July 17, 1962 J. FULLEMANN 3,044,684

CENTRIFUGAL COMPRESSOR CONSTRUCTION

Filed Feb. 24, 1961 2 Sheets-Sheet 1

Fig. 1.

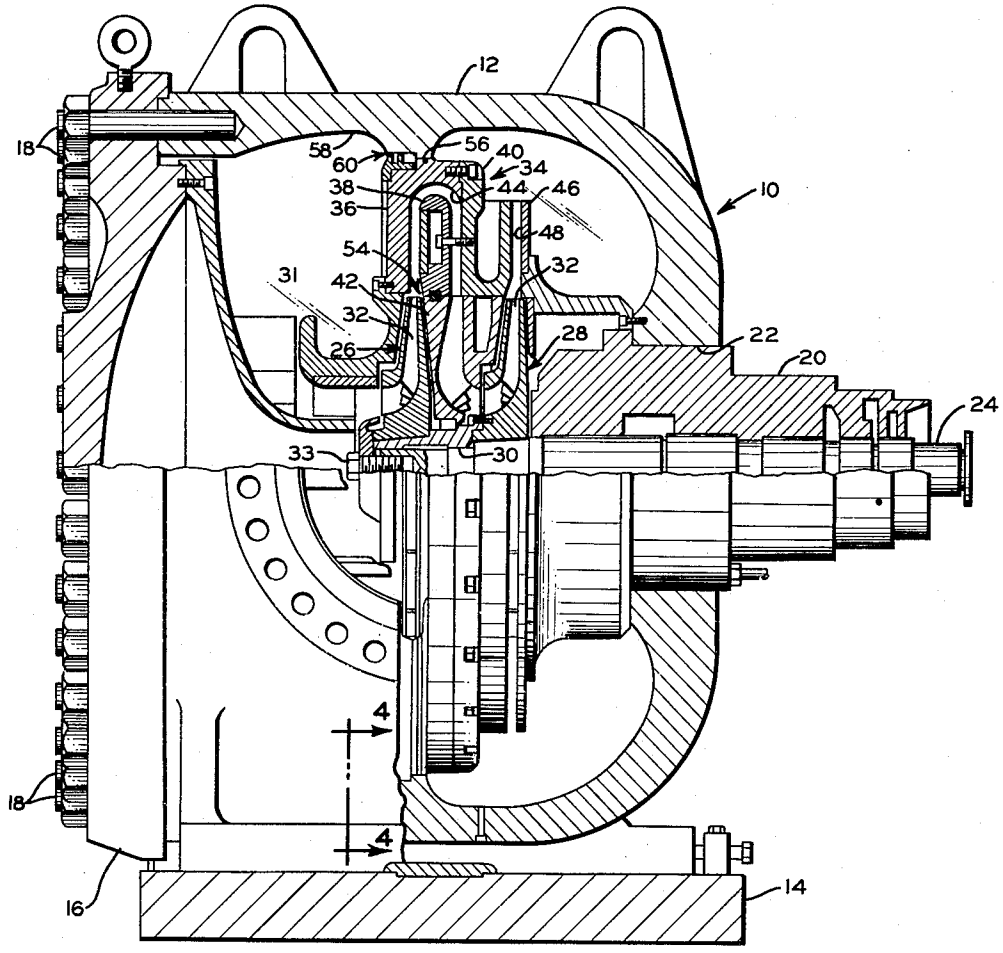
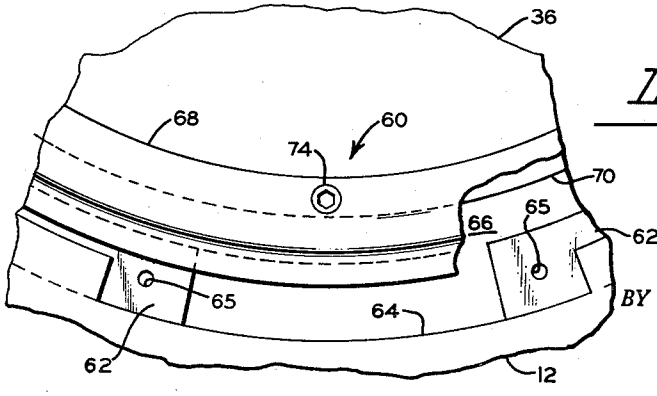


Fig. 4.



