

Nov. 26, 1957

K. A. DARROW ET AL

2,814,431

COMPRESSOR

Filed Sept. 29, 1954

2 Sheets-Sheet 1

Fig. 1.

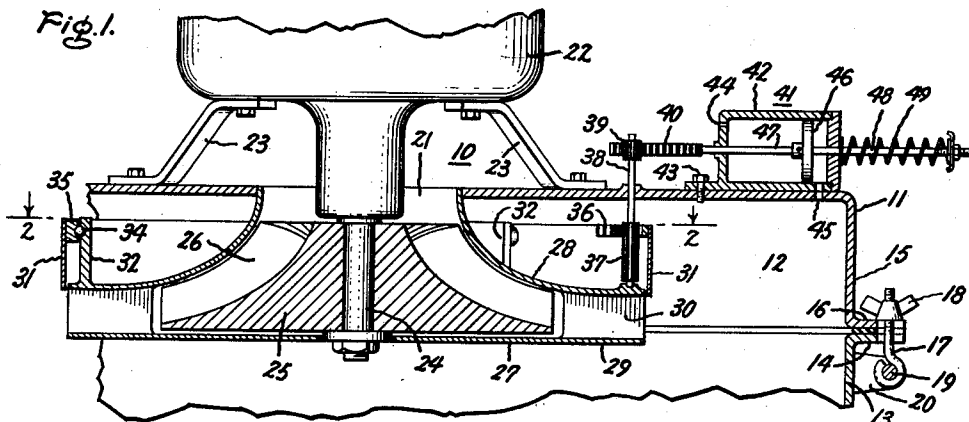


Fig. 2.

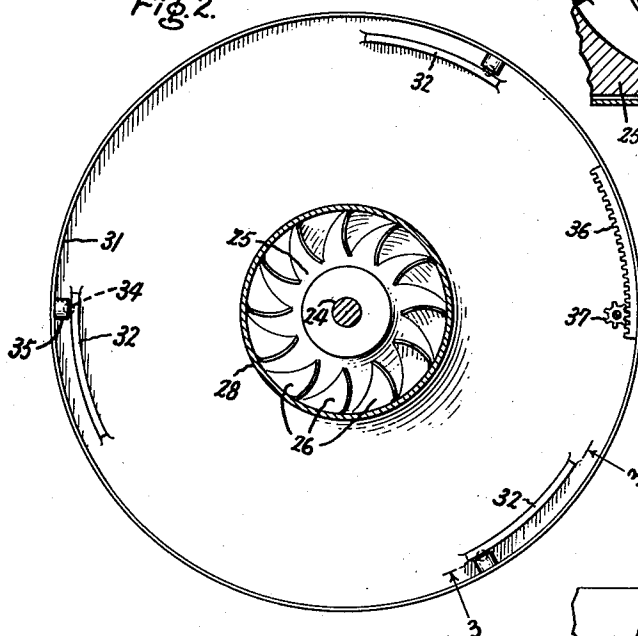


Fig. 5.

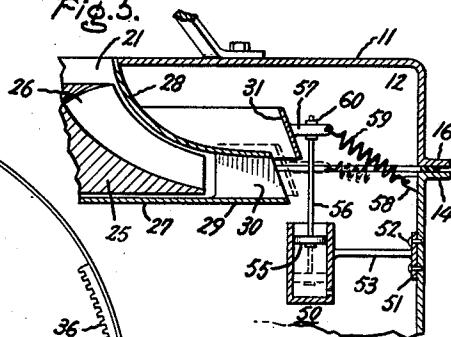


Fig. 6.

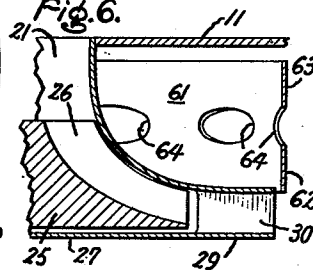


Fig. 3.

