Aug. 1, 1967 J. C. VRANA 3,333,762

DIFFUSER FOR CENTRIFUGAL COMPRESSOR

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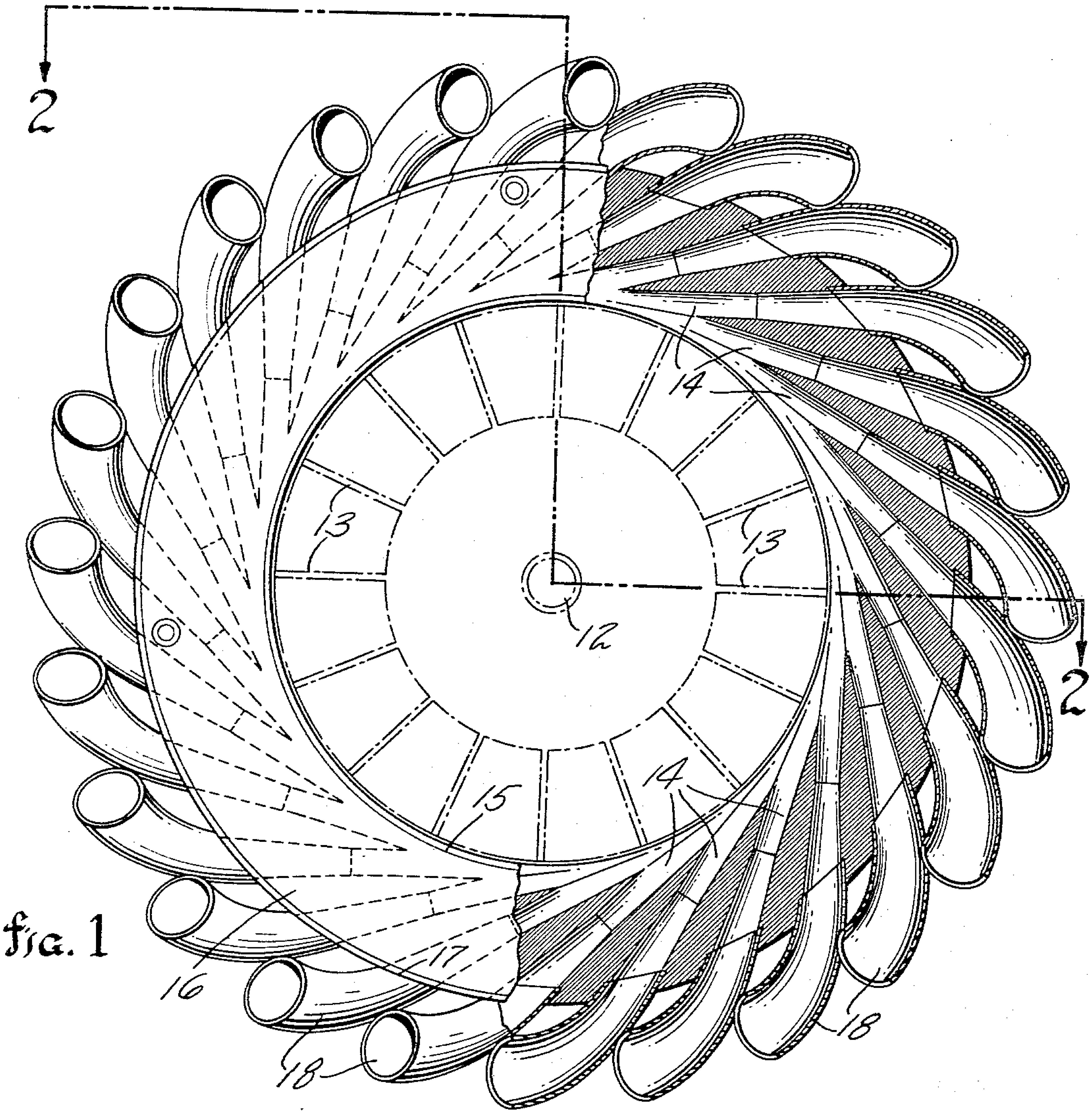