INVENTOR.
JOHN FULLEMANN
BY
Owen & Owen
ATTORNEYS

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Filed Feb. 24, 1961 2 Sheets-Sheet 2

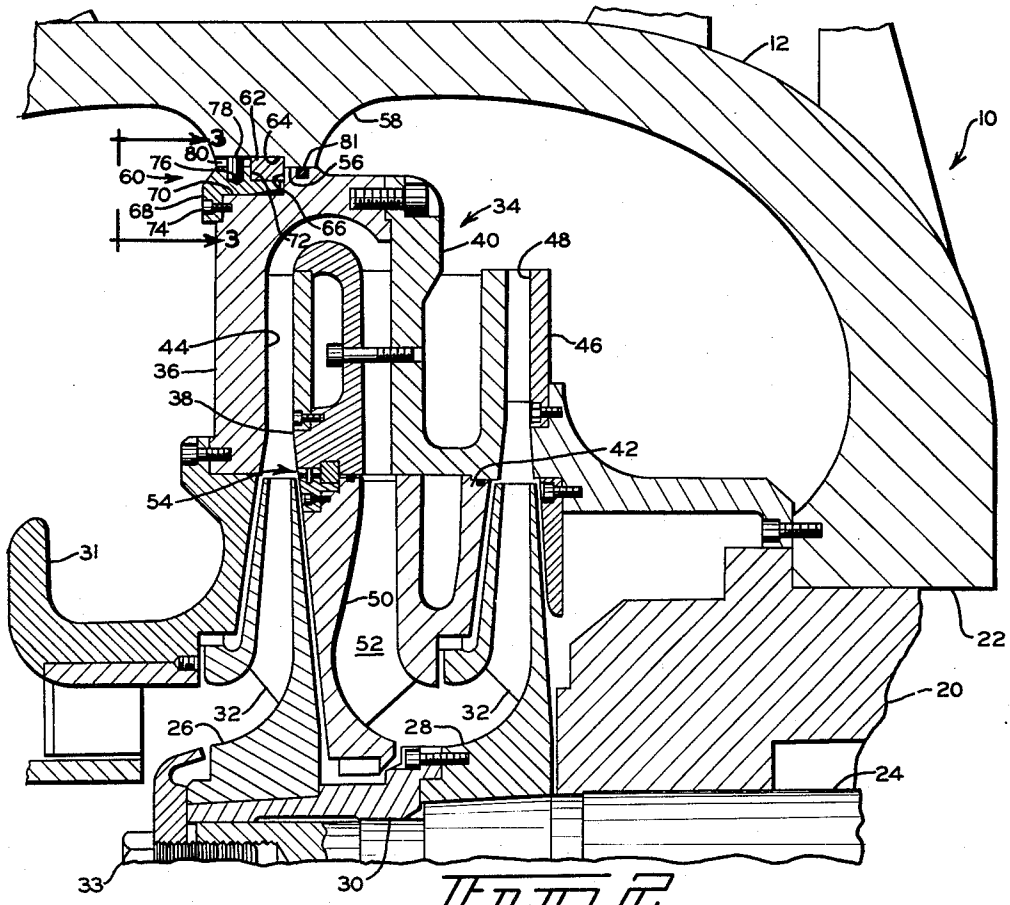


Fig. 2.

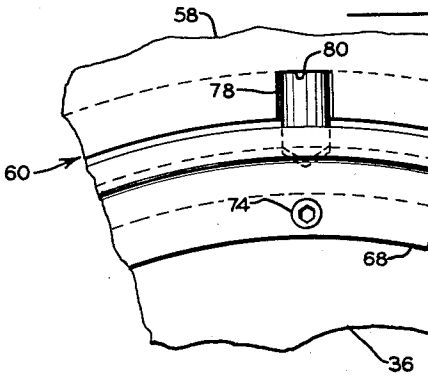


Fig. 3.

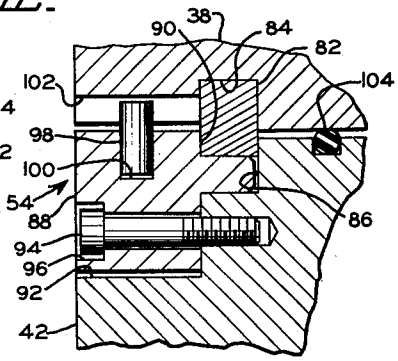


Fig. 5.

