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Moellmann

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[54] **TURBOMACHINERY AND METHOD OF MANUFACTURING DIFFUSERS THEREFOR**

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[52] **U.S. Cl.**............. **415/207,** 415/211, 415/219 C, 29/156.8 CF

[51] **Int. Cl.**........................ **F04d 29/44,** F04d 29/54

[58] **Field of Search**..................... 415/207, 211, 181

[56] **References Cited**

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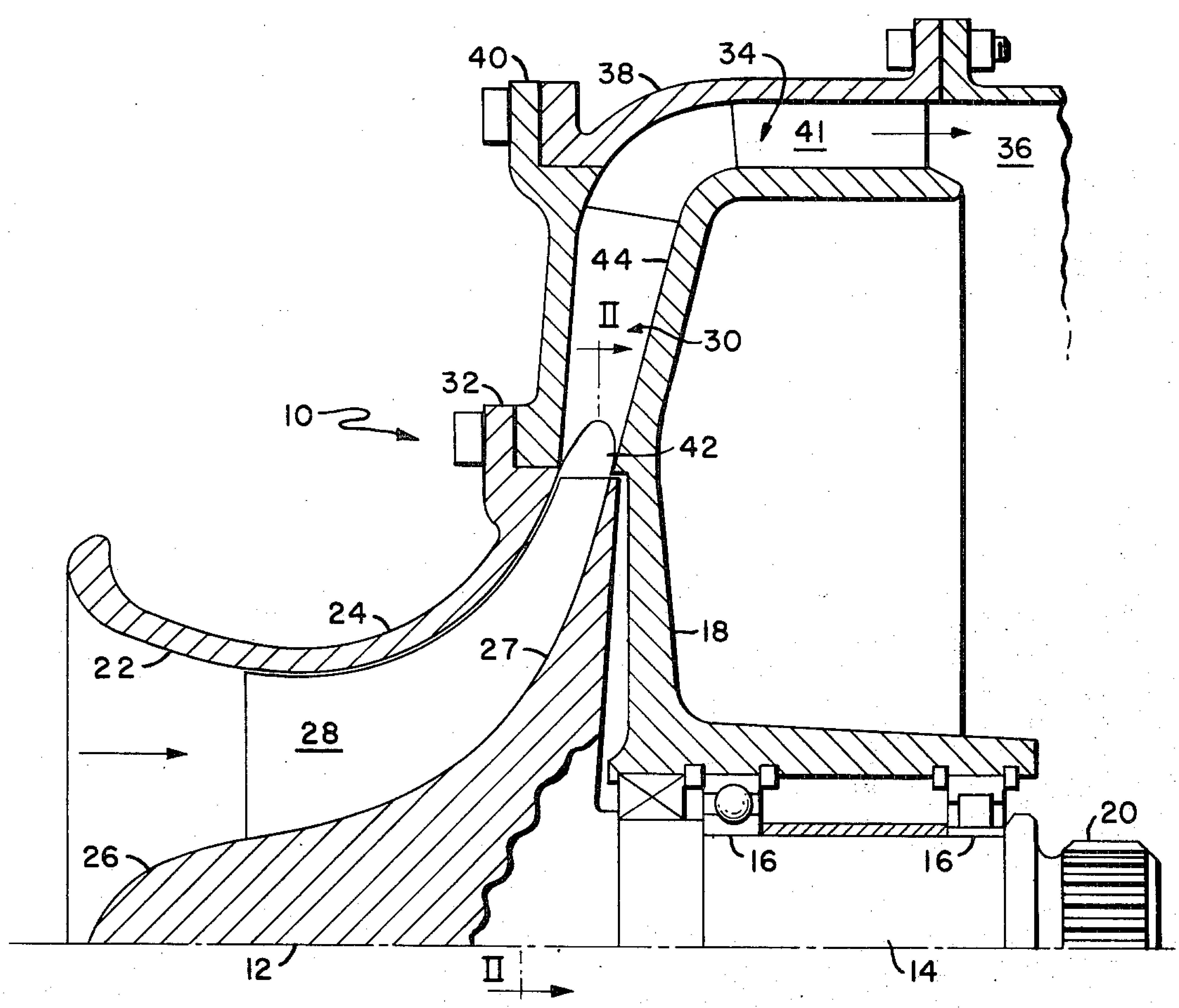
[57] **ABSTRACT**

A radial flow compressor is described which includes a diffuser having an annular entrance chamber surrounding the circumferential discharge of the impeller of the compressor. Diffuser channels extend from this annular chamber to an axial flow diffuser from which the compressed air is discharged into a collection chamber. The annular chamber is provided with contoured nodes from which the channel diffusers respectively extend at relatively low angles, tangentially in relation to the periphery of the impeller.

