

Feb. 11, 1969

D. H. SILVERN
COMPRESSOR APPARATUS

3,426,964

Filed Oct. 11, 1966

Sheet 1 of 2

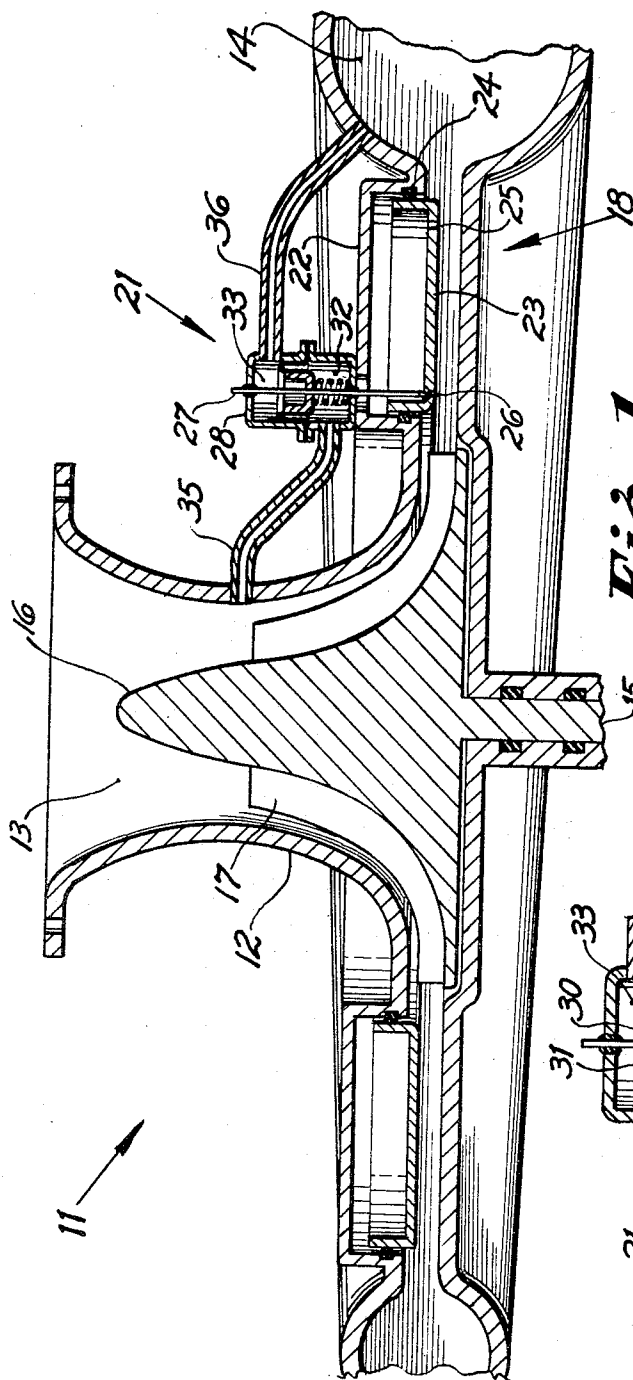


Fig. 1.

