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2,955,745

TEMPERATURE RESPONSIVE SURGE CONTROL

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Filed Dec. 17, 1956, Ser. No. 628,359

7 Claims. (Cl. 230—115)

This invention relates to a safety system for a compressor and, more particularly, to a safety system wherein the pressure on the discharge or output side of a compressor is relieved when a surge condition is approached.

A surge condition may be caused by a stoppage of the flow of fluid in the discharge conduit of a compressor. For example, it may be caused by the closing of a valve in the discharge conduit while the compressor is operating. The surge condition is characterized by excessively high temperatures in the discharge conduit, reversal of flow of the fluid in the discharge conduit, and noise and excessive air vibrations which may produce bending of the compressor blades and ultimately complete failure of the compressor.

It is an object of the present invention to provide a safety control system for operating a relief valve in the discharge conduit of the compressor which during normal operating conditions will be closed but under conditions indicating surge will be opened to prevent damage to the compressor.

A mere increase in pressure in the discharge conduit of the compressor is not necessarily indicative of surge because many compressors operate under conditions which require substantial variations in the discharge head of the compressor. It has been discovered, however, that as the surge condition approaches, there is a sudden increase in temperature at the inlet of the compressor. The present invention utilizes the detection of this increase of temperature at the inlet of the compressor to initiate the operation of means for opening the relief valve.

Accordingly, in the control system of the present invention two temperature sensing devices are produced in the inlet or supply conduit of the compressor, one in proximity to the compressor and the other considerably upstream thereof, and means is provided to open the relief valve in the discharge line of the compressor in the event that the temperature in proximity to the compressor inlet exceeds the temperature upstream of the compressor inlet. The control system, however, is not effective to open the relief valve in the discharge line of the compressor in the event of fluctuations in the temperature of the fluid to be compressed which are not indicative of a surge condition.

For a complete understanding of the present invention, reference may be made to the detailed description which follows and to the accompanying drawing in which:

Figure 1 is a schematic representation of the control system of the present invention, and

Figure 2 is a cross-section view of one of the temperature sensing devices employed therein.

Referring to the drawings, the reference numeral 10 represents the inlet or supply conduit of a centrifugal compressor 11, and the reference numeral 10a represents the discharge conduit thereof. A centrifugal compressor has been shown in the drawing for purposes of illustration only, but the present invention is also applicable to

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continuous flow compressors (axial) as well. A relief conduit 12 communicates with the conduit 10a upstream of any control valve for regulating the output of the compressor. The conduit 12 may exhaust to atmosphere or to a waste line. The flow through the conduit 12, however, is normally prevented by the closed relief valve 13 pivotally mounted therein.

The relief valve 13 is adapted to be opened by a pressure controlled actuator 14. The flexible diaphragm 14a of the actuator is connected by means of a rod 15 to the arm 13a of the pivotal relief valve 13. A compression spring 14b acts against the diaphragm to maintain the relief valve closed. The relief valve is adapted to be opened by pressure supplied to the interior of the actuator from the compressor discharge line 10a through a conduit 16. The pressure, however, is prevented from building up in the actuator 14 because of the escape of fluid through the opening 17 in the vent line 16a. To avoid unnecessary pressure drops in the discharge line 10a during normal operating conditions of the compressor, a pressure regulator 19 and a restricted orifice 20 are interposed in the conduit 16 between the discharge line 10a and the vent opening 17.

The vent opening 17 is adapted to be closed by the longitudinal movement of a needle valve 21. The needle valve 21 is formed at the end of a piston rod which is attached to a piston 22. The piston 22 is movably mounted within a chamber of a housing 23. The piston 22 is acted upon on opposite sides by compression springs 24 and 25, the compression spring 25 offering resistance to the movement of the piston 22 which would cut off the flow through the vent opening 17 and the compression spring 24 urging the piston in a direction which would cause the needle valve to close the vent opening 17.

The position of the piston 22, and hence also of the needle valve 21, during normal operation of the compressor can be fixed by an adjustable set screw 27. The set screw adjusts the position of a disk 28 which serves as a retaining wall for the compression spring 24.

It is understood that when the piston 22 is moved to the left as viewed in Figure 1, the needle valve 21 will gradually close the opening 17 and build up back pressure in the conduit 16, thereby permitting the buildup of pressure in the chamber of the actuator 14 to move the relief valve 13 to open position.

The movement of the piston 22 is adapted to be controlled by the difference in temperatures detected by the temperature sensing devices 30 and 31. The temperature sensing device 31 is placed in the conduit 10 of the compressor in proximity to the compressor inlet, and the temperature sensing device 30 is placed substantially upstream of the compressor inlet so that it will not detect changes in the temperature of the compressor.

