

April 29, 1947.

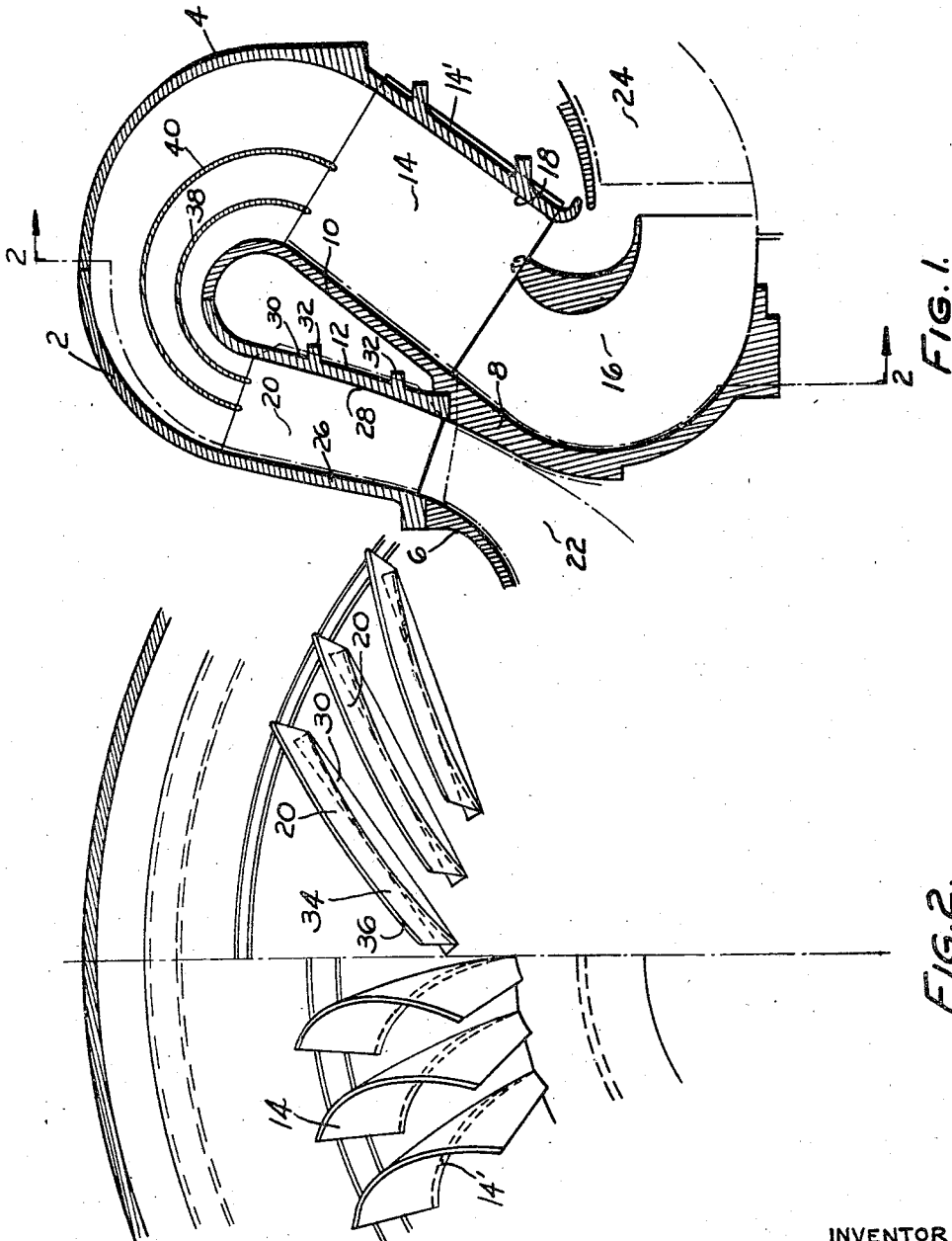
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2,419,669

DIFFUSER FOR CENTRIFUGAL COMPRESSORS

Filed May 8, 1942

3 Sheets-Sheet 1



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DIFFUSER FOR CENTRIFUGAL COMPRESSORS

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3 Sheets-Sheet 2

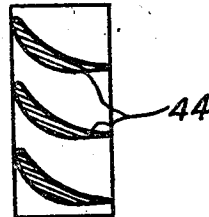


FIG. 6.

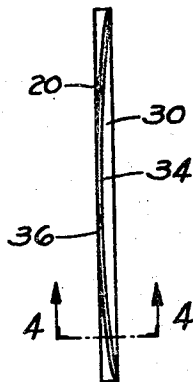


FIG. 3.

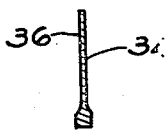


FIG. 4.

