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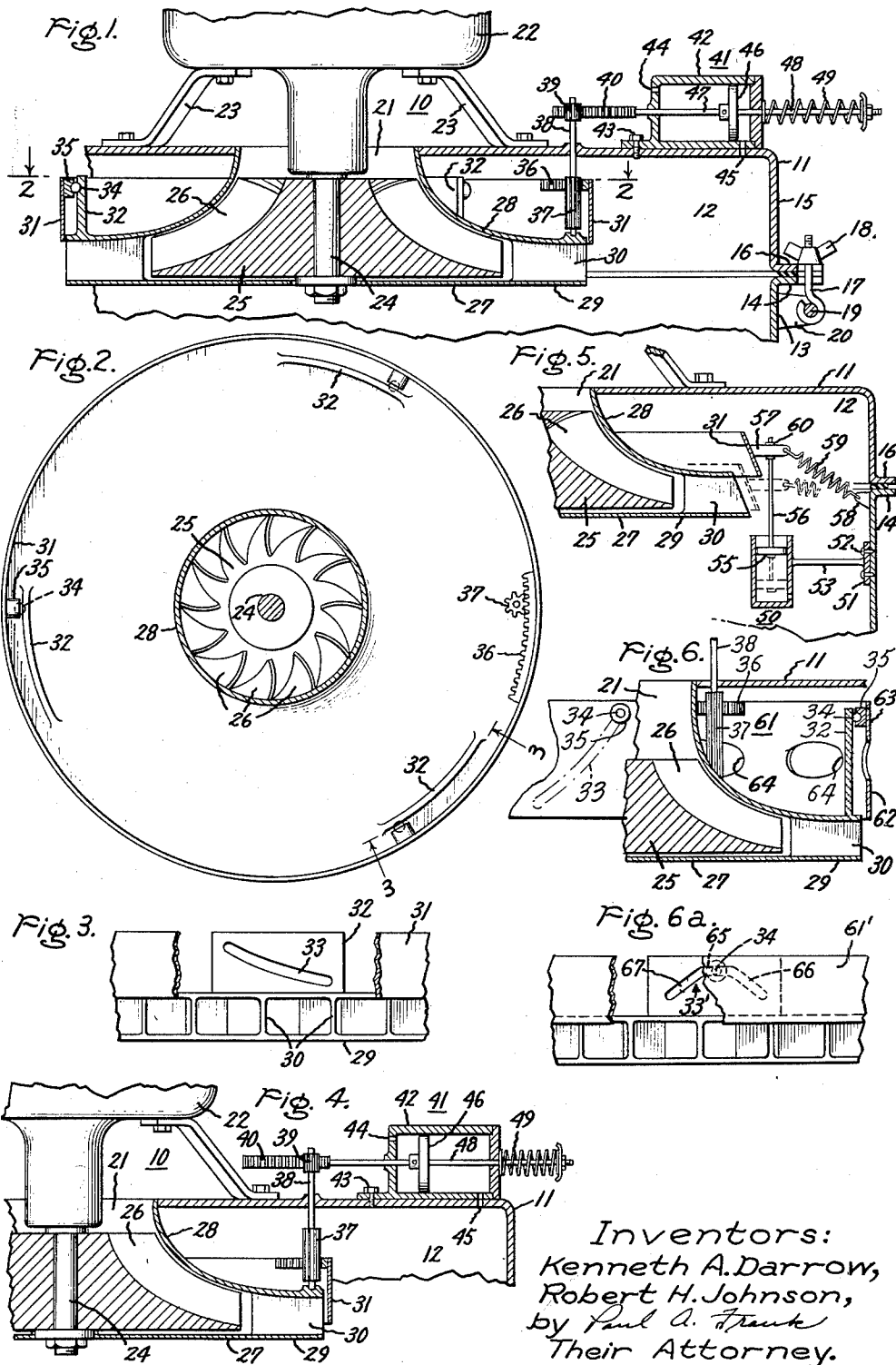
K. A. DARROW ET AL

