

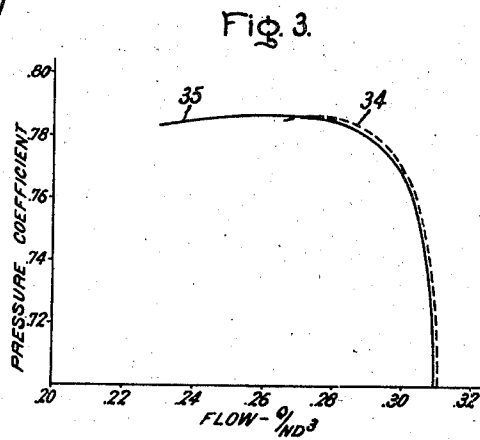
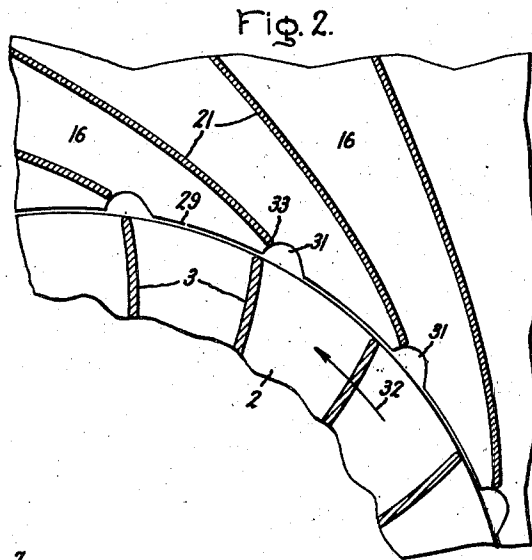
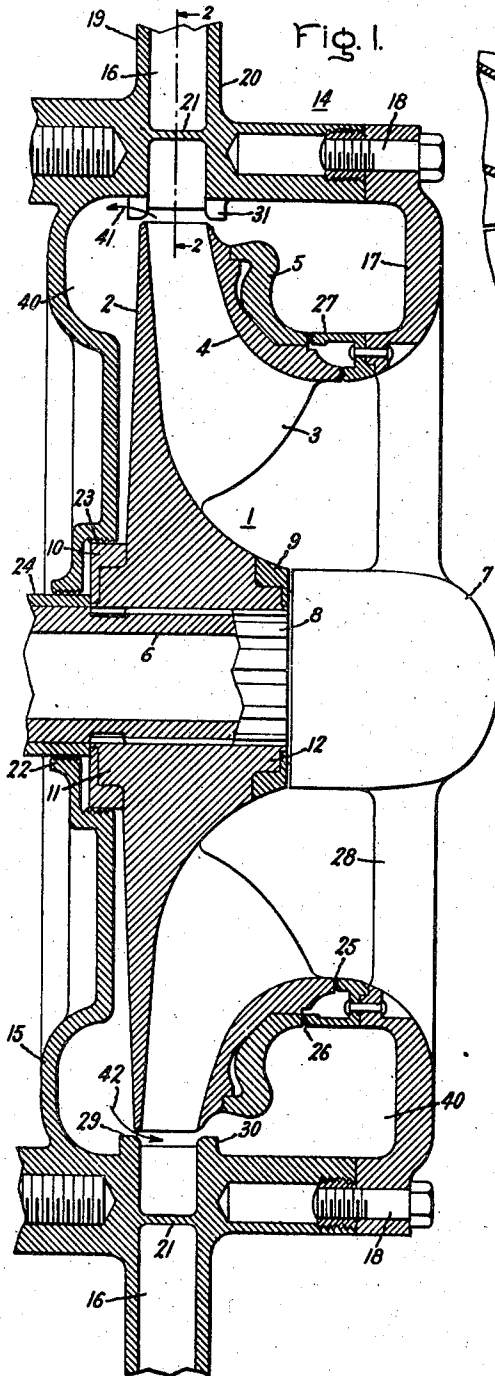
Nov. 9, 1948.

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2,453,524

CENTRIFUGAL COMPRESSOR

Filed March 31, 1945



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UNITED STATES PATENT OFFICE

2,453,524

CENTRIFUGAL COMPRESSOR

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Application March 31, 1945, Serial No. 585,906

3 Claims. (Cl. 230—127)

1 This invention relates to centrifugal pumps for increasing the pressure of a compressible fluid, more particularly to the type of centrifugal compressor comprising a rotating impeller having radially disposed fluid passages and a diffuser surrounding the impeller and arranged to convert part of the kinetic energy of the fluid leaving the impeller into pressure energy.

An object of the invention is to provide a centrifugal compressor having improved operating characteristics. A specific object is to increase the operating range of such a compressor so as to make it capable of maintaining a given pressure ratio with good efficiency over a wide range of flow rates. Another object is to provide a vane type diffuser for a centrifugal compressor designed to give improved operating characteristics, particularly increased range.

