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J. C. GREENLEES ET AL

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SURGE CONTROLLER FOR COMPRESSORS AND PUMPS

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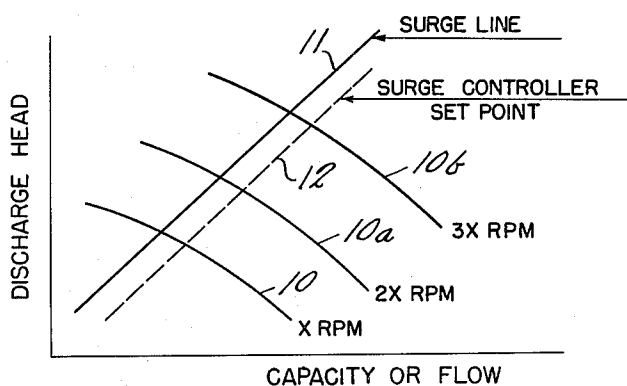


FIG. 1.

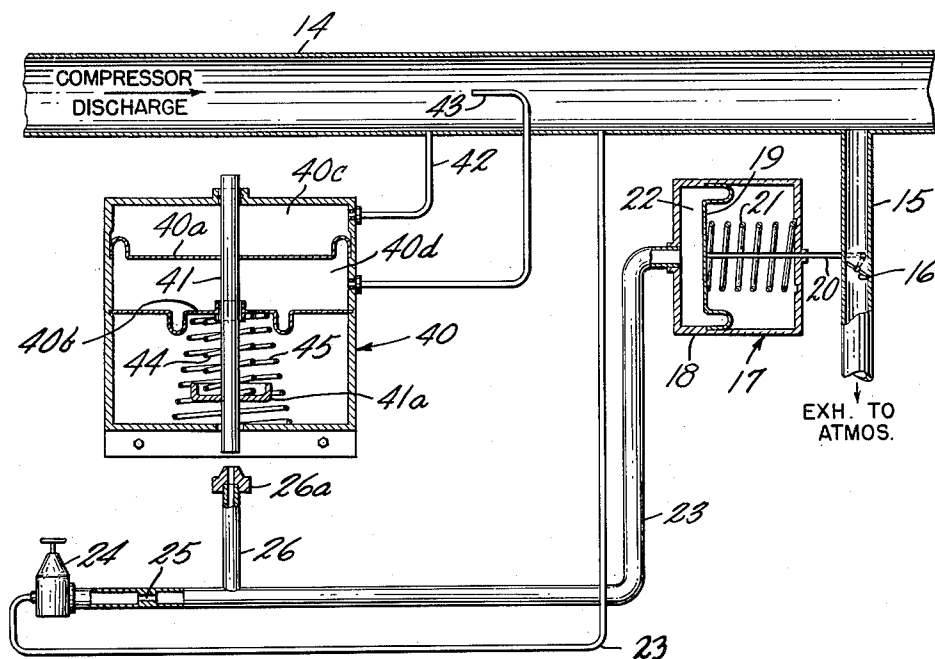


FIG. 2.

INVENTORS.
JAMES C. GREENLEES &
WILLIAM C. MEYER

BY
Campbell, Brumfough, Tree & Thayer
their ATTORNEYS

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3,002,521 SURGE CONTROLLER FOR COMPRESSORS AND PUMPS

James C. Greenlees, Oakdale, and William C. Meyer, Central Islip, N.Y., assignors to Fairchild Stratos Corporation, a corporation of Maryland

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This invention relates to a safety control system wherein pressure on the discharge side of the compressor is relieved when a surge condition is approached.

When the discharge flow of a compressor is decreased, such as by closing a valve in the discharge line of the compressor, a phenomenon known as "surge" may occur. Surge is an unstable condition of operation which within a short time may be characterized by pressure surges, substantial increases in temperature and bending of the compressor blades, and ultimately complete failure of the compressor. The conditions at which surge will occur in a compressor can be described by any two of three operating conditions: (1) the speed of operation of the compressor, (2) the pressure ratio across the compressor, and (3) the capacity or discharge flow of the compressor. For all practical purposes, the inlet pressure of the compressor may be ignored because it will be relatively constant; consequently, the discharge head can be used in describing the surge condition instead of the pressure ratio across the compressor.

