June 24, 1947. G. F. WISLICENUS 2,422,763

CENTRIFUGAL COMPRESSOR

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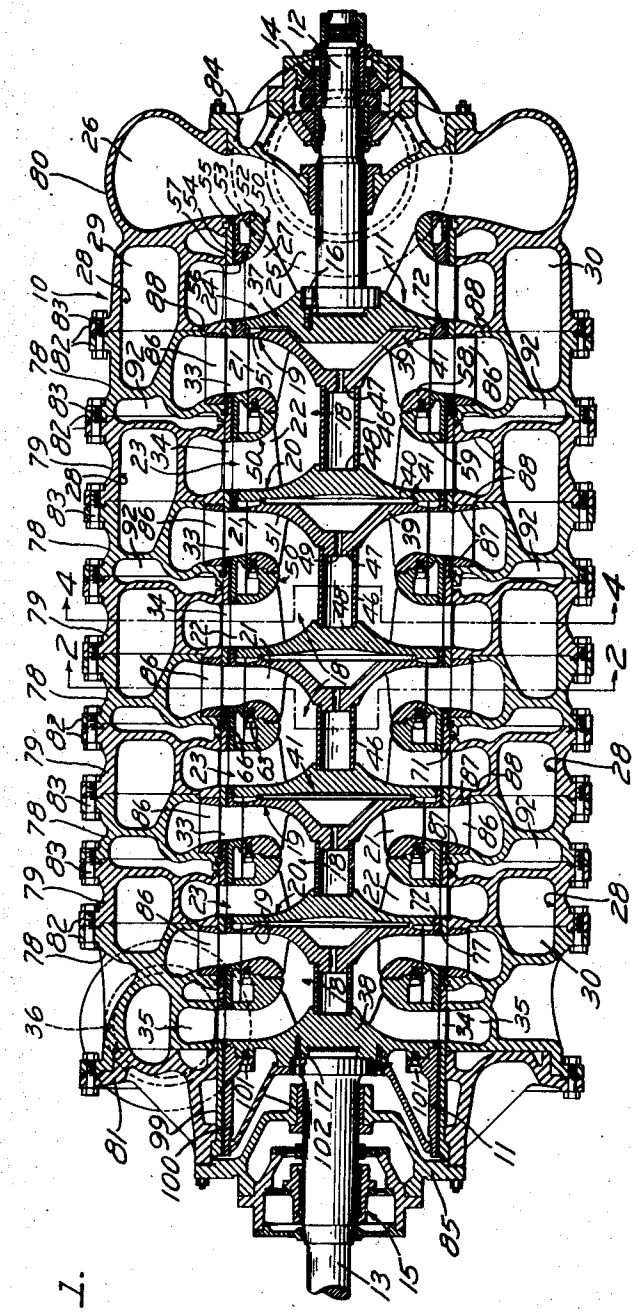


Fig. 1.

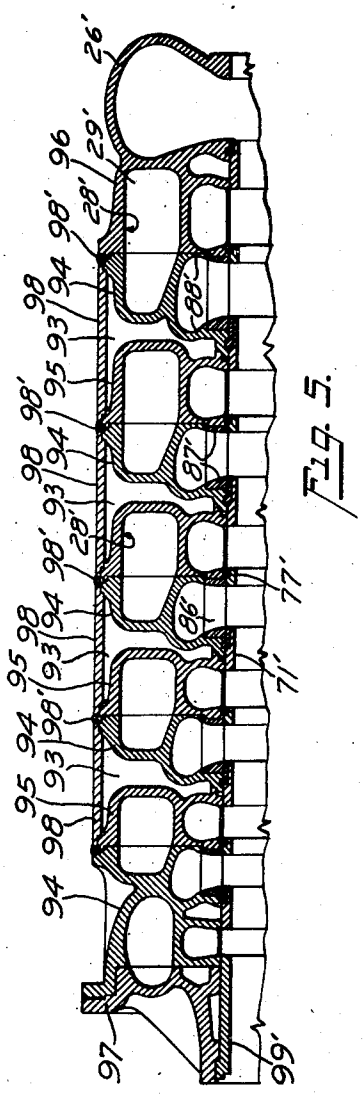


Fig. 5.

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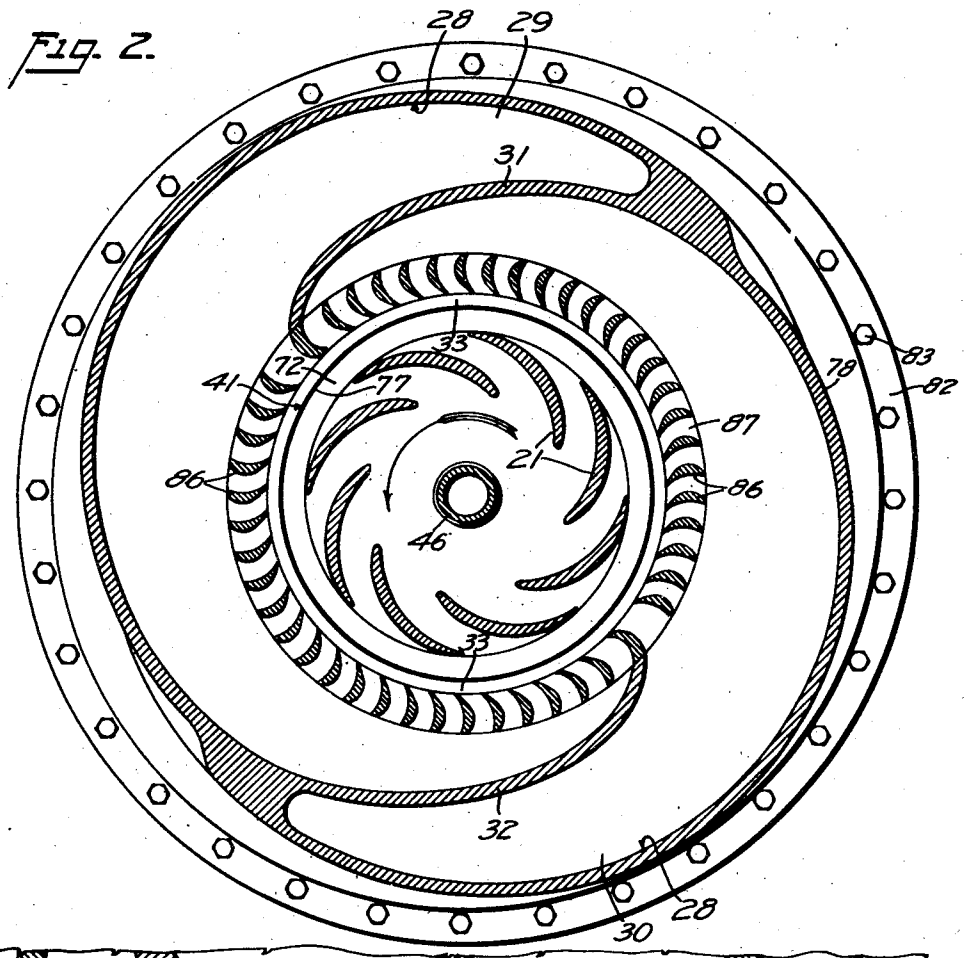
BY Robert Meyer
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CENTRIFUGAL COMPRESSOR

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Fig. 2.