1 Claim, 9 Drawing Figures



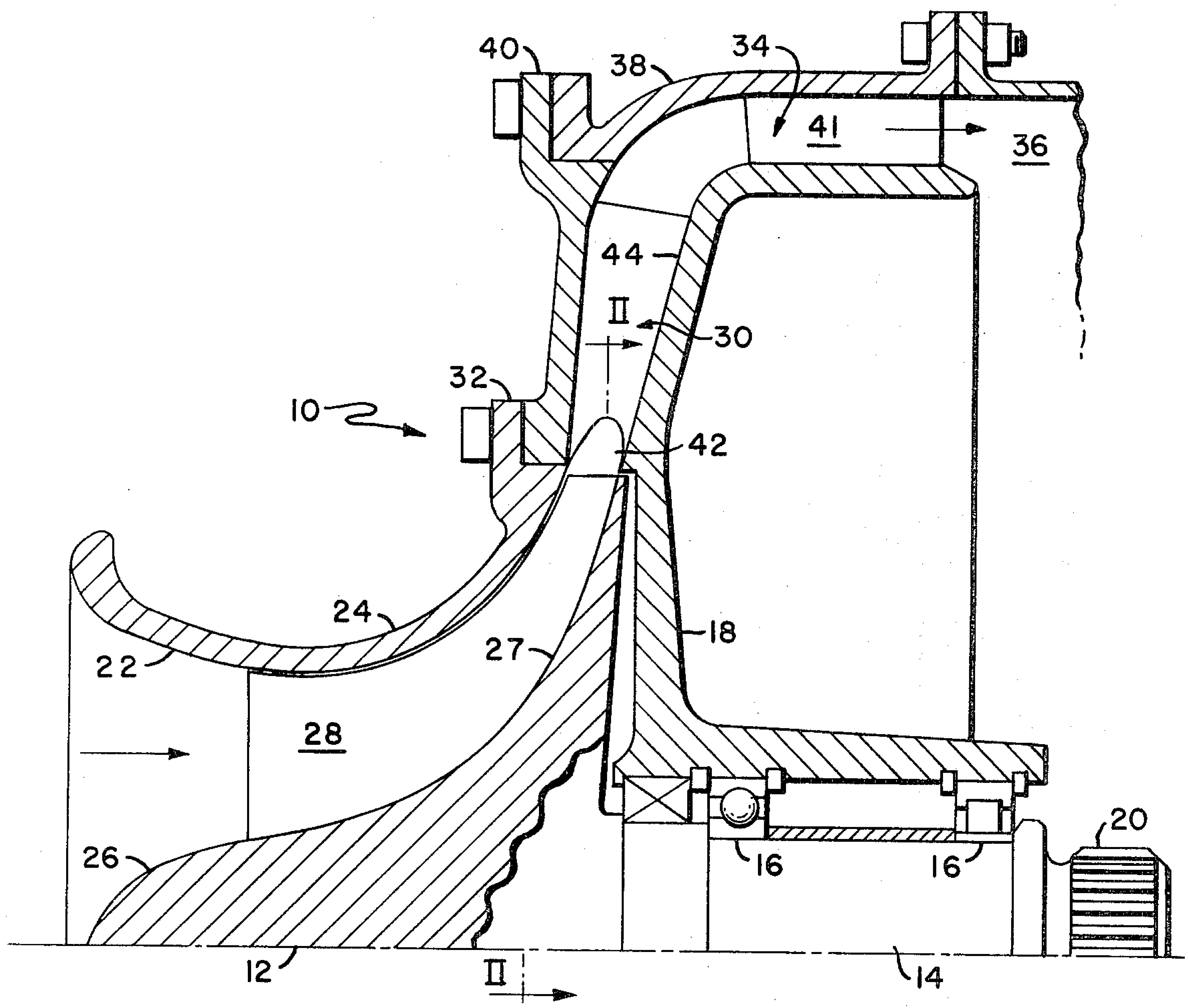


Fig 1

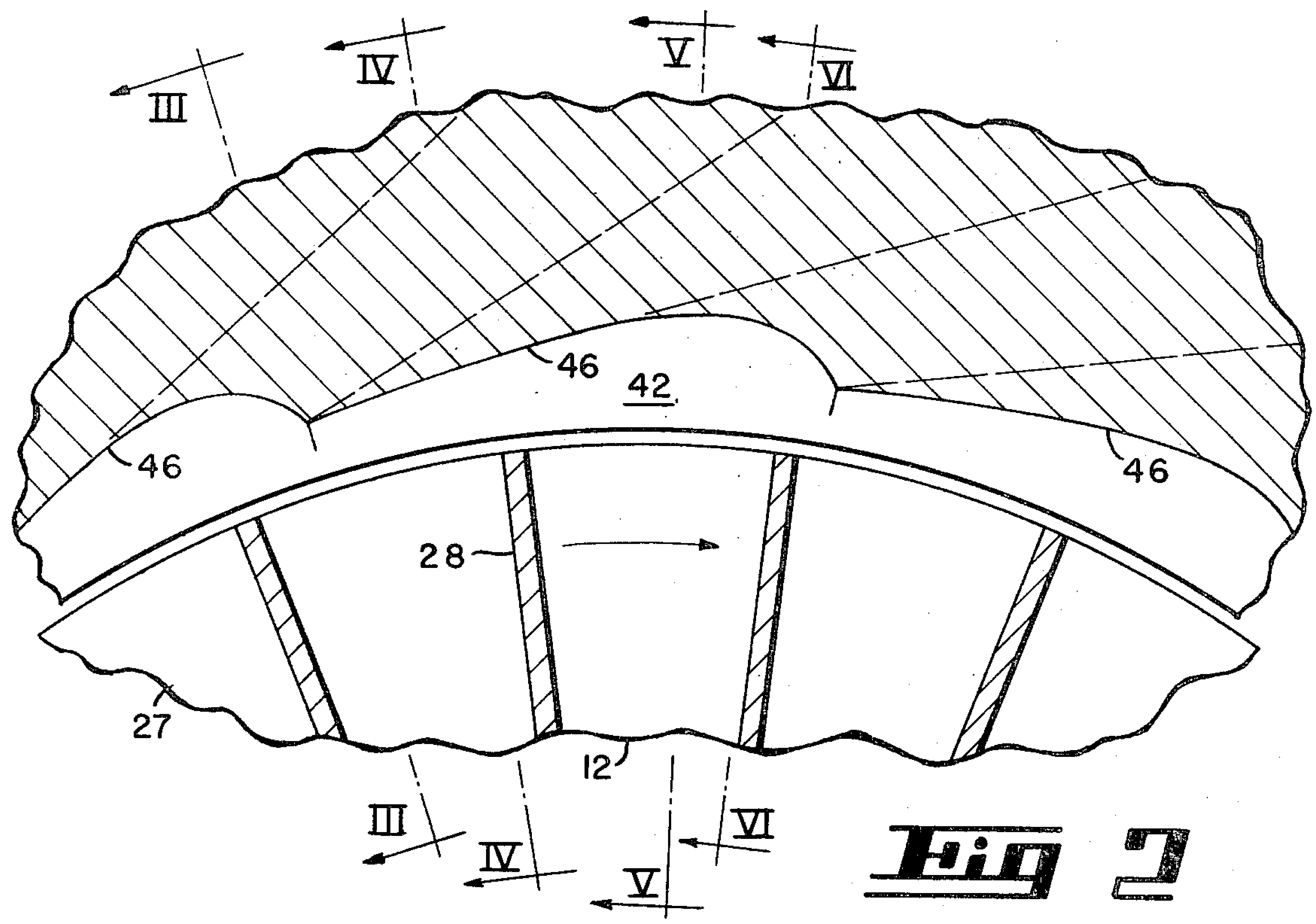


Fig 2

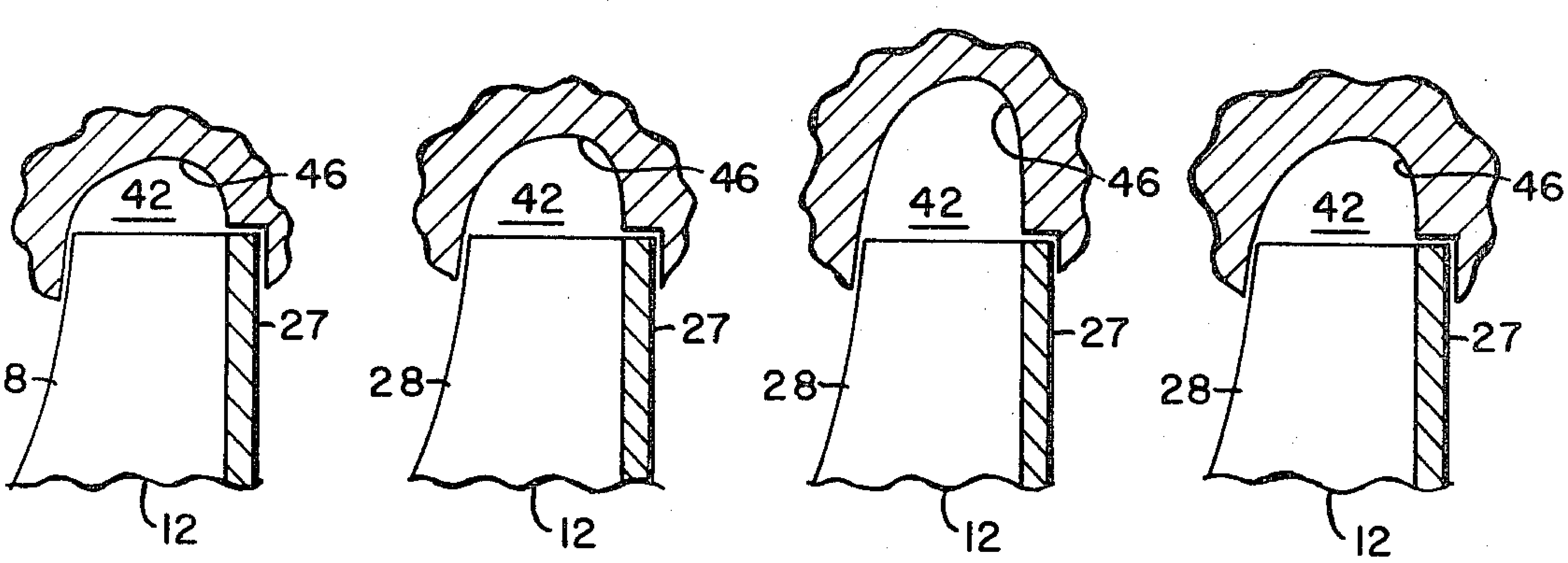


Fig 3 Fig 4 Fig 5 Fig 6

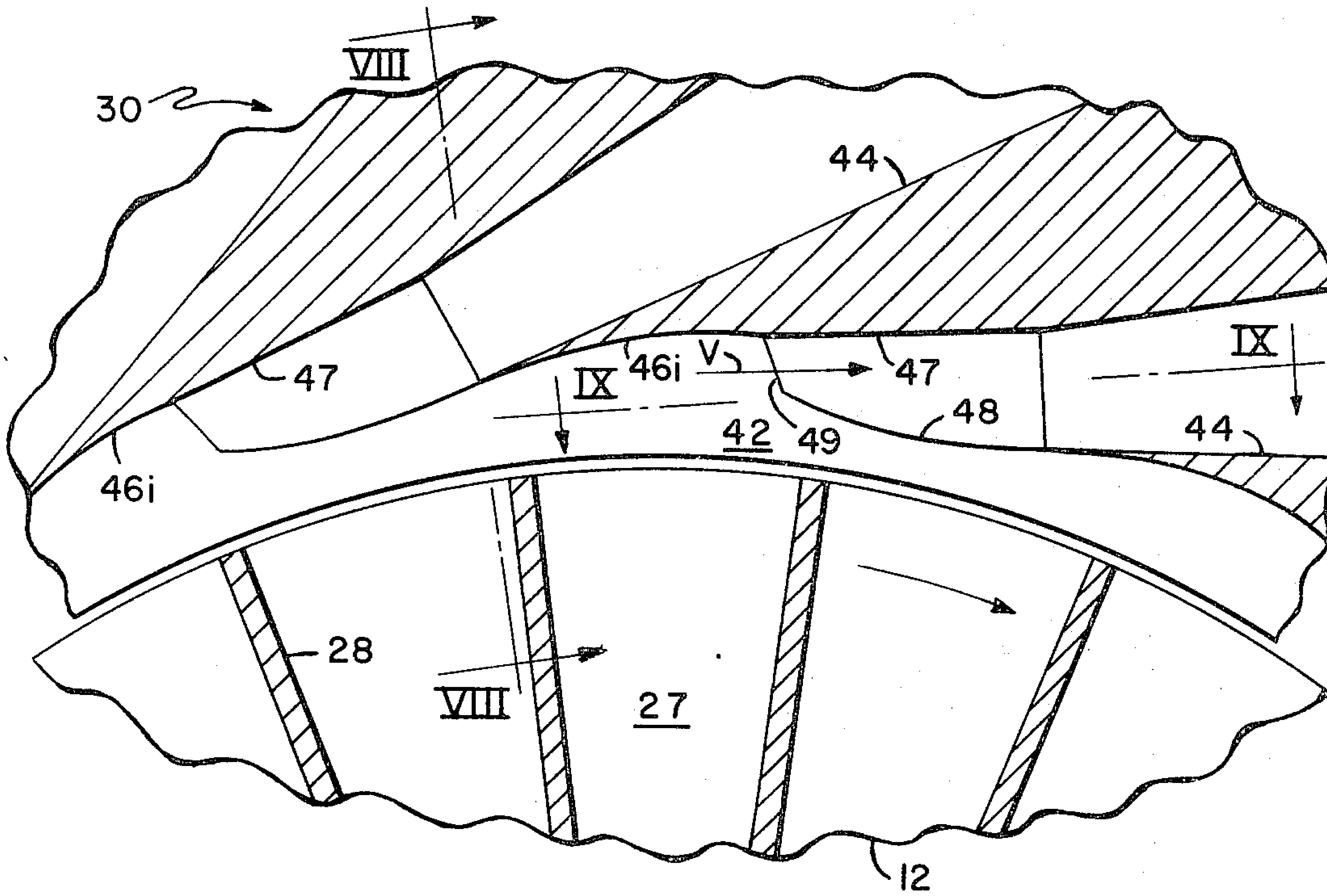


Fig 7

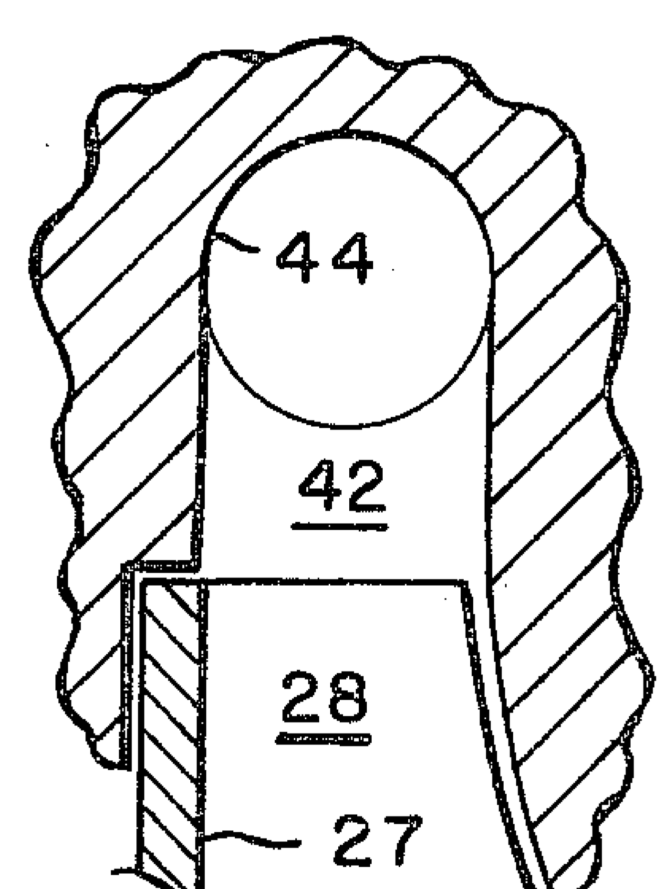


Fig 8

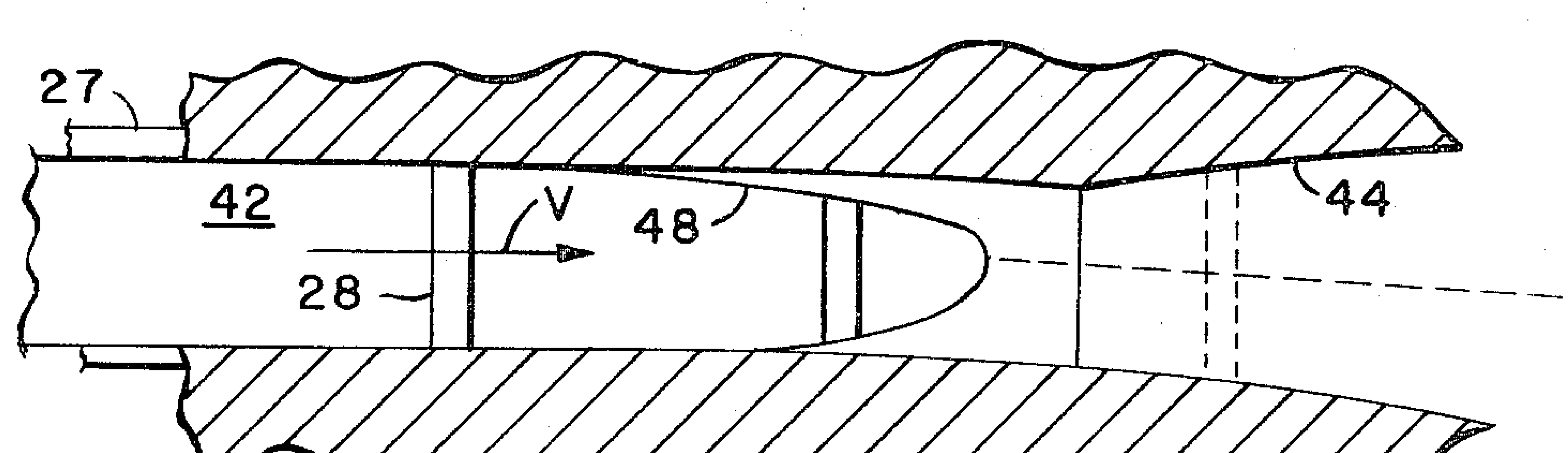


Fig 9

TURBOMACHINERY AND METHOD OF MANUFACTURING DIFFUSERS THEREFOR

The present invention relates to improvements in turbomachines and more particularly to improvements in compressors and diffusers therefor as well as methods of making same.

Transitional flow of high velocity fluids, such as a gas stream, from a rotor to a diffuser and/or a turning cascade has long posed great difficulties, not only in minimizing losses, but in manufacture as well. While the invention is not necessarily so limited, such problems are greatly pronounced in radial flow compressors and diffusers therefor. While certain advantages are found in the type of diffuser described in U.S. Pat. No. 