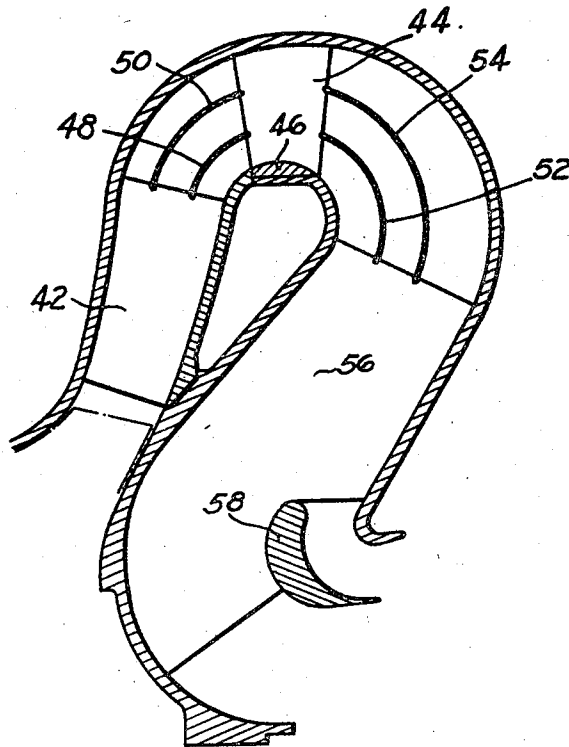


FIG. 5.

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DIFFUSER FOR CENTRIFUGAL COMPRESSORS

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3 Sheets-Sheet 3

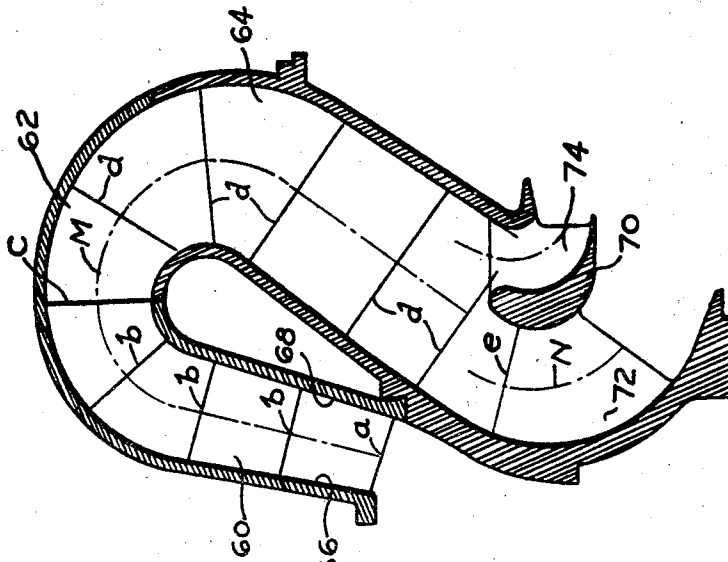


FIG. 7

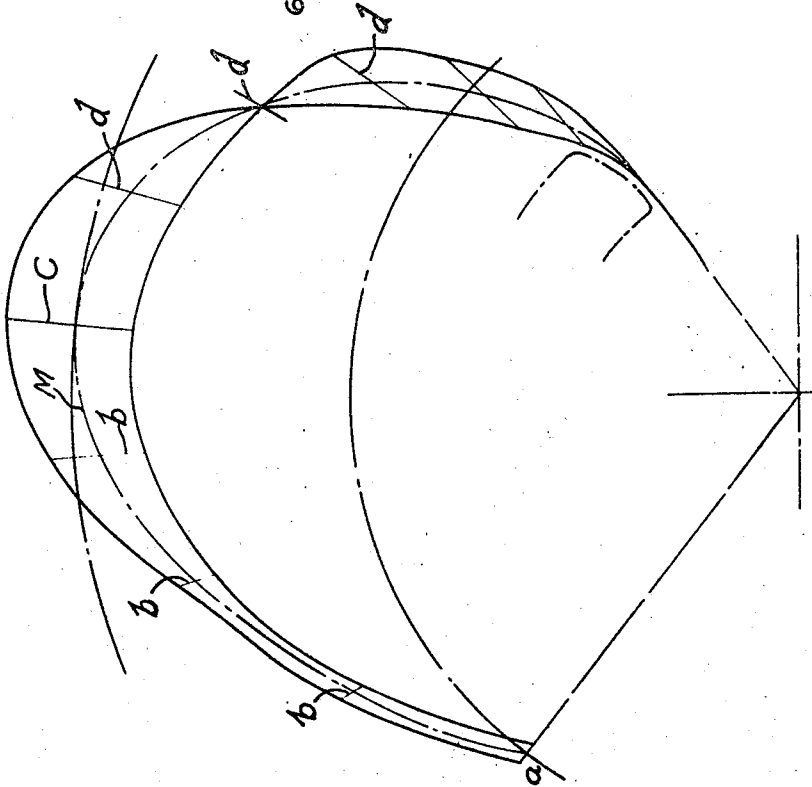


FIG. 8

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UNITED STATES PATENT OFFICE

2,419,669

DIFFUSER FOR CENTRIFUGAL
COMPRESSORS

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mesne assignments, to Federal Reserve Bank
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States of America

Application May 8, 1942, Serial No. 442,264

25 Claims. (Cl. 230—127)

1

This invention relates to diffusers for centrifugal compressors designed for the improvement of the efficiency thereof. The diffusers forming the subject of this invention are also adapted to be associated, if necessary, with a transfer arrangement for directing compressed elastic fluid from one stage of a centrifugal compressor to a subsequent stage, particularly under conditions where compactness is important.

