

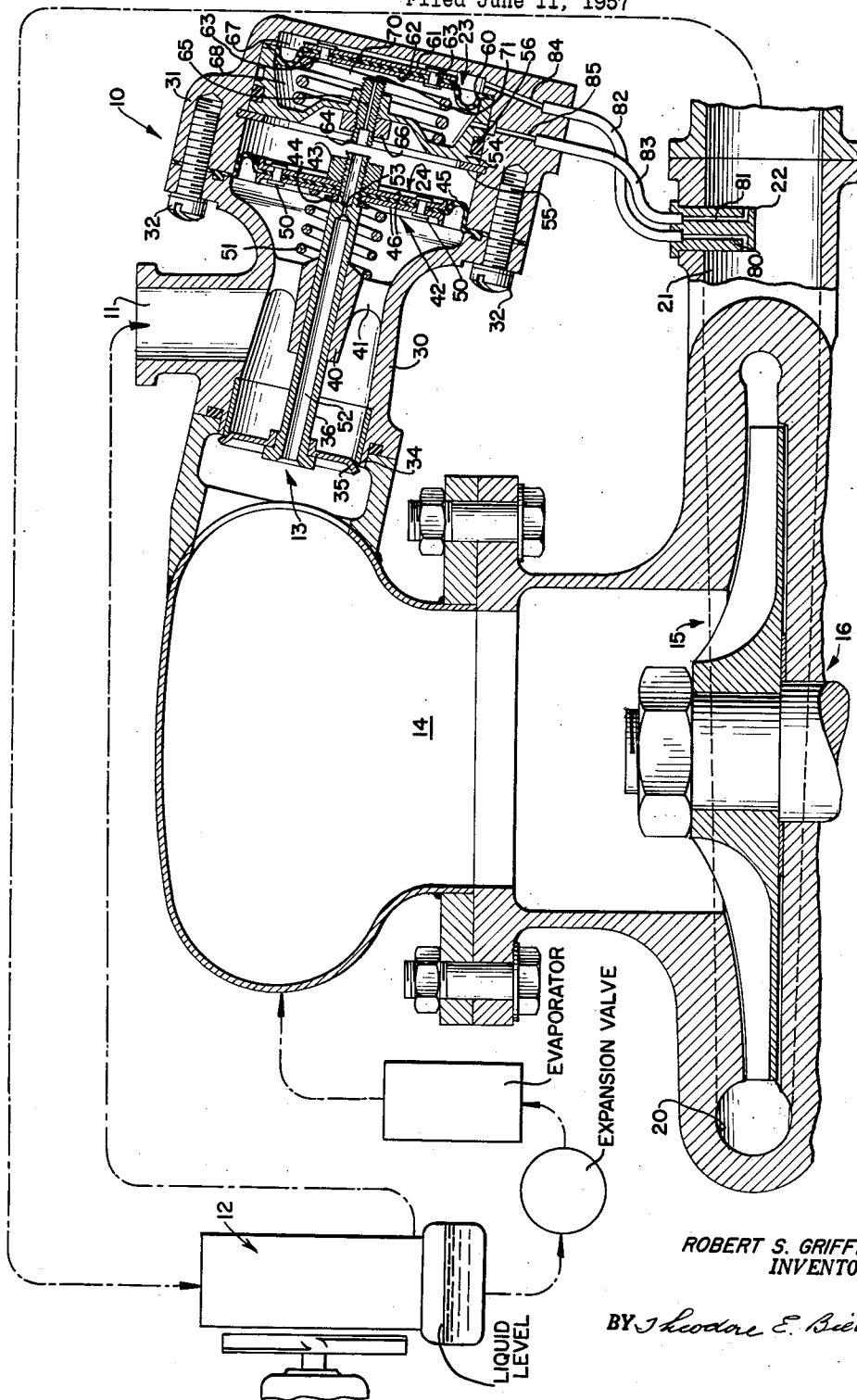
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SURGE CONTROL DEVICE FOR CENTRIFUGAL COMPRESSORS

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SURGE CONTROL DEVICE FOR CENTRIFUGAL COMPRESSORS

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This invention pertains to centrifugal compressors, and more particularly to a surge controlling device for a centrifugal compressor.