3,333,762, wherein pipes or channels intersected tangentially of a compressor impeller discharge to form a fluted annular entry chamber surrounding the compressor impeller. The resulting configuration has been ascertained to have undesirable losses which are particularly pronounced when operating outside of a very narrow range of parameters selected for maximum efficiency and generally known as the design point.

Formation of an annular diffuser entrance chamber, as referenced above, by drilling intersecting holes through a ring of material provides a simple and economical method of obtaining an effective diffuser. However, the configuration of the annular entrance chamber is inflexibly established by the cross section and size of the diffuser channels and the spacing therebetween. Not only is the channel configuration determined by these constraints but the configuration of the diffuser channel entrances is also established thereby. Further inflexibility is also added by the fact, that, for most diffusers, the channels therefor are straight and circular in cross section.

A further problem, again most apparent in radial flow compressors, is that the velocity vector direction of the primary or main flow stream will vary from that of the boundary layer of the flow stream. Further, such variations differ between the impeller disc from which the impeller blades project and the shroud which surrounds the tip ends of such blades. These variations in velocity vector direction, as well as the differences in vector magnitude, contribute to the losses which are associated with pipes or channel diffusers.

While the present invention is particularly motivated by the problems referenced above in conjunction with radial flow compressors, similar problems, in varying degrees, exist in axial flow compressors as well as in the turbine discharge of gas turbine engines employed for the jet propulsion of aircraft.

