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AXIAL FLOW CENTRIFUGAL COMPRESSOR AND SURGE CONTROL SYSTEM THEREFOR

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1 Claim. (Cl. 230—115)

This invention relates to a safety system for a fluid rotary compressor wherein the pressure on the discharge or output side of the device is relieved when a surge condition is approached. It is a continuation-in-part application of the pending application of David U. Hunter, Serial No. 613,231, filed October 1, 1956.

As a compressor approaches a surge condition, the output pressure fluctuates at first rather gently and then very violently. The latter condition is accompanied by excessive outlet temperatures, reversal in the flow of the fluid in the discharge line of the compressor, noise and excessive air vibrations which may produce bending of the compressor blades and, ultimately, complete failure of the compressor.

One object of the present invention is to relieve surge conditions in the discharge line of a compressor to prevent damage to the compressor or to the fluid system. This object is achieved by a safety control system which operates a relief valve on the discharge side of the compressor. During normal operating conditions this relief valve will be closed, but upon the occurrence of conditions indicating surge the relief valve will be opened to prevent damage to the compressor or to the fluid system. Sudden positive or negative variations in pressure are indicative of surge, and in the safety system of the present invention sudden increases or decreases of pressure in the discharge line of the compressor are operative to open the relief valve for the duration of these sudden variations. Gradual variations in pressure in the discharge line, such as those which occur during normal operation, will not be operative to open the relief valve.

It has been discovered that it is possible to increase the safe operating range of a rotary compressor by imparting a swirling motion to the fluid to be compressed. In other words, when the compressor is approaching a surge condition, by imparting a swirling motion to the fluid to be compressed, said swirl being in the direction of rotation of the compressor rotor, it is possible to increase the safe operating range of the compressor and thereby either eliminate surge completely or at least reduce the amount of flow through the relief valve which is necessary to prevent damage by the surge condition.

Therefore, it is still another object of the present invention to impart a swirling motion to the fluid to be compressed by the operation of a rotary compressor when the fluid system is dangerously close to a surge condition. This is accomplished in the present invention by conducting all or part of the fluid relieved from the discharge line of the compressor and introducing it in a swirling motion in the intake line of the compressor.

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 present invention, partly in cross-section;

Figure 2 is a view taken along the line 2—2 of Figure 1, looking in the direction of the arrows; and

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Figure 3 is a fragmentary view illustrating an alternative embodiment of the present invention.

Referring to the drawing, the conduit 10 represents the discharge line of a centrifugal rotary compressor driven by suitable means, such as an engine A. A relief conduit 12 communicates with the conduit 10 upstream of any control valve for regulating the output of the compressor. For purposes of relieving a surge condition in the conduit 10, the relief conduit 12 may exhaust to atmosphere or to a waste line. However, in order to impart a swirling or rotary motion to the fluid in the intake conduit 13 about to be compressed, the conduit 12 may, as shown in Figure 1, be connected to the intake conduit 13 so that this fluid may be utilized to impart a swirling motion to the fluid in the intake conduit 13 when a surge condition is approached. Normally, however, the flow through the conduit 12 is prevented by the closed relief valve 14.

The relief valve 14 is adapted to be operated by a pressure controlled actuator 15. The movable diaphragm 15a of the actuator is connected by means of a rod 15b to the arm 14a of the pivotal relief valve 14. A compression spring 15c acts against the diaphragm. Thus, when the pressure increases within the chamber of the actuator 15, the relief valve 14 is pivoted to open position. Pressure is supplied to the actuator 15 for opening the relief valve through a conduit 16 which communicates with the discharge line 10 upstream of the conduit 12. The pressure, however, is prevented from building up in the actuator 15 because fluid is permitted to escape from the pressure conduit 16 through a vent opening 17 in the upright vent pipe 18.

The escape of fluid through the vent opening 17 is controlled by the position of the axially movable needle valve 21. The needle valve 21 is formed at the end of a piston rod which is connected at its opposite end to a piston 22. The piston 22 is movably mounted within a chamber of a housing 23 which is formed integrally with the discharge conduit 10 of the compressor. 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 cause the needle valve to cut off the flow through the vent 17, and the compression spring 24 urging the piston in a direction which would cause the needle valve to close the vent 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 a 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 right, as viewed in Figure 1, the needle valve 21 will tend to close the escape passage through the vent 17, thereby reducing or preventing entirely the escape of fluid and permitting the build-up of pressure in the chamber of the actuator 15 to open the relief valve 14.

To avoid an unduly large travel of the needle 21 in the vent 17 and a consequent waste of air, a pressure regulator 19 and a restricted orifice 20 are interposed in the conduit 16 between the discharge line 10 and the vent opening 17. Incidentally, it should be apparent that the needle valve may be applied at the orifice 20.

The position of the piston 22 is determined by the difference in pressure in the chambers 30 and 31. The chamber 30 communicates with the interior of the piston housing to the left of the piston 22 through an opening 30a, and the chamber 31 communicates with the interior of the piston housing to the right of the piston 22 through an opening 31a.

The chamber 30 communicates with the discharge line 10 of the compressor via an opening 32, and the flow into the chamber through the opening 32 is controlled by an inlet check valve 33 normally urged by a compression

spring 34 to closed position. The chamber 30 is also provided with a bleed opening 36 to the conduit 10, which bleed opening 36 is considerably smaller than the opening 32.