fig. 1

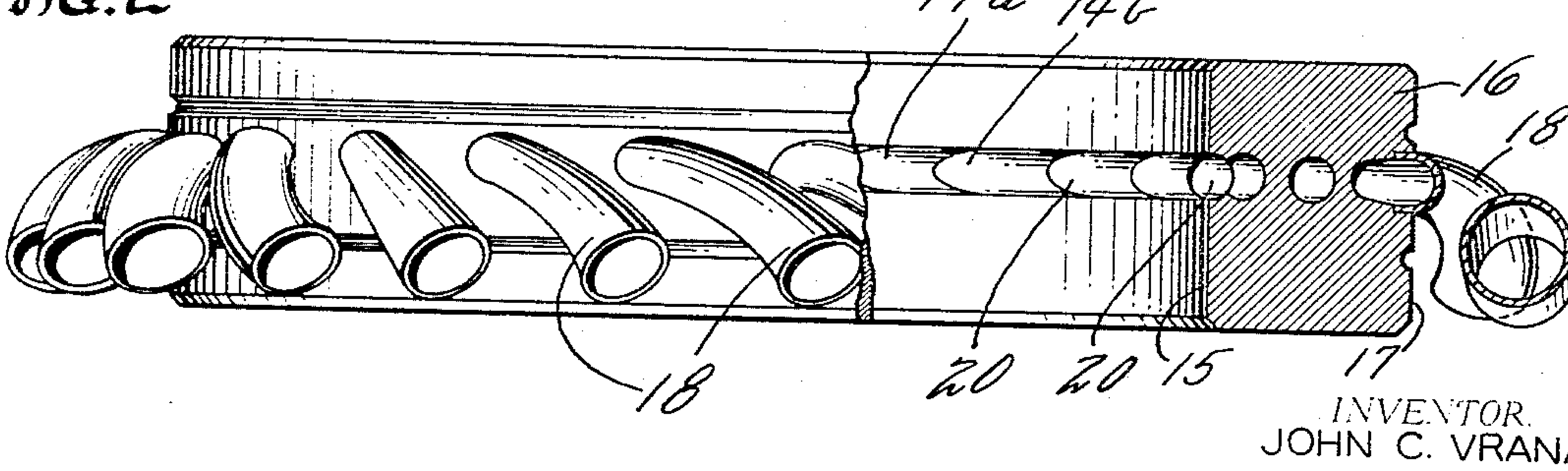

fig. 2

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DIFFUSER FOR CENTRIFUGAL COMPRESSOR