Accordingly, one object of the present invention is to minimize losses in the transitional flow of a pressurized gas from an impeller, or the like, to a relatively stationary diffuser cascade wherein kinetic energy is converted to static pressure rise and, in doing so, to increase efficiency over a wide range of operating conditions outside the design point.

Another object of the invention is to provide an improved method for manufacturing a diffuser accomplishing the above ends.

Another and more specific object of the invention is to provide an improved radial flow compressor having a channel or pipe type diffuser wherein transition flow losses and entry losses into the individual channels are greatly minimized.

A further object of the invention is to provide an improved method of maintaining channel type diffusers for radial flow compressors and in doing so to provide a high degree of configurational flexibility, while minimizing the expenses of such manufacture.

The above ends are attained, in the broader aspects of the invention, in a turbomachine which may take the form of either a compressor or an energy extracting turbine. Both the compressor and turbine have a bladed rotor, downstream and in series relationship with which there is provided a diffuser which includes an annular entrance chamber for the rotor discharge. The annular chamber is of generally curved U-shaped cross section providing an increased flow path area leading to the entrances of diffuser channels extending therefrom. This arrangement provides a diffuser effect for the rotor discharge and minimizes the detrimental effect of differences in vector velocity and direction in the transitional flow of pressurized gas into the diffuser channels and further minimizes losses over a broad operating range.

Other preferred features are found in the provision of nodes of increased flow area formed in the annular chamber and from which the diffuser channels respectively extend. More specifically the nodes may be of a generally convolute form having their maximum curvature at their downstream ends, as related to the direction of rotor rotation.