The object of the present invention is to provide a control system for operating a relief valve on the discharge side of the compressor which during normal operating conditions will be closed, but which upon conditions indicating surge will be opened to prevent damage to the compressor. In this control system, two of the three operating conditions mentioned above are measured and so balanced against each other that unless one of these values changes abnormally in relation to the other, the relief valve will remain closed. However, in the event of an abnormal unbalance, indicating a surge condition, the relief valve will be opened to relieve the pressure.

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

FIGURE 1 is a diagram representing the relationship between discharge head and capacity or flow at different speeds of operation of the compressor; the diagram also includes a line representing the surge condition and a line indicating the conditions under which the relief valve is opened by the control system of the present invention to prevent the occurrence of surge;

FIGURE 2 is a view partly in cross-section illustrating the invention.

Referring to FIGURE 1 of the drawings, the curves 10, 10a and 10b represent the relationship between total discharge head and the capacity or rate of flow for a rotary compressor over a portion of its operating range at different speeds of operation of the compressor rotor. Line 11 represents the conditions at which surge occurs. This line is shown as a straight line for the portion of the operating range of the compressor represented in the figure, although for more extended ranges it may appear as a curved line. In general, the area to the right of the surge line represents satisfactory conditions of operation of the compressor, and the area to the left of the surge line represents unstable operating conditions which within a short time, a matter of seconds, may be characterized by substantial pressure fluctuations, temperature increases, mechanical bending of the blades and ultimate failure of the unit.

From FIGURE 1 it is evident that, regardless of the speed of operation of the compressor unit, the surge con-

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dition can be described as (a) a function of total discharge head and discharge flow of the compressor unit, (b) as a function of speed of the compressor and discharge flow or (c) as a function of speed of the compressor and total discharge head.

By triggering the action of the surge control device of the present invention to relieve the pressure on the discharge side of the compressor at any point along the broken line 12 (which is on the safe side of the surge line 11), it is possible to eliminate the occurrence of the surge condition.

Referring to FIGURE 2 of the drawings, the reference numeral 14 represents the discharge line of a compressor (not shown). A relief conduit 15 communicates with the line 14 upstream of any control valve for regulating the output of the compressor. The flow through the conduit 15, however, is prevented by the normally closed relief valve 16 therein.

The relief valve 16 is adapted to be controlled by the operation of the actuator 17. The actuator 17 comprises a housing 18, a flexible diaphragm 19, and a mechanical linkage 20 connecting the diaphragm and the valve 16. A compression spring 21 acts against the diaphragm 19 and normally maintains the relief valve 16 closed. The relief valve, however, is adapted to be opened by an increase in pressure within the chamber 22 sufficient to overcome the action of the spring 21. The chamber 22, in turn, is connected by means of a conduit 23 to the discharge line 14, and under normal operating conditions a small quantity of the compressed fluid from the line 14 is permitted to escape through an exhaust vent 26 in the conduit 23. A pressure regulator 24 and a restricted passage or orifice 25 are interposed in the conduit 23 upstream of the exhaust vent 26 to reduce the loss of pressure in the conduit 14. The exhaust vent 26 may also have a restricted passage or orifice 26a at the end thereof to further reduce the loss in pressure.

Because of the escape of fluid through the exhaust vent 26, the conduit 23 normally does not transmit sufficient pressure to the chamber 22 of the actuator 17 to effect the opening of the valve 16. The closing of the exhaust vent 26 to effect the operation of the actuator 17 is controlled by the lower end of a single, axially displaceable shaft 41. The shaft 41 is rigidly attached to the flexible diaphragm 40a of the actuator 40, and the diaphragm defines an upper chamber 40c within the actuator housing. The actuator is also provided with a flexible diaphragm 40b spaced apart and beneath the diaphragm 40a so that a chamber 40d is defined between the diaphragms 40a and 40b. The shaft 41 is axially displaceable with respect to the diaphragm 40b.

The conduit 42 transmits to the chamber 40c a pressure corresponding to the static pressure head in the conduit 14. A Pitot tube 43 transmits to the chamber 40d a pressure corresponding to the total pressure head in the conduit 14. Since the rate of flow of the fluid through the conduit 14 is proportional to the difference between the total pressure head and the static pressure head, the shaft 41 will be displaced axially in response to a change in the rate of flow. More specifically, the shaft will be displaced upwardly as the rate of flow increases, and downwardly as the rate of flow decreases.