Some centrifugal compressors have a tendency to surge or hunt when operating under low load conditions. The surging or hunting of a centrifugal compressor manifests itself in a backflow of fluid into the compressor impeller and adversely affects the efficient operation of the unit, and in extreme conditions, may actually damage the compressor.

This invention would solve the above problems by providing a by-pass valve to by-pass a portion of the compressor flow from the discharge side back to the inlet side to increase the load on the compressor when the compressor tends to surge, and thus prevent surging. The by-pass valve is operated by a pneumatic actuator which is responsive to two pressures which indicate the rate of flow from the discharge of the compressor. Thus, the by-pass valve may maintain a predetermined minimum rate of flow through the compressor regardless of the actual load on the compressor. The maintaining of a predetermined minimum rate of flow through the compressor eliminates any tendency of the compressor to surge or hunt.

Accordingly, it is the principal object of this invention to provide a novel by-pass valve for a centrifugal compressor which is operated so as to maintain a minimum flow through the compressor.

Another object of this invention is to provide a novel design for a by-pass valve in which the by-pass valve, the actuator used for positioning the by-pass valve, and the control valve which controls the admission of fluid to the actuator are all mounted in a common housing.

Still another object of this invention is to provide a unique by-pass valve which is operated by a single-ended actuator which, in turn, is operated by the fluid being circulated by the compressor.

These and other objects and advantages of this invention will be more apparent to those skilled in the art from the following detailed description of a preferred embodiment when taken in conjunction with the accompanying drawing showing:

A by-pass valve constructed according to this invention installed on a centrifugal compressor designed to handle vapor cycle refrigerants.

Referring to the drawing, there is shown, incorporated in a conventional vapor cycle refrigeration system consisting of a compressor, a condenser, an expansion valve and an evaporator, a by-pass valve 10 having an inlet 11 connected, by way of illustration, to the refrigeration system near the bottom, but above the liquid refrigerant level, of the condenser 12. It is to be understood, however, that the by-pass valve would operate effectively to prevent surge if the inlet 11 were connected to the discharge conduit of the compressor upstream of the condenser. The outlet 13 of the by-pass valve is connected by means of a short tubular section to the inlet conduit 14 of the compressor 16. The inlet conduit 14 is aligned with the inlet eye 15 of the compressor which draws fluid in through the inlet eye, and, in this case, (for a centrifugal compressor) discharges it radially outward into the scroll-shaped chamber 20. From the scroll-

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shaped chamber the fluid flows through the discharge conduit 21 of the compressor to the condenser 12 of the refrigeration system. Mounted in the discharge conduit 21 of the compressor is a sensing probe 22 which senses two pressures whose difference is a measure of the rate of flow through the discharge 21. The two pressures sensed by the probe 22 are applied to the opposite sides of the diaphragm which operates the flow control or pilot valve 23. The flow control valve 23, in turn, controls the amount of pressurized fluid admitted to the actuator 24 which is used to position the by-pass valve 10.

The by-pass valve has a tubular-shaped valve body formed from a tubular section 30 which is secured to an end cover 31 by means of a plurality of circumferentially spaced cap screws 32. A valve seat insert is positioned in the outlet or open end of the tubular section 30 of the valve body and has a valve seat 34 form on its extreme end. A valve disc 35 is disposed so as to engage the valve seat 34 and is provided with a valve stem 36 which extends through a valve stem guide 40 located centrally in the tubular section 30. The valve disc 35 and the valve stem 36 may be formed as a single piece unit or may be formed of separate pieces which are fastened together to form a unitary structure. The valve stem guide 40 is supported by a plurality of circumferentially spaced radial webs 41 extending from the inner surface of the tubular section 30. The inlet opening 11 of the by-pass valve is formed in the wall of the tubular section 30.