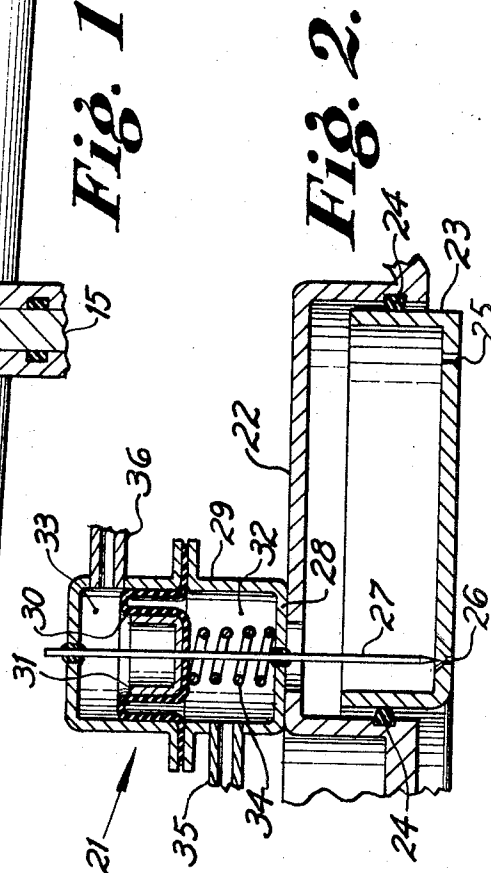


Fig. 2.

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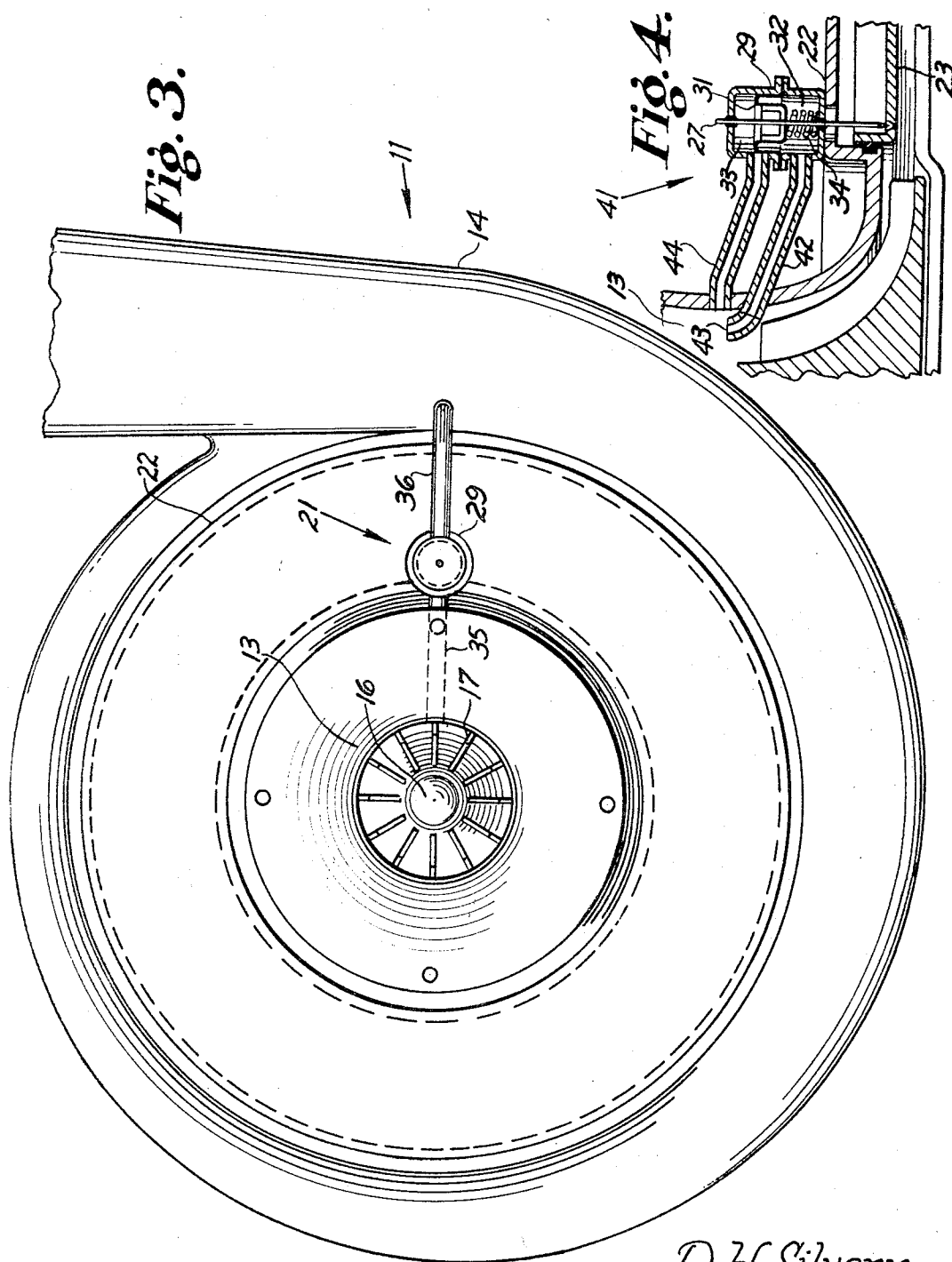
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COMPRESSOR APPARATUS