The invention, in its more specific aspects, may take the form of a radial compressor wherein a diffuser is provided with an annular entrance chamber surrounding the circumferential discharge of its impeller. The annular chamber may be of generally curved U-shaped cross section, with a plurality of diffuser channels extending tangentially outwardly from the entrance chamber. The entrance chamber may also be provided with a series of nodes of increased flow area spaced therearound. The channel diffusers may, advantageously, be of circular cross section, intersecting and extending from the intersections of the nodes of the annular entrance chamber.

Further, the impeller of the radial flow compressor may include a disc from which blades project. The nodes of the annular chamber as well as the diffuser channels then may be angled, relative to the axis of the impeller, away from the blade side of the disc.

The method aspects of the invention are found in forming a generally curved U-shaped groove in a suitable work piece. Holes are formed which extend from the bottom of such groove and are angled relative thereto thereby controlling the entrance configuration for what will ultimately become diffuser channels, as a function of the configuration of the groove and the holes. For a diffuser to be employed in a radial flow compressor such groove is formed in the inner surface of an annular work piece. The holes are then formed generally in the same plane as the groove. Additionally, in forming the annular groove, nodes of increased areas will be formed therearound and the holes may be formed to intersect the intersection of the nodes.

The above and other related objects and features of the invention will be apparent from a reading of the following description, in which reference is made to the accompanying drawings, and the novelty thereof pointed out in the appended claims.

In the drawings:

FIG. 1 is a longitudinal half section of a radial flow compressor embodying the present invention;

FIG. 2 is a section taken generally on line II—II in FIG. 1, but showing the compressor diffuser only partially fabricated;

FIG. 3 is a section taken on line III—III in FIG. 2;

FIG. 4 is a section taken on line IV—IV in FIG. 2;

FIG. 5 is a section taken on line V—V in FIG. 2;

FIG. 6 is a section taken on line VI—VI in FIG. 2;

FIG. 7 is a section also taken on line II—II in FIG. 1, but showing the completed diffuser;

FIG. 8 is a section taken on line VIII—VIII in FIG. 7; and

FIG. 9 is a section taken generally on line IX—IX in FIG. 7.

FIG. 1 illustrates a centrifugal compressor **10** comprising an impeller **12** having a shaft **14** projecting from one side thereof and journaled by bearings **16** on a frame **18.** The outer end of the shaft **14** is splined at **20** to provide a drive input thereto, as by connection with a turbine shaft where the compressor **10** is incorporated as a component part of a gas turbine engine.

The inlet to the compressor **10** is defined by a bellmouth **22** formed on a housing **24.** The inner portion of the inlet is defined by a bullet nose **26** on the impeller **12.** The impeller **12** is outwardly curved to a disc portion **27** in progressively decreasing spaced relation to a similarly curved portion of the housing **24.** The impeller further has blades **28** projecting toward the housing **24,** which functions as a shroud therefor, all in accordance with known constructions of this type of compressor.

With the impeller **12** rotating, air enters the compressor inlet, is pressurized and then discharged in an essentially radial direction, relative to the impeller axis and tangentially, at a low angle, to the outer periphery of the impeller.

Air discharged from the impeller **12** enters a radial diffuser **30,** see also FIG. **7,** which may be formed in the frame **18.** The housing **24** is secured to the frame **18** by a flange connection **32.** Pressurized air, after discharge from the radial diffuser **30** may then be turned into an axial flow diffuser **34** to be discharged into a collection chamber **36.** Pressurized air may be drawn from the collection chamber **36** for utilization where required, as in the combustor of a gas turbine engine.

The compressor assembly may further comprise an outer housing **38** for the diffuser **34** which is secured to the frame **18** by a flange connection **40.** Vanes **41** may be mounted in the axial diffuser **34** to turn the flow of air in an axial direction as it is discharged into the chamber **36.**

The radial diffuser **30** comprises (FIGS. **1, 7–9**) an annular chamber **42** surrounding the impeller **12** and a plurality of channel diffusers **44** extending tangentially therefrom, at relatively low angles, and discharging into the curved annular entrance to the axial diffuser **34.**

The radial diffuser **30** is better understood by reference to FIG. **2** which illustrates a preliminary step in its fabrication. As indicated above, the diffuser **30** may be formed in the frame **18.** One step, and usually the first step, in manufacture of the diffuser **30** is to form an annular groove on an inner surface of the frame **18.** The groove so formed becomes the annular chamber **42** in the finished diffuser and is so numbered in FIGS. **2–6.** The groove is formed with a generally curved U-shaped cross section. Further, in forming this groove, node chambers **46,** of increased area, are also formed around the groove.