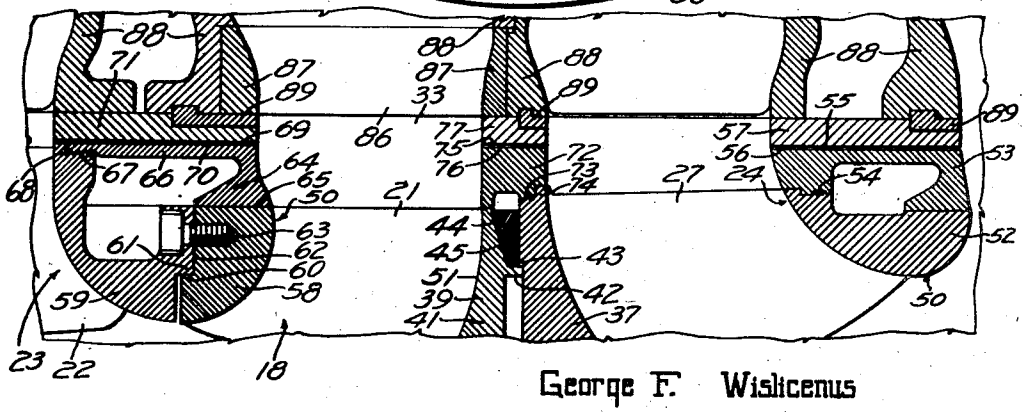


Fig. 3.

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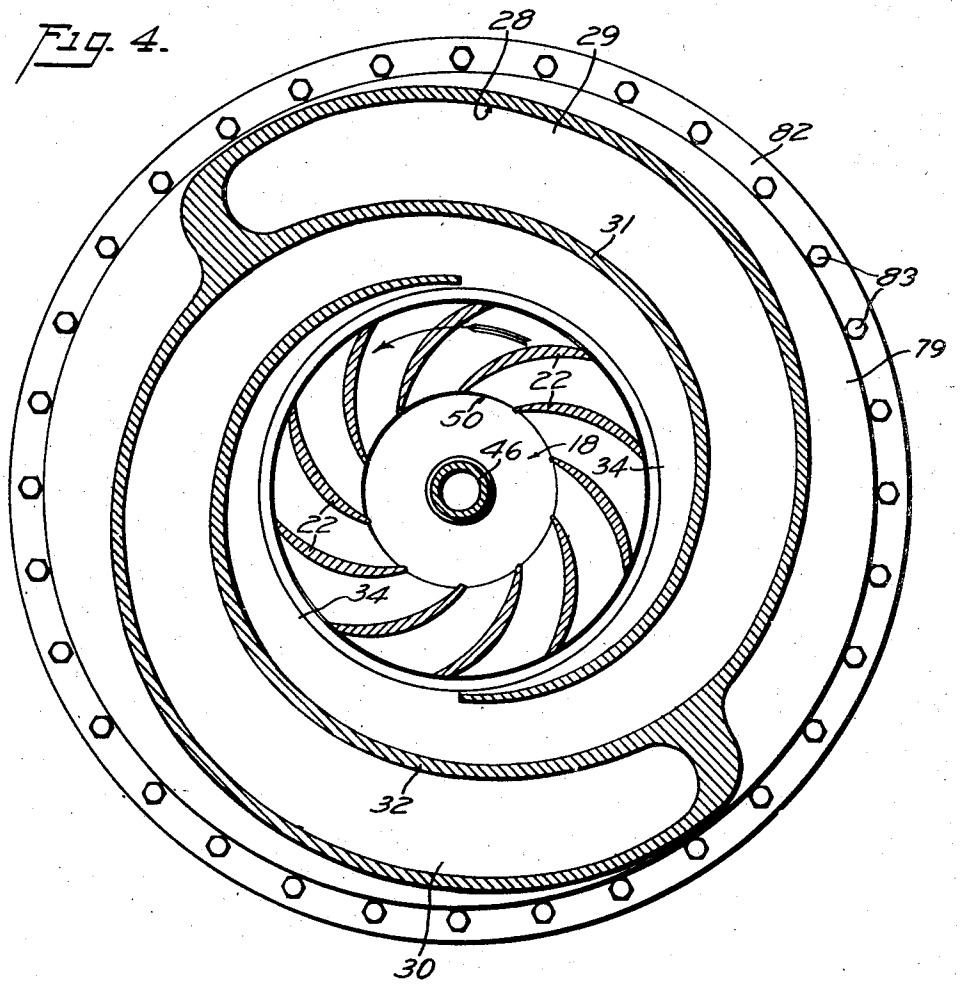
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Fig. 4.



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CENTRIFUGAL COMPRESSOR

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Fig. 6.

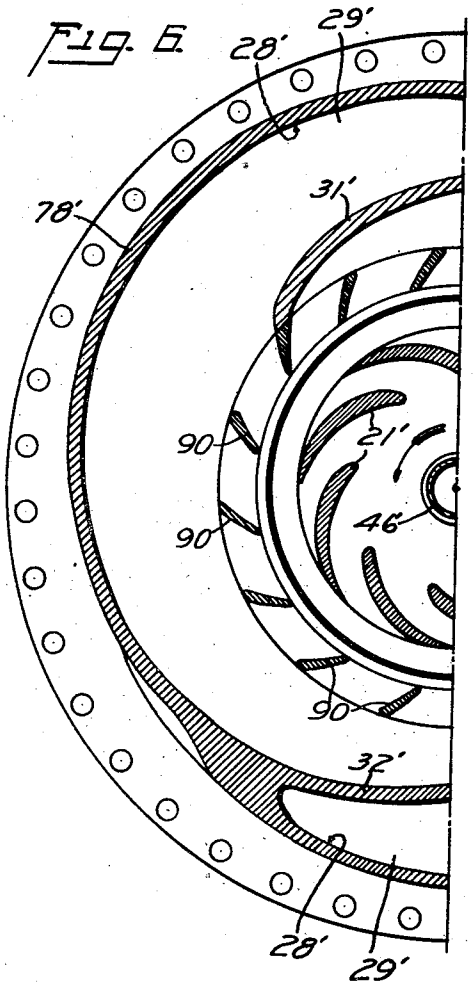
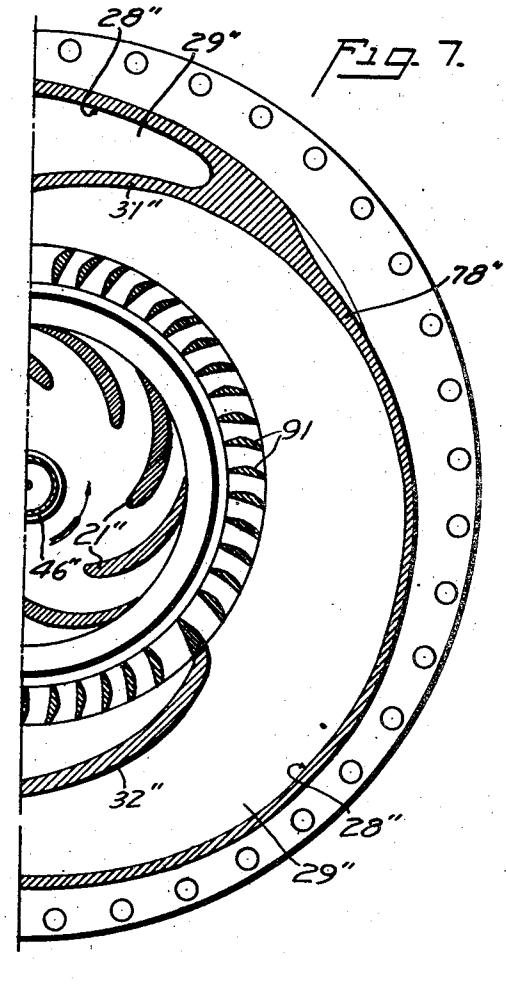