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21 Claims

ABSTRACT OF THE DISCLOSURE

A centrifugal compressor includes a vaneless diffuser having a movable wall defined by an annular piston in an annular cylinder chamber. The cylinder chamber communicates with regions of different pressure in the diffuser through two radially spaced apertures in the piston. Flow through one aperture is controlled by a needle valve which is secured to a diaphragm exposed to compressor inlet pressure on one side and compressor discharge pressure on the other side. The diaphragm is moved by changes in the relative differential pressures to control the flow through the one of the piston apertures and therefore control the pressure within the annular cylinder and the position of the movable wall. In an alternative arrangement, the pressures acting on the opposite sides of the diaphragm are the inlet static pressure and inlet dynamic pressure respectively.

This invention relates generally to compressors and more particularly to apparatus for eliminating pulsation in centrifugal compressors.

Surge or pulsation is an unstable operating condition of centrifugal compressors. Typically, surge operation occurs when the flow rate in the compressor has been reduced to some value below the designed operating point of the machine either by throttling the inlet or outlet thereof. Flow in both the impeller and diffuser becomes separated from the wall along the entire length of the flow passage and a momentary flow reversal occurs that tends to reduce discharge line pressure which has become greater than the head produced by the compressor. As the discharge line pressure is reduced, stable flow is resumed and discharge line pressure is re-established. However, if the flow rate again falls below the surge point, line flow is again interrupted and the flow reversal repeated. The surge frequency is inversely proportional to the volume of the discharge system with large discharge systems producing low frequency surges of high intensity and low discharge volume systems producing high frequency surges of relatively low intensity. The intensity of the surge can vary from a level which causes an audible rattle to one which produces a violent shock that can be destructive to the labyrinth seals and impeller blading. Extremely severe surges can even produce bending of the rotor shaft.

Many methods and structures have been devised in attempts to reduce or eliminate surge conditions. These include, for example, reducing the backward slope of the impellers, utilizing adjustable inlet guide vanes, connecting check valves in the compressor discharge, throttling the suction valve, etc. Also known for use with large centrifugal compressors are flow control systems which maintain the inlet volume in excess of the surge.

The above surge control methods are primarily applicable to constant-speed compressors. For variable speed compressors, the simplest and most efficient method of surge prevention entails the use of devices which reduce rotational speed. Although most such prior methods have been somewhat effective in controlling surge, they also have exhibited undesirable traits such as

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requiring external sources of power, limiting useful applications of a given compressor, reducing efficiency, etc.

The object of this invention, therefore, is to provide a centrifugal compressor with an improved method for eliminating the occurrence of surge operation.

A primary feature of this invention is the provision, in a centrifugal compressor having a diffuser, of an adjustment mechanism actuated by the gases flowing through the diffuser so as to vary its cross-sectional area and prevent the occurrence of surge operation.

Another feature of this invention is the provision of a centrifugal compressor of the above featured type wherein the adjustment mechanism includes a piston assembly adapted for movement into the volume defined by the diffuser and an associated cylinder which receives pneumatic pressure from the air flow through the diffuser.

