the circuit, the switch 24 cannot close. Thus, the refrigerating system will not operate without the protection of the timer circuit.

We claim: 1. In a refrigerating system having a refrigerating compressor including a lubrication pump for circulating lubricant in said compressor and a motor for driving said compressor, control circuitry for said motor including a condition responsive switching means and electrically powered means including energizing circuitry controlled by said condition responsive switch and operative to energize said motor when said electrically powered means is energized, second and third switching means in said energizing circuitry, said second switching means having first and second alternate switching positions, said third switching means normally open and including electrically energized means to close said third switching means and cooperate with said condition responsive switch to complete said energizing circuitry, electrically responsive timer means to deenergize said electrically energized means a period after energization of said electrically energized means, said electrically responsive timer means having an energizing circuit including said first alternative switching position of said second switching means, said second switching means being operative in its second alternative switching position to deenergize said timer means and complete a shunt circuit around said third switching means, and means responsive to lubrication oil pressure conditions in said pump and compressor for shifting said second switching means from said first alternate position to said second alternate position.

2. A refrigerating system as defined in claim 1 in which said electrically powered means and said electrically energized means each comprise a solenoid.

3. A refrigerating system as defined in claim 1 in which said timer means is automatically reset in response to interruption of its energizing circuit whereby conditions are established for initiating a time period upon reenergization thereof.

4. A refrigerating system as defined in claim 3 in which said electrically responsive means includes a transistor controlling energization of said electrically energized means, a biasing circuit for said transistor including a capacitor and resistor regulating the charging rate of said capacitor, and means to discharge said capacitor when said electrically responsive timer is deenergized.

5. A refrigerating system as defined in claim 3 including normally closed manually operated switching means for selectively interrupting the energizing circuit of said timer means.

6. In a refrigerating system comprising a refrigerating compressor including a lubricating system having a lubricant pump and a motor for driving said compressor, a control system for said motor including condition responsive means to initiate and terminate operation of said compressor, timer means operative to terminate operation of said compressor after a limited period following initiation of operation of said compressor means forming a cylinder, a piston movably in said cylinder, means urging said piston towards one end of said cylinder, means connecting said one end of said cylinder with the discharge of said lubricant pump, means connecting the other end of said cylinder with the intake of said pump, and means operated by movement of said piston to a predetermined position away from said one end of said cylinder for
rendering said timer means ineffective to terminate operation of said compressor.

7. In a control system for apparatus requiring maintenance of a fluid pressure differential during operation thereof, electrically powered means operative to effect and maintain operation of said apparatus when said means is energized, an energizing circuit for said electrically powered means, switch means to control energization of said circuit, said circuit including timer means to provide an effective energizing current to said electrically powered means when said circuit is initially energized by closure of said switch means and after a period of energization to render said circuit ineffective to energize said electrically powered means, and means responsive to the presence of said fluid pressure differential for maintaining operation of said apparatus irrespective of the ineffective condition of said electrically powered means.

8. A control system for apparatus as defined in claim 7 further characterized by said electrically powered means comprising a solenoid, said timer means comprising a field effect transistor, a transistor having its base connected with the emitter of said field effect transistor, and an RC circuit including a condenser connected with the base of said field effect transistor.

9. A control system for apparatus as defined in claim 7 further characterized by the means responsive to the pressure of said fluid differential being operative to interrupt the circuit to said timer means substantially simultaneously with maintaining operation of said apparatus.

10. In a motor driven mechanism having lubricated moving parts and including a lubrication pump for circulating lubricant, control circuitry for said motor including a condition responsive switching means and electrically powered means including energizing circuitry controlled by said condition responsive switch and operative to energize said motor when said electrically powered means is energized, second and third switching means in said energizing circuitry, said second switching means having first and second alternate switching positions, said third switching means normally open and including electrically energized means to close said third switching means and cooperate with said condition responsive switch to complete said energizing circuit electrically responsive timer means to deenergize said electrically energized means a period after energization of said electrically energized means, said electrically responsive timer means having an energizing circuit including said first alternative switching position of said second switching means, said second switching means being operative in its second alternative switching position to deenergize said timer means and complete a shunt circuit around said third switching means, and means responsive to lubrication oil pressure conditions in said pump and mechanism for shifting said second switching means from said first alternate position to said second alternate position.

11. A motor driven mechanism as defined in claim 10 in which said electrically powered means and said electrically energized means each comprises a solenoid.

12. In a refrigerating system having a refrigerant compressor including a lubrication pump for circulating lubricant in said compressor, and a motor for driving said compressor, control circuitry for said motor including a control switching means and electrically powered means including energizing circuitry controlled by said control switching means and operative to energize said motor when said electrically powered means is energized, second and third switching means in said energizing circuitry, said second switching means having first and second alternate switching positions, said third switching means normally open and including electrically energized means to close said third switching means to thereby cooperate with said condition responsive switch to complete said energizing circuit, electrically responsive timer means having alternative parallel circuits, one of which parallel circuits includes said electrically energized means, said timer means comprising switching means operative in response to energization of said timer means for a period to change the flow of current from one of said parallel circuits to the other parallel circuit and thereby control the energization of said electrically energized means, an energizing circuit for said electrically responsive timer means including said first alternative switching position of said second switching means, and means responsive to lubrication oil pressure conditions in said pump and compressor for shifting said second switching means from said first alternative position to said second alternative position.

13. A refrigerating system as defined in claim 12 further characterized by said second switching means being operative in its second alternative switching position to deenergize said timer means and complete a shunt circuit around said third switching means.

14. A refrigerating system as defined in claim 12 further characterized by said electrically energized means being connected in said other parallel circuit of said electrically energized timer means.