The right-hand end of the valve stem 36 is secured to a diaphragm assembly 42 by means of a nut 43 which threads over the end of the valve stem. The nut 43 secures the diaphragm assembly against a washer 44 which bears against a shoulder formed on the end of the valve stem 36. The diaphragm assembly consists of a diaphragm 45, the outer edges of which are secured between the mating flanges of the tubular section 30 and top cover 31 and two diaphragm support plates 46 which are fastened together by any desired means such as a plurality of circumferentially spaced rivets 50. A compression spring 51 is mounted on the left-hand side of the diaphragm assembly 42 and reacts against the radial webs 41 to force the diaphragm assembly to the right to close the by-pass valve. A passageway 52 is formed in the center of the valve stem 36 to connect the right side of the diaphragm assembly 42 with the inlet of the compressor. A portion of the passageway 52 is reduced in size to form a flow control orifice means 53.

The above described construction thus provides a poppet type by-pass valve which is positioned or controlled by means of a single-ended fluid operated actuator. The actuator is spring biased in a direction to close the poppet valve and is opened by admitting pressurized fluid from the discharge of the compressor to the right-hand side of the diaphragm assembly 42, as will be described below.

A closed chamber is formed in the end cover 31 of the valve body by means of a rigid radial wall 54 which is retained in position by means of a snap ring 55 which fits in a cooperating groove formed on the inner surface of the end cover 31. The outer surface of the radial wall is sealed to the inner surface of the end cover by means of an O-ring 56 which fits in a cooperating groove formed on the outer surface of the radial wall. The closed chamber is divided into two separate sections 67 and 68 by a second diaphragm 60, the outer edge of which is retained between the end of the radial wall 54 and a shoulder formed on the end cover 31. The center portion of the diaphragm 60 is retained between two diaphragm plates 61 and 62 which are fastened together by means of a plurality of circumferentially spaced rivets 63. The diaphragm plate 62, in addition, acts as a valve to open and close the end of a passageway 65 formed in

a tubular member 64, as will be explained more fully below. A light compression spring 70 is mounted in the left section 68 of the closed chamber and reacts against the radial wall 54 to urge the diaphragm 60 to the right.

The tubular member 64 threads into a central opening in the radial wall 54 and is locked in position by means of a locking nut 66 which threads over the left-hand end of the tubular member 64. The tubular member 64 is provided with a restricted passageway 65 in its center which acts as a flow control orifice. The position of the tubular member is adjusted so that its right-hand end 71 is slightly spaced from the diaphragm plate 62 under normal operating conditions, as will be explained more fully below.

Two passageways 80 and 81 are formed in the pressure sensing probe 22. The ends of the passageways 80 and 81 are turned at right angles to the main axis of the probe so that the open end of passageway 80 faces in the opposite direction of the flow through the discharge 21 while the open end of the passageway 81 faces in the same direction as the flow through the discharge 21. The passageway 81 could alternately be turned at right angles to the passage 80 so that it senses only the static pressure in the discharge conduit 21. The fluid pressure sensed by the open ends of the passageways 80 and 81 are supplied to the two sections 67 and 68 of the closed chamber by means of tubes 82 and 83, respectively. The tubes 82 and 83 are connected to passageways 84 and 85 formed in the end cover 31 of the by-pass valve and opening into the two sections 67 and 68, respectively.

When the compressor of the above invention is operated, it will draw fluid through the inlet opening 14 and discharge it radially outward into the scroll-shaped chamber 20. From the scroll-shaped chamber 20, the fluid flows out the discharge 21 to the condenser 12. When the compressed fluid flows by the sensing probe 22, the passageway 80 will sense a fluid pressure equal to the discharge pressure plus a portion of the velocity head, while the passageway 81 will sense a pressure equal to the discharge pressure minus a portion of the velocity head. Thus, under normal operating conditions, the passageway 80 will sense a fluid pressure which exceeds the pressure sensed by the passageway 81. The higher pressure of the two pressures is applied to the right-hand surface of the diaphragm 60, thus urging it towards the left so that the plate 62 will close the end 71 of the passageway 65 formed in the tubular member 64. When the passageway 65 is closed, no fluid pressure can flow through the passageway 65 into the chamber formed by the diaphragm 45 and the radial wall 54. Any small amount of pressurized fluid which leaks through the passageway 65 will quickly be vented by the passageway 52 formed in the valve stem 36, hence the pressure in the chamber formed by the diaphragm 45 and the radial wall 54 will be close to that of the compressor inlet. Thus, under normal operating conditions, the spring 51 will hold the valve disc 35 in contact with the valve seat 34 to prevent any flow from the condenser 12 back to the suction inlet 14 of the compressor.