The node chambers **46** are convolute, having a maximum curvature at their downstream ends, related to the direction of impeller rotation, as indicated in FIG. **2.** The node chambers **46** are also angled, relative to the impeller axis away from the side of the disc from which the blades project, as will be evident from FIGS. **3–6.**

Having formed an annular groove with the node chambers **46,** the channel diffusers **44** are then machined in the frame **18.** The outlines of the channel diffusers are indicated by broken lines in FIG. **2** to illustrate the relationship thereof to the junctures, or intersections, of the node chambers **46.** When the diffuser channels are formed, as by drilling through the bottom of the described groove, the configuration illustrated in FIGS. **7-9** results. The outer surface **47** of each channel diffuser is generally parallel with and spaced slightly inwardly of the relatively flat upstream end **46*i*** of a node **46.** This outer surface is also spaced from the inner surface of the next adjacent diffuser channel by a portion of the annular chamber wall surface. The inner surface of the diffuser channel intersects the relatively flat surface of a node chamber **46** at **49** and a resultant entrance lip **48** spaced from the inner periphery of the diffuser **30** is created as illustrated in FIGS. **7** and **9.** This entrance lip, advantageously, angles toward the axis of the diffuser.

While a preferred configuration has been described, it is to be understood that the described method of manufacture economically provides a wide degree of flexibility in forming diffusers and controlling the transitional flow through an annular chamber, as well as controlling the entrance configuration for individual channel diffusers. All of this is of importance because of the widely varying flow, velocity and pressure requirements of different compressor designs. The techniques for forming the groove **42** and channel diffusers may take various forms. Electrochemical machining may advantageously be employed to form the nodular groove while a simple drilling and reaming operation may be employed for the diffuser channels. As illustrated, the channel diffusers have a divergent conical section. However, they may be provided with an initial cylindrical section followed by a conical section, as will be apparent to those skilled in the art. While such circular cross sections are preferred, other cross sections may also be employed. All of this emphasizes the configurational control that may be obtained through selection of the groove cross section, the curvature of the nodes and the location and the cross section of the holes formed from the bottom of the groove to define the diffuser channel entrances. It will also be apparent that the outer portions of the diffuser channels could be separately formed and later assembled, where desired.

Another factor to be considered is that the flow direction of air discharged from the impeller **12** is three dimensional in character. Thus the velocity vector V, indicated in FIGS. **7** and **9,** has components radially of, laterally of and axially of the axis of the impeller **12.** The tangential disposition of the channel diffusers, together with the axial (relative to the impeller axis) angling of the node chambers **46** and diffuser channels **44** minimizes losses which might otherwise be attributable to these vector components, providing a resultant increase in the efficient operating range.

Thus, in being discharged from the impeller **12,** the air is guided in this three-dimensional direction by the nodular portions of the annular chamber **42** to the entrances of the diffuser channels **44.** Further, in being so guided through an increasing passageway area a diffuser action is provided. This combination of effects enables the differences between the velocity vector directions of the main flow stream and the boundary layer flow to adjust and balance so that losses attributable to these differences, are minimized. Likewise differences in boundary layer vector direction and between the shroud side and the disc side of the impeller, are minimized by the cross sectional contour of the annular chamber **42** which in effect angles flow away from the blade side of the disc. **27.**

While the invention has been described in connection with a preferred embodiment of a radial flow compressor, it will be apparent to those skilled in the art that the broader aspects of the invention will have utility in axial flow compressors as well as turbines incorporating diffusers. The spirit and scope of the present inventive concepts is therefor to be derived solely from the following claims.

Having thus described the invention, what is claimed as novel and desired to be secured by Letters Patent of the United States is:

1. A turbomachine comprising

a rotor from which pressurized fluid is discharged at a relatively high velocity,

a diffuser in series flow relationship with said rotor, said diffuser including an annular entrance chamber having an inner periphery into which the rotor discharge flows and diffuser channels having generally circular inlets extending from the bottom of said annular chamber, said annular chamber being further characterized by a series of convolute node chambers of increased flow area spaced therearound from which said diffuser inlets extend, said convolute node chambers having upstream wall sections of a U-shaped cross section extending outward from the inner periphery of said chamber in a direction generally parallel to and spaced slightly outwardly with respect to the outer walls of the diffuser inlets and downstream wall sections defining with the circular diffuser inlets scalloped leading edges terminating at points spaced radially outward from the inner periphery of said entrance chambers,

whereby there is a preliminary diffusion of the compressed gas as it flows through the annular chamber and the differences in vector magnitude and direction of the gas are minimized.

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