Fig. 7.



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Patented June 24, 1947 2,422,763

UNITED STATES PATENT OFFICE

2,422,763

CENTRIFUGAL COMPRESSOR

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Application March 2, 1944, Serial No. 524,712

29 Claims. (Cl. 230—45)

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This invention relates to centrifugal machines, and more particularly to a centrifugal compressor embodying a novel casing and rotor structure.

An object of the present invention is to provide a centrifugal compressor of the multistage type in which the casing and rotor thereof are of such design as to permit axial removal of the rotor intact from the casing by merely detaching one or both end covers of the casing.

Another object is to provide a centrifugal machine wherein the rotor embodies individual stage impellers having inward and outward flow fluid deflecting or guiding vanes of such construction and arrangement as to unite the impellers into a unitary structure in such manner as to eliminate the necessity of a rotor shaft.

Another object is to provide a centrifugal machine wherein stage impellers are fixedly related in such manner as to eliminate the necessity of a rotor shaft as far as the inner portions of the machine are concerned, and in which coaxial means are interposed between the impellers for hydraulic reasons only to eliminate instability of the flow at the center of rotation.

Another object is to provide a centrifugal machine having a rotor provided with fluid deflecting or guiding vanes co-acting with the body structure of the rotor in such manner as to function as strut means for resisting deflection of the rotor.

Another object is to provide a centrifugal compressor of the multistage type which is characterized by exceptionally high compressing efficiency in that the inlet (eye) diameter of the outward flow impellers may be made the same as for a corresponding single stage overhung pump, the latter being the type of pump with which the highest pump efficiencies have been obtained in the past.

Another object is to provide a centrifugal compressor embodying a casing structure comprising an assembly of casing rings or stage pieces in which the stage distances may be assured through accurate pre-machining of the individual pieces, and in which the design will be essentially the same for positive, zero or negative pre-rotation at the inlet of each inward flow impeller section.

Another object is to provide a centrifugal compressor of the multi-stage type wherein the rotor comprises impellers permanently or semi-permanently connected into a unitary structure, and in which the running joints in the casing and the

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compressor of the multistage type wherein the impellers of the rotor are permanently connected into a unitary structure, in which the impellers embody fluid passages generally U-shaped in cross section and open through the annular perimeter of the rotor, and in which the annular perimeter of the rotor and the casing are provided with co-acting wearing surfaces of such relative diameters as to permit axial removal of the rotor intact from the casing without necessitating horizontal or vertical separation of the casing.

With these and other objects in view, as may appear from the accompanying specification, the invention consists of various features of construction and combination of parts, which will be first described in connection with the accompanying drawings, showing a centrifugal compressor of a preferred form embodying the invention, and the features forming the invention will be specifically pointed out in the claims.

In the drawings:

Figure 1 is a longitudinal sectional view of a centrifugal compressor in accordance with the present invention.

Figure 2 is an enlarged sectional view taken along the line 2—2 of Figure 1.

Figure 3 is an enlarged, fragmentary sectional view of the impeller structure.

Figure 4 is an enlarged sectional view taken along the line 4—4 of Figure 1.

Figure 5 is a fragmentary, longitudinal sectional view of a modified form of casing structure.

Figure 6 is an enlarged, fragmentary sectional view of the casing structure illustrating a system of inlet guide vanes for positive pre-rotation of the fluid.

Figure 7 is an enlarged, fragmentary sectional view illustrating a system of inlet guide vanes for zero pre-rotation of the fluid.

Referring more particularly to the drawings, Figure 1 illustrates a compressor casing 10 within which is contained a rotor 11 having axially spaced but co-axial shaft parts 12 and 13. Bearings 14 and 15 at the opposite ends of the casing 10 support the shaft parts 12 and 13, respectively. The first stage end of the rotor 11 is bolted at 16 to the shaft part 12, while the other end of the rotor is bolted at 17 to the shaft part 13. The driving shaft part 13 may be connected in any suitable manner to any approved type of

specific type of service for which the compressor is designed.

The rotor 11 has an annular contour of uniform diameter from end to end and includes annular and axially spaced fluid passages 18 generally U-shaped in cross-section. The legs 19 and 20 of the respective passages 18 open outwardly through the annular perimeter of the rotor and comprise fluid inlets and fluid outlets, respectively. Inward flow vanes 21 are contained in the inlets 19 and outward flow vanes 22 are contained in the outlets 20. Accordingly, the rotor 11 embodies a series of stage impellers 23. All the impellers are of similar construction except as to width and volumetric capacity with the exception of the first stage impeller, the latter having a fluid outlet passage 24 communicating with an eye 25 having communication with a suction inlet 26 through which the gas or vapor can enter the compressor. Outward flow vanes 27 are provided in the passage 24.

The casing 10 is provided with double or twin volutes 28 in the respective stages of the compressor as clearly shown in Figure 4 of the drawings, and each comprising two volute passages 29 and 30 for co-action with the fluid passages 18 and 25. The defining walls 31 and 32 curve circumferentially and laterally so that the volute passages 29 and 30 have outlets 33 and inlets 34 communicating with the inlet and outlet legs 19 and 20, respectively. Thus the fluid passages 18 are in series communication with the stage volute passages 29 and 30, and the outlet 20 in the last stage of the compressor communicates with volute passages 35 in the casing 10 and leading into a discharge 36.

In the present construction of centrifugal machine or compressor for compressing gas or vapor, the pressure of fluid compressed increases in geometric progression from stage to stage with the absolute discharge pressure of each stage bearing approximately a constant ratio to its inlet pressure. By reference to Figure 1, it will be noted that, notwithstanding the uniform diameter of all the impellers and the casing chamber within which the rotor is contained, the fluid passages in the rotor 11 and the casing 10 are of decreasing volumetric capacities successively from the first through the last stage of the compressor.