The temperature sensing devices 30, 31 are actually conventional temperature transducer elements which convert changes in temperature to mechanical motion. As shown in greater detail in Figure 2, the transducer element comprises outer casing 33 having radial fins 34 attached thereto, a cylindrical bellows 35 supporting a movable base 36 within the casing, a liquid filled chamber 37 enclosed between the casing and the bellows, a valve element 38 attached to the movable base 36, and a compression spring 39 which acts against the pressure of the liquid against the base 36. The pressure of the enclosed liquid increases and decreases in accordance with changes in temperature, thereby moving the base 36 against the action of a compression spring 39 and causing the bellows 35 to contract or expand. As the bellows contracts or expands, the movable valve element 38 is accordingly raised or lowered. Various conventional temperature transducer elements of this general organization are avail-

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able, and these elements form no part of the present invention.

The temperature sensing device 30 serves to regulate the pressure on the left side of the piston 22, and the temperature sensing device 31 serves to regulate the pressure on the right side of the piston 22. Thus, the position of the piston 22 will serve to reflect the difference in temperatures in the conduit 10 at a point in proximity to the compressor inlet and at a point considerably upstream thereof. Accordingly, the needle valve 21 will be moved toward or away from the opening 17 in response to this differential pressure.

The temperature sensing device 30 is operative to regulate the pressure on the left side of the piston 22 by a conduit 40, one end of which communicates with the interior of the piston housing on the left side of the piston and the other end of which is open to atmosphere. The conduit 40 is connected by means of the conduit 40a and orifice 40b to the pressure line 16, and a small amount of fluid from the discharge conduit 10a is permitted to exhaust to atmosphere through the open end of the conduit 40. As mentioned above, the size of the opening is determined by the position of the valve element 38. As the temperature detected by the temperature sensing device 30 increases, the valve 38 reduces the size of the opening, and as the temperature decreases the size of the opening increases. It is evident that as the valve 38 closes the opening in the conduit 40, pressure will build up on the left side of the piston 22, and as the valve 38 increases the size of the opening the pressure will be reduced on the left side of the piston.

The temperature sensing device 31 serves to regulate the pressure on the right-hand side of the piston 22 in identical fashion. The movable valve 38 of the temperature sensing device 31 controls the size of the vent opening of the conduit 41 which communicates with the interior of the piston housing on the right side of the piston. The conduit 41 is connected to the discharge line of the compressor via the conduit 41a and orifice 41b. Just as described above in connection with the temperature sensing device 30, as the valve 38 closes the opening in the conduit 41, the pressure will build up on the right side of the piston 22, and as the valve 38 increases the opening, the pressure will be reduced on the right side of the piston.

In normal operation, the temperature in proximity to the compressor inlet will be substantially the same as the temperature in the conduit 10 upstream of the compressor inlet. In this case, the valve 21 will be so spaced apart from the vent opening 17 that pressure will not build up in the actuator 14, and the relief valve 13 will remain closed. If the temperature of the fluid to be compressed increases or decreases, the positions of the valves 38 relative to the vent openings of the conduits 40, 41 will vary, but as long as the temperature of the fluid at the temperature detecting device 30 is substantially the same as that at the temperature detecting device 31, there will be no movement of the piston 22 and, therefore, no movement of the valve 21 in relation to the vent opening 17.

In the event of a surge condition, however, the temperature detected by the temperature sensing device 31 will become substantially higher than that detected by the temperature sensing device 30, with the result that the piston 22 will move to the left, causing the valve 21 to reduce substantially the size of the vent opening 17 or to close the vent opening 17 altogether. When this occurs, the pressure of the line 16 will be permitted to build up against the diaphragm 14a of the actuator 14, and the actuator will function to open the relief valve 13 in the exhaust passage 12, thereby preventing damage to the compressor.

The invention has been shown in a single preferred form and by way of example only, and obviously many variations and modifications may be made therein without departing from the spirit of the invention. For example,

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it is evident that the temperature in the inlet line of the compressor can be measured by various other means, such as resistance thermometers or thermocouples, in which event it may be advantageous to operate the relief valve 13 electrically in response to a substantial increase in temperature at the inlet of the compressor. The invention, therefore, is not to be limited to any specified form or embodiment, except in so far as such limitations are set forth in the appended claims.

I claim:

1. In combination, a compressor, intake and discharge conduits therefor, and a control device for relieving the pressure in the discharge conduit of the compressor in the event of a surge condition, said control device comprising temperature sensing means in the intake conduit responsive to the temperature of the fluid to be compressed at a point in proximity to the compressor, temperature sensing means in the intake conduit responsive to the temperature of the fluid to be compressed at a point substantially upstream of the compressor, a normally closed relief valve in communication with the discharge conduit of the compressor, and means operatively connected to both temperature sensing means and the relief valve for opening the relief valve in response to an increase in the temperature of the fluid to be compressed in proximity to the compressor in relation to the temperature of the fluid in the intake conduit substantially upstream thereof.