In order to transform the kinetic energy of elastic fluid leaving the vanes of a centrifugal impeller into the desired pressure energy, an arrangement known as a diffuser must be used to effect this result by properly slowing down the gas with a minimum of turbulence which would decrease the pressure rise effected in the diffuser. The simplest form which a diffuser passage may take is merely that of an annular region without guiding vanes into which the elastic fluid is discharged from the impeller and in which its absolute velocity decreases, with the result that it is ultimately withdrawn from the diffuser region at relatively low velocity and increased pressure. Such a passage, however, is ineffective as a diffuser, particularly if the impeller is operating at very high tip speeds, since the ratio of decrease of absolute velocity is only approximately the ratio of the outer diameter of the impeller to the maximum diameter of the diffuser region. To increase the energy transformation with reasonable dimensions of the impeller housing, it is, therefore, customary to provide vanes which tend, by decreasing more rapidly the rotation of the elastic fluid, to cut down its absolute velocity, thereby to effect in a shorter path of flow transformation of its kinetic energy into pressure.

In these diffusers, therefore, the vanes depart outwardly from a logarithmic spiral form, the rate of departure being limited by the consideration that it must not be so great as to cause the flow to break away from the inside walls of the vanes.

In compressors as heretofore constructed, the diffuser passages are bounded in an axial direction by planes extending substantially at right angles to the axis of rotation of the impeller. From such diffuser passages, the gas, if it is to pass to a second stage, is deflected axially and then inwardly to the entrance of the next impeller.

2

One object of the present invention is to provide an improved diffuser for a centrifugal compressor designed for the efficient transformation of kinetic energy to pressure. The diffuser passages are so constructed as to receive smoothly the elastic fluid leaving the impeller without substantial deviation from the flow direction which it has at the outlet from the impeller passages, and thereafter to deflect the flow outwardly from its normal path while moving it axially through passages of proper cross-section to secure smooth flow. The diffuser is designed particularly for impellers discharging the fluid with a quite substantial axial component of motion.

A further object of the invention is to provide an improved diffuser which constitutes a substantial part of a set of transfer passages designed to lead the fluid from one impeller to an impeller of a subsequent stage. In the most desirable form of this arrangement, the elastic fluid will approach the impeller of the second stage with an absolute velocity having substantially only an axial component of flow without substantial spin.

Still another object of the invention relates to an improved construction of diffuser vanes whereby smooth surfaces may be readily secured by machining.

Other objects of the invention relate to the provision of improved flow guiding and spin removing means.

These and other objects of the invention, particularly relating to details, will become apparent from the following description, read in conjunction with the accompanying drawings, in which:

Figure 1 is a diagrammatic sectional view indicating the fashion in which the improved diffuser and transfer passages are designed, which view may be regarded as a projection on an axial plane of a skew-shaped passage and vanes by projecting points circumferentially;

Figure 2 is a section of the subject-matter of Figure 1 taken on the broken surface the trace of which is indicated at 2—2 in Figure 1;

Figure 3 is an edge elevation illustrating the construction of one of the diffuser vanes;

Figure 4 is a transverse section taken on the plane indicated at 4—4 in Figure 3;

Figure 5 is a diagrammatic sectional view sim-

3

ilar to Figure 1, but showing a modified construction;

Figure 6 is a fragmentary developed section showing the form of spin removing vanes used in the modification of Figure 5;

Figure 7 is a diagrammatic sectional view similar to Figure 1, but showing still another modification; and

Figure 8 is a diagrammatic view illustrating in axial projection the elementary surface of one of the vanes of the modification of Figure 7.

Referring first to the modification of Figures 1 to 4, inclusive, there is illustrated therein a portion of a centrifugal compressor embodying a preferred form of diffuser and transfer passage. The compressor comprises a plurality of casing sections 2, 4 and 6, together with an annular wall 8 having an extension 10 forming, together with a separate annular member 12 a diaphragm separating the diffuser passages from the transfer passages. Between the annular wall 8, including its extension 10, and the casing section 4, there are provided spin removing vanes 14. Secured to the annular ring 12, as will be described hereafter, are diffuser vanes 20, which extend into contact with the casing section 2. The arrangement just indicated is designed to receive air or other gas flowing from an impeller 22, transform its kinetic energy into pressure energy and deliver the gas without substantial spin, or with slight spin opposite the direction of impeller rotation, to the next stage impeller indicated at 24. As specifically shown, these impellers may be constructed in accordance with the principles set forth in my Patents Nos. 1,926,225 and 1,959,703, dated, respectively, September 12, 1933, and May 22, 1934, and in accordance with my application Serial No. 441,686, filed May 4, 1942. While the invention is not limited to a diffuser construction for such impellers, these impellers are frequently desirably designed, particularly for high speed operation, to discharge the compressed elastic fluid with a substantial axial component of motion, and the improved type of diffuser is very well adapted for the efficient handling of elastic fluid so discharged.