Specifically, the rotor 11 comprises two end discs 37 and 38 to which the stub shafts 12 and 13 are respectively connected as shown in Figure 1, and inlet side discs or webs 39 and outlet side discs or webs 40 which are arranged in co-axial relationship with and between the two end discs 37 and 38. One disc 39 lies face to face with the end disc 37 and is fixed thereto, while each of the remaining inlet-side discs 39 lies face to face with outlet-side disc 40 and is fixed thereto so that the rotor includes a series of annular wall structures 41 arranged at right angles to the axis of the rotor and isolating the fluid passages 18 and 24 one from the other.

Annular flanges 42 are provided on the inner faces of the discs 39 which flanges have peripheral engagement with annular shoulders 43 on the discs 40 and the end disc 37, as clearly shown in Figure 3 of the drawings. The flanges 42 and the shoulders 43 are of smaller diameters than the discs 39 and 40 and the end disc 37, with the marginal faces of the discs 39 angled away from their respective discs 40 and the end disc 37 to provide circumferential channels 44 for the reception of welds 45 which connect the paired discs into the unit wall structures 41.

Connectors 46 are interposed between the wall structures 41 in co-axial relationship at the axis of the rotor 11. One end of each connector 46 is mounted on a short post or axial extension 47 on its respective disc 39, and the opposite ends of the connectors are pressed into shallow bores 48 in the respective discs 40 and the end disc 38. Small ports 49 are provided in the discs 39 which permit air to escape from between the united discs during construction of the welds 45. The connectors 46 may be in the form of cylindrical tubes as shown in Figure 1 of the drawings, if desired.

If it is so desired, the discs 39 and 40 may be of dished contour, with the discs 39 dished in a greater degree, so that the wall structures 41 are of hollow formation. While a dished contour is absent in the end disc 37, the associated disc 39 is dished in such a degree that the wall structure 41 at the first stage of the compressor is also of hollow formation. However, this construction is not essential to the design or advantages of the invention.

Shroud ring assemblies 50 are arranged between the wall structures 41 and are spaced from the concaved faces 51 on the discs 39 and 40 and the end disc 38 and co-act therewith and with the tubes 46 to define the respective fluid passages 18. While the tubes 46 are located at the axis of the rotor, these tubes perform no shaft function as far as the transmission of power is concerned, but are included in the rotor structure between the impellers for hydraulic reasons only to eliminate instability of flow at the center of rotation.

Means for fixedly connecting all the wall structures 41 into the rotor structure 11 comprise the shroud ring assemblies 50 and the inward flow vanes 21 and the outward flow vanes 22, with the exception of the shroud ring assembly 50 defining one wall of the first stage fluid passage 24. The first stage shroud ring assembly 50 is made a fixed part with the rotor 11 by the vanes 27, which are fixedly connected with the end disc 37 and an annular ring section 52 comprising a part of the ring assembly. A wearing ring 53 is threadedly connected at 54 with the ring section 52 to complete the shroud ring assembly. The wearing ring 53 encircles the ring section 52 and is provided with a wearing surface 55 co-acting with the wearing surface 56 on a casing ring 57 attached to the casing 10.

Specifically, the shroud ring assemblies defining one wall of the respective fluid passages 18 comprise ring sections 58 to which the inward flow vanes 21 are fixedly connected, these vanes being fixedly connected with the respective discs 39. Second ring sections 59 are fixedly connected with the respective outward flow vanes 22, the latter being fixedly connected with the respective discs 40 and the end disc 38. Annular shoulders 60 and 61 are formed on the respective ring sections 58 and 59 which engage one with the other to accurately align the paired ring sections in true concentric relationship. The paired ring sections 58 and 59 have end face engagement at 62 and are fixedly connected together by bolts 63. Rings 64 engage at 65 with the respective ring sections 58 and include annular walls 66 which are threadedly connected at 67 with the ring sections 59. The walls 66 have edge engagement with stop flanges 68 on their respective ring sections 59. All the walls 66 have wearing sur-

faces 69 arranged in co-active relationship with wearing surfaces 70 on casing rings 71 attached to the casing 10.

While the shroud ring assemblies 50 are of hollow formation and the bolts 63 are accessible only from a position inside the assemblies, the bolts 63 are made easily accessible by unthreading the peripheral rings 64 from their respective ring sections 59 and then shifting the peripheral rings 64 axially to one side sufficiently far to expose the bolts. These bolts are preferably of the type having sockets in their heads to facilitate manipulation thereof with a suitable tool.

Peripheral rings 72 are included in the wall structures 41. These rings embrace the annular perimeters of their respective discs 39 and 40 and the end disc 37, and the rings are threadedly connected at 73 with the discs 40 and the end disc 37. Stop flanges 74 are provided on the discs 40 and the end disc 37 for engagement with their respective peripheral rings 72. Wearing surfaces 75 are provided on the peripheral rings 72, these wearing surfaces being arranged in co-active relationship with wearing surfaces 76 on casing rings 77 attached to the casing 10.

In Figure 1, the casing 10 comprises stage pieces or annular casing members 78 and 79 arranged alternately and in end to end engagement and two end pieces or members 80 and 81. All the members 78, 79, 80, and 81 are flanged at 82 and connected into a unitary structure by blots 83. The members 78, 79, and the end member 80 join in the planes of the respective wall structures 41 and shroud ring assemblies 50, with the exception of first and last stage shroud ring assemblies in the compressor. The suction inlet 26 is contained in the end member 80, while the latter member and the members 78 and 79 are internally contoured to provide the volute passages 29, 30, and 35. The last stage member 78 differs from the remaining members 78 in that the volute passages 35 are contained entirely within this member, whereas the volute passages 29 and 30 are defined or completed only through uniting of the remaining members 78 and 79 and the end member 80. End covers 84 and 85 are bolted to the end members 80 and 81, respectively. The bearing 14 is carried by the end cover 84 and the bearing 15 is carried by the end cover 85.

The wearing surfaces 55, 69, and 75 on the rotor 11 are of the same diameter. This is also true of the wearing surfaces 56, 70, and 76 in the casing 10, these wearing surfaces constituting the smallest inside diameter of the casing 10. Accordingly, the rotor 11 may be axially removed intact from the casing 10 without removing or opening any stationary parts except one or both end covers 84 and 85. Since the wearing surfaces on the rotor are of diameters at least equal to the outside diameters of the respective impellers, the centrifugal machine herein described is completely devoid of any stationary parts which reach between the impellers of the individual stages.

The casing 10, which contains all the stationary fluid passages, need not be parted either "horizontally" in the plane of its axis or "vertically" at right angles to its axis. In addition, the running joints in the casing as well as on the rotor can be machined in one setting to automatically assure perfect alignment. The rotor may also be dynamically balanced as a whole. Provision of inward flow vanes in the rotating inlet fluid passage make the multistage rotor very bending-

stiff without depending in any way on shaft stiffness, since the inward flow and outward flow impeller vanes form a continuous mechanical structure of large diameter (large moment of inertia). With this form of construction, a central shaft becomes actually unnecessary, as shown, the shaft parts 12 and 13 being employed for bearing purposes and the transmission of driving torque.