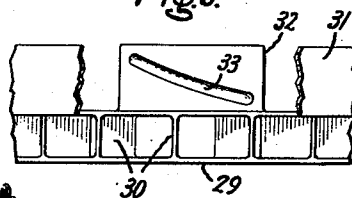
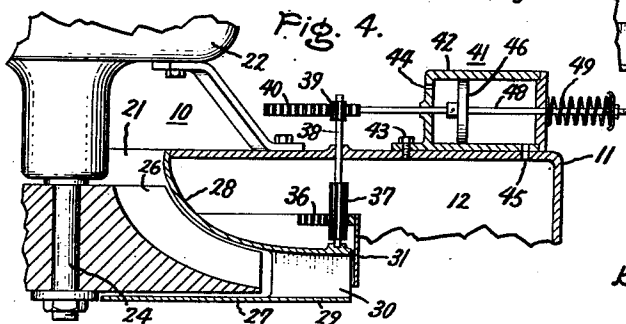


Fig. 4.



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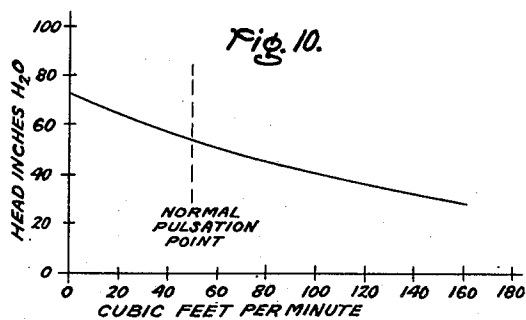
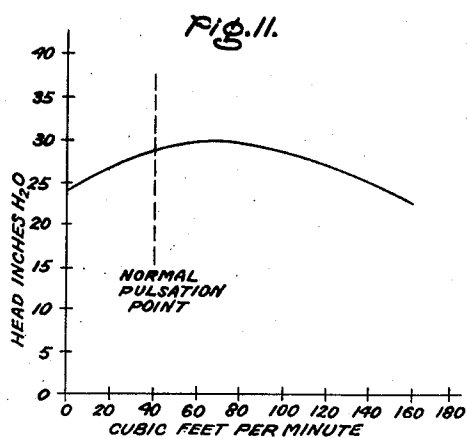
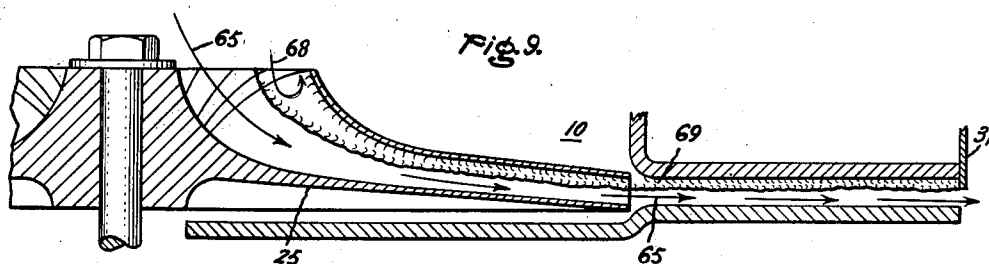
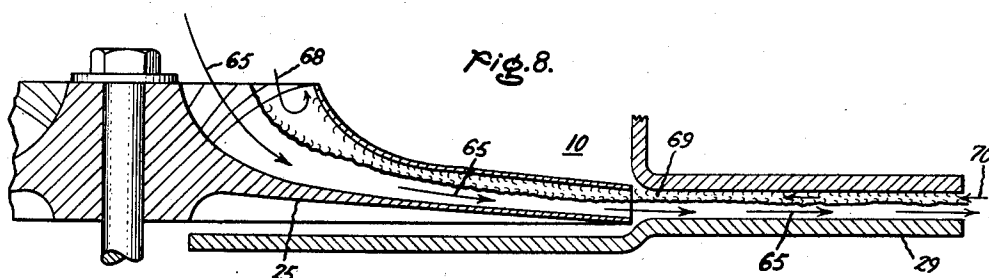
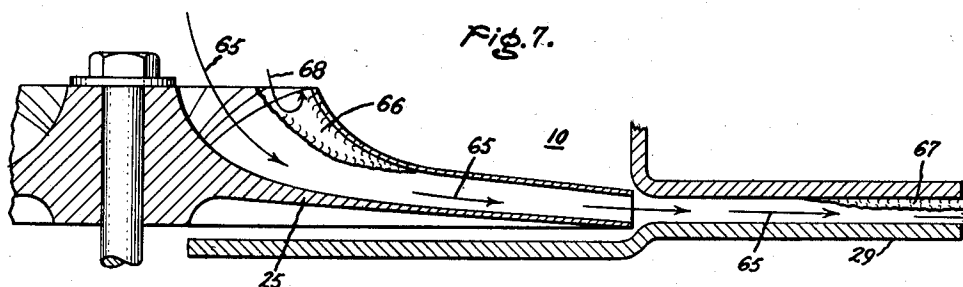
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2 Sheets-Sheet 2