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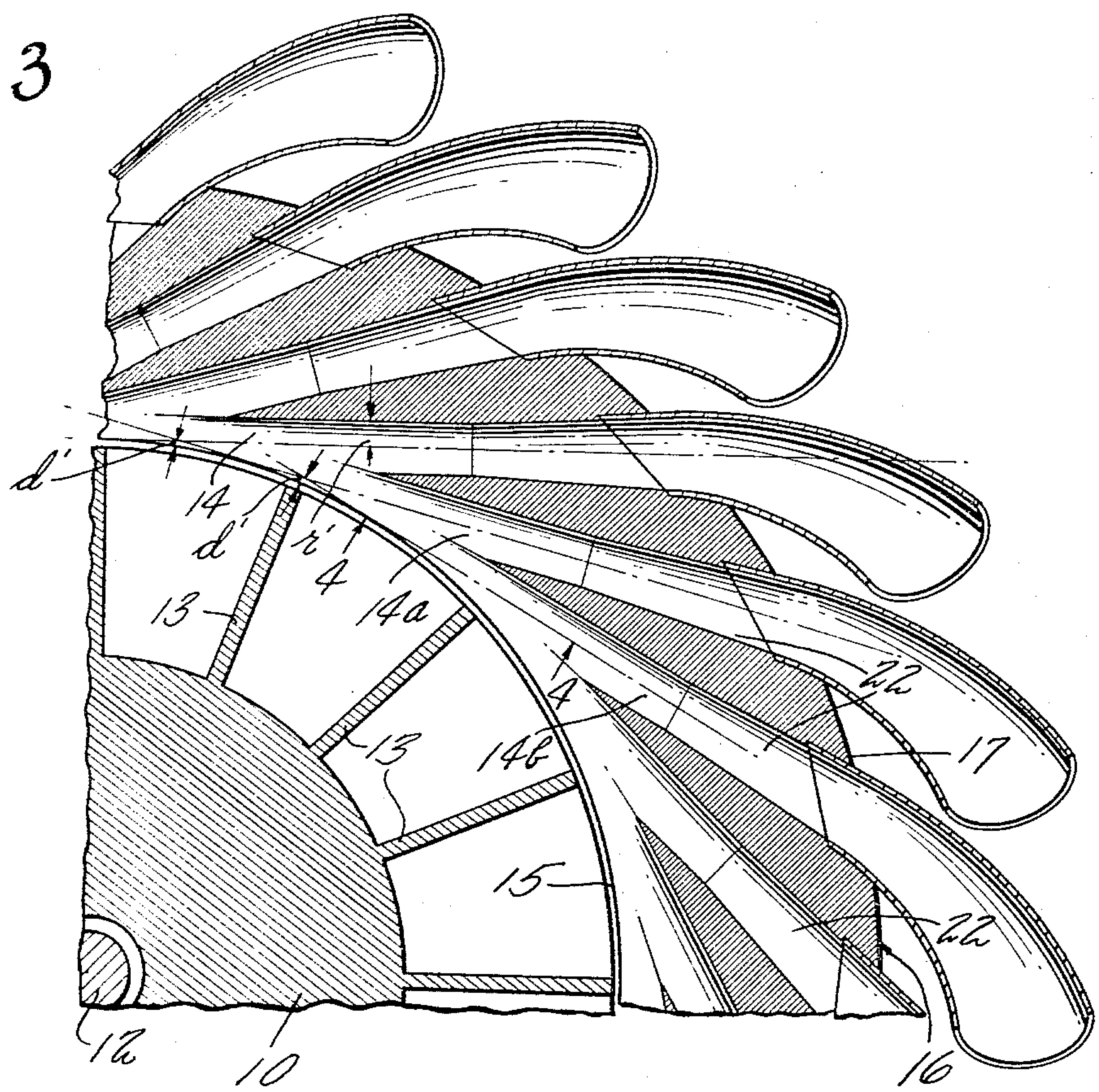
fig. 3



