United States Patent [19]

Bandukwalla

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[54] **DIFFUSER**

[75] Inventor: **Phiroze Bandukwalla,** Indianapolis, Ind.

[73] Assignee: **General Motors Corporation,** Detroit, Mich.

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[52] **U.S. Cl.** **415/181;** 415/211; 415/DIG. 1

[51] **Int. Cl.²** **F04D 29/44**

[58] **Field of Search** ..... 415/211, 181, DIG. 1

[56] **References Cited**

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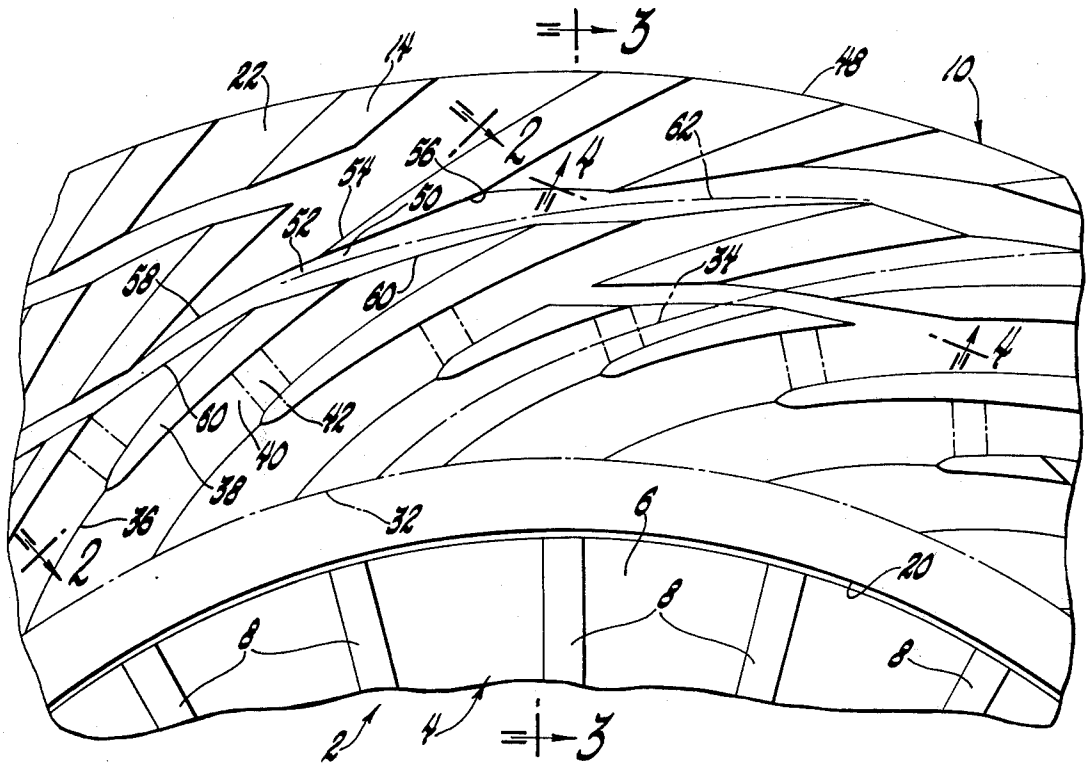
Primary Examiner—Henry F. Raduazo

Attorney, Agent, or Firm—J. C. Evans

[57] **ABSTRACT**

A diffuser for centrifugal compressors includes a first plurality of passages therein, curved to receive expanding vortical flow from the impeller and having an inlet configuration to each of the first plurality of passages for accepting supersonic flow from a radial flow impeller and including a second plurality of passages located aft of throat regions in each of the first plurality of passages to produce an increased diffuser exit area in a subsonic flow region downstream of each of the throats of the first plurality of passages to improve subsonic diffuser pressure recovery.