2,933,237

COMPRESSOR

Filed May 20, 1957

2 Sheets-Sheet 1



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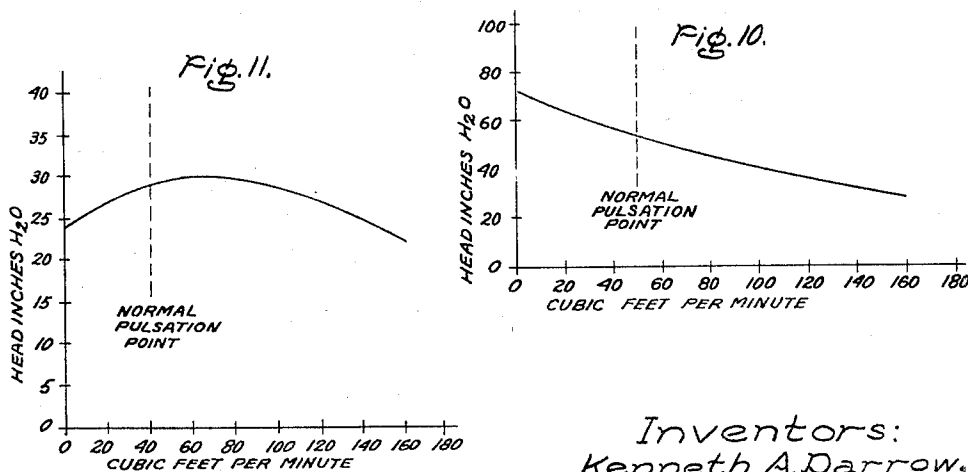
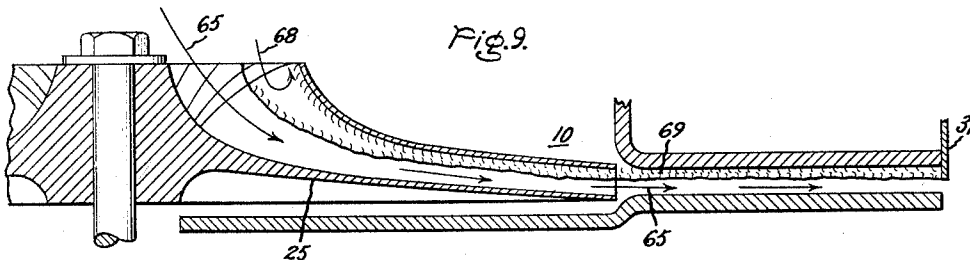
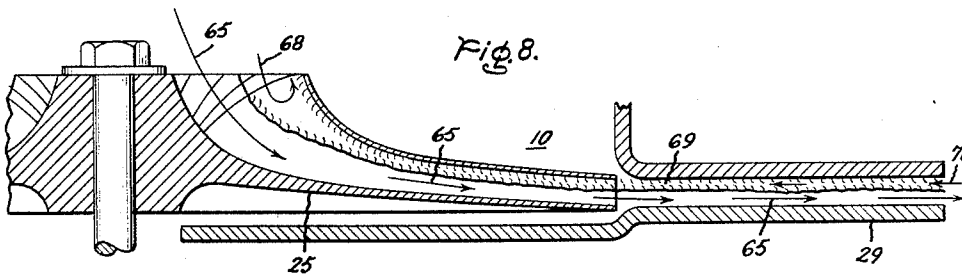
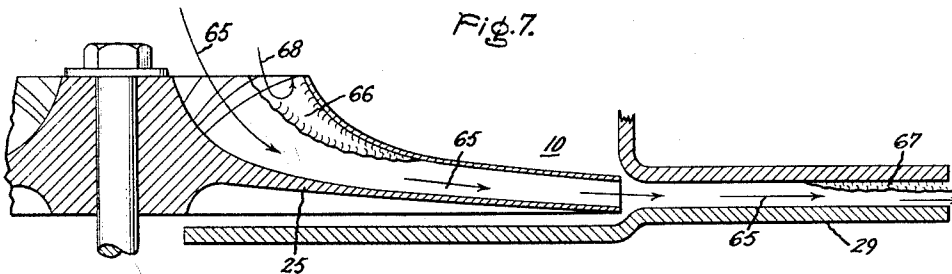
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2 Sheets-Sheet 2