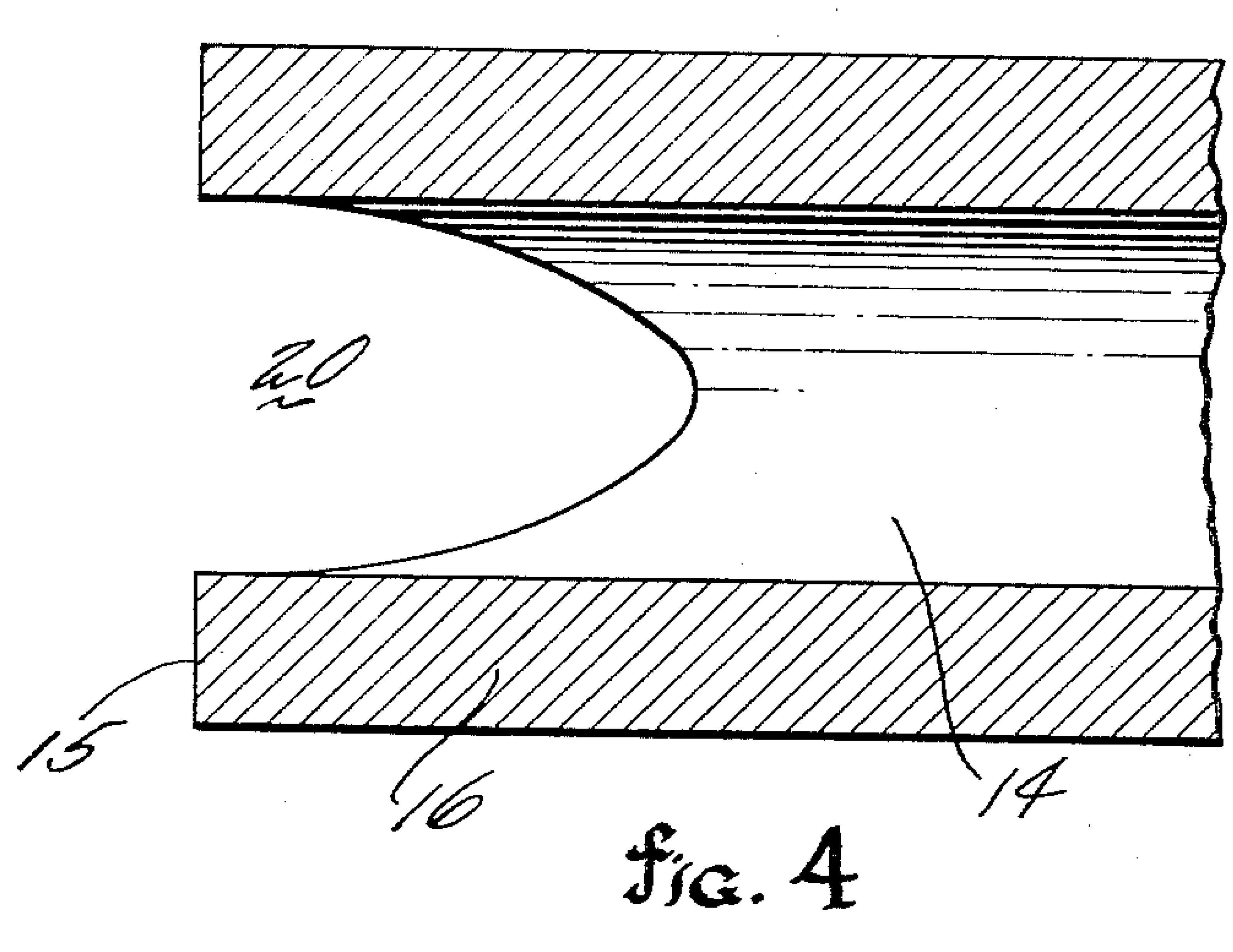


fig. 4

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DIFFUSER FOR CENTRIFUGAL COMPRESSOR

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ABSTRACT OF THE DISCLOSURE

The diffuser for the centrifugal compressor has a plurality of intersecting passages extending outwardly from the inner circumference, which passages are curvilinear in transverse section and have their center lines all tangent to a common tangency circle which is substantially the same diameter as the periphery of the impeller with the center lines of the several passages intersecting with one another at a distance outwardly from the common tangency circle.

The present invention relates to improvements in the construction of diffusers for centrifugal compressors and more particularly to a diffuser capable of operating over a wide range of pressure rise through the compressor.

This is a continuation-in-part application of application Ser. No. 410,642, filed Nov. 12, 1964.

In most centrifugal compressors a rotating impeller is arranged to add energy by accelerating the true flow of gas which is then decelerated in a stationary diffuser where a pressure rise is produced. In most prior diffusers an arrangement of stationary diffuser vanes is positioned in such a manner as to produce passages expanding in area for the purpose of diffusing the flow. Since the mass flow entering the diffuser is normally of extremely high velocity, it is necessary to provide means for preventing or reducing shock waves. Accordingly, each of the diffuser vanes utilized for this purpose must be provided with a profiled leading edge directed toward the impeller and a great care must be taken in the profiling of these edges and the assembly of the vanes relative to each other and to the impeller if losses are to be avoided and a geometrically balanced diffuser is to be obtained. In order to obtain the desired profile extreme care must be taken in the finishing of the machining of the vanes.

The present invention provides a diffuser configuration which produces a unique reduction in entry shock while at the same time reducing to a minimum the necessity for machining or otherwise profiling the separate vanes and otherwise simplifies the making and assembly of such a device.

More specifically the present diffuser construction embodies an annular member closely surrounding the impeller and having a plurality of circumferentially spaced passages curvilinear in cross section and extending through the member in such a manner as to be tangent to a common circle substantially equal in diameter to the periphery of the impeller and with each passage disposed so that it intersects with the next adjacent passage near to the inner circumference of the annular member. Therefore the center lines of adjacent passages intersect at a point outside the tangency circle with the distance from the common tangency circle to the point of intersection of the center lines of adjacent passages less than one-half the maximum transverse dimension of the passages. If the passages are circular in cross section, this means in effect that the distance from the common tangency circle to the point of intersection of the center lines of the adjacent passages is less than the radius of the passages. Where the passages break through the inner periphery of

the diffuser member, a substantially elliptical opening is formed and the elliptical openings of adjacent passages intersect and overlap in such a manner as to leave an uninterrupted annular space or opening in the inner surface of the annular member which opening surrounds the periphery of the impeller blades. The opposite side walls of this annular space may be somewhat undulating by reason of the circular or curvilinear transverse cross section of the passages although the effect of this undulating or wavy edge may be reduced by increasing the number and/or diameter of the passages.