All the inward flow and outward flow vanes 21 and 22 have their greater portions lying at the same radial distances from the axis of the rotor, and the ring sections 58 and 59 abut face to face at 62 at the same radial distances from the axis of the rotor. All the foregoing radial distances including the circumferential welds 44, terminate closely adjacent the maximum diameter of the rotor. Thus the inward flow and outward flow vanes function additionally as strut means co-acting with the wall structures 41 and the shroud ring assemblies 50 to resist deflection of the rotor.

The presence of inward flow vanes or impellers make it possible to design highly efficient outward flow impellers with considerably steeper vanes than used so far in highly efficient single stage centrifugal machines. Increased steepness of the vanes make the outward flow impellers more a resistant against high centrifugal forces, encountered in high head compressors. The inward flow vanes 21 with their very flat outer ends define smaller maximum diameters than the outward flow vanes 22 in order to keep the centrifugal forces low.

The present centrifugal machine structure is such that the design will be essentially the same for positive, zero or negative prerotation at the inlet of each inward flow impeller section. Figures 1 and 2 illustrate the casing 10 as being provided with inlet guide vanes 86 for negative prerotation at the inlet of each inward flow impeller section. The vanes in each set are fixedly connected with two annular members 87, and these annular members are connected with some of the walls 88 comprising portions of the respective casing members 78, 79, and 80 defining the respective fluid outlets 33 and fluid inlets 34, as shown in Figure 1. The casing rings 57, 71, and 77 are also attached to the walls 88 and are held in place by split locking rings 89.

Another advantage of the centrifugal machine structure shown resides in the fact that the inlet (eye) diameter of the outward flow impellers can be made the same as for a corresponding single stage overhung pump, the latter being the type of pump with which the highest pump efficiencies have been obtained in the past. Heretofore, considerable difficulty has been experienced in effectively securing impellers to their supporting shaft, particularly in high speed machines. The centrifugal stresses in a bored member rotated at high speed are at their maximum at the center hole. Even though the members are fitted tightly to the shaft, the centrifugal stresses are such as to tend to loosen the members so that it is difficult to maintain a tight fit. In the construction shown, the impellers are effectively connected into a unitary structure through the medium of the vane structure and do not depend upon a shaft mount such as has been employed in the past.

In Figure 6, the centrifugal machine structure shown therein is equipped with inlet guide vanes 90 for positive prerotation at the inlet of the inward flow impeller. In other respects the structure of Figure 6 is identical with that of Figure

2. The same holds true of Figure 7 wherein inlet guide vanes 91 for zero prerotation at inlet of the inward flow impeller section are shown. Obviously, adjustable guide vanes may be employed at the inlet of every inward flow impeller section. Such an arrangement permits the control of the compressor performance at constant speed within relatively wide limits.

Since the multistage rotor 11 is axially removable intact from the casing 10, the casing may be cast in one piece. The advantages of building up the casing of individual and small castings resides in the simplification of foundry problems and low pattern costs. This type of construction also facilitates cleaning of the fluid passages, and the exact stage distances are assured by premachining the individual casing pieces before assembling the pieces into a finished casing structure. Final machining of the casing is done after the casing pieces have connected together.

In Figure 1, the casing members 78 and 79 are contoured to provide cooling chambers 92 between the stages of the machine. Larger cooling chambers 93 are provided in the structure of Figure 5, wherein the casing is built up of casing members 94 and 95 and two end members 96 and 97 of the same general structure as the parts 78, 79, 80, and 81, respectively, of Figure 1. However, the parts 94, 95, and 96 are connected into a unitary structure by shell sections 98 arranged end to end about the members 94 and 95 and secured into a connected structure by welds 98', which welds also fixedly relate the members 94 and 95. The members 94 and 95 and the shell sections 98 define the cooling chambers 93.

Figure 1 illustrates the end member 81 as being provided with a wearing sleeve 99 which is mounted inside the end member and encircles a sleeve 100 bolted at 101 to the end member 38. A balancing drum 102 is attached to the end member 38.

In assembling the rotor 11, the discs in the respective wall structures 41 are first united by the welds 45. One peripheral ring 64 is inserted over each set of inward flow vanes 21. The wall structures 41 and the tubes 46 are then assembled and connected together stage by stage. As each wall structure 41 is placed in position, axial alignment is assured through engagement of the shoulders 60 and 61 one with the other on the ring sections 58 and 59, respectively. Tightening of the bolts 63 brings the ring sections 58 and 59 into face engagement at 62, which automatically determines the axial spacing of the wall structures. The peripheral rings 64 are threaded home after tightening the bolts 63 in their respective shroud ring assembly 50. It will thus be seen that the individual parts of the rotor may be easily assembled and connected into a unitary structure which slips easily into position in the casing 10 and need not be dismantled when removed from the casing 10.

The term "gas" employed in the specification and claims embraces atmospheric air. While a compressor has been shown and described, the foregoing structure may be easily adapted to centrifugal pumps, turbines, and the like without departing from the spirit of the present invention.

It will be understood that the invention is not to be limited to the specific construction or arrangement of parts shown, but that they may be widely modified within the invention defined by the claims.

What is claimed is:

1. In a centrifugal machine, a casing having a rotor chamber and a suction inlet and a discharge respectively communicating with said chamber, said casing having axially spaced stage fluid passages respectively communicating with said chamber, a rotor in said chamber, said rotor comprising stage impellers fixedly related in end to end relationship and each having a fluid passage generally U-shaped in cross-section, said second mentioned fluid passages arranged in operative series communication with said first-mentioned fluid passages and with said suction inlet and said discharge to provide a continuous fluid passage from said suction inlet to said discharge, inward flow and outward flow fluid deflecting vanes in the respective second mentioned fluid passages, said vanes being located at such radial distances from the axis of the rotor and co-acting with their respective impellers so as to resist deflection of the rotor without aid of an axial shaft, said impellers comprising axially spaced annular wall structures, annular spacers between said wall structures, shroud rings located between said wall structure, said wall structures, said spacers and said shroud rings being contoured to define said second mentioned fluid passages, said shroud rings comprising sections and the sections in each impeller being respectively connected with the inward and outward flow vanes therein, said casing having wearing surfaces in the planes of said wall structures arranged in co-active relationship with said first mentioned wearing surfaces, said second mentioned wearing surfaces having diameters at least equal to the outside diameters of the impellers whereby the rotor may be removed intact from said chamber.

2. In a centrifugal machine for compressing gas or vapor, a casing having stage fluid passages, a rotor in said chamber, said rotor comprising stage impellers arranged end to end, said fluid passages and said impellers decreasing in volumetric capacities from the first stage through the final discharge stage, said impellers including wall structures and shroud rings co-acting therewith to provide fluid passages generally U-shaped in cross-section, inward flow and outward flow vanes in the respective second-mentioned fluid passages, said inward flow and outward flow vanes being fixedly related to their respective shroud rings and wall structures, means for connecting said impellers into a unitary structure, said connecting means, said shroud rings and said inward flow and outward flow vanes being located at such radial distances from the axis of the rotor as to make the rotor deflection resistant without the aid of an axial shaft, and stub shafts at the ends of the rotor for rotatably supporting the latter in said casing.