Another feature of this invention is the provision of a centrifugal compressor of the above featured types wherein gas communication between the cylinder and diffuser is provided by apertures located in the piston and spaced apart in the direction of gas flow through the diffuser so as to lie in different pressure regions and including a needle valve adapted for movement into one of the apertures so as to vary their relative gas conductivity.

Another feature of this invention is the provision of a centrifugal compressor of the above featured types wherein the needle valve is controlled by a flexible membrane which divides first and second pressure chambers of a control housing and actuates the valve in response to changes in the differential pressure between the pressure chambers.

Another feature of this invention is the provision of a centrifugal compressor of the above featured types wherein the first and second pressure chambers are connected for gas communication with regions of the compressor which normally operate at different pressures.

Another feature of this invention is the provision of a centrifugal compressor of the above featured type wherein the first and second pressure chambers are connected for gas communication with the compressor inlet and discharge so as to render the needle valve responsive to changes in difference between compressor inlet and discharge pressures.

Another feature of this invention is the provision of a centrifugal compressor of the next above featured type wherein the first pressure chamber is connected for gas communication with a device which senses the compressor's static inlet pressure and the second pressure chamber is connected to a pressure sensing device which measures both the static and kinetic energy pressures at the compressor inlet thereby rendering the needle valve responsive to changes in dynamic pressure at the compressor inlet.

These and other features and objects of the present invention will become more apparent upon a perusal of the following specification taken in conjunction with the accompanying drawings wherein:

FIG. 1 is a partial cross-sectional view of a preferred compressor embodiment of the present invention;

FIG. 2 is an enlarged cross-section of the adjustment mechanism shown in FIG. 1;

FIG. 3 is a partial plan view of the compressor shown in FIG. 1; and

FIG. 4 is an enlarged partial cross-section illustrating a modified control arrangement for the adjustment mechanism shown in FIG. 1.

Referring now to FIGS. 1-3, there is shown the centrifugal compressor 11 having the compressor casing 12 which defines a compression chamber between the flanged inlet 13 and the discharge chamber 14. Positioned within the casing 12 adjacent the inlet 13 and mounted for rota-

tion with the shaft 15 is the centrifugal blower impeller 16 having blades 17 adapted to drive air downwardly and outwardly from the inlet 13, as viewed in FIG. 1. Surrounding the impeller 16 is the annular vaneless diffuser 18 which directs air from the impeller into the discharge chamber 14.

The adjustment mechanism 21 includes the annular cylinder 22 and the associated annular piston 23 mounted for movement within the cylinder 22 and into the volume enclosed by the diffuser 18. Inner and outer circumferential seals between the inner surface of the cylinder 22 and the outer surface of the piston 23 are provided by the circular O-ring gaskets 24. Gas communication between the diffuser 18 and cylinder 22 is made possible by the apertures 25 and 26 located in the end of the piston 23 and spaced apart in the direction of gas flow so as to lie in regions of different pressure during compressor operation. Projecting into the aperture 26 is the end of the needle valve stem 27 which is mounted for reciprocative movement in the end walls 28 of the control housing 29. The mid-portion of the valve stem 27 extends through openings in and is attached for movement with the flexible roll membrane 30 and associated cup-shaped piston 31 which separate the first and second pressure chambers 32 and 33 of the control housing 29. Upward biasing of the piston 31 is produced by the compression spring 34 supported from the housing end wall 28.

The pressure line 35 allows gas conductance between the compressor inlet 13 and the first pressure chamber 32 so as to establish static compressor inlet pressure therein and the pressure line 36 establishes static compressor discharge pressure in the second pressure chamber 33. Thus, the flexibly supported piston 31 and attached valve stem 27 will move in response to changes in the difference between the compressor's static inlet and discharge pressures.