If discharge from an impeller took place into a diffuser without vanes and bounded axially by radial planes, the laws of flow and energy transformation indicate that theoretically the streamlines of the fluid should be very nearly logarithmic spirals. A logarithmic spiral has the well known property that its tangent always makes a constant angle with its radius vector, or, in other words, with any circle drawn through the point of tangency and concentric with the origin. This means that normally in such a diffuser without vanes the radial and peripheral components of the absolute velocity would decrease in the same proportion. As indicated above, the diffuser action thus resulting is relatively ineffective because not only is the theoretical reduction of absolute velocity at any point only proportional to the increase in radius of that point over the radius of discharge of the impeller, but the diffuser transformation is attained only as the fluid follows the spiral path, prolonging its circumferential contact with the walls of the diffuser. Frictional effects proportional to the length of this type of contact, and turbulence, arise so that the actual diffusing effect is far less efficient than would be predicted by theoretical considerations based on perfect behavior of the fluid.

Accordingly, diffuser vanes have heretofore

4

been constructed so as to be at their entrance edges parallel to the direction of flow of the fluid leaving the impeller, or, in other words, at their entrance edges tangent to the theoretical logarithmic spirals which the flow would normally tend to follow. Beyond the entrance, however, these vanes were deflected gradually outwardly from the logarithmic spiral paths at a rate of departure such as to avoid breaking of the fluid away from the passage walls, the departure being a maximum consistent with that limitation in order to reduce flow path and attendant friction losses in accomplishing the desired diffuser effect. This rate of departure has been, and is, in connection with the present invention, in accordance with standard practice as given in works on compressor design and need not be specified in detail. While from the standpoint of motion in a circumferential direction, this construction of vanes is satisfactory and is adopted herein, the present invention has as one of its features the proper design of the axial boundaries of the diffuser passages to insure proper smooth flow from the standpoint of axial flow. To this end, the axial bounding surfaces 26 and 28 are substantially hyperboloids of revolution diverging outwardly from each other. This gives rise to smooth flow, since a hyperboloid is the locus of a straight line bearing a skew relationship to an axis and rotating about said axis. At the exit edges of the impeller vanes, the elastic fluid will be flowing along substantially straight lines bearing the skew relationship to the axis of rotation. These approximately hyperboloidal surfaces 26 and 28 are properly generated by straight lines in the direction of the absolute velocity of flow of the elastic fluid as it leaves the impeller at the forward and rearward axial limits of the impeller passages or vanes. The vectorial absolute velocities at these points may be readily calculated from the rated speed of rotation of the impeller and the quantity of elastic fluid which it delivers and the surfaces 26 and 28 are laid out therefrom. As will be pointed out hereafter, some departures from these theoretical surfaces are permissible, and they may be approximated by one or more circular arcs, depending upon the degree of accuracy of construction which is desired. In the present instance, for reasons which will become immediately apparent, the surface 28 is rather closely hyperboloidal in form.

Heretofore it has been customary to cast diffuser vanes with portions of a diaphragm or housing, thereafter smoothing wetted surfaces of the vanes by grinding or the like, since smoothness is very necessary to secure good efficiency. These grinding operations are difficult hand jobs, and are particularly difficult if the diffuser surfaces are substantially warped, as in the case illustrated, in which discharge from the impeller has a substantial axial component. Advantage may be taken of the hyperboloidal nature of the surface 28 to secure a highly advantageous construction and mounting for the diffuser vanes. For this purpose, slots are formed, having parallel side walls, in the surface 28 by milling along the straight line elements of this surface. To secure the necessary support, the surface is desirably backed by annular ribs 32 into which deep slots extend. Within each of these slots there is then inset and secured by doweling, welding or in any other fashion the rectangular bases 30 of the diffuser vanes 20. The particular form of these diffuser vanes is illustrated in Figures 3 and 4.

Each of them is formed from a flat blank of metal having parallel faces by turning the opposite surfaces 34 and 36 of the blade to cylindrical form with a large radius of curvature followed by the rounding of the vane tips by filing or grinding to provide airfoil edges. The cylindrical surfaces have radii of curvature equal to the theoretical mean radius of curvature of the vane surfaces which, through the relatively small angular extent which is used, may be closely approximated by such cylindrical surfaces. It will be obvious that the cylindrical surfaces lie in skew relationship to the axis of rotation and, by reason of their chords lying along the straight line elements of the hyperboloidal surface 28, they closely approximate the theoretically proper skew surfaces diverging outwardly from logarithmic spirals to effect diffuser action. It will be obvious that the surfaces may thus be made very smooth in the machining operation, while a rigid, strong construction is provided despite the fact that the vanes may be made very thin and hence increase to a maximum degree the circumferential space available for the flow of the elastic fluid. This is particularly advantageous in that in accordance with the invention the number of diffuser vanes is increased greatly over the number heretofore used, as will be described below. After the vanes are inserted in the ring 28, their outer edges may be turned so as to fit tightly against the casing section 2 when the compressor is assembled.