3. In a centrifugal machine for compressing gas or vapor, a casing having stage fluid passages, a rotor in said chamber, said rotor comprising stage impellers arranged end to end, said fluid passages and said impellers decreasing in volumetric capacities from the first stage through the final discharge stage, said impellers comprising wall structures and cylindrical spacers between the wall structure at the axis of the rotor, shroud rings positioned between said wall structures and co-acting with the latter and said spacers to provide fluid passages generally U-shaped in cross-section, inward flow and outward flow vanes in the respective second mentioned fluid passages, said inward flow and out-

ward flow vanes being fixedly attached to their respective shroud rings and wall structures, said cylindrical spacers connecting said impellers into a unitary structure, said spacers, said shroud rings and said inward flow and outward flow vanes being located at such radial distances from the axis of the rotor as to make the rotor deflection resistant without the aid of an axial shaft and co-axial shaft elements at the ends of the rotor for rotatably supporting the rotor in said casing.

4. In a centrifugal machine for compressing gas or vapor, a casing having stage fluid passages, a rotor in said chamber, said rotor comprising stage impellers arranged end to end, said fluid passages and said impellers decreasing in volumetric capacities from the first stage through the final discharge stage, said impellers including wall structures and shroud rings co-acting therewith to provide fluid passages generally U-shaped in cross-section, inward flow and outward flow vanes in the respective second-mentioned fluid passages, said inward flow and outward flow vanes being fixed to their respective shroud rings and wall structures, means for connecting said impellers into a unitary structure, said means, said shroud rings and said inward flow and outward flow vanes being located at such radial distances from the axis of the rotor as to make the rotor deflection resistant without the aid of an axial shaft, stub shafts at the ends of the rotor for rotatably supporting the latter in said casing, said casing having wearing surfaces, said wall structures and said shroud rings having wearing surfaces co-acting with the respective first-mentioned wearing surfaces, and said second mentioned wearing surfaces having diameters at least equal to the outside diameters of the respective impellers.

5. In a centrifugal machine for compressing gas or vapor, a casing having stage fluid passages, a rotor in said chamber, said rotor comprising stage impellers arranged end to end, said fluid passages and said impellers decreasing in volumetric capacities from the first stage through the final discharge stage, said impellers comprising wall structures and cylindrical spacers between the wall structure at the axis of the rotor, shroud rings positioned between said wall structures and co-acting with the latter and said spacers to provide fluid passages generally U-shaped in cross-section, inward flow and outward flow vanes in the respective second mentioned fluid passages, said inward flow and outward flow vanes being fixed to their respective shroud rings and wall structures, means for connecting said impellers in a unitary structure, said means, said shroud rings and said inward flow and outward flow vanes being located at such radial distances from the axis of the rotor as to make the rotor deflection resistant without the aid of an axial shaft, stub shafts at the ends of the rotor for rotatably supporting the rotor in said casing, said casing comprising annular members arranged end to end and secured into a unitary structure, and inlet guide vanes secured between certain of said annular members at the fluid inlets of said second mentioned fluid passages.

6. In a centrifugal machine for compressing gas or vapor wherein the pressure of material compressed increases in geometric progression from stage to stage with the absolute discharge pressure of each stage bearing a substantially constant ratio to its inlet pressure, a casing having stage fluid passages, a rotor in said chamber, said

rotor comprising stage impellers arranged end to end, said fluid passages and said impellers decreasing in volumetric capacities from the first stage through the final discharge stage, said impellers comprising wall structures and cylindrical spacers between the wall structure at the axis of the rotor, shroud rings positioned between said wall structures and co-acting with the latter and said spacers to provide fluid passages generally U-shaped in cross-section, inward flow and outward flow vanes in the respective second mentioned fluid passages, said inward flow and outward flow vanes being fixed to their respective shroud rings and wall structures, means for connecting said impellers in a unitary structure, said means, said shroud rings and said inward flow and outward flow vanes being located at such radial distances from the axis of the rotor as to make the rotor deflection resistant without the aid of an axial shaft, co-axial shaft elements at the ends of the rotor for rotatably supporting the rotor in said casing, said casing comprising annular members arranged end to end and secured into a unitary structure, inlet guide vanes for zero prerotation of the fluid at the inlets of the respective second mentioned fluid passages, and said inlet guide vanes being secured between certain of said annular members.

7. In a centrifugal machine, a casing having stage fluid passages, a rotor in said chamber, said rotor comprising stage impellers arranged end to end, said impellers comprising wall structures and cylindrical spacers between the wall structure at the axis of the rotor, shroud rings positioned between said wall structures and co-acting with the latter and said spacers to provide fluid passages generally U-shaped in cross-section, inward flow and outward flow vanes in the respective second mentioned fluid passages, said inward flow and outward flow vanes being fixed to their respective shroud rings and wall structures, means for connecting said impellers in a unitary structure, said means, said shroud rings and said inward flow and outward flow vanes being located at such radial distances from the axis of the rotor as to make the rotor deflection resistant without the aid of an axial shaft, stub shafts at the ends of the rotor for rotatably supporting the rotor in said casing, said casing comprising annular members arranged end to end and secured into a unitary structure, and inlet guide vanes for negative prerotation at the inlets of the respective second mentioned fluid passages, said inlet guide vanes being secured between certain of said annular members.

8. In a centrifugal machine for compressing gas or vapor, a casing having stage fluid passages, a rotor in said chamber, said rotor comprising stage impellers arranged end to end, said impellers comprising wall structures and cylindrical spacers between the wall structure at the axis of the rotor, shroud rings positioned between said wall structures and co-acting with the latter and said spacers to provide fluid passages generally U-shaped in cross-section, inward flow and outward flow vanes in the respective second mentioned fluid passages, said inward flow and outward flow vanes being fixed to their respective shroud rings and wall structures, said cylindrical spacers connecting said impellers in a unitary structure, said cylindrical spacers, said shroud rings and said inward flow and outward flow vanes being located at such radial distances from the axis of the rotor as to make the rotor deflection resistant without the aid of an axial

shaft, stub shafts at the ends of the rotor for rotatably supporting the rotor in said casing, and said casing comprising annular members arranged end to end and bolted into a unitary structure, said first mentioned fluid passages comprising twin volutes at each stage of the machine, said annular members being internally contoured to define said twin volutes when assembled end to end.

9. In a centrifugal machine, a casing having stage fluid passages, a rotor in said chambers, said rotor comprising stage impellers arranged end to end, said impellers comprising wall structures and cylindrical spacers between the wall structure at the axis of the rotor, shroud rings positioned between said wall structures and co-acting with the latter and said spacers to provide fluid passages generally U-shaped in cross-section, inward flow and outward flow vanes in the respective second mentioned fluid passages, said inward flow and outward flow vanes being fixed to their respective shroud rings and wall structures, means for connecting said impellers in a unitary structure, said cylindrical spacers, said shroud rings and said inward flow and outward flow vanes being located at such radial distances from the axis of the rotor as to render the rotor deflection resistant without the aid of an axial shaft, and stub shafts at the ends of the rotor for rotatably supporting the rotor in said casing, said casing comprising annular members welded into a unitary structure, said first-mentioned passages comprising twin volutes and said annular members being internally contoured to define said twin volutes when arranged end to end.