Within the diffuser the intersecting passages define therebetween a wall surface, the leading edge of which is substantially elliptical with the major axis of the ellipse parallel substantially to the plane defined by the center lines of the several passages. This leading edge is such that its incidence varies to approximate the typical flow of the air leaving the impeller. This elliptical leading edge produces a highly swept configuration such that it counteracts the otherwise detrimental three-dimensional flow pattern resulting from a non-uniform velocity profile entering the diffuser. The device is therefore capable of operating both at subsonic and at supersonic flow and is equally effective in transonic flow. This substantially elliptical configuration results from the formation of the passages in the annular member and no additional particular or specific machining operation is necessary to produce the sharp leading edge that is essential for the effective operation of the device. The machining of the adjacent passages produces the particular leading edge for this divider and the particular configuration may obviously be varied to some extent by selection of the transverse shape of the adjacent passages. Obviously, changes in transverse cross section of the passages may be utilized to produce variations from the true elliptical shape.

Trumpet-like diffusers are inserted in each of the passages bored through the annular members so as to increase the initial diameter of each passage as it extends outward in order to decelerate the flow as the mass flow proceeds through the widening portion thereby being diffused and causing an increase in the static pressure.

Having thus generally described the nature of the invention, particular reference will be made to the accompanying drawings showing by way of illustration a preferred embodiment thereof, and in which:

FIG. 1 is a partly sectional view of the impeller and diffuser as seen downstream of the impeller section to show the intersecting passages surrounding the diffuser ring in accordance with the invention.

FIG. 2 is a cross-sectional view of FIG. 1 as seen along the line **2—2**.

FIG. 3 is an enlarged detail view of a portion of the diffuser ring shown in FIG. 1 to illustrate more clearly the intersecting passages.

FIG. 4 is a sectional view along line **4—4** of FIG. 3.

With particular reference to FIGURE 1 of the drawings showing by way of illustration a portion of centrifugal compressor wherein an impeller **10** is mounted for axial rotation about a center shaft **12**. The impeller **10** is provided with blades **13** and the diffuser ring **16** of the invention is mounted externally so as to surround the outer tips of the blades **13** as shown most clearly in FIGURE 3. The diffuser ring is an annular member having inner and outer peripheral surfaces **15** and **17**, the inner surface being closely adjacent to the outer periphery of the impeller, as shown.

A main feature of the present invention is the formation of a plurality of passages **14** extending through the annular member **16** and so closely spaced circumferentially that adjacent passages intersect one another, as shown. While the passages **14** are shown as being straight-sided cylindrical passages, it is contemplated that they may be conical or any other formation that is curvilinear in cross section without departing from the scope of the invention. The center lines of the several passages **14** are tangent to a common circle which has approximately the same diameter as the periphery of the impeller. This common tangency circle in the particular arrangement shown is coincident with the inner substantially cylindrical surface **15** of the annular member **16**. Although the center lines of the passages **14** are shown in FIG. 2 as being in a transverse radial plane, it will be understood that they may be inclined at a moderate angle to this plane without departing from the scope of the invention.

Each passage (**14***b* for example) intersects an adjacent passage **14***a* at a small distance *d'* outwardly from the circle of common tangency. The distance *d'* must be less than the radius *r'* of the passages **14**, measured at a point near the intersection of adjacent passages or, in the event that the passages are curvilinear in cross section without being precisely circular the distance *d'* is less than one-half of the maximum transverse dimension of the passage. If the distance *d'* were greater than one-half the transverse dimension of the passage **14** the adjacent passages would leave a solid segment of material at the inner surface **15** of the diffuser **16** rather than providing, as shown in FIG. 2, a continuous diffusing space or zone **20**. This space **20** surrounds the impeller blades and provides for uninterrupted entry of the air from the impeller blades flowing into the diffuser member.