The chamber 31 communicates with the discharge line 10 of the compressor through an opening 38, and the flow out of the chamber through the opening 38 is controlled by an outlet check valve 39 normally urged by means of a compression spring 40 to closed position. The chamber 31 is also provided with a bleed opening 42, the size of which is very small in comparison to the size of the opening 38.

During normal operating conditions of the compressor, the bleed openings 36 and 42 will insure equal pressures in the chambers 30 and 31, and the needle valve 21 will be so adjusted in relation to the vent opening 17 that sufficient pressure will not be transmitted to the diaphragm of the actuator 15 to open the relief valve 14. Preferably during normal operating conditions, the inlet and discharge check valves 33, 39, respectively, will be closed. Obviously, gradual variations in pressure in the discharge line 10 of the compressor will not affect the movement of the piston 22 because the pressure within the chambers 30 and 31 will be equalized by the passage of fluid into or out of the chambers via the bleed openings. In the event of a sudden pressure increase, however, the inlet check valve 33 will be opened, permitting the pressure to build up in the chamber 30 at a faster rate than it is permitted to build up in the chamber 31, with the result that the piston 22 will be moved to the right as viewed in the drawing. As explained above, the movement of the piston to the right will cause the needle valve to close the vent opening 17 so that the actuator 15 will be operative to open the relief valve 14 by an amount proportional to the pressure in the discharge line 10.

Likewise, in the event of a sudden decrease in pressure in the discharge line 10, the outlet check valve 39 will be opened to permit the pressure in the chamber 31 to decrease at a more rapid rate than the pressure in the chamber 30, with the result that the relief valve 14 will be opened to relieve the pressure in the discharge line 10. Of course, when normal operating conditions are resumed, that is to say, as soon as the pressures in the chambers 30 and 31 are equalized, the valve 14 will be automatically closed.

It is, of course, necessary that the response time of the check valves 33, 39 be of much shorter duration than the bleed-off time through the openings 36, 42. The bleed-off time should preferably be at least four to eight times the variation frequency of the pressure in the discharge line 10 as the surge condition is approached, and the filling time of the chamber 30 and the evacuation time of the chamber 31 should be at most two or three cycles of the variation frequency of the pressure in the discharge line 10 of the compressor.

As an alternative embodiment, provision may be made for controlling the speed of the engine A driving the compressor. Accordingly, a valve 50 is provided in the manifold 51 of the engine, and the valve is adapted to be controlled by a pressure responsive actuator 52. The actuator 52 has a flexible diaphragm 53 which is connected to the valve 50 by a mechanical linkage 54. A chamber 55 is defined within the actuator on one side of the diaphragm, and the chamber 55 is in communication with the pressure chamber of the actuator 15 via a conduit 56. A spring 57, lighter than the spring 15c, also acts upon the diaphragm to maintain the valve 50 open. In this embodiment, in the event of a surge condition, the valve 50 will be closed to reduce the speed of the engine before the actuator 15 is operative to open the valve 14 to dump the fluid via the relief line 12.

Instead of dumping the fluid relieved from the con-

duit 10 to atmosphere or to a storage tank, as described above, this fluid can be used in whole or in part to increase the safe operating range of the compressor or to reduce the amount of fluid which must be relieved in the conduit 10 to prevent damage to the system by the surge condition. Toward this end, the opposite end of the conduit 12 communicates with the suction or intake conduit 13 of the compressor, and means is provided to introduce fluid flowing through this by-pass into the conduit 13 in a rotary or swirling motion, which motion is in the same direction as the rotation of the rotor of the compressor. The fluid is introduced into the intake or suction conduit by a more or less radially disposed perforated pipe 60 which communicates with the by-pass conduit 12. The pipe 60 contains a series of openings 61 therein which direct the fluid into the conduit 13 in a swirling motion, thereby imposing a swirling motion on the fluid to be compressed. In addition to the other advantages stated above, this by-pass also has the effect of appreciably reducing the horsepower requirements of the compressor when the surge sensing device calls for a full opening of the surge relief valve 14.

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

I claim:

A centrifugal compressor and surge control system therefor comprising a rotor, a housing for the rotor, an axial intake passage for supplying fluid to the housing in the direction of the axis of the rotor, a tangential discharge passage through which fluid under pressure is discharged from the housing, a conduit connecting the discharge and intake passages, a normally closed relief valve in the said conduit, a valve control member movable in response to a differential pressure acting thereon to open the valve, a pair of chambers in communication with the discharge passage, the pressures therein exerting forces in different directions on said valve control member, a restricted passage connecting each of the chambers with the discharge passage, whereby gradual changes in the fluid pressure tend to equalize the pressures in said chambers, a larger passage connecting at least one of the chambers with the pressure to be controlled, a normally closed one-way valve associated with said passage so as to open in the event of a sudden pressure variation, producing a differential pressure on said valve control member to displace it and open the normally closed relief valve, and a port in said axial intake passage for introducing fluid from the discharge passage through the said conduit when the relief valve is open into the axial intake passage tangentially to produce a swirling motion in the same general direction as the direction of rotation of the rotor, thereby to pre-swirl the intake fluid and increase the safe operating range of the compressor.

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