10. The invention claimed in claim 8 wherein said members are contoured to provide cooling chambers.

11. The invention claimed in claim 8 wherein shell means are welded to said annular members, with said shell means and said annular members so contoured as to provide cooling chambers.

12. In a centrifugal machine, a casing having stage fluid passages, a rotor in said chamber, said rotor comprising stage impellers arranged end to end, said impellers comprising wall structures and cylindrical spacers between the wall structures at the axis of the rotor, shroud rings positioned between said wall structures and co-acting with the latter and said spacers to provide fluid passages generally U-shaped in cross-section, inward flow and outward flow vanes in the respective second mentioned fluid passages, said inward flow and outward flow vanes being fixed to their respective shroud rings and wall structures, means for connecting said impellers in a unitary structure, said means, said shroud rings and said inward flow and outward flow vanes being located at such radial distances from the axis of the rotor as to make the rotor deflection resistant without the aid of an axial shaft, stub shafts at the ends of the rotor for rotatably supporting the rotor in said casing, said casing having wearing surfaces, said shroud rings comprising first and second sections fixedly connected together, the first sections being respectively connected with said inward flow vanes and the second sections being respectively connected with the outward flow vanes, and peripheral rings encircling the respectice first and second sections and anchored to at least one thereof, said peripheral rings having wearing surfaces arranged in co-active relationship with said first-mentioned wearing surfaces.

13. In a centrifugal machine, a rotor comprising a plurality of stage impellers each consisting of an inlet-side disc and an outlet-side disc, a connector connecting said discs at their axes, and fluid deflecting vanes connected to and connecting said discs outwardly of their axes to form a rigid shaft-free rotor.

14. In a centrifugal machine, a rotor comprising a plurality of stage impellers each consisting of an inlet-side disc and an outlet-side disc, a connector connecting said discs at their axes, and fluid deflecting vanes connected to and connecting said discs outwardly of their axes, the outlet-side disc of one impeller being attached to the inlet-side disc of the impeller next thereto thereby forming rigid shaft-free rotor.

15. In a centrifugal machine, a rotor comprising a plurality of stage impellers each consisting of an inlet-side disc and an outlet-side disc, a connector connecting said discs at their axes, and fluid deflecting vanes connected to and connecting said discs outwardly of their axes, the outlet-side disc of one impeller being attached to the inlet side disc of the impeller next thereto thereby forming rigid shaft-free rotor, and supporting stub shafts connected to and extending outwardly from the ends of the rotor.

16. In a centrifugal machine, a rotor comprising a plurality of stage impellers each consisting of an inlet-side disc and an outlet-side disc, a connector connecting said discs at their axes, and fluid deflecting vanes connected to and connecting said discs outwardly of their axes to form a rigid shaft-free rotor, the connector of each stage progressively from the first stage being shorter than the connector of the stage which discharges thereinto whereby the volumetric capacity of the stages progressively decreases from the initial inlet to the final discharge outlet of the rotor.

17. In a centrifugal machine, the combination of a casing having stage fluid passages, a rotor in said chamber, said rotor comprising stage impellers arranged end to end, said impellers comprising wall structures and cylindrical spacers between the wall structures at the axis of the rotor, shroud rings positioned between said wall structures and co-acting with the latter to provide fluid passages generally U-shaped in cross section, inward flow and outward flow vanes in the respective second-mentioned fluid passages, said inward flow and outward flow vanes being fixed to their respective shroud rings and wall structures, means for connecting said impellers into a unitary structure, said means, said shroud rings and said inward flow and outward flow vanes being located at such radial distances from the axis of the rotor as to make the rotor deflection resistant, said casing having wearing surfaces, said shroud rings comprising first and second sections fixedly connected together, said first sections being respectively connected with said inward flow vanes and the second sections being respectively connected with the outward flow vanes, peripheral rings encircling the respective first and second sections and anchored to at least one thereof, said peripheral rings having wearing faces arranged in co-active relationship with said first-mentioned wearing surfaces, and inlet guide vanes for positive prerotation of the fluid at the inlets of the respective second-mentioned fluid passages.

18. In a centrifugal machine for compressing gas or vapor, the combination of a casing having stage fluid passages, a rotor in said chamber, said rotor comprising stage impellers arranged end to end, said impellers comprising annular

wall structures arranged in co-axial relationship, shroud rings positioned between said wall structures and co-acting with the latter to provide fluid passages arranged in series relationship with the casing fluid passages, inward flow and outward flow vanes in the respective second-mentioned fluid passages, said inward flow and outward flow vanes being fixedly related to their respective shroud rings and wall structures, said shroud rings comprising first and second sections fixedly connected together, said first sections being respectively connected with said inward flow vanes and said second sections being respectively connected with said outward flow vanes, peripheral rings encircling the respective first and second sections and anchored to at least one thereof, said peripheral rings having wearing surfaces arranged in co-active relationship with said first-mentioned wearing faces, said wall structures comprising discs welded together, peripheral rings encircling the respective wall structures and anchored to at least one disc thereof, said second-mentioned peripheral rings having wearing surfaces, and wearing surfaces in said casing arranged in co-active relationship with the wearing surfaces on said second-mentioned peripheral rings.

19. In a centrifugal machine of the multistage type, the combination of a casing having a rotor chamber and provided with axially spaced stage fluid passages, said fluid passages having first inlets and first outlets communicating with said chamber, said casing having a suction inlet and a discharge, a rotor in said chamber and having axially spaced stage fluid passages provided with second inlets and second outlets arranged in series communication with said first outlets and first inlets, respectively, to provide a continuous fluid passage extending from said suction inlet to said discharge, said rotor being of such contour with respect to the contour of said chamber as to be axially removable therefrom intact, fluid impinging vanes in said second-mentioned stage fluid passages, said rotor including shroud rings fixedly related thereto and defining one wall of each of said second-mentioned stage fluid passages, said shroud rings each comprising two sections, and means for connecting the sections in each pair one with the other.

20. In a centrifugal machine of the multistage type, the combination of a casing having a rotor chamber and provided with axially spaced stage fluid passages, said fluid passages having first inlets and first outlets communicating with said chamber, said casing having a suction inlet and a discharge, a rotor in said chamber and having axially spaced stage fluid passages provided with second inlets and second outlets arranged in series communication with said first outlets and first inlets, respectively, to provide a continuous fluid passage extending from said suction inlet to said discharge, said rotor being of such contour with respect to the contour of said chamber as to be axially removable therefrom intact, fluid impinging vanes in said second-mentioned stage fluid passages, said rotor including axially spaced annular walls, each of said walls comprising two sections, the sections in each pair being welded one to the other in face to face relationship, and annular means attached to and encircling each wall.