If the diameters and angles of the passages are properly selected the leading edge defined by the intersecting passages between adjacent passages will begin at a point closely adjacent to the inner wall surface **15** of the diffuser and will sweep back, as shown in FIG. 4, to a center line in the plane of the center lines of the passages and this leading edge, if the passages are circular, will be substantially elliptical. The axis of the ellipse will lie substantially in the plane defined by the center lines of the several passages and will accordingly provide a sweep back in the direction of flow which sweep back becomes steeper toward the center line of the flow path. This swept back leading edge which is produced to the configuration shown merely by the formation of the intersecting passages provides the desired sweep back for most effective operation of the diffuser. No further machining on the diffuser is necessary to produce the configuration of this leading edge. The configuration desired is obtained by having the intersecting passages curvilinear in transverse cross section and selection of a particular cross-sectional shape may be utilized to vary the elliptical configuration. The leading edge incidence varies from wall-to-wall of the diffusing space **20** and the configuration is such as to adapt the leading edge to the typical flow of air leaving the impeller. It will be apparent that the rate of flow is slower at the wall surfaces of the space **20** than it is in the middle of the space.

The particular configuration of this leading edge adapts the diffuser to supersonic flow from the impeller such that stall within the diffuser will develop progressively without becoming catastrophic at any point along the leading edge. Further, the arrangement of this particular leading edge allows the boundary layer to be as undisturbed as possible. It will further be apparent that the intersection between the two passages which produces this leading edge at the same time leaves this leading edge sharp from end-to-end which again makes the device adapted for supersonic flow. It has been found that this particular configuration will permit a substantially greater pressure rise from the impeller inlet to diffuser discharge than has previously been considered possible in centrifugal compressor constructions. This large pressure rise is also obtained with good efficiency.

The number of passages provided in the annular diffuser member **16** is obviously dependent on the volume and conditions of the mass flow. Any practical number of passages is permissible within the scope of the invention provided that adjacent passages be so located with respect to one another that the intersection between them is so located as to produce this substantially elliptical shape of leading edge on the dividing wall between the passages with the ends of this leading edge adjacent to opposite walls of the diffusing space **20** being located closely adjacent to the inner wall surface **15** of the diffuser.

With the construction shown and described, it will be apparent that the cross-sectional flow area for air leaving the impeller vanes increases until the air enters the passages **14** beyond the downstream part of the dividing wall between adjacent passages. From this point, the passages **14** if they are of constant cross-sectional area, produce no further diffusion until downstream of this point the passages **14** begin to taper through the outer portion of the annular member **16**.

Thus, each of these passages **14** has a tapered portion **22** at the outer end to accommodate one of a plurality of tapering trumpet-like nozzles **18** which are mounted on annular member **16**. As the air flow leaves the impeller blades, it is forced into the diffusing zone **20** at high speeds. The flow enters each of the passages **14** and as it progresses through the suitably shaped nozzles **18**, deceleration of the flow continues to occur thus increasing the static pressure.

As will be obvious, by reference to the accompanying drawings and preceding description, the present diffuser construction provides good geometry in fabrication, relatively low cost in manufacture and a good aerodynamic configuration. The present design also makes it possible to vary the capacity of the diffuser ring to suit any requirement by varying the number and dimensions of the passages **14**.

It is to be understood that the invention is not limited to the specific embodiment herein illustrated and described, but may be used in other ways without departure from its spirit as defined by the following claims.

I claim:

1. In a centrifugal compressor of the type having a rotary impeller, a diffuser comprising an annular member having an inner circumference closely surrounding the impeller, a plurality of intersecting passages in said annular member extending outwardly from said inner circumference, each of said passages being substantially straight from the inner end of the passage to a point downstream of its intersection with adjacent passages, said passages being curvilinear in transverse section, the center lines of the substantially straight portions of said passages being tangent to a common tangency circle having approximately the same diameter as the impeller, said center lines being also adapted to intersect the center lines of adjacent passages at a distance outward from said common circle having a length less than one-half the maximum transverse dimension of the passage measured at a point near the intersection of adjacent passages.