2. A control device as set forth in claim 1 wherein the means operatively connected to both temperature sensing means and the relief valve includes a pressure controlled actuator connected to the relief valve for opening the relief valve, a pressure transmitting passage between the pressure controlled actuator and a source of pressure, an exhaust opening in said pressure transmitting passage which normally prevents transmission of the pressure necessary to the operation of the pressure controlled actuator, a control valve operable to regulate the flow of fluid through said exhaust opening, first and second pressure transmitting passages, means controlled by one of said temperature sensing means for varying the pressure in the first pressure transmitting passage in response to a change in temperature, means controlled by the other of said temperature sensing means for varying the pressure in the second pressure transmitting passage in response to a change in temperature, and means operatively connected to the control valve and communicating with said first and second pressure transmitting passages for controlling the position of said control valve in response to the differential pressure in said pressure transmitting passages, the control valve operating to close the exhaust opening when the differential pressure is high, thereby causing the pressure controlled actuator to open the relief valve.

3. A control device as set forth in claim 1 wherein the source of pressure for operating the pressure controlled actuator is the pressure in the discharge conduit of the compressor.

4. In combination, a compressor, supply and discharge conduits therefor, and a control device for relieving the pressure in the discharge conduit of the compressor in the event of a surge condition, said control device comprising a normally closed relief valve communicating with the discharge conduit of the compressor, an actuator operatively connected to said relief valve, a pair of temperature sensing means in the supply conduit of the compressor, one of said temperature sensing means being in proximity to the compressor inlet and the other being considerably upstream thereof, a piston housing, a piston within said piston housing, pressure transmitting passages communicating with the piston housing on opposite sides of said piston, means controlled by one of the temperature sensing means to vary the pressure in one of the pressure transmitting passages in response to the temperature sensed, means controlled by the other of the temperature

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sensing means to vary the pressure in the other of the pressure transmitting passages in response to the temperature sensed, whereby a disproportionate increase in the temperature at the compressor inlet in relation to the temperature considerably upstream thereof produces relative movement between the piston and the piston housing, and means controlled by the relative movement between the piston and piston housing for controlling the operation of the actuator to open the relief valve.

5. In combination, a compressor, supply and discharge conduits therefor, and a control device for relieving the pressure in the discharge conduit of a compressor in the event of a surge condition, said control device comprising a normally closed relief valve communicating with the discharge conduit of the compressor, an actuator operatively connected with the relief valve, a pair of temperature sensing means in the supply conduit of the compressor, one of the said temperature sensing means being in proximity to the compressor inlet and the other being upstream thereof, a piston housing, a piston within said piston housing, pressure transmitting passages communicating with said piston housing on both sides of said piston, means controlled by one of said temperature sensing means for varying the pressure in one of said pressure transmitting passages, means controlled by the other of said temperature sensing means for varying the pressure in the other of said pressure transmitting passages, whereby a differential pressure is transmitted to opposite sides of the piston when the temperature in proximity to the compressor increases disproportionately to the temperature upstream thereof, said differential pressure producing relative movement between the piston and the piston housing, a pressure transmitting passage connected to the actuator, and a valve controlled by the relative movement between the piston housing and the piston and communicating with the pressure transmitting passage connected to the actuator to control the operation of the actuator, whereby the said relative displacement between the piston and piston housing causes the relief valve to open.

6. In combination, a compressor, intake and discharge conduits therefor, and means for relieving the pressure in the discharge conduit of a compressor in the event of a surge condition, said means comprising a normally closed relief valve communicating with the discharge conduit, pressure responsive control means operatively connected with the relief valve and operating in response to an unbalanced force for opening the relief valve, pressure transmitting passage means connected with the pressure responsive control means to produce a balanced force thereon, a pair of temperature sensing means in the intake

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conduit of the compressor, one in proximity to the compressor and the other upstream thereof, and means controlled by the temperature sensing means in response to a disproportionate increase in the temperature in proximity to the compressor in relation to the temperature upstream thereof for unbalancing the pressure transmitted to the pressure responsive control means through the pressure transmitting passage means, whereby the pressure responsive control means opens the relief valve.

7. In combination, a compressor, intake and discharge conduits therefor, and means for relieving the pressure in the discharge conduit of a compressor in the event of a surge condition, said means comprising a normally closed relief valve in communication with said discharge conduit, a pressure controlled displaceable control member operatively connected to the relief valve, a pair of pressure chambers in communication with the discharge conduit of the compressor, the differential pressure in the chambers controlling the displacement of the control member to open said relief valve, bleed passages from each of the chambers, a pair of temperature sensing means in the intake conduit of the compressor, one in proximity to the compressor and the other considerably upstream thereof, a valve operatively connected with one of said temperature sensing means to control the rate of bleed from one of said bleed passages, and a valve operatively connected with the other of said temperature sensing means to control the rate of bleed from the other of said bleed passages, whereby if the temperature sensing means in proximity to the compressor senses a substantially higher temperature than the upstream temperature sensing means, the valves operatively connected with the respective temperature sensing means will produce a pressure differential between the chambers which will operate the displacement control member to open the relief valve.

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