At the very high velocities of flow involved in centrifugal compressors to which the invention is particularly applicable, difficulties occur wherever an attempt is made to cause the flow to occur with a small radius of curvature. To carry the gas from the diffuser passages into the region between the spin removing vanes, if a multiple stage compressor is to be provided in as small an axial extent as possible, it is necessary to carry the flow through substantially 180°, as viewed in the circumferential projection, in a quite small axial space. This may be successfully accomplished by providing within this space annular guide vanes such as indicated at 38 and 40, conveniently formed of sheet metal in sections which may be secured together during assembly and properly located in spaced relationship by insertion in slots or notches in the discharge edges of the diffuser vanes and in the inlet edges of the spin removing vanes as shown in Figure 1. As indicated in Figure 1, these annular guide vanes are not equally spaced across the cross-section of the flow passage, but rather should be so arranged that the inner one 38 is somewhat less than one-third the distance from the inside to the outside while the outer one, if two are used, may be approximately midway of the space between the inside and the outside of the passage. With this arrangement of vanes, in effect crowding them toward the inside of the passage, smooth guidance is effected, and the flow takes place in a spiral direction about the axis to the entrance portions of the spin removing vanes 14.

The form of the spin removing vanes is indicated in Figure 2, from which it will be seen that at their upper entrance edges they form an angle approximately equal to and opposite that of the exit angle of the diffuser vanes 20. The gas is thus received smoothly, and from a circumferential standpoint is gradually diverted to a substantially radial direction, the spin thus being removed. It is sometimes desirable, in fact, that they be continued to provide some spin opposite the direction of rotation of the impellers, 75

or at any rate are so directed beyond a radial condition of their outlet edges to insure that, despite crowding of flow at high velocities to the outside of the passages they define, the flow approaching the next impeller will be without any substantial spin component. From Figure 1, it will be noted that the direction of flow from the standpoint of its axial components is turned in the direction of the impeller 22 and this direction is then reversed through somewhat more than 90° about the annular corner guide vane 16. The passages through the spin removing region are of fairly large cross-section, so that the velocities are substantially reduced, and hence the flow about the final bend may be properly guided by the single vane 16, which is of an airfoil shape having a bulbous entrance edge and tapering at its exit edge to a quite thin section. As will be noted from Figure 1, this vane 16 is located closer to the inside of the curve than to the outside, which arrangement is most effective to secure smooth flow throughout the entire area of the passage. The number of spin removing vanes is determined by considerations, in accordance with aerodynamic theory, of the lift coefficient required to prevent flow separation, analogous to the matters taken into consideration in ascertaining the proper number of corner vanes to be used in the corners of a wind tunnel. The lift coefficient should be fairly small, of the order of 0.5 to 0.6 or less, which, generally speaking, leads in the present case to a number of spin removing vanes approximately the same as the number of diffuser vanes, i. e., a number of the order of forty as pointed out hereafter, though a less number may be used with satisfactory results.

The precise shape of the spin removing vanes 14 is relatively unimportant so long as they receive the compressed gas as stated and deliver it without substantial spin. Such vanes may be cast, but in accordance with the invention, an improved construction thereof is provided whereby they may be made of sheet metal. For this purpose, a thin cutting tool moving in a circular arc in a lathe or boring machine may be caused to cut in the conical surface 18 of the casing portion 4 a series of grooves 14' along circular arcs having the necessary radius of curvature so that when sheet metal vanes 14 are secured therein, the resulting vanes will have not only the proper curvature, but properly located and directed inlet and outlet edges. While this construction is shown as applied to the spin removing vanes, it will be evident that the diffuser vanes may also be formed of sheet metal inset into circular grooves cut into the hyperboloidal wall 28 previously described, though it is preferred to use the construction described above and illustrated particularly in Figures 3 and 4.

Heretofore it has been customary to use a number of diffuser vanes of the order of 15 to 17, but in accordance with the present invention, it is desirable to use a much larger number of vanes, for example a number of the order of about 40. This makes it possible to provide within a given radial distance of the diffuser, without exceeding permissible values of diffuser vane divergence, the greatest possible diffuser discharge area and the greatest possible diffuser discharge angle. With a small number of diffuser vanes, this is impossible without exceeding permissible divergence values. With a larger number of vanes and the larger discharge angle permitted thereby, there is much less residual spin required to be removed in additional guide vanes, and the lower

discharge velocity means lower losses in the tortuous path from the diffuser discharge to the inlet of the following impeller. Such large number of diffuser vanes is possible using either the construction shown at 20 or by using inset sheet metal vanes as described in connection with spin removal.