INVENTOR.
JOHN FULLEMANN
BY
Owen & Owen
ATTORNEYS

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CENTRIFUGAL COMPRESSOR CONSTRUCTION

John Fullemann, Mount Vernon, Ohio, assignor to The Cooper-Bessemer Corporation, Mount Vernon, Ohio, a corporation of Ohio

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8 Claims. (Cl. 230—130)

This invention relates to an improved overhung centrifugal compressor and more particularly to an improvement in the construction of the casing retaining elements of such a compressor.

In recent years there has been a trend towards the introduction of engine driven centrifugal compressors for pipeline booster stations. With a typical flow of 500–750,000,000 cubic feet per day the compressors have been driven by engines or turbines in the 4000 horsepower to 6000 horsepower class, and a single stage booster compressor was used. Recently economic considerations appear to favor the use of gas turbine driven compressors capable of absorbing greater power (10,000 horsepower and over). In these larger sizes two-stage compressors are more efficient than single-stage compressors when the average line volume is moderate and the boost pressure involved is high and fewer booster stations are used on the line, since the greater power available will permit greater spacing of the booster stations. When the average volume of flow through the pipe line becomes even higher, however, it will then become necessary to increase the number of stations and to decrease the pressure boost at any single station. When this condition is reached, single-stage compressors are better suited and a change in the compressor rotors becomes necessary.

Two-stage compressors capable of absorbing very high horsepowers are presently made with through-shafting in which a rotor is carried by a shaft extending through the casing and journaled at each end. The compressors of the present invention, on the other hand, are of the overhung type requiring but one high pressure seal and but one removable cover or end wall to achieve maximum accessibility.

In one compressor constructed in accordance with the present invention, the casing is a steel casting having an internal diameter of about 64 inches and a wall thickness varying between 3 inches and 4 inches. If a conventional bolted flange construction were used for fastening the inter-stage elements in the casing, the bolted endwall or access opening would have to be increased by several inches. Calculations indicate that the weight of the casing casting is reduced by about 15 percent by use of the present invention and that it is possible to eliminate about 75 one inch bolts and the machining of their receiving holes.

Thus the construction of the casing and fastening elements enables all of the compressor components to be contained within a smaller casing than is otherwise possible if the compressor is made in the conventional bolted flange design. The new construction comprises a locking ring connection positioned between a part of the casing and the inter-stage elements of the two-stage compressor. A similar locking ring connection can be used between various components of the stationary vane section to fasten them together, and to aid in more easily disassembling these components.

According to the present invention, a smaller size casing is possible because the usual bolt flanges which are commonly employed to retain the inter-stage elements in place in the casing are eliminated and are replaced by the new smaller, separate locking ring connection. With the bolt flange eliminated, the size of the access opening in the casing through which the parts must be assembled can also be reduced.

The locking ring connection according to the invention includes a locking ring which is located in a groove in the casing with a shoulder of the stationary vane section bearing against one side of the ring to resist the forces acting longitudinally of the compressor. A clamping ring is then bolted to the vane section on the side of the ring opposite the shoulder to clamp the locking ring in position and thereby prevent movement of the vane section in the opposite direction. The clamping ring also includes at least one pin extending radially therefrom which engages an elongated notch in the casing which is formed laterally of the annular groove in which the clamping ring is received. The pin and recess prevents circumferential movement of the clamping ring and the inter-stage vane assembly to which it is bolted.

It is, therefore, a principal object of the invention to provide a multistage centrifugal compressor which is readily accessible from one end and which can be contained in a smaller casing than is needed for conventional compressors of the same capacity.

Another object of the invention is to provide an improved connection, using fewer bolts, for connecting an intermediate stage, stationary vane section of a multistage compressor to a compressor casing.

Still another object of the invention is to provide improved locking means for connecting a circular body to the inner surfaces of a generally cylindrical casing and for locking the body against both longitudinal and circumferential movement within the casing.