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2,933,237

COMPRESSOR

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Application May 20, 1957, Serial No. 660,243

4 Claims. (Cl. 230—114)

This invention relates to compressors and more particularly to a method and apparatus for eliminating pulsation in such compressors, and is a continuation-in-part of our copending application, Serial No. 459,041, filed September 29, 1954, assigned to the same assignee as the present invention and now U.S. Patent No. 2,814,431.

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;

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Fig. 6A is a modification of Fig. 6 wherein a continuous diffuser ring is employed;

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;

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 toward 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, centrif-

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ugal action of the impeller blades 26 drives air from inlet 21 downwardly and outwardly toward 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 unloading 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 of 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 continuous body portions 62 and 63 with a plurality of spaced apertures 64 in a circumferential row in the intermediate portion 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.

The modification as disclosed in Fig. 6 may be more clearly understood when, for example, it is applied to the well known tank type vacuum cleaner wherein a motor driven compressor is connected by means of a flexible tube to a rug cleaning tool or nozzle. The vacuum or low pressure conditions created at the nozzle through the action of the compressor serves to remove loose particles or dirt from the rug or other surfaces. Assuming now, in the first instance, that the tool is raised from the floor or, as is generally done, removed from the tube for the purpose of changing to another tool. Under these conditions, there is a high flow rate of air through the compressor and a resultant low pressure. This low pressure which also exists in cylinder 12 is just sufficient to overcome the biasing action of spring 49 to move piston 46 and gears 40, 39, 37 and 36, to position the first or lower portion 62 of ring 61 over the diffuser outlet, and effectively reduce the power input to the motor which may exceed safety requirements due to an unloaded compressor. In the second instance, assume that the tool is

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being applied to a surface for cleaning thereof. In this condition flow through the tool or nozzle is reduced and consequently flow through the compressor is reduced to a predetermined design point. Reduced flow then permits an increase in speed and efficiency of the impeller, with a resultant rise in pressure. This pressure within cylinder 42 acts against piston 46 to overcome the biasing force of spring 49 and accordingly position the ring 61, through the aforementioned gears, so the second or intermediate portion with openings 64 are in alignment with the diffuser outlet and normal flow conditions are established. In the third instance, assume that the cleaning tool or nozzle is pressed against the surface or the opening becomes otherwise restricted by large particles taken up by the cleaning process. In this condition, the low flow rate permits an even higher r.p.m. of the compressor with a resultant increase in pressure to the pulsation range. This increase in pressure serves to progressively move piston 46 in cylinder 42 to position the upper or third portion 63 of ring 61 over the diffuser outlet. The problems or disadvantages associated with an uncontrolled compressor to this exemplary application is in the first instance, high flow conditions and thus a high power input to the motor drive, an input, in watts, which may exceed safety requirements of the electric motor and the conductor thereto, and in the third instance deleterious pressure pulsations.

