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ROTARY COMPRESSORS

2,970,748

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2 Sheets-Sheet 1

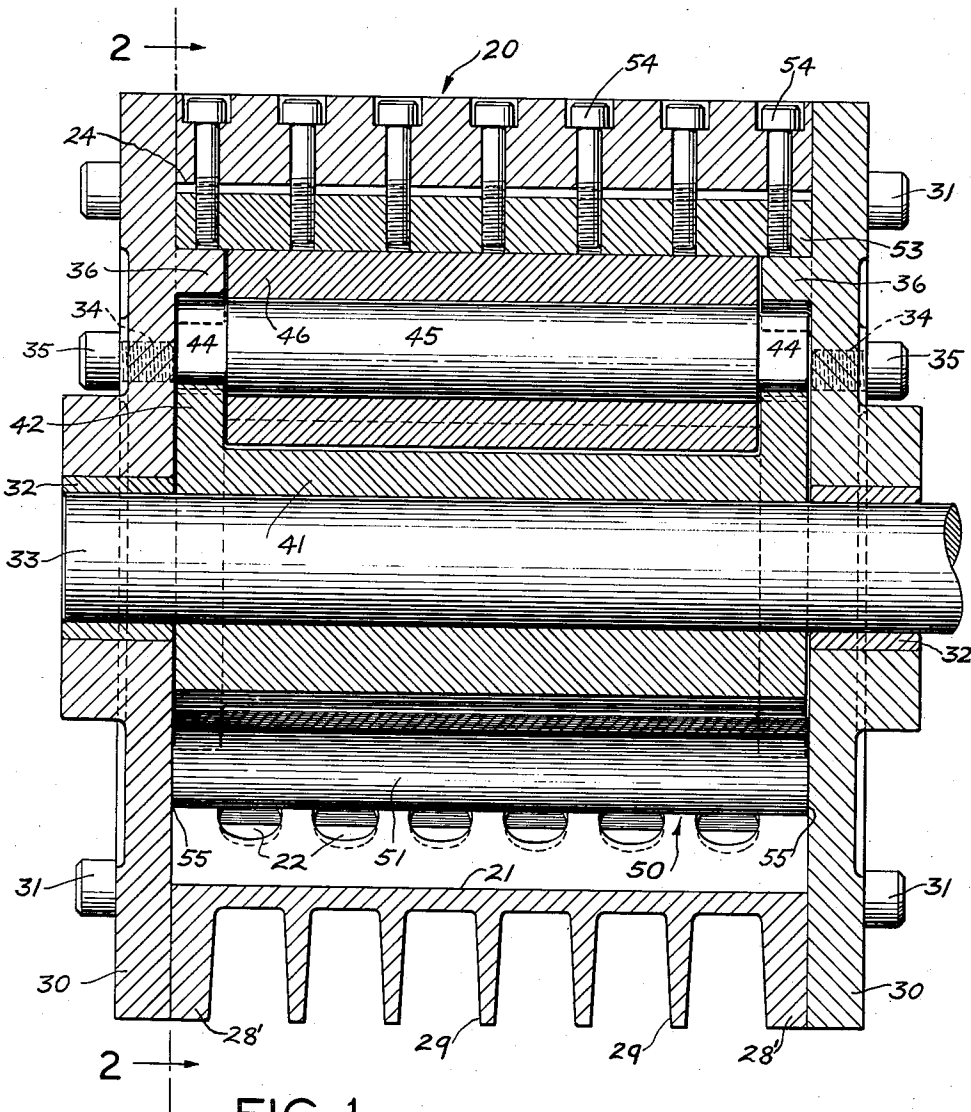


FIG. 1

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