Other objects and advantages of the invention will be apparent from the following detailed description of a preferred embodiment thereof, reference being made to the accompanying drawings, in which:

FIG. 1 is an overall side view, with parts broken away and with parts in cross section, of a two-stage, overhung compressor embodying locking ring connections according to the invention;

FIG. 2 is a greatly enlarged view in vertical cross section of a portion of the compressor shown in FIG. 1;

FIG. 3 is a fragmentary front view of a portion of the compressor casing and the locking connection of FIGS. 1 and 2;

FIG. 4 is a fragmentary front view of another portion of the compressor casing showing the cut-away section in which the ends of the locking ring are located; and

FIG. 5 is a greatly enlarged view in vertical cross section of a portion of the compressor and one of the connections shown in FIG. 1.

Referring now to the drawings, and more particularly to FIG. 1, a compressor embodying the principles of the invention is indicated at **10** and includes a casing **12** having a base **14** and a separable end wall or cover **16** fastened to the casing **12** by a plurality of bolts and nuts **18**.

A single bearing unit **20** (FIGS. 1 and 2) extends through and is fastened in a central opening **22** in one end of the casing **12**. This unit **20** comprises a number of components of standard design which do not constitute part of the invention; therefore, the unit is shown as a single piece and is not disclosed in detail. A drive shaft **24** is rotatably supported by the bearing unit **20** and extends outwardly to receive a driving force from a turbine or other prime mover and inwardly to carry a rotor having first and second stage impellers **26** and **28**. Each of the impellers **26** and **28**, which are separated by a tapered spacer hub **30**, includes blading **32** of appropriate design for compressing gas supplied to the compressor **10**, and the entire rotor is fixed against endwise movement relative to the shaft **24** by an end nut **33**. Gas is guided into the first compressor stage by an inlet shroud member **31**.

An annular, stationary inter-stage guide vane section **34** is located between the impellers **26** and **28** and in-

cludes three principal outer annular parts 36, 38 and 40 and an inner annular part 42. The three outer parts 36, 38 and 40 form a U-shaped inter-stage passage 44 which connects the first and second compressor stages. The latter outer part 40 also cooperates with an annular flange member 46 to form an outlet passage 48 for the second stage, the flange member 46 being fastened to the casing 12 around the opening 22. The inner annular part 42 of the vane section 34 forms an inlet passage 50 for the second stage and contains second stage inlet guide vanes 52.

The inner annular part 42 is fastened to the outer annular parts 36–40 of the section 34 by a locking ring connection 54 (see FIGS. 2, 3 and 4) and the intermediate section 34, through the part 36, is fastened to an inner edge 56 of an integral rib 58 of the casing 12 by a locking ring connection 60. These ring connections, particularly the latter one, effect a very substantial saving of space by eliminating the usual bolt flanges which would otherwise be used to connect the parts. The new connections also enable easier disassembly of the compressor 10 because of the fact that fewer bolts can be employed, as will subsequently be apparent, so that fewer bolts need be loosened and tightened for disassembly and assembly. The new locking ring connections also provide an extremely high resistance to endwise thrust and are relatively light and the parts are easy to handle for maintenance purposes.

Referring in more detail to FIGS. 2 and 3, the outer ring connection 60 comprises a locking ring 62 located in an annular groove 64 cut in the inner facing surface 56 of the rib 58. The locking ring 62 comprises a band of steel or cast iron that has a normal diameter somewhat larger than the outer diameter of the groove 64, and a circumference that is less than the circumference of the groove, so that the ring is inserted into and removed from the groove by compressing its ends together. For this purpose each end of the ring is provided with a blind hole or recess 65 into which an appropriate compressing tool can be inserted to temporarily reduce the diameter of the ring and allow it to be inserted into and removed from groove 64. When the ring is inserted in its groove 64, its ends spring apart as shown in FIG. 4 and the ring body abuts a shoulder 66 formed on the outer part 36 of the intermediate vane section 34 to prevent the section 34 from moving longitudinally of the casing 12 (toward the left as shown in the drawing) in response to pressures developed in the compressor. On the opposite side of the locking ring 62 is a clamping ring 68, lying partially in an annular recess 70 cut in the part 36, which has a shoulder 72 abutting the ring 62 on the side opposite the shoulder 66. The clamping ring 68 thereby cooperates with the locking ring 62 to prevent longitudinal movement of the vane section 34 toward the right, as shown in the drawings. The clamping ring 68 is bolted to the first outer part 36 by a plurality of bolts 74 located circumferentially around the ring. The clamping ring 68 also has one or more blind holes 76 therein in which are located one or more radially extending pins 78, the outer ends of which extend into one or more grooves 80 which are cut in the rib 58 and extend laterally of the locking ring groove 64. The pins 78 (if more than one is used) are moved into the grooves 80 when the clamping ring 68 is bolted to the stationary vane section 34 after the locking ring 62 has been placed in the groove 64, which is accomplished immediately after the section 34 is properly located in the casing 12 with respect to the rib 58. The pins 78 cooperate with the sides of the grooves 80 of the rib 58 to prevent circumferential movement of the stationary vane section 34. A suitable seal such as an O-ring 81 is also located between the section 34 and the rib 58 to prevent leakage between the stages of the compressor.