21. In a centrifugal machine of the multistage type, the combination of a casing having a rotor chamber and provided with axially spaced stage fluid passages, said fluid passages having first inlets and first outlets communicating with said chamber, said casing having a suction inlet and a discharge, a rotor in said chamber and having axially spaced stage fluid passages provided with second inlets and second outlets arranged in series communication with said first outlets and first inlets, respectively, to provide a continuous fluid passage extending from said suction inlet to said discharge, said rotor being of such contour with respect to the contour of said chamber as to be axially removable therefrom intact, fluid impinging vanes in said seccond-mentioned stage fluid passages, said rotor including axially spaced annular walls, each of said walls comprising two sections, the sections in each pair being welded one to the other in face to face relationship, annular means attached to and encircling each wall, and inlet guide vanes for zero rotation of the fluid at said second inlets, said inlet guide vanes being attached to said casing.

22. In a centrifugal machine of the multistage type, the combination of a casing having a rotor chamber and provided with axially spaced stage fluid passages, said fluid passages having first inlets and first outlets communicating with said chamber, said casing having a suction inlet and a discharge, a rotor in said chamber and having axially spaced stage fluid passages provided with second inlets and second outlets arranged in series communication with said first outlets and first inlets, respectively, to provide a continuous fluid passage extending from said suction inlet to said discharge, said rotor being of such contour with respect to the contour of said chamber as to be axially removable therefrom intact, fluid impinging vanes in said second-mentioned stage fluid passages, said rotor including shroud rings fixedly related thereto and defining one wall of each of said second-mentioned stage fluid passages, said shroud rings each comprising two sections, means for connecting the sections in each pair one with the other, and inlet guide vanes for negative prerotation of the fluid at said second inlets, said guide vanes being attached to said casing.

23. In a centrifugal machine of the multistage type, the combination of a casing having a rotor chamber and provided with axially spaced stage fluid passages, said fluid passages having first inlets and first outlets communicating with said chamber, said casing having a suction inlet and a discharge, a rotor in said chamber and having axially spaced stage fluid passages provided with second inlets and second outlets arranged in series communication with said first outlets and first inlets, respectively, to provide a continous fluid passage extending from said suction inlet to said discharge, said rotor being of such contour with respect to the contour of said chamber as to be axially removable therefrom intact, fluid impinging vanes in said second-mentioned stage fluid pasages, said rotor including shroud rings fixedly related thereto and defining one wall of each of said second-mentioned stage fluid passages, said shroud rings each comprising two sections, means for connecting the sections in each pair one with the other, and inlet guide vanes for positive prerotation of the fluid at said second inlets, said guide vanes being carried by said casing.

24. In a centrifugal machine of the multistage type, the combination of a casing having a rotor chamber and provided with axially spaced stage fluid passages, said fluid passages having first inlets and first outlets communicating with said chamber, said casing having a suction inlet and

a discharge, a rotor in said chamber and having axially spaced stage fluid passages provided with second inlets and second outlets arranged in series communication with said first outlets and first inlets, respectively, to provide a continuous fluid passage extending from said suction inlet to said discharge, said rotor being of such contour with respect to the contour of said chamber as to be axially removable therefrom intact, fluid impinging vanes in said second-mentioned stage fluid passages, said rotor including axially spaced annular walls, each of said walls comprising two sections, the sections in each pair being welded one to the other in face to face relationship, annular means attached to and encircling each wall, and inlet guide vanes for zero prerotation of the fluid at said second inlets, said guide vanes being attached to said casing.

25. In a centrifugal machine of the multistage type, the combination of a casing having a rotor chamber and provided with axially spaced stage fluid passages, said fluid passages having first inlets and first outlets communicating with said chamber, said casing having a suction inlet and a discharge, a rotor in said chamber and having axially spaced stage fluid passages provided with second inlets and second outlets arranged in series communication with said first outlets and first inlets, respectively, to provide a continuous fluid passage extending from said suction inlet to said discharge, said rotor being of such contour with respect to the contour of said chamber as to be axially removable therefrom intact, fluid impinging vanes in said second-mentioned stage fluid passages, said rotor including axially spaced annular walls, each of said walls comprising two sections, the sections in each pair being welded one to the other in face to face relationship, annular means attached to and encircling each wall, and inlet guide vanes for negative prerotation of the fluid at said second inlets, said guide vanes being attached to said casing.

26. In a centrifugal machine of the multistage type, the combination of a casing having a rotor chamber and provided with axially spaced stage fluid passages, said fluid passages having first inlets and first outlets communicating with said chamber, said casing having a suction inlet and a discharge, a rotor in said chamber and having axially spaced stage fluid passages provided with second inlets and second outlets arranged in series communication with said first outlets and first inlets, respectively, to provide a continuous fluid passage extending from said suction inlet to said discharge, said rotor being of such contour with respect to the contour of said chamber as to be axially removable therefrom intact, fluid impinging vanes in said second-mentioned stage fluid passages, said rotor including axially spaced annular walls, each of said walls comprising two sections, the sections in each pair being welded one to the other in face to face relationship, annular means attached to and encircling each wall, and inlet guide vanes for positive pre-rotation of the fluid at said second inlets, said guide vanes being attached to said casing.

27. In a multistage centrifugal machine, a casing, a rotor in said casing composed of a plurality of connected stage sections including an inlet end disc and an outlet end disc, connectors connecting said discs at their axial portions, vanes on each of said discs, shroud ring sections integral with the vanes on each of said discs, means connecting the shroud ring section on one disc to the shroud ring section on the other disc to detachably connect the disc one to the other near their periphery, and a closure ring detachably connected to one of said shroud ring sections overlapping the joint between the shroud ring sections and engaging the shroud ring section other than the one to which it is connected.

28. In a multistage centrifugal machine, a casing, a rotor in said casing composed of a plurality of connected stage sections including an inlet end disc and an outlet end disc, connectors connecting said discs at their axial portions, vanes on each of said discs, shroud ring sections integral with the vanes on each of said discs, means connecting the shroud ring section on one disc to the shroud ring section on the other disc to detachably connect the discs one to the other near their periphery, a closure ring detachably connected to one of said shroud ring sections overlapping the joint between the shroud ring sections and engaging the shroud ring section other than the one to which it is connected, the outlet end disc of one stage section abutting and attached to the inlet disc of the adjacent stage section of the rotor, and a wear ring detachably connected to one of said discs and overlapping the joint formed by the abutting surfaces of the discs.

29. In a multistage centrifugal machine, a casing, a rotor in said casing composed of a plurality of connected stage sections, each of said stage sections including an inlet end disc and an outlet end disc connectors connecting said discs at their axial portions, means detachably connecting said discs near their peripheries, the outlet end disc of one stage section abutting and welded to the inlet end disc of the adjacent stage section.

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REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
846,971	Akimoff	Mar. 12, 1907
912,882	Oraker	Feb. 16, 1909
1,363,315	Dron	Dec. 28, 1920
2,030,560	Adams, Jr.	Feb. 11, 1936
1,213,889	Lawaczeck	Jan. 30, 1917

FOREIGN PATENTS

Number	Country	Date
23,923	Great Britain	Nov. 20, 1905
495,303	France	June 26, 1919
4,793	Great Britain	1911
843,638	France	Apr. 3, 1939