2 Claims, 4 Drawing Figures



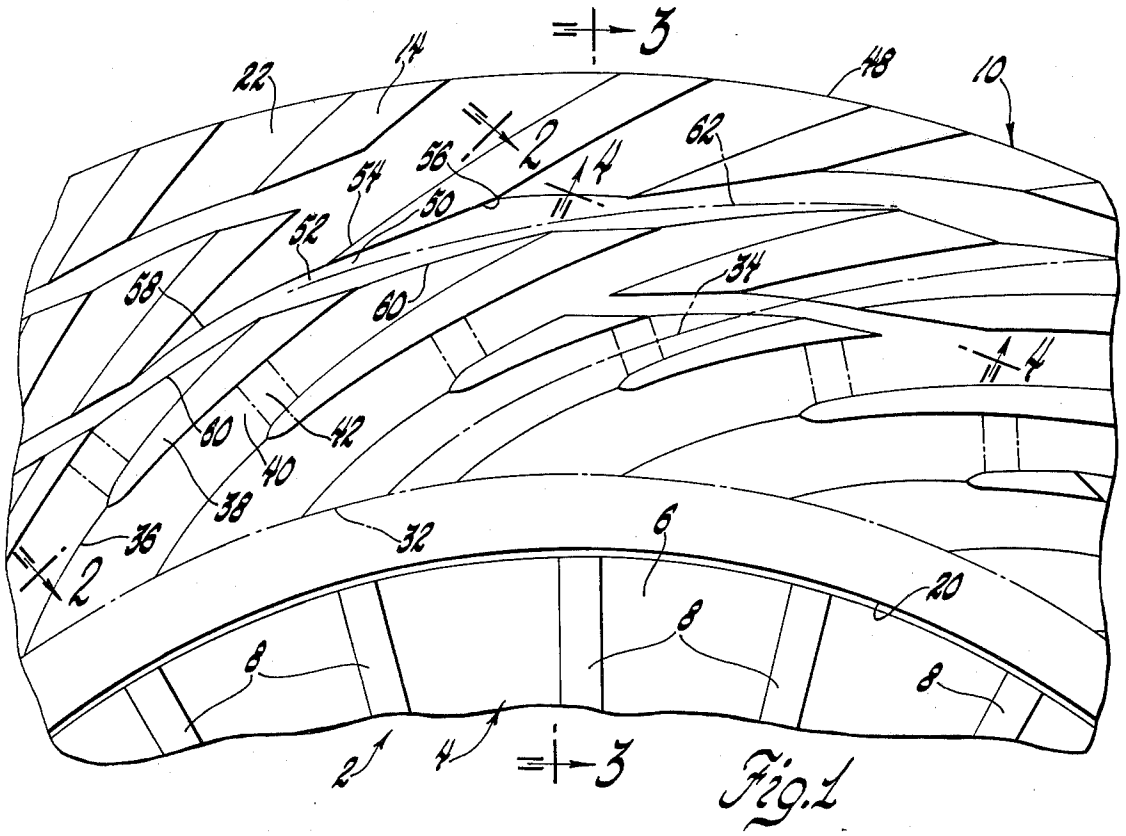


Fig. 1

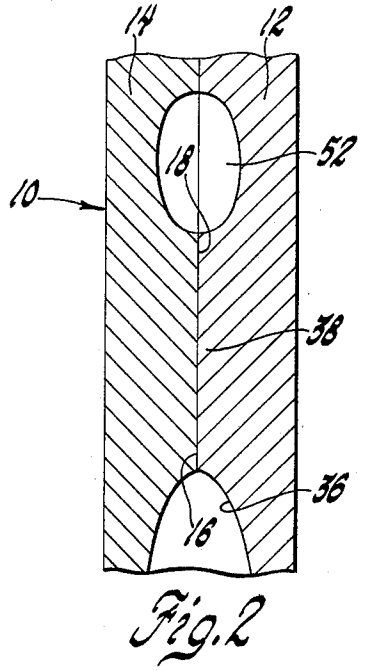


Fig. 2

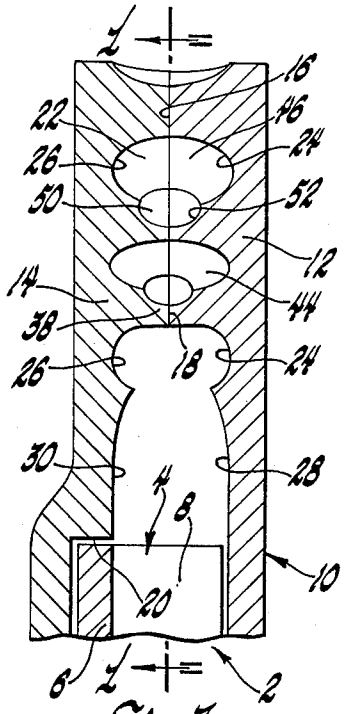


Fig. 3

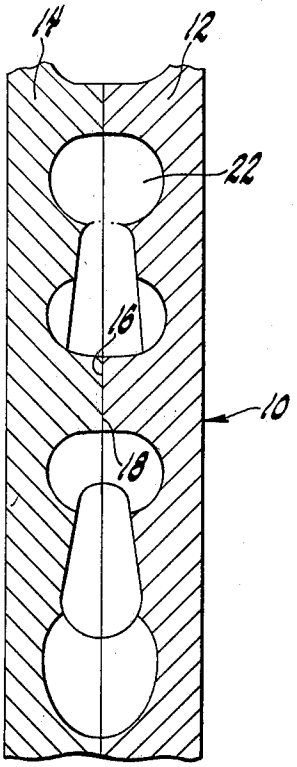


Fig. 4

DIFFUSER

This invention is directed to diffusers for centrifugal compressors in which the flow from the rotor is supersonic and more particularly to a construction for improving subsonic flow in a vortical diffuser arrangement by bleeding flow downstream of a plurality of primary vortical flow passages in the diffuser through intersecting passages that direct flow from a pressure surface in one of the first plurality of passages to a suction surface in an adjacent vortical flow passage to improve the flow condition from the inlet to the outlet of the diffuser while increasing subsonic diffuser pressure recovery.

Centrifugal compressors are characterized by having a bladed rotor or impeller that impels air (or other gas) in a tangential and radial direction thereby to impart a high velocity to the air. Such air as delivered from the impeller flows radially and circumferentially of the axis of rotation of the impeller and is delivered to a diffuser for converting the kinetic energy of the air from the impeller to a potential energy of pressure. Examples of centrifugal compressors of this type are disclosed in U.S. Pat. No. **2,819,012** issued Jan. **7, 1958,** to Atkinson and are further disclosed in U.S. Pat. Nos. **3,706,510** and **3,743,436** issued to O'Connor on Dec. **19, 1972,** and July **3, 1973,** respectively. A radial diffuser for such centrifugal compressors having an improved passage configuration to receive an expanding vortical flow from a centrifugal impeller is set forth in my U.S. Pat. No. **3,778,186** issued Dec. **11, 1973.**