Further objects and advantages will be apparent from the following description and the appended claims taken in connection with the accompanying drawings, in which Fig. 1 is a sectional view of a centrifugal compressor arranged in accordance with the invention; Fig. 2 is a partial side view in section of the discharge portion of the impeller and the inlet portion of the diffuser; and Fig. 3 is a graphic representation of the improvement in operating characteristics accomplished by the invention.

It is well known that the performance of centrifugal compressors is limited by an unstable condition known as pulsation or surging, which occurs when the rate of volume flow through the impeller and/or diffuser decreases to a certain critical value. In accordance with our invention the operating range of a compressor is increased by an arrangement which permits operation with smaller rates of flow without breakdown of the steady flow conditions which manifests itself as pulsation or surging.

The compressor shown in Fig. 1 consists of an impeller 1 having a web portion 2, a plurality of radially disposed blades 3 secured to the web, and a shroud portion or cover plate 4 forming the remaining wall of the fluid passages through the impeller. A reinforcing ring 5 of high tensile strength material is pressed onto the shroud 4. This type of impeller is disclosed and claimed in the patent of Kenton D. McMahan, No. 2,392,858, 50

2 issued January 15, 1946, and assigned to the same assignee as the present application.

The impeller is supported on a hollow shaft 6 carried by a suitable bearing in the housing 7 and other bearings (not shown). The impeller 1 may be secured to the shaft 6 by any suitable means, which may be the splines 8, or a simple keyed connection, or any one of many other types of fastening. The impeller may be made of a light alloy such as aluminum or magnesium, in which case it may be preferable to provide reinforcing rings 9 and 10 shrunk onto the hub portions 11 and 12 surrounding the shaft opening through the impeller. It has been found that in high speed operation such an impeller stretches, all of its dimensions, including the diameter of the shaft bore, tending to increase by an appreciable amount in a radial direction. If the impeller is operated at a sufficiently high speed, the material of which it is made may be stretched beyond its yield point and thereby take a permanent set. It will be readily understood that any such stretching during operation may result in looseness of the joint between the impeller and its shaft; and it will also be obvious that any permanent stretch of the impeller bore would produce permanent looseness of the joint. The reinforcing rings 9 and 10 are made of a material such as an alloy steel having a higher yield strength than the impeller material and are designed to prevent this radial stretching of the impeller bore.

The impeller is surrounded by a casing 14 consisting of the main casting 15 and a second casting 17 secured to the main casting by suitable threaded fastenings 18. The casting 15 incorporates the radially extending diffuser passages 16 formed between the side walls 19 and 20 and the circumferentially spaced vanes 21. While the diffuser herein is shown as being formed as one casting integral with the casing, it will be understood by those skilled in the art that the diffuser may be fabricated and arranged in many other ways.

The main casting 15 is provided with a labyrinth seal 22 cooperating with the sleeve 24 on shaft 6 and a seal 23 cooperating with the outer circumference of reinforcing ring 10. The front casting 17 is likewise provided with labyrinth seals 25 and 26 cooperating with a surface of the

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impeller 3 and reinforcing ring 5 respectively. The sealing arrangement shown comprises a separable ring 27 riveted to the casting 17, but other arrangements will be obvious. The bearing housing 7 is supported by a plurality of streamlined struts 28. The specific details of the bearings and fluid sealing means are not material to an understanding of the invention.

The outer circumferences of the impeller web 2 and shroud 4 are arranged to form close clearances with the inner circumferential portions 29 and 30 of the diffuser side walls 19 and 20. We have discovered that the performance of a centrifugal compressor of the type described is greatly improved by providing scallops or cutout portions in one or both of the diffuser wall portions 29 and 30. The arrangement of these cutouts 31 is shown in Fig. 2. It will be seen that the cutouts 31 are arranged immediately adjacent the inlet edge of the diffuser vanes 21 and on the "approach" side of the inlet edge, so that an impeller blade 3 rotating in the direction indicated by the arrow 32 passes a cutout 31 immediately before reaching the inlet portion 33 of vane 21. The scallops 31 may be arcs of circles or other shapes, but it has been found advantageous to shape them as shown in Fig. 2 so that the area of the cutout increases gradually in the direction of rotation of the impeller.

Adjacent the scalloped diffuser edge portions 29 and 30 bounding the clearance space between the impeller exit and diffuser inlet there are provided in the casings 14 and 15 annular "surge chambers" 40. These chambers are obviously in communication with the clearance space between the impeller and diffuser by means of the pressure relief passages 31.