During operation of the compressor 11, centrifugal action of the impeller blades 17 drives air from the compressor inlet 13 downwardly and outwardly (as viewed in FIG. 1) into the vaneless diffuser 18. With a normal flow rate, the pre-selected relative conductivities of the apertures 25 and 26 are such as to develop within the cylinder 22 a gas pressure which is insufficient to produce movement of the diffuser piston 23 into the volume enclosed by the diffuser 18. These relative conductivities are, of course, created by selection of the aperture sizes and the spring constant of the biasing spring 34 which determines the position of the valve stem 27. However, upon a flow reduction which approaches surge conditions, the pressure increase in the discharge chamber 14 and connected pressure chamber 33 will cause downward movement of the piston cup 31 and attached valve stem 27. The resultant reduction in gas conductivity of the low pressure aperture 26 coupled with the constant conductivity of the high pressure aperture 25 will effect a pressure increase in the cylinder 22. This pressure increase will drive the piston 23 downwardly into the volume enclosed by the diffuser 18 until equilibrium is established between the various gas pressures and the force provided by the biasing spring 34. Because of the reduction in the diffuser's cross-sectional area, separation of gas flow from its walls and the associated surge are prevented. Similarly, a subsequent return to a normal flow rate will produce a pressure decrease in the discharge chamber 14 and connected pressure chamber 33 causing upward movement of the valve stem 27 to increase the gas conductivity of the low pressure aperture 26. The resultant pressure decrease within the cylinder 22 will permit retraction of the diffuser piston 23 thereby again exposing the full cross-sectional area of the diffuser 18.

Thus, with a suitable selection of control constants, the adjustment mechanism 21 will establish a correct diffuser cross-section for all compressor flows. In this way flow separation and surge operation are prevented. Furthermore, it will be appreciated that the valve stem 27 is controlled by difference between compressor inlet and dis-

charge pressures rather than by any absolute pressure. Accordingly, the compressor 11 can be utilized in any application regardless of the absolute pressures existing at the compressor inlet 13 and discharge 14.

FIG. 4 shows another invention embodiment which utilizes a modified adjustment mechanism 41 for controlling the position of the diffuser piston 23. The control housing 29 and associated valve stem 27 are identical to the similarly numbered elements in FIG. 1 and function in the same manner to regulate the pressure within the cylinder 22. However, in this embodiment the first pressure chamber 32 is connected by the pressure tube 42 to the Pitot tube 43 adapted to measure the dynamic pressure at the compressor inlet 13 and the second pressure chamber 33 is connected to the static pressure tube 44 adapted to sense the static pressure at the compressor inlet 13. Thus, the adjustment mechanism 41 will be responsive to the compressor's dynamic inlet pressure. Since flow velocity is directly related to dynamic pressure, the adjustment mechanism 41 again will control the cross-section of the diffuser 18 as described in connection with the embodiment of FIG. 1, but in dependence upon compressor flow velocity rather than upon static inlet and discharge pressure differential.

Obviously, many modifications and variations of the present invention are possible in light of the above teachings. For example only, diffuser area adjustment mechanisms other than the simple differential pressure devices shown in FIGS. 1 and 4 can be advantageously utilized. Such other mechanisms can include suitable pneumatic devices for measuring compressor volume flow or pressure ratio. Also, although a single stage compressor is illustrated for reasons of simplicity, it will be appreciated that the invention is suitable for use with multi-stage compressors. It is, therefore, to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described.

What is claimed is:

1. A compressor apparatus comprising
 - a casing defining a compression chamber, an inlet to said compression chamber, and a discharge chamber;
 - an impeller positioned within said compression chamber; a diffuser located within said compression chamber between said impeller and said discharge chamber;
 - means movable relative to said casing for varying the flow area of said diffuser; pressure responsive actuating means for moving said movable means; and means communicating said pressure responsive actuating means with the gas flowing through said diffuser.
2. A compressor apparatus according to claim 1 said movable means comprising an annular member defining a portion of one wall of said diffuser.
3. A compressor apparatus according to claim 1 and passage means providing gas communication between said diffuser and said pressure responsive actuating means.
4. A compressor apparatus according to claim 3 said passage means comprising at least two passages opening to said diffuser at positions spaced apart in the direction of gas flow through the diffuser.
5. A compressor apparatus according to claim 1 said movable means comprising an annular piston, received in an annular cylinder provided in said casing, and defining a portion of one wall of said diffuser; and said piston and cylinder defining said pressure responsive actuating means for moving said movable means.
6. A compressor apparatus according to claim 5 and passage means providing gas communication between said diffuser and said cylinder.
7. A compressor apparatus according to claim 6 said passage means comprising at least two passages through said piston, communicating said cylinder and said diffuser; and said passages opening to said