An object of the present invention is to improve the efficiency of centrifugal compressors and associated diffusers of the type set forth in the aforesaid patents by the provision of improved means for increasing the downstream flow area of the diffuser by providing intersecting passages between primary diffusing passages that follow a spiral curvature and include a supersonic flow region up to a throat in each of the passages and wherein the intersecting passages have an inlet at a pressure surface in one of the primary diffusing passages downstream of its throat and an outlet at a suction surface in an adjacent one of the primary diffusing passages again downstream of the throat region therein thereby to improve the flow condition in the diffuser to increase subsonic diffuser pressure recovery.

Further objects and advantages of the present invention will be apparent from the following description, reference being had to the accompanying drawings wherein a preferred embodiment of the present invention is clearly shown.

FIG. **1** is a partial radial sectional view of a centrifugal compressor perpendicular to the axis of rotation of a plane indicated by the line **1—1** in FIG. **3**;

FIG. **2** is a fragmentary sectional view taken along the line **2—2** of FIG. **1** looking in the direction of the arrows;

FIG. **3** is a fragmentary vertical sectional view taken along the line **3—3** of FIG. **1** looking in the direction of the arrows; and

FIG. **4** is a fragmentary sectional view taken along the line **4—4** in FIG. **1** looking in the direction of the arrows.

The general arrangement of centrifugal compressors is well known and for this reason overall drawings of such devices are omitted and only component parts are included as necessary for an understanding of the present invention.

As illustrated in FIGS. **1** and **3** the compressor **2** includes a rotor or impeller **4** having an annular disc **6** with a plurality of circumferentially spaced radially outwardly directed blades **8** extending across the face of the disc.