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2,814,431

COMPRESSOR

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3 Claims. (Cl. 230—114)

This invention relates to compressors and more particularly to a method and apparatus for eliminating pulsation in such compressors.

Pulsation is a serious problem in centrifugal or axial flow compressors because it greatly reduces compressor performance at low flow rates and limits the minimum flow rate possible. Such pulsation 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 of the compressor becomes completely separated along the full length of the flow passages to produce pulsation. In large compressors, the pulsating vibrations may destroy the machine.

Accordingly, it is an object of our invention to provide a novel apparatus to eliminate compressor pulsation.

It is another object of the invention to provide an improved diffuser structure which will eliminate pulsation in the compressor.

It is another object of the invention to provide an improved compressor which has a longer, useful operating range.

It is another object of the invention to provide an improved compressor in which higher efficiencies are maintained at the low flow range near or below the normal pulsation point.

It is another object of the invention to provide an improved compressor in which power input is reduced at extremely high flows by throttling at the diffuser outlet.

It is another object of the invention to provide an improved compressor in which a stable non-pulsating flow is maintained from normal flow to zero flow conditions.

It is a further object of the invention to provide a novel method of eliminating pulsation in a compressor.

In carrying out our invention in one form, a ring or flow prevention member is positioned adjacent the periphery of the diffuser of the compressor to provide a correct diffuser outlet area for all compressor flows, and to block the flow separation area of the diffuser.

These and various other objects, features and advantages of the invention will be better understood from the following description taken in connection with the accompanying drawings in which:

Fig. 1 is a sectional view of a centrifugal compressor which embodies our invention;

Fig. 2 is a top plan view taken along lines 2—2 of Fig. 1;

Fig. 3 is a view taken along lines 3—3 of Fig. 2;

Fig. 4 is a sectional view similar to Fig. 1 with the ring member in a closed position;

Fig. 5 is a sectional view of a modified centrifugal compressor;

Fig. 6 is a sectional view of a modified centrifugal compressor;

Fig. 7 is a sectional view of a centrifugal compressor in which the fluid has partially separated from the walls;

Fig. 8 is a sectional view similar to Fig. 7 in which the fluid has completely separated from the walls;

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Fig. 9 is a sectional view similar to Fig. 8 in which a closure member is provided to block the low kinetic energy path;

Fig. 10 is a graph of compressor pressure rise plotted against fluid flow at variable speed; and

Fig. 11 is a graph of compressor pressure rise plotted against fluid flow at constant speed.

In Fig. 1 of the drawing, a centrifugal compressor, shown generally at 10, comprises a casing 11 to define a chamber 12 therein. Casing 11 comprises a lower wall portion 13 with an outwardly extending flange 14 at its upper end upon which an upper wall 15 is seated by means of an outwardly extending flange 16 at its lower end. Upper wall 15 is removably secured to lower wall 13 by any convenient means, such as, for example, a hook 17 with a wing nut 18 thereon. Hook 17 is pivotally mounted on a pin 19 which extends from a bracket 20 on the outer surface of wall 13.

An air inlet or aperture 21 is centrally disposed in upper wall 15. An electric motor 22 is preferably secured at the marginal edge of opening 21 and spaced therefrom by any suitable spacing elements 23. Motor 22 has a shaft 24 to project downwardly into chamber 12 on which is mounted a suitable centrifugal blower impeller 25 with a plurality of curved blades 26 thereon. Centrifugal action of impeller blades 26 drives air from inlet 21 downwardly and outwardly towards the inner wall of casing 11. Impeller 25 has a back plate or wall 27 and a forward wall 28 which extend laterally outwardly to form a diffuser 29 with a plurality of vanes 30.