Referring now to the modification of Figures 5 and 6, this is essentially the same as that of Figure 1, with the exception that the spin is removed from the gas at the maximum distance from the axis of rotation. The diffuser vanes may be of the same type previously described, and are indicated at 42, the diffuser passage also being hyperboloidal at its axial bounding walls, which diverge as indicated in the drawing. In the case of this modification, however, there are provided in the upper portion of the cross-over passage a plurality of spin removing vanes 44, which may be secured to a sectional annular base member 46, being cast integrally therewith. As indicated in the developed sectional view of Figure 6, these spin removing vanes are of airfoil shape and are arranged to receive the spirally flowing gas tangentially to its flow and deflect the same relatively rapidly to an axial direction. At this maximum distance from the axis of rotation, the velocity of flow is substantially reduced as compared with the velocity through the diffuser passages, and with vanes properly shaped as indicated, the spin may be removed in a quite short path of flow. For the same reasons as required the presence of the annular guide vanes 38 and 40 in the modification of Figure 1, there are provided the guide vanes 48 and 50 between the diffuser vanes and the spin removing vanes 44 and beyond the spin removing vanes there are located further guide vanes 52 and 54, also of annular spun type arranged to lead the flow smoothly to the radially arranged guide vanes 56, between which the flow takes place to the next stage, passing about the annular corner vane 58. From the exit of the spin removing vanes to the next impeller the flow has no circumferential component of motion, and while radial guide vanes such as 56, located in axial planes, and of either cast or sheet metal type, are desirable, their functions are minor, and there need be relatively few of them. If cast, the vanes 56 should have airfoil leading edges and tapered trailing edges to provide smooth flow with a minimum of turbulence.

In the modifications heretofore described, the diffuser guiding and spin removing elements have been arranged in discontinuous fashion. It is possible, however, to provide complete guidance of the flow with diffuser and spin removing action by continuous vane elements from the discharge of one impeller to the entrance of the next. This is illustrated in Figures 7 and 8. As before, a sectional casing houses the various vanes indicated in this case as continuous from 60, 62 and 64 to 72 and 74, there being a break, as indicated at c, to separate the vanes for assembly, when assembly is effected, however, there being presented smooth guiding surfaces past this joint. At the entrance, the axial boundary surfaces are, as before, approximately hyperboloidal, and these surfaces are indicated at 66 and 68. The diffuser vanes deviate, as indicated above, from logarithmic spirals and then pass over the upper bend of the transfer passage, as indicated at 62 and extend as indicated at 64 in the form of spin removing elements delivering the elastic fluid to the next stage by the guidance of the portions

72 and 74 of the vanes on opposite sides of the annular corner guide vane 70 corresponding to that previously described at 16. As will be evident from Figure 8, which diagrammatically shows one of the theoretical surfaces as viewed in an axial direction, the flow takes a spiral path through a quite large angle from the entrance at a to the exits at 72 and 74. This substantial spacing is desirable so as to avoid any turbulence due to an attempt to remove too rapidly the spin component of the flow.

The vane surface is desirably laid out from the mean center line M in the form of straight lines such as indicated at b, d and e, all passing through the axis of rotation and extending to equal extents on opposite sides of the center line M. A ruled surface of this type, containing straight line elements through the axis of rotation, is highly desirable as giving smooth flow with a minimum of distortion of cross-sections which might give rise to tendencies toward rotation of the fluid about lines in the general direction of flow. It may be remarked that the surfaces previously described for effecting both diffuser action and spin removal approximate closely the ruled surfaces just described, i. e., to a fairly close approximation they also have substantially straight line elements passing through the axis of rotation.

While the vane surfaces just described in connection with the modification of Figure 7 may be continuous (except for a mechanical break such as indicated at c), it will be evident that this need not be the case, but that various sections of this surface may be used for each of the vanes with spacing between the sections, for example, for the accommodation of annular guide vanes such as 48, 50, 52 and 54. Even if such sections are used, the smoothness of flow will be retained provided the leading and trailing edges of the vane sections have airfoil form. Furthermore, the surfaces may be made up of various parts, either smoothly continuous with each other or with spacings, for example for guide vanes as mentioned, which parts may be constructed in the fashions described above, for example for the diffuser vanes 20 or the spin removing vanes 14.

What I claim and desire to protect by Letters Patent is:

1. In combination, a rotary impeller arranged to discharge gas with an absolute velocity having substantial peripheral, radial and axial components, and means providing passages opening approximately in line with said absolute velocity to receive said discharged gas, each of said passages being bounded by walls substantially conforming to inner and outer surfaces of revolution and a pair of skew surfaces, said inner and outer surfaces of revolution being substantially hyperboloidal at the entrance portion of the passage and diverging from each other along the flow path, and said skew surfaces diverging, at their entrance portions, from each other along the flow path and also outwardly from logarithmic spirals tangent to them at their entrance edges, each of said skew surfaces having straight line elements passing substantially through the axis of rotation of said impeller, and said surfaces of revolution and skew surfaces beyond the entrance portion of the passage providing a smooth deviation of the passage to a discharge portion thereof opening in a direction without a substantial peripheral component.

2. In combination, a rotary impeller arranged to discharge gas with an absolute velocity having substantial peripheral, radial and axial components, and means providing passages opening approximately in line with said absolute velocity to receive said discharged gas, each of said passages being bounded by walls substantially conforming to inner and outer surfaces of revolution and a pair of skew surfaces.

3. In combination, a rotary impeller arranged to discharge gas with an absolute velocity having substantial peripheral, radial and axial components, and means providing passages opening approximately in line with said absolute velocity to receive said discharged gas, each of said passages being bounded by walls substantially conforming to inner and outer surfaces of revolution and a pair of skew surfaces, said inner and outer surfaces of revolution diverging from each other along the flow path.