The gas from the second stage of the compressor has a pressure substantially higher than that entering the first stage in a typical instance being 300 p.s.i. higher. Because the areas of the surfaces upon which this pressure differential acts are large, a force of many thousands of pounds act upon the intermediate vane section 34 and urge it toward the left, as shown. However, this force is resisted by the shoulder 66 which abuts the locking ring 62, the ring being prevented from moving by the left wall of the groove 64 in which it is seated. No attempt is made to absorb any of this force in the clamping ring 68 which serves only to maintain the ring 62 in position and to hold the pins 76 in order to prevent circumferential movement of the stationary inter-stage assembly. Hence, relatively few of the bolts 74 are needed because the only force acting upon them is a shearing force resulting from the circumferential force or torque acting upon the intermediate, stationary section 34.

Referring more particularly to FIG. 5, the preferred construction of the inner locking connection 54 is quite similar to the construction of the locking connection 60 described above, and includes a spring locking ring 82 located in a groove 84 in the inwardly disposed face of the second outer part 38, abutting a shoulder 86 of the inner stationary part 42. A locating and clamping ring 88 has a shoulder 90 engaging the side of the ring 82 opposite the shoulder 86, the ring in this instance being substantially flush in an annular recess 92 of the part 42. The clamping ring 88 is fastened to the part 42 by bolts 94 which are flush in recesses 96. The entire locking connection 54 is thus flush with the parts 36 and 42. Radially extending pins 98 are held in blind holes 100 of the clamping ring 88 and are received in grooves 102 of the part 38 to prevent circumferential movement of the parts. An O-ring seal 104 is also located between the inner and outer parts 38 and 42 of the vane section.

In disassembling the compressor according to the present invention, the casing end nuts 18 are removed which permits the entire casing end bell 16 to be taken away from the remainder of the housing. When this is done, the inlet shroud 31 may also be removed to expose the end of the rotor and the interior interstage elements 36, 38 and 40. The rotor shaft end screw 33 can be removed which will permit the rotor to be removed apart from its driving shaft 24.

The retaining or clamping ring 68 is then removed by removing the peripheral series of holding screws 74 which will permit the retaining ring to be slid outwardly and taken away through the end of the casing. The locking ring 62 is thus exposed. As shown in FIG. 4 the ends of the locking rings 62 are disposed in a cut out portion of the casing, preferably at the bottom. The locking ring can be compressed by inserting a tool in previously prepared holes 65 in the now exposed surface of the ring, compressing it until its circumference is less than the open circumference of the groove 64 so that the ring resides wholly in the annular recess 70 in the inter-stage elements. The locking ring can then be passed out through the open end of the casing. The inter-stage elements and the rotor are now free of the casing and can then be slid as a unit out of the end of the casing for inspection and repair.

While the present invention has been specifically described in connection with a two-stage compressor, it will be understood that the stationary elements separating the inlet and discharge ends of a single-stage compressor may be held in the casing by the same means. Thus the invention makes it possible to substitute a single-stage rotor in the casing previously utilized in a two-stage machine. Further, it should be understood that the invention is equally applicable to turbine construction in which energy is derived from the entering gas rather than being supplied to it. Thus the introductory clause of the appended claims is intended to include rotary machines of both energy consuming and energy supplying types.

What I claim is:

1. In an assembly of a centrifugal compressor or the like having a rotor and casing wall means forming a cylindrical chamber in which said rotor is concentrically

located, a stationary element removably mounted in said casing and separating the inlet and discharge ends of said rotor, means on said casing forming an annular groove, a shoulder on said stationary element axially opposite a wall of said groove, a locking ring in said groove and in abutting relationship with said shoulder, a clamping ring adjacent said locking ring on the side thereof opposite said shoulder, means for fastening said clamping ring to prevent inward displacement of said locking ring, a plurality of elongated notches in said casing wall intersecting said groove, and at least one pin held in said clamping ring and extending into said notches to prevent rotational displacement of said stationary element.