It is to be noted that the pilot valve 23 is actuated in response to small changes in differential pressure to admit pressurized fluid to the right-hand side of diaphragm assembly 42. However, the admission of fluid pressure into the chamber formed by the diaphragm 45 and the radial wall 54 creates a comparatively large differential across the diaphragm assembly 42 as the pressure of the fluid acting on the valve disc 35 cancels the pressure of the fluid acting on an equal area of the left-hand side of the diaphragm assembly 42. Thus a small change in the differential in the pressures in passageways 80 and 81 will produce a comparatively large force to positively actuate the valve disc 35.

When the flow through the discharge 21 of the compressor is reduced, which would signal the approach to compressor surge conditions, the fluid pressures sensed

by the open ends of the passageways 80 and 81 will be closer to equality. When the flow through the compressor discharge 21 tends to fall below the predetermined minimum flow for which the by-pass valve 10 is set, the spring 70 will lift the diaphragm 60 and plate 62 from the end 71 of the tubular member 64 to open the passageway 65. Pressurized fluid from the compressor discharge will then flow into the chamber formed by the diaphragm 45 and the radial wall 54. When the pressure of the fluid acting on the right-hand side of the diaphragm 45 is sufficient to overcome the force of the spring 51 and the net pressure of the fluid acting on the left-hand side of the diaphragm the valve disc 35 will be lifted off the valve seat 34, thus opening the by-pass valve to by-pass fluid directly from the condenser 12 back to the suction inlet 14 of the compressor. As long as the flow of fluid through the discharge conduit 21 tends to fall below the predetermined set minimum the valve disc 35 will modulate and the additional fluid which is added to the amount being circulated by the compressor will prevent the flow through the discharge 21 from decreasing below the predetermined minimum and thus eliminate any tendency of the compressor to surge. When the flow through the discharge 21 exceeds the predetermined minimum, the pressure sensed from the passageways 80 and 81 is sufficiently unbalanced so that the diaphragm 60 will be forced to the left and the plate 62 will close off the end of the restricted passageway 65 in the tubular member 64 and the valve 35 will close.

The restricted passageway 65 should be of sufficient size so that when it is uncovered it can admit more fluid into the chamber formed by the diaphragm 45 and the radial wall 54 than can be vented through the flow control orifice 53 in the passageway 52. Also, the force of the spring 70 should be chosen so that it will maintain the predetermined minimum flow through the discharge 21 of the compressor. The minimum flow through the compressor may also be varied by adjusting the position of the tubular member 64 in relation to the diaphragm plate 62. The maintaining of a predetermined minimum flow through the discharge 21 will eliminate any tendency of the compressor to surge. In addition to the above features, the by-pass valve of this invention utilizes the pressure of the fluid being circulated by the compressor to operate the actuator which is used to position the by-pass valve. This eliminates the need for separate sources of pressurized fluid for operating the valve. Also, all of the operating members of the by-pass valve are mounted on a common axis in a unitary housing which results in a simple and compact structure.

While the above description relates to the preferred embodiment of this invention, various modifications and improvements can be made without departing from its broad spirit and scope.

I claim:

1. A surge control device comprising: a by-pass valve including a tubular valve body having an inlet connection for by-pass fluid, said tubular valve body being closed at one end and open at the other end; a valve member in the open end of said tubular valve body arranged to control flow of by-pass fluid through said by-pass valve; a first diaphragm having its peripheral portion attached to the sides of said tubular valve body; a valve stem fastened at one end to said valve member and extending into said tubular valve body, the other end of said valve stem being secured to said first diaphragm; a restricted passageway formed in said valve stem and connecting one side of said first diaphragm with a zone of lower pressure; a first spring disposed in said tubular valve body to urge said first diaphragm in a direction to close said valve member; a rigid wall mounted in said tubular valve body parallel to and axially spaced from said first diaphragm to form a first chamber, said diaphragm being arranged to exclude by-pass fluid from said first chamber, said rigid wall in combination with the closed end of said