4. In combination, a rotary impeller arranged to discharge gas with an absolute velocity having substantial peripheral, radial and axial components, and means providing passages opening approximately in line with said absolute velocity to receive said discharged gas, each of said passages being bounded by walls substantially conforming to inner and outer surfaces of revolution and a pair of skew surfaces, said inner and outer surfaces of revolution being substantially hyperboloidal at the entrance portion of the passage.

5. In combination, a rotary impeller arranged to discharge gas with an absolute velocity having substantial peripheral radial and axial components, and means providing passages opening approximately in line with said absolute velocity to receive said discharged gas, each of said passages being bounded by walls substantially conforming to inner and outer surfaces of revolution and a pair of skew surfaces, said skew surfaces diverging, at their entrance portions, outwardly from logarithmic spirals tangent to them at their entrance edges.

6. In combination, a rotary impeller arranged to discharge gas with an absolute velocity having substantial peripheral, radial and axial components, and means providing passages opening approximately in line with said absolute velocity to receive said discharged gas, each of said passages being bounded by walls substantially conforming to inner and outer surfaces of revolution and a pair of skew surfaces, said skew surfaces diverging, at their entrance portions, from each other along the flow path outwardly from logarithmic spirals tangent to them at their entrance edges.

7. In combination, a rotary impeller arranged to discharge gas with an absolute velocity having substantial peripheral, radial and axial components, and means providing passages opening approximately in line with said absolute velocity to receive said discharged gas, each of said passages being bounded by walls substantially conforming to inner and outer surfaces of revolution and a pair of skew surfaces, said skew surfaces diverging, at their entrance portions, outwardly from logarithmic spirals tangent to them at their entrance edges, each of said skew surfaces having straight line elements passing substantially through the axis of rotation of said impeller.

8. In combination, a rotary impeller arranged to discharge gas with an absolute velocity having substantial peripheral, radial and axial compo-

nents, and means providing passages opening approximately in line with said absolute velocity to receive said discharged gas, each of said passages being bounded by walls substantially conforming to inner and outer surfaces of revolution and a pair of skew surfaces, said skew surfaces diverging, at their entrance portions, outwardly from logarithmic spirals tangent to them at their entrance edges, and said surfaces of revolution and skew surfaces beyond the entrance portion of the passage providing a smooth deviation of the passage to a discharge portion thereof.

9. In combination, a rotary impeller arranged to discharge gas with an absolute velocity having substantial peripheral, radial and axial components, and means providing passages opening approximately in line with said absolute velocity to receive said discharged gas, each of said passages being bounded by walls substantially conforming to inner and outer surfaces of revolution and a pair of skew surfaces, said inner and outer surfaces of revolution being substantially hyperboloidal at the entrance portion of the passage and diverging from each other along the flow path, and said skew surfaces diverging, at their entrance portions, from each other along the flow path and also outwardly from logarithmic spirals tangent to them at their entrance edges, each of said skew surfaces having straight line elements passing substantially through the axis of rotation of said impeller.

10. In combination, a rotary impeller arranged to discharge gas with an absolute velocity having substantial peripheral, radial and axial components, and means providing passages opening approximately in line with said absolute velocity to receive said discharged gas, each of said passages being bounded by walls substantially conforming to inner and outer surfaces of revolution and a pair of skew surfaces, said inner and outer surfaces of revolution being substantially hyperboloidal at the entrance portion of the passage and diverging from each other along the flow path, and said skew surfaces diverging, at their entrance portions, from each other along the flow path and also outwardly from logarithmic spirals tangent to them at their entrance edges, each of said skew surfaces having straight line elements passing substantially through the axis of rotation of said impeller, and said surfaces of revolution and skew surfaces beyond the entrance portion of the passage providing a smooth deviation of the passage to a discharge portion thereof.

11. In combination, a rotary impeller arranged to discharge gas with an absolute velocity having substantial peripheral, radial and axial components, and means providing passages opening approximately in line with said absolute velocity to receive said discharged gas, each of said passages being bounded by walls substantially conforming to inner and outer surfaces of revolution and a pair of skew surfaces, and said surfaces of revolution and skew surfaces beyond the entrance portion of the passage providing a smooth deviation of the passage to a discharge portion thereof opening in a direction without a substantial peripheral component, and with a substantial radial inward component.

12. In combination, a rotary impeller arranged to discharge gas with an absolute velocity having substantial peripheral, radial and axial components, and means providing passages opening approximately in line with said absolute velocity to receive said discharged gas, each of said passages

11

being bounded by walls substantially conforming to inner and outer surfaces of revolution and a pair of skew surfaces, and said surfaces of revolution and skew surfaces beyond the entrance portion of the passage providing a smooth deviation of the passage to a discharge portion thereof opening in a direction with a substantial radial inward component.