2. In a rotary, overhung compressor, a casing, a stationary member interposed between the inlet and outlet sides of said compressor, locking ring means extending partially into a groove in said casing, means on said stationary section abutting said locking ring and preventing movement of said stationary section in a direction longitudinally of said casing, clamping means fastened to that one of said intermediate section and said casing having said abutting means for holding said locking ring to prevent movement of said section longitudinally of said casing, and means on said clamping means cooperating with notches in that one of said casing and said stationary section into which said locking ring extends for preventing circumferential movement of said section relative to said casing.

3. In an assembly of a centrifugal compressor or the like having a rotor and wall means concentric therewith, stationary means cooperating with said rotor and said wall means to separate the inlet and discharge ends of said rotor, means on said wall means forming an annular groove, a shoulder on said stationary means, a locking ring in said groove and in abutting relationship with said shoulder, a clamping ring adjacent said locking ring on the side thereof opposite said shoulder, means for fastening said clamping ring to said stationary means, at least one elongated notch in said wall means and at least one pin held in said clamping ring and extending into said notch to prevent rotational displacement of said stationary means.

4. In a rotary, overhung, multi-stage centrifugal compressor or the like, a stationary element between two stages of the compressor, a rigid member upon which said stationary element is removably mounted, said rigid member having a groove on the inner surface thereof, locking ring means extending partially into said groove, means on said stationary element abutting said ring means and preventing movement of said stationary element relative to said rigid member in one direction longitudinally thereof, clamping means fastened to said stationary element for holding said ring means in abutting relationship with respect to said abutting means, and means on said clamping means for preventing circumferential movement of said ring means and said stationary element relative to said rigid member.

5. In a rotary, overhung, multi-stage centrifugal compressor or the like, a casing, a stationary inter-stage vane section within said casing between two stages of the compressor, said casing forming an annular groove on the inner surface thereof, a locking ring extending partially into said groove, a shoulder on said inter-stage vane section abutting said ring and preventing movement of said section in one direction longitudinally of said casing, a clamping ring fastened to said section on the side of said locking ring opposite the shoulder for holding said ring in abutting relationship with respect to said shoulder, said casing having a notch near said groove, and a pin held by said clamping ring extending into said notch for preventing circumferential movement of said clamping ring and said section relative to said casing.

6. The combination of elements defined in claim 5 and an O-ring seal between said casing and said inter-stage vane section.

7. In an assembly of a centrifugal compressor or the like having a rotor and a casing wall forming a cylindrical chamber in which said rotor is concentrically located, a stationary element having means forming an inter-stage vane section between compression stages on said rotor and separating the inlet and discharge ends of said rotor, means on said casing and said stationary elements forming an annular groove, a shoulder on said stationary element, a locking ring in said groove and in abutting relationship with said shoulder, a clamping ring adjacent said locking ring on the side thereof opposite said shoulder, means for fastening said clamping ring to prevent inward displacement of said locking ring, at least one elongated notch in said casing wall intersecting said groove, at least one pin held in said clamping ring and extending into said notch to prevent rotational displacement of said clamping ring, inwardly disposed removable means fastened to said stationary element forming an inlet passage for a subsequent compressing stage, means forming a groove in said stationary element, means forming a shoulder on said inwardly disposed means, a second locking ring seated in said groove and cooperating with said shoulder to prevent longitudinal displacement of said inwardly disposed means, and a second clamping ring preventing inward displacement of said second locking ring, and means to prevent rotational displacement of said second clamping ring.

8. In a compressor or the like having a rotor mounted for rotation about a longitudinal axis and a rigid member fixedly mounted concentric with said axis, a stationary element removably mounted on said rigid member between the inlet and discharge ends of said rotor, an annular groove in said rigid member adjacent said stationary element, a locking ring having portions of opposed surfaces thereof in contact with the sides of said groove, a portion of one of said surfaces being in engagement with said stationary member, a clamping ring in engagement with a portion of the opposite surface of said locking ring, and means for securing said clamping ring to said stationary element.

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