While the preferred form of this invention has been specifically described, other modifications may be equally applicable. In this respect, reference is now made to Fig. 6A. In Fig. 6A, there is shown a ring 61', having no openings, which may also be employed in the invention disclosed in Fig. 1 together with the control device 41. As heretofore described, the exemplary sequence of operation is, first, a high flow rate accompanied by a low pressure; second, a reduced flow rate accompanied by a higher pressure; and, third, a still further reduced flow rate accompanied by a still higher pressure. Therefore, in each instance an increasing pressure must serve to successively position ring 61' first to partially close the diffuser outlet, second to open the diffuser outlet and third to again partly close the diffuser outlet. In order to move a solid ring 61' to each of these three positions through the unidirectional movement of piston 46, some means would be necessary to reverse the direction thereof. Alternately, however, in one form of this invention, cam surface 33 of Fig. 3 may be in curved form 33', as shown in Fig. 6A, having a horizontal section 65 between two slowly descending sections 66 and 67. In this manner, with respect to the first condition of the sequence of high flow, low pressure, the ring 61' is positioned through the action of ball 34 in section 67 of cam groove 33' partially covering the diffuser outlet. During the second condition of increasing pressure and reduced flow, movement of piston 46 serves to position ring 61' through the action of ball 34 engaging section 65 of cam groove 33' to the optimum cleaning position of opening the diffuser outlet. Upon the third condition of the sequence, of reduced flow and still higher pressure, continued movement of the piston 46 further rotates ring 61' where balls 34 engage section 66 of cam groove 33' and ring 61', again partially covers the diffuser outlet. It should be noted that during non-operation of the compressor, or conditions of very low pressures, spring 49 positions ring 61' to the position wherein the balls 34 engage section 67 of cam groove 33'.

There has thus been described a compressor control which automatically provides proper flow for all throttling conditions at a compressor inlet.

In Fig. 7, fluid which is shown 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 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 cooperating 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. A compressor control which comprises in combination, a tapered impeller, a diffuser surrounding said impeller, a casing surrounding said diffuser, a movable annular ring member surrounding said diffuser outlet movable to cover and uncover said diffuser outlet, and unidirectional means operatively connected to said annular ring member to position said annular member throughout a position range including partially covering the diffuser outlet, second, uncovering said diffuser outlet, and lastly, partially covering said diffuser outlet, said unidirectional means responsive solely to a pres-

sure rise within said casing for positioning said annular member throughout said range in the said range in the given sequence, said movement of said annular ring member being from the said tapered side of said impeller towards the other side.

2. A compressor control which comprises in combination, an impeller, a diffuser surrounding said impeller, a casing surrounding said diffuser, an axially and rotatably movable annular ring member surrounding said diffuser outlet and adapted to cover the diffuser outlet with the annular wall surface perpendicular to the flow from said diffuser, said ring member comprising a first annular continuous portion, a second portion having a circumferential row of openings therein, and a third annular continuous portion, and means responsive to increasing pressure in said casing for unidirectionally positioning said ring member throughout a range of positions, said range including partially covering the diffuser outlet with the first continuous portion of said annular ring, aligning the openings in said ring member with the diffuser outlet, and thirdly, partially covering the diffuser outlet with said third continuous portion of said ring member.

3. A compressor control which comprises in combination, an impeller, a diffuser surrounding said impeller, a casing surrounding said diffuser, an annular continuous ring member surrounding said diffuser outlet and adapted to cover the diffuser outlet with the annular wall surface perpendicular to the flow from said diffuser, means for supporting said annular ring for rotatable and axial motion, means responsive to the pressure in said casing for unidirectionally rotating said annular ring member to move said annular ring member axially through a range of axial positions, said range including a first position wherein said ring partially covers the diffuser outlet, a second position wherein said ring uncovers said diffuser outlet, and a third position wherein said annular ring partially covers said diffuser outlet.

4. In an electric motor-driven centrifugal compressor, means for controlling the pulsation of flow from the impeller and limiting the power input to the motor drive which comprises, an annular ring member interjected into the flow of said impeller, axially and rotatably supporting cam means for said ring, means responsive to a pressure rise in said compressor to unidirectionally rotate said ring and at the same time to position said ring axially during said pressure rise in a sequence of operations including interjecting said ring into the flow of the impeller, withdrawing said ring from the flow, interjecting said ring into the flow.

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