13. In combination, a rotary impeller arranged to discharge gas with an absolute velocity having substantial peripheral, and radial components, and means providing passages opening approximately in line with said absolute velocity to receive said discharged gas, each of said passages beyond its entrance portion deviating smoothly to a discharge portion thereof opening in a direction with a substantial radial inward component.

14. In combination, a rotary impeller arranged to discharge gas with an absolute velocity having substantial peripheral, radial and axial components, and means providing passages opening approximately in line with said absolute velocity to receive said discharged gas, each of said passages being bounded by walls substantially conforming to inner and outer surfaces of revolution and a pair of skew surfaces, said skew surfaces being provided by substantially cylindrical surfaces chords of which bear a skew relationship to the axis of rotation.

15. In combination, a rotary impeller arranged to discharge gas with an absolute velocity having substantial peripheral, radial and axial components, and means providing passages opening approximately in line with said absolute velocity to receive said discharged gas, each of said passages being bounded by walls substantially conforming to inner and outer surfaces of revolution and a pair of skew surfaces, said skew surfaces being provided by curved surfaces chords of which bear a skew relationship to the axis of rotation.

16. In combination, a rotary impeller arranged to discharge gas with an absolute velocity having substantial peripheral, radial and axial components, and means providing passages opening approximately in line with said absolute velocity to receive said discharged gas, each of said passages being bounded by walls substantially conforming to inner and outer surfaces of revolution, of which at least one is substantially hyperboloidal, and a pair of skew surfaces, said skew surfaces being provided by substantially cylindrical surfaces chords of which are substantially straight line elements of said substantially hyperboloidal surface.

17. In combination, a rotary impeller arranged to discharge gas with an absolute velocity having substantial peripheral, radial and axial components, and means providing passages opening approximately in line with said absolute velocity to receive said discharged gas, each of said passages being bounded by walls substantially conforming to inner and outer surfaces of revolution, of which at least one is substantially hyperboloidal and a pair of skew surfaces, said skew surfaces being provided by curved surfaces chords of which are substantially straight line elements of said substantially hyperboloidal surface.

18. In combination, a rotary impeller arranged to discharge gas with an absolute velocity having substantial peripheral, radial and axial components, and means providing passages opening approximately in line with said absolute velocity to receive said discharged gas, each of said passages being bounded by walls substantially conforming to inner and outer surfaces of revolution, of which

12

at least one is substantially hyperboloidal, and a pair of skew surfaces, said skew surfaces being provided by curved surfaces chords of which are substantially straight line elements of said substantially hyperboloidal surface, said skew surfaces being defined by vanes carried by base members secured in slots in said hyperboloidal surface extending along said straight line elements thereof.

19. In combination, a rotary impeller arranged to discharge gas with an absolute velocity having substantial peripheral, radial and axial components, and a diffuser structure having gas guiding passages of which at least one portion is bounded axially by surfaces of revolution deviating substantially from radial planes, and provided with guide vanes, said guide vanes extending from slots in the form of circular arcs in one of said surfaces of revolution.

20. In combination, a rotary impeller arranged to discharge gas with an absolute velocity having substantial peripheral, radial and axial components, means providing diffuser passages opening approximately in line with said absolute velocity to receive said discharged gas, and spin removing vanes beyond said diffuser passages, said spin removing vanes being located at a region of the gas passage at a maximum radius from the axis of rotation.

21. In combination, a rotary impeller arranged to discharge gas with an absolute velocity having substantial peripheral and radial components, means providing diffuser passages opening approximately in line with said absolute velocity to receive said discharged gas, an annular region beyond said diffuser passages arranged to deflect said flow inwardly towards the axis of rotation, and annularly arranged guide vanes in said region.

22. In combination, a rotary impeller arranged to discharge gas with an absolute velocity having substantial peripheral and radial components, means providing diffuser passages opening approximately in line with said absolute velocity to receive said discharged gas, an annular region beyond said diffuser passages arranged to deflect said flow inwardly towards the axis of rotation, and annularly arranged guide vanes in said region, said guide vanes being crowded towards the inside of the deflecting curvature of said region.

23. In combination, a rotary impeller arranged to discharge gas with an absolute velocity having substantial peripheral, radial and axial components, and a diffuser structure having gas guiding passages of which at least one portion is bounded axially by surfaces of revolution deviating substantially from radial planes, and provided with guide vanes, said guide vanes extending from slots in the form of circular arcs in one of said surfaces of revolution and substantially abutting the other of said surfaces of revolution.

24. In combination, a rotary impeller arranged to discharge gas with an absolute velocity having substantial peripheral, radial and axial components, and a diffuser structure having gas guiding passages of which at least one portion is bounded axially by surfaces of revolution deviating substantially from radial planes, and provided with guide vanes of sheet metal, said guide vanes extending from slots in the form of circular arcs in one of said surfaces of revolution and being shaped thereby.

25. In combination, a rotary impeller arranged to discharge gas with an absolute velocity having substantial peripheral, radial and axial com-

ponents, and a diffuser structure having gas guiding passages of which at least one portion is bounded axially by surfaces of revolution deviating substantially from radial planes, and provided with guide vanes, said guide vanes extending from slots in the form of arcs in one of said surfaces of revolution.

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