The rotor **4** turns clockwise as illustrated in FIG. **1** to discharge air with a substantial radial component and normally a greater circumferential component of velocity from the perimeter of the rotor **4** into a stationary diffuser **10.** The diffuser **10** is made up of a back plate **12** and a front plate **14,** preferably meeting on a plane surface defined by juxtaposed faces **16, 18** formed on the back plate **12** and front plate **14,** respectively. The diffuser portions in the plates **12, 14** are preferably symmetrical in nature. The plates continue toward the axis of rotation of the rotor **4** to define a housing with an inner peripheral surface at **20** around the compressor rotor. Likewise the diffuser **10** may be fixed to a housing with such a peripheral surface for the rotor **4.**

The diffuser **10** may be machined from two annular plates having plane mating surfaces such as the faces **16, 18** as shown in FIG. **3.** The forward surface of the plate **12** represented by the face **16** and the rear surface of the front plate **14** as represented by the face **18** are machined or otherwise formed to provide primary diffuser passages **22** with half of each of the passages in the back plate **12** and half in the front plate **14** as defined by grooved surfaces **24, 26** formed therein respectively.

A cross section of each of the passages **22,** as is best illustrated in FIG. **3,** is preferably elliptical with it being understood that cross sections of circular forms are a special case of an ellipse.

The faces **16, 18** of the front and back plate **12, 14** respectively at a point adjacent to the periphery of the rotor as indicated by reference numerals **28, 30** respectively in FIG. **3** may be of a plane configuration. As illustrated in FIG. **1** the entrance to each of the diffuser passages **22** begins at a cylindrical surface indicated by the broken line **32** in FIG. **1.**

Each passage **22** has a curved, generally logarithmic spiral center line indicated by the broken center line **34** in FIG. **1.** The initial portions of each of the passages **22** merge due to the intersection of the grooves **24, 26** to define a generally elliptical leading edge **36** as shown best in FIG. **2** which merges into a solid divider rib **38** formed between each of the passages **22.** Each of the divider ribs **38** and the side grooves **24, 26** define an initial converging passage portion **40** leading to a throat region **42.** Beyond the throat region **42** the passage **22** diverges as indicated by the successfully larger cross sections **44, 46** in FIG. **3.**

Each primary diffuser passage **22** ultimately terminates at the exterior periphery **48** of the diffuser **10.** The relatively slowly moving flow of air at the outer periphery is then supplied to a suitable plenum surrounding the diffuser (not illustrated) thence to the point of use.

The supersonic flow entering the diffuser at the leading edges **36** of each of the passages **22** is diffused in the initial converging portion **40** of the diffuser up to the throat **42.** Since the center lines **34** of each of the diffuser passages **22** are curved to match the naturally vortexing flow from the rotor **4,** diffusion is effectively and smoothly handled without a shock build-up at the entrance to each of the throats **42.**

While the diffuser passages **22** in the diverging part of the diffuser may have a straight center line, it is preferred that the center line continue to curve in a spiral fashion as indicated in the drawing to avoid unnecessary deflection of a diffusing gas flow.

In accordance with the present invention the subsonic flow downstream of the throat region **42** in each of the passages **22** is further improved by the provision of a plurality of intersecting passages **50** formed through each of the ribs **38** to intersect adjacent ones of the primary diffuser passages **22.** Each of the passages **50** include an inlet **52** at a pressure surface **54** on the rib **38.** Passage **50** enlarges the diffusion flow area downstream of a throat region **42** and will direct flow from the pressure surface **54** to a suction surface **56** on a rib **38** forming part of an adjacent passage **22.** Thus the flow pattern through the passages **50** will improve the subsonic flow in the diffuser **10** by enlarging the flow area downstream of the throat regions **42** and by bleed of flow from one passage **22** at a pressure surface **54** thereof through the intersecting passage **50** to the suction surface **56** in an adjacent passage **22.** This improves the general boundary flow condition through the diffuser **10** and will increase conversion of kinetic energy in the air to potential energy of pressure.

In the illustrated arrangement each of the passages **50** can be formed in the front and back plates **12, 14** by a cutting tool of the type that forms the surfaces **24,** 26 resulting in the primary diffuser passages **22.** The grooves that cut across each of the divider ribs **38** between the passages **22** will produce a slight ridge pattern at **58, 60** in each of those passages **22.** The slight ridges **58, 60** will serve as a means for directing flow from the passageway **22** at the pressure surface **54** for flow through the intersecting passage **50** thence to the suction surface **56** for further improvement of conversion of kinetic energy to pressure energy as flow is directed through the diffuser **10.**