diffuser at positions spaced apart in the direction of gas flow through the diffuser.

8. A compressor apparatus according to claim 4 and control means for varying the gas conductivity of said passages. 5
9. A compressor apparatus according to claim 8 said control means further comprising a valve member disposed for movement relative to one of said passages to variably restrict the flow of gas therethrough. 5
10. A compressor as set forth in claim 9 said control means comprising a pressure responsive actuator for moving said valve member; said actuator defining opposed pressure surfaces communicating with first and second pressure chambers. 10
11. A compressor apparatus according to claim 10 passage means communicating said first pressure chamber with said compressor inlet; passage means communicating said second pressure chamber with said discharge chamber; and said control means being therefore responsive to the pressure difference between the inlet pressure and the discharge pressure of the compressor apparatus. 15
12. A compressor apparatus according to claim 10 passage means communicating said first pressure chamber with a static pressure sensing device positioned in said compressor inlet; passage means communicating said second control pressure chamber with a dynamic pressure sensing device positioned in said compressor inlet; and said control means being therefore responsive to the pressure difference between the inlet static pressure and the inlet dynamic pressure. 20
13. A compressor apparatus comprising a casing defining a compression chamber, an inlet to said compression chamber, and a discharge chamber; an impeller positioned within said compression chamber; a diffuser located within said compression chamber between said impeller and said discharge chamber; means movable relative to said casing for varying the flow area of said diffuser; differential pressure responsive control means for controlling the movement of said movable means; and passage means communicating said control means with at least two selected pressure points within said casing. 25
14. A compressor apparatus according to claim 13 said control means comprising an actuator defining opposed pressure surfaces communicating with first and second pressure chambers; and said passage means communicating said first and second pressure chambers with respective selected pressure points within said casing. 30
15. A compressor apparatus according to claim 14 a first of said passage means communicating said first pressure chamber with said compressor inlet; a second of said passage means communicating said second pressure chamber with said discharge cham- 35

ber; and said control means being therefore responsive to the pressure difference between the inlet pressure and the discharge pressure of the compressor apparatus.

16. A compressor apparatus according to claim 14 a first of said passage means communicating said first pressure chamber with a static pressure sensing device positioned in said compressor inlet; a second of said passage means communicating said second control pressure chamber with a dynamic pressure sensing device positioned in said compressor inlet; and said control means being responsive to the pressure difference between the inlet static pressure and the inlet dynamic pressure. 40
17. A compressor apparatus according to claim 13 said movable means comprising an annular member defining a portion of one wall of said diffuser. 45
18. A compressor apparatus according to claim 14 said movable means comprising an annular piston, received in an annular cylinder provided in said casing, and defining a portion of one wall of said diffuser and said control means controlling the flow of pressure fluid into and out of said cylinder. 50
19. A compressor apparatus according to claim 18 and passage means providing gas communication between said diffuser and said cylinder; said control means controlling the flow of gas through said passage means. 55
20. A compressor apparatus according to claim 19 said passage means communicating said cylinder and said diffuser comprising at least two passages opening to said diffuser at positions spaced apart in the direction of gas flow through the diffuser; and said control means controlling the flow of gas through one of said passages.
21. A compressor apparatus according to claim 20 said control means including a valve member movable relative to said one passage to variably restrict the flow of gas therethrough.

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