A ring member 31, which is coaxial to and of slightly larger diameter than the outlet diameter of diffuser 29, is located adjacent the periphery of the diffuser. Ring 31 is maintained in position by three cams 32 which are mounted on the upper surface of wall 28. If it is desired, any number of cams could be employed. As it is best shown in Figs. 2 and 3, each of cams 32 is provided with an axial groove 33 in which a ball bearing 34 slides. Each ball bearing 34 is supported by a hemispherical oilite bearing 35 on the rear wall of ring 31. Ball bearings 34 move ring 31 both rotatably and in an axial direction to open and close the diffuser outlet.

Movement of ring 31 is controlled by a force multiplying or transmitting means such as a circular section of rack 36 on the rear wall thereof which meshes with a pinion 37 on the upper surface of wall 28. A shaft 38 connects pinion 37 to a pinion 39 outside of casing 11. Pinion 39 meshes with a rack 40 which is operated by a differential pressure control device 41. Control device 41 comprises a casing 42 which is secured to the outer surface of upper wall 15 by any suitable means, such as a bolt 43. Casing 42 is provided with apertures 44 and 45 which communicate with the atmosphere and chamber 12, respectively. A piston 46 is positioned within casing 42 to control rack 40 through a shaft 47. A shaft 48, which is connected to the opposite side of piston 46, is provided with a spring 49 to control the movement thereof.

In Fig. 4, centrifugal compressor 10 is shown with ring 31 in a partially closed position across the diffuser outlet. Such a position is attained when compressor 10 approaches zero flow condition to provide a small exit area which maintains high velocity flow from the diffuser outlet.

In the operation of centrifugal compressor 10, centrifugal action of impeller blades 26 drives air from inlet 21 downwardly and outwardly towards the inner wall of casing 11. Ring 31 remains in a position above the diffuser outlet until fluid begins to separate from the wall of diffuser 29. The increase in pressure in chamber 12 to move piston 46 outwardly within its casing 42 is produced by an increase in speed which results from un-

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loading impeller 26 with a decreased flow. Progressive separation of flow from the walls of impeller 26 and diffuser 29 is produced by this decreased flow which is seen from continuity considerations. Piston shaft 47 moves rack 40 to mesh with pinion 39 and turn pinion 37. Pinion 37 meshes with rack 36 to cause ring 31 to descend over the diffuser outlet. Such closure or partial flow blockage prevents fluid in diffuser 29 from separating completely from the wall thereof. As a decrease in pressure occurs in chamber 12 piston 46 moves outwardly to slide ring 31 up from the diffuser outlet. The closure, which is provided by ring 31 eliminates pulsation which would otherwise result upon continuous separation of fluid from one wall of impeller 25 and diffuser 29.

In Fig. 5, a modified compressor is shown in which the outlet of diffuser 29 is tapered to position a tapered ring 31 thereon. Ring 31 is supported within casing 11 by a control device 50. Device 50 comprises a base 51 which is secured to the inner wall of casing 11 by any suitable means, such as bolts 52. A member 53 is secured to base 51 to support a cylinder 54 in which is positioned a piston 55 with a connecting rod 56. A bracket 57 on the outer surface of ring 31 is connected to a bracket 58 on the inner casing wall by a spring 59. Rod 56 is secured to bracket 57 by nuts 60. Spring 59 tends to retain ring 31 across the diffuser outlet. Air flow through diffuser 29 forces ring 31 upwardly from the outlet thereof. A decrease in fluid flow allows ring 31 to form a closure for diffuser 29 until normal flow is attained. Such closure prevents separation of the fluid flow from the walls of the diffuser to prevent pulsation.

In Fig. 6, a modified ring member 61 is shown which comprises lower and upper body portions 62 and 63 with a plurality of spaced apertures 64 therebetween to provide air passages. Member 61 may be used in compressor 10 in Fig. 1 to limit the fluid flow and power input thereof. In the operation of compressor 10 with member 61 at high fluid flow the low pressure in chamber 12 positions body portion 62 across the diffuser outlet. If flow is reduced to the design point, the increased speed of the motor and impeller raises the pressure to move apertures 64 in alignment with the diffuser outlet to give unrestricted flow. Further throttling increases the speed and pressure of the compressor motor to position upper body portion 63 of ring 61 across the diffuser outlet at very low flow.