2. A centrifugal compressor as in claim **1** in which adjacent passages are so closely spaced that the wall surfaces of adjacent passages meet at a point outward of the inner circumference of the diffuser and define at their intersections a substantially sharp dividing wall having a curvilinear leading edge that is swept back in the direction of flow through the diffuser.

3. A centrifugal compressor as in claim **1** in which the passages are circular in cross section.

4. A centrifugal compressor as in claim **2** in which the passages are circular and the leading edge of the dividing wall is substantially elliptical.

5. In a centrifugal compressor of the type having an impeller, a diffuser comprising an annular member having an inner and an outer circumference, a plurality of straight intersecting passages in said annular member extending outwardly from said inner circumference, said passages being curvilinear in cross section, the center lines of said passages being tangent to a common tangency circle, said center lines being also adapted to intersect the center line of adjacent passages at a distance outward from said common circle having a length which is less than one-half the maximum transverse dimension of said passage measured at a point near the intersections of adjacent passages.

6. A centrifugal compressor as defined in claim 5, in which the said passages are circular in cross section for at least a portion of their length at the point of intersection of adjacent passages.

7. A centrifugal compressor as defined in claim 5 characterized in that said passages have defining walls intersecting the defining walls of adjacent passages to form a dividing wall between adjacent passages providing a leading edge disposed within said diffuser and adapted to engage fluid flowing through the diffuser in a manner to minimize diffuser entry losses.

8. A centrifugal discharge means having an impeller, characterized in that an annular discharge member is provided, said annular discharge member having inner and outer circumferential surfaces in the plane of the vertical axis of said impeller and being located as to surround said impeller, a plurality of straight passages of circular cross section in said annular member in spaced relationship and constituting fluid passages therethrough extending from said member inner circumferential surface to said outer circumferential surface with said passages being substantially tangent to a common circle, and that each passage intersects an adjacent passage at a point spaced inwardly from said inner circumferential surface to provide an annular passage about said inner circumferential surface disposed in line with and surrounding the outer periphery of said impeller, and wherein the center lines of said intersecting passages intersect the center lines of adjacent passages at a distance having a length which is equal to or less than the radius of the passage measured at a point near the intersection of adjacent passages, whereby fluid discharged from said impeller flows into said annular passage and from said passage through said fluid passages and out of said annular member, said intersecting passages acting to smooth the discharge flow of said fluid.

9. A centrifugal discharge means as claimed in claim 8, characterized in that said discharge means is a pump for liquids, slurries and other fluids.

10. In a centrifugal compressor of the type having an impeller, a diffuser comprising an annular member having an inner circumference and an outer circumference mounted about the periphery of said impeller, a plurality of straight passages of circular cross section extending in said annular member from said inner circumference to said outer circumference, the center lines of these passages being tangent to a common tangency circle, said center lines being also adapted to intersect the center line of adjacent passages at a distance outward from said common circle having a length which is equal to or less than the radius of said passage measured at a point near the intersection of adjacent passages, whereby each of said passages intersects an adjacent tangent passage in order to form an uninterrupted annular space in said annular member about said impeller periphery.

11. A centrifugal compressor as claimed in claim 10 wherein each of said passages terminates in a trumpet-shaped extension adapted to create a deceleration of said fluid.

12. In a centrifugal compressor of the type having an impeller, a diffuser comprising an annular member having an inner circumference and an outer circumference and being mounted about the periphery of said impeller, a plurality of straight passages of circular cross section extending in said annular member from said inner circumference to said outer circumference, said passages being tangent to a common circle, with at least one of said tangent passages intersecting an adjacent passage so that the center lines of said passages are tangent to a common circle, said center lines being also adapted to intersect the center line of said adjacent passage at a distance outward of said common circle having a length which is equal to or less than the radius of said passage measured at a point near the intersection of adjacent passages, whereby an annular space is formed in said annular member forming a flow diffusion zone adjacent said impeller.

13. A centrifugal compressor as claimed in claim 5, wherein the center lines of the passages are inclined at a moderate angle with respect to the plane of the tangency circle.

14. A centrifugal compressor as claimed in claim 11 wherein said trumpet-shaped extensions protrude outwardly from the outer circumference of said annular member.

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