Fig. 3 illustrates graphically the improvement in performance which has been found to result from the use of the invention. The abscissa of the curves represents the rate of flow through the impeller in terms of a dimensionless parameter Q/ND^3 in which Q is the volume flow through the impeller per unit of time, N is the speed in revolutions per unit of time, and D is the tip diameter of the impeller. The ordinate is a dimensionless pressure coefficient, which may be considered to represent the efficiency with which the impeller creates the pressure rise in the fluid, as compared with a theoretical ideal impeller. A conventional impeller-diffuser combination not embodying the present invention may be found to have an operating curve such as that represented by the dotted curve 34, extending from a maximum value of Q/ND^3 of about .31 to a minimum value of .27, below which pulsation occurs. The range is expressed as the ratio of the maximum to the minimum value, and is in this case about 1.15.

It has been found that with a diffuser arranged in accordance with our invention, the same compressor can be given an operating characteristic represented by curve 35 in Fig. 3, for which the minimum flow has been reduced to approximately .23, giving a range of approximately 1.35.

While the exact process by which the invention produces its favorable effect on the performance of a centrifugal compressor is not known, it is believed to be somewhat as follows. It is known that when the blades 3 of a centrifugal compressor approach the inlet portions 33 of the diffuser vanes in a conventional vane type diffuser, a certain shock is produced in the fluid and a higher pressure is built up on the "approach side" of the diffuser vane inlet portion, especially at values of flow near the pulsation point. As a given blade 3

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passes a given inlet portion 33 it also produces a decreased pressure on the "under side" of the vane, that is, on the side opposite from the approach side. This shock phenomenon sometimes produces vibration of the diffuser vanes and has been known to result in actual mechanical failures of the vanes. Furthermore, the unequal distribution of pressure produced across the entrance to the diffuser passage is believed to have an adverse effect on diffuser efficiency, and is thought to be related to the breakdown phenomena which occur at the pulsation point.

We believe that the scallops 31 act as pressure relief passages permitting the high pressure built up at the approach side of the diffuser vane inlet portion to escape laterally into the surge chambers 40 as indicated by arrow 41. As a result, a slight pressure is built up in the surge chambers over that obtaining across the remainder of the diffuser inlet bounded by the edge portions 29 and 30 which form a close clearance with the impeller. Therefore, some fluid from the surge chamber will circulate back into the clearance space between the impeller circumference and diffuser inlet through the clearance between edge portions 29 and 30 and the impeller circumference, as indicated by arrow 42. This circulation from the high pressure portion of the diffuser inlet laterally outward into the surge chamber and then back in through the close clearance between the impeller circumference and the diffuser portions 29 and 30 is believed to produce the improvement noted in the operating range of the compressor. The surge chambers 40 provide a fluid "cushion" which absorbs and smoothes out the pulsations of fluid coming from the cutout portions 31, and form a source of supply of fluid at slightly elevated pressure to be fed back into the diffuser inlets through the close clearances between the impeller exit and the circumferential diffuser edge portions 29 and 30.

While the accompanying drawings show both the circumferential edge portions 29 and 30 as provided with the scallops 31 and with surge chambers 40 on both sides of the impeller, it may be found that similar improvement, though perhaps to a lesser degree, may be obtained by a surge chamber on only one side of the impeller with scallops 31 cut in only one circumferential edge portion of the diffuser. It may also be noted that the exact size of the surge chambers is not very critical. In some cases merely a generous clearance space between the web of the impeller 2 and the adjacent wall of the casing may act as a surge chamber if the diffuser is provided with pressure relief openings at the high pressure side of the diffuser passage inlets in accordance with our invention. We believe it advantageous, however, to provide generous surge chambers, for improved "cushioning" effect, as shown in Fig. 1.

In addition to improving the operating range of the compressor, our invention also serves to reduce the fluid shocks imparted to the diffuser vane inlet portions and thus helps to prevent mechanical failures of the vanes.

While the drawings show a shrouded or closed type of centrifugal impeller, it will be obvious to those skilled in the art that the invention is equally applicable to an "open" type of impeller having a web and blades fastened thereto, with a stationary shroud associated with the casing forming one boundary of the impeller passages.

It will be seen that our invention provides a novel form of diffuser for a centrifugal compressor having improved operating characteristics, par-

ticularly with respect to range, and being less subject to mechanical failure of the inlet portions of the vanes.

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

1. In a centrifugal compressor, the combination of an impeller having a web defining one side of the impeller passages, a shroud defining the opposite side of the impeller passages, both web and shroud having substantially parallel outer circumferential edge portions, a diffuser surrounding the impeller having at least one expanding diffusing passage and an inner circumferential edge portion arranged to form a close clearance with one of said outer circumferential edge portions, a casing surrounding the impeller and defining an annular surge chamber adjacent the clearance space between impeller exit and diffuser inlet, the inner circumferential edge portion of the diffuser being shaped to define a pressure relief passage communicating between the surge chamber and the clearance space between impeller and diffuser at the high pressure side of the diffusing passage inlet.