While the primary diffuser passages **22** start off as a circular cross section and become elliptical towards their outer ends as illustrated in FIG. **3** the entire cross section of the passage might be elliptical if desired, and the long axis of the ellipse may be in a radial direction relative to the axis of rotation of rotor **4** rather than parallel to the axis of rotation as illustrated in FIG. **3.** By virtue of the gradual entrance of the gas into the diffuser passages **22** at the leading edge **36,** and the conformity of the passages to the natural approximately logarithmic spiral flow of the vortexing gas, there is no forced turning of the gas and smooth outlet conditions from the impeller and through the diffuser **10** are obtained. Likewise the path of the center line of the passages **50** as shown by the center line **62** are also curved in a spiral fashion as indicated in FIG. **1** of the drawing to avoid unnecessary deflection of flow through the intersecting passages **50.** The flow through the intersecting passages **50** also utilizes pressure differentials between the pressure surfaces **54** and the suction surfaces **56** and further is aided by the formation of the slight ridges **58, 60** in the surfaces **24, 26** of each of the passages **22.** This arrangement as in the case of the formation of the primary diffuser passages **22** will accommodate flow of vortexing gas without forced turning of the gas and with a smooth inlet and outlet conditions of flow throughout the impeller from the radially inwardly located surface **32** thereof to the exterior periphery **48** thereof.

While the mating surfaces of the sections **12, 14** have been referred to as flat surfaces, obviously these surfaces could depart somewhat from a flat condition, for example, they might be in the shape of a very blunt cone or follow a spherical surface of large radius.

It will be apparent that the passages **22** and **50** can be formed by milling with a spherical mill in a numerically controlled machine. Also, the diffuser **10** may be a precision cast two piece unit. In a two piece arrangement the plates **12, 14** may be bolted, cemented or brazed together to define the complete annular diffuser construction.

While the embodiments of the present invention, as herein disclosed, constitute a preferred form, it is to be understood that other forms might be adopted.

What is claimed is:

1. A centrifugal compressor comprising a rotor discharging radially and tangentially of the axis of the rotor and a diffuser body having a first set of diffuser passages with entrances adjacent the periphery of the rotor, said first plurality of diffuser passages each having arcuate cross sections and merging adjacent the rotor so that the body defines approximately elliptical leading edges at the intersections of the passage boundaries, each diffuser passage including a first converging portion with a spiral center line terminating at a throat region and a second diverging portion beginning at and extending in a continuous spiral downstream from the throat region, a divider rib located between each of said first plurality of diffuser passages, each of said ribs including a pressure surface thereon and a suction surface thereon, a bleed passage directed through each of said ribs having an inlet intersecting one of said diffuser passages at a pressure surface and an outlet intersecting an adjacent one of said first plurality of diffuser passages at a suction surface, each of said inlets being located downstream of one of said throat regions and operative to direct subsonic flow downstream of one of said throat regions from a pressure surface through one of said bleed passages to a suction surface for improving boundary flow at the suction surface and to increase the diffuser exit area between the entrance of each of said first plurality of diffuser passages and the exterior periphery of said diffuser body.

2. A centrifugal compressor comprising a rotor discharging radially and tangentially of the axis of the rotor, a diffuser body located radially outwardly of said rotor including an inner circumferential surface thereon having a plurality of circumferentially arranged primary diffuser passages each having entrances adjacent the outer periphery of the rotor, each of said primary diffuser passages having an arcuate cross section and merging adjacent the rotor to form an approximately elliptical leading edge into each of said primary diffuser passages, each of said primary diffuser passages including a converging portion terminating at a throat region and a second diverging portion beginning at and extending downstream from the throat region, a divider rib located between each of said passages including a pressure surface thereon and a suction surface thereon, an intersecting passageway through said rib communicating adjacent ones of said primary diffuser passages, said intersecting passage including an inlet located at a pressure surface on said rib within one of said diffuser passages and including an outlet thereon at a suction surface in an adjacent one of said primary diffuser passages, said intersecting passage di-

recting subsonic flow downstream of the throat region in one of said passages into an adjacent one of said primary diffuser passages to increase the flow area through said diffuser body from the inner periphery to the outer periphery thereof for improved conversion of kinetic energy to pressure energy, said intersecting passage serving to direct flow from a pressure surface to a suction surface to improve boundary layer flow through adjacent ones of said primary diffuser passages.

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