A spring 44 is accommodated on the shaft 41 between the flexible diaphragm 40b and a retaining ring 41a attached to the shaft. The characteristic of this spring is such that it will maintain the lower end of the shaft 41 in position to prevent escape of fluid from the vent 26 unless the rate of flow is sufficiently high to lift the shaft away from the discharge nozzle 26a of the vent.

Thus, it may be observed that during normal operation if the static pressure increases with a corresponding increase in flow, there is no resulting downward movement

of the shaft 41. If, however, the static pressure increases without a proportional increase in flow, the shaft 41 will move downwardly and close the exhaust vent 26 which, as explained above, effects operation of the actuator 17 to open the relief valve 16.

Another spring 45 is provided in the arrangement shown in FIGURE 2 to oppose the pressure against the diaphragm 40b (inasmuch as the force level of the total pressure is considerably higher than that on the diaphragm 40a). The spring 45, therefore, establishes an equilibrium position but does not otherwise affect the general motions discussed above, although it will affect the degree of motion.

The separation between the lower end of the control rod 41 and the open end of the vent pipe 26 provides a lost motion control whereby limited movement of the control rod not indicative of a surge condition is permitted without opening the relief valve.

We claim:

1. A control device for relieving the pressure in a conduit comprising a biased closed relief valve in communication with the conduit, means controlling operation of the relief valve including a movable control member, means for displacing the movable control member to an operative position when the ratio of the velocity pressure head to the static pressure head falls below a safe value and away from the operative position when a sufficiently high ratio is maintained between the velocity pressure head and the static pressure head in the conduit, said means including a movable member connected to said control member and a movable member independent of said control member, means defining pressure chambers on both sides of said movable member connected to said control member, means for transmitting a pressure to one of said chambers which is a function of the static pressure head in the conduit, the pressure in said chamber exerting a force on said movable member which tends to displace the control member in a direction to effect opening of the relief valve, means for transmitting a pressure to the other of said chambers which varies with the velocity pressure head in the conduit, said other of said chambers being defined between said movable members, said pressure which varies with the velocity head exerting a force on the movable member connected to the control member which tends to displace the control member away from the operative position, and a spring which acts on the movable control member to displace it to a position which insures opening of the relief valve when the ratio of the velocity pressure head to the static pressure head falls below a safe value.

2. A control device as set forth in claim 1 including means to exert a force against the movable member which is independent of the control member whereby the degree of motion imparted to the control member in response to a variation in the velocity pressure head in the conduit is modulated.

3. A control device for relieving the pressure in a con-

duit in the event of a surge condition comprising a biased closed relief valve in communication with the conduit, means controlling operation of the relief valve including a movable control member, a lost motion control means between the movable control member and the relief valve whereby limited movement of the control member not indicative of a surge condition is permitted without opening the relief valve, said limited movement of the control member corresponding to a range in which the proper ratio is maintained between the velocity pressure head and the static pressure head in the conduit, and a pressure controlled actuator for displacing the movable control member to an operative position when the ratio of the velocity pressure head to the static pressure head falls below a safe value, said pressure controlled actuator including a movable diaphragm connected to said control member and a movable diaphragm independent of said control member, means defining pressure chambers on both sides of said movable diaphragm connected to said control member, means for transmitting a pressure to one of said chambers which is a function of the static pressure head in the conduit, the pressure in said chamber exerting a force on said movable diaphragm which tends to displace the control member in a direction to effect opening of the relief valve, means for transmitting a pressure to the other of said chambers which varies with the velocity pressure head in the conduit, said other of said chambers being defined between said movable diaphragm, said pressure exerting a force on the diaphragm connected to the control member which tends to displace the control member away from the operative position, a spring which acts on said movable control member to displace it to a position which insures opening of the relief valve unless the value of the differential pressure between the pressure chambers is such as to overcome the effect of the spring, and a spring to exert a force against the diaphragm which moves independently of the control member to oppose movement of said diaphragm in response to an increase in the velocity pressure head and to accentuate movement of said diaphragm in response to a decrease in the velocity pressure head.

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