tubular valve body forming a second chamber; a second diaphragm having its peripheral portion attached to the sides of said valve body and dividing said second chamber into two sections; a valve seat formed on said rigid wall, said valve seat having passage means including a restricted opening to permit fluid communication between one of said sections and said first chamber, one end of said passage means being located adjacent one surface of said second diaphragm; a second spring disposed in said second chamber to urge said second diaphragm away from the said one end of said passage means; means adapted to sense a first fluid pressure and a second fluid pressure; and conduit means for connecting said first and second fluid pressures to the opposite sections of said second chamber, said second diaphragm modulating in response to the forces acting on opposite sides thereof so that one side of said second diaphragm coacts with said valve seat to open and close the passage means, thereby controlling the flow of said sensed fluid through said restricted opening into said first chamber to operate said valve member.

2. A surge control device comprising: a by-pass valve including a tubular valve body having an inlet connection for by-pass fluid, said tubular valve body being closed at one end and open at the other end; a valve member in the open end of said tubular valve body arranged to control flow of by-pass fluid through said by-pass valve; a first diaphragm having its peripheral portion attached to the sides of said tubular valve body; a valve stem fastened at one end to said valve member and extending into said tubular valve body, the other end of said valve stem being secured to said first diaphragm; a restricted passageway formed in said valve stem and connecting one side of said first diaphragm with a zone of lower pressure; a first spring disposed in said tubular valve body to urge said first diaphragm in a direction to close said valve member; a rigid wall mounted in said tubular valve body parallel to and axially spaced from said first diaphragm to form a first chamber, said diaphragm being arranged to exclude by-pass fluid from said first chamber, said rigid wall in combination with the closed end of said tubular valve body forming a second chamber; a second diaphragm having its peripheral portion attached to the sides of said valve body and dividing said second chamber into a first section and a second section; a tube extending through the rigid wall and terminating in the first section; a restricted passageway through the tube communicating between the first section and the first chamber; a second spring disposed in the second chamber to urge said second diaphragm away from the end of said tube; means for adjusting the tube longitudinally relative to the rigid wall; means adapted to sense a first fluid pressure and a second fluid pressure; and conduit means for connecting said first and second fluid pressures to the opposite sections of said second chamber, said second diaphragm modulating in response to the forces acting on opposite sides thereof so that one side of said second diaphragm coacts with the end of said tube to open and close the passageway therethrough, thereby controlling the flow of sensed fluid into said first chamber to operate said valve member.

3. A surge control device comprising: a by-pass valve including a tubular valve body having an inlet connection for by-pass fluid, said tubular valve body being closed at

one end by a cap and open at the other end; said valve body and said cap forming a joint therebetween; a valve member in the open end of said tubular valve body arranged to control flow of by-pass fluid through said by-pass valve; a first diaphragm having its peripheral portion clamped in the joint between the cap and said tubular valve body; a valve stem fastened at one end to said valve member and extending into said tubular valve body, the other end of said valve stem being secured to said first diaphragm; a restricted passageway formed in said valve stem and connecting one side of said first diaphragm with a zone of lower pressure; a first spring disposed in said tubular valve body to urge said first diaphragm in a direction to close said valve member; said cap having an internal bore closed at one end by an end wall portion of the cap; a rigid wall in said bore parallel to and axially spaced from said first diaphragm to form a first chamber, said diaphragm being arranged to exclude by-pass fluid from said first chamber, said rigid wall in combination with the end wall of said cap forming a second chamber; a second diaphragm having its peripheral portion clamped between the rigid wall and said end wall and dividing said second chamber into a first section and a second section; means securing the rigid wall in position in said bore; a tube extending through the rigid wall and terminating in the first section; a restricted passageway through the tube communicating between the first section and the first chamber; a second spring disposed in the second chamber to urge said second diaphragm away from the end of said tube; means for adjusting the tube longitudinally relative to the rigid wall; means adapted to sense a first fluid pressure and a second fluid pressure; and conduit means for connecting said first and second fluid pressures to the opposite sections of said second chamber, said second diaphragm modulating in response to the forces acting on opposite sides thereof so that one side of said second diaphragm coacts with the end of said tube to open and close the passageway therethrough, thereby controlling the flow of sensed fluid into said first chamber to operate said valve member.

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