In Fig. 7, fluid which is designated by arrows 65 is forced from the air inlet through impeller 25 and diffuser 29 toward the inner wall of the compressor casing. Initial separation of fluid from the walls of the impeller and diffuser is shown by areas 66 and 67. Fluid which has separated from the impeller wall reverses its direction of flow as shown by arrow 68.

In Fig. 8, pulsation conditions are shown in a conventional compressor which is not provided with a member 31 to break a continuous low kinetic energy path which is designated 69. Path 69 is produced by complete separation of fluid along the full length of the flow passage. Pulsation is caused by a feedback through low kinetic energy path 69 of air which is shown by arrows 70.

In Fig. 9, ring member 31 prevents complete separation and pulsation in compressor 10 because a correct diffuser outlet area is maintained for any particular flow. Thus, there is no low kinetic energy path through which an air feedback occurs.

In Fig. 10, a graph of compressor pressure rise in head inches of water (H_2O) is plotted against fluid flow in cubic feet per minute at variable speed. The speed of the impeller increased as the load was decreased with decreasing flow. As the normal pulsation point was approached, the diffuser outlet area was decreased to break the continuous low kinetic energy path to prevent separation. This outlet area was progressively decreased with

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decreasing flow to the zero flow point. The primary reason that the pressure increased with decreasing flow is the increased speed of the impeller.

In Fig. 11, a graph of compressor pressure rise in head inches of water (H_2O) is plotted against fluid flow in cubic feet per minute at a constant impeller speed of 15,000 revolutions per minute. This graph discloses the increase in operating range below the normal pulsation point through the use of ring member 31. All of the pressure rise will occur centrifugally in the impeller at zero flow.

As will be apparent to those skilled in the art, the objects of our invention are attained by the use of a ring member which is positioned adjacent the periphery of the diffuser of the compressor to provide a correct diffuser outlet area for all compressor flows. It will be appreciated by those skilled in the art that while specific co-operating mechanical structures have been described, other apparatus can be employed to operate the ring member in response to pressure variations within the compressor.

While other modifications of this invention and variations of apparatus which may be employed within the scope of this invention have not been described the invention is intended to include all such as may be embraced within the following claims.

What we claim as new and desire to secure by Letters Patent of the United States is:

1. In a centrifugal compressor comprising an impeller, a diffuser having a pair of spaced apart walls and surrounding said impeller to receive flow therefrom, and a casing surrounding said diffuser to receive flow from said diffuser, the combination comprising, an annular ring encircling said diffuser outlet, said annular ring being axially and rotatably movable, the combined movement arranged to position the annular ring to partially block the diffuser outlet over a continuous circumferential area, pressure responsive means in said casing to apply movement to said annular ring to position the annular ring such that the normal air flow from the compressor strikes a planar surface perpendicular to the flow, thereby blocking the flow separating area contributing to compressor pulsations.

2. In a centrifugal compressor comprising an impeller, a diffuser having a pair of spaced apart walls surrounding said impeller to receive flow therefrom, and a casing surrounding said diffuser to receive flow from said diffuser, the combination comprising a ring encircling said diffuser, camming means supporting said ring to permit axial and rotatable movement, differential pressure means responsive to the pressure within and without said casing, motion transmitting means between said pressure responsive means and said ring whereby said ring is moved to block that part of the diffuser outlet subject to flow separation under compressor pulsing conditions.

3. In a centrifugal compressor having a tapered impeller, a diffuser surrounding said impeller having a pair of spaced apart walls, one wall being correspondingly tapered to conform with said tapered impeller, and a casing surrounding said impeller, the combination comprising, an annular ring surrounding the diffuser outlet, means to position said ring from a first position uncovering the diffuser outlet to a second position partially closing said outlet from the tapered wall of the diffuser in a direction toward the other wall of said diffuser, and means responsive to the pressure within said casing to position said ring.

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