2. In a centrifugal compressor the combination of an impeller including a web defining one side of the impeller passages and having an outer circumferential edge portion, a shroud defining the opposite side of the impeller passages and having an outer circumferential edge portion substantially parallel to the web edge portion, a diffuser surrounding the impeller and including spaced annular side walls with inner circumferential edge portions arranged to form close clearances with the web and shroud edge portions, circumferentially spaced vanes supported between the side walls and defining therewith a plurality of diffuser passages, a casing enclosing the impeller and forming an annular surge chamber adjoining the clearance space between the impeller and diffuser, the inner circumferential edge portion of the diffuser side wall between the clearance space and the surge chamber being shaped to define pressure relief passages therebetween at the high pressure side of the diffuser passage inlets.

3. In a centrifugal compressor the combination of an impeller with web and shroud portions defining opposite sides of the impeller passages and radially extending blades between the web and shroud, a vane type diffuser having inner circumferential edge portions arranged to form close clearances with the outer circumferential portions of the web and shroud, a casing for the impeller having walls defining an annular surge chamber adjacent the clearance space between impeller and diffuser, one of the inner circumferential edge portions of the diffuser being provided with scallops forming pressure relief passages communicating between the clearance space and the surge chamber.

4. In a centrifugal compressor the combination of an impeller having a web defining one side of the impeller passages, a shroud defining the opposite side of the impeller passages, both web and shroud having substantially parallel outer circumferential edge portions, a diffuser surrounding the impeller and having a plurality of expanding diffuser passages and inner circumferential edge portions arranged to form close clearances with the outer circumferential portions of the web and shroud, a casing enclosing the impeller and defining a first annular surge chamber adjacent the outer circumferential portion of the web and a second surge chamber ad-

jacent the outer circumferential portion of the shroud, the inner circumferential edge portions of the diffuser being shaped to define pressure relief passages communicating between the surge chambers and the clearance space between impeller and diffuser at the high pressure side of the respective diffuser passage inlets.

5. In a centrifugal compressor the combination of a casing, an impeller rotatably disposed therein, and a vane type diffuser disposed around the impeller and including spaced annular side walls and a plurality of circumferentially spaced vanes supported between the side walls, said side walls having inner circumferential edge portions forming a close clearance with the impeller and cooperating with radially inner portions of the vanes to form the inlets of the diffusing passages, at least one of said side walls having a lateral pressure relief passage therethrough adjacent the approach side of each vane, and said casing forming an annular chamber adjacent the impeller-to-diffuser clearance space and communicating therewith and with said pressure relief passages.

6. In a centrifugal compressor, the combination of a casing, an impeller rotatably disposed therein, and a diffuser disposed adjacent the impeller outlet, said diffuser comprising axially spaced side walls and at least two circumferentially spaced vanes supported between the side walls and defining therewith a diffusing passage, the inner edge of at least one of said side walls forming a close clearance with the impeller over the major portion of the diffusing passage inlet and having a lateral pressure relief opening through the side wall at the high pressure side of the diffusing passage inlet, said casing forming a chamber axially adjacent the impeller-to-diffuser clearance space and communicating therewith and with the pressure relief passage, whereby fluid expelled into said chamber through the pressure relief passage is recirculated directly back into said clearance space at the low pressure portion of the inlet.

7. In a centrifugal compressor, the combination of a casing, an impeller rotatably disposed therein, and a diffuser disposed adjacent the impeller outlet, said diffuser comprising axially spaced side walls and a plurality of vanes supported between the side walls and defining therewith circumferentially spaced diffusing passages, said side walls having inner circumferential edge portions forming annular clearance spaces with the impeller and cooperating with radially inner portions of the vanes to form the inlets of the diffusing passages, at least one of said annular clearance spaces being of substantially constant minimum size at the low pressure portions of the inlets and having a materially larger area at the high pressure portion of the inlet on the approach side of each vane, said casing forming a surge chamber at one side of said impeller-to-diffuser clearance space and communicating therewith, whereby fluid expelled laterally outward into the surge chamber through the larger portions of said clearance space recirculates directly back into the diffuser inlet through the minimum portions of said clearance space.

8. A diffuser for a centrifugal impeller comprising axially spaced annular side walls and a plurality of circumferentially spaced vanes supported between the side walls and cooperating therewith to form diffusing passages, at least one of said side walls having a radially inner circumferential edge cooperating with the radially

inner portions of the vanes to form the inlets to the diffusing passages, said side wall inlet edge including arcuate portions having a common center at the axis of the diffuser and subtending the low pressure portion of each inlet, said side wall inlet edge having also a scallop adjacent each vane at the high pressure side of the inlet.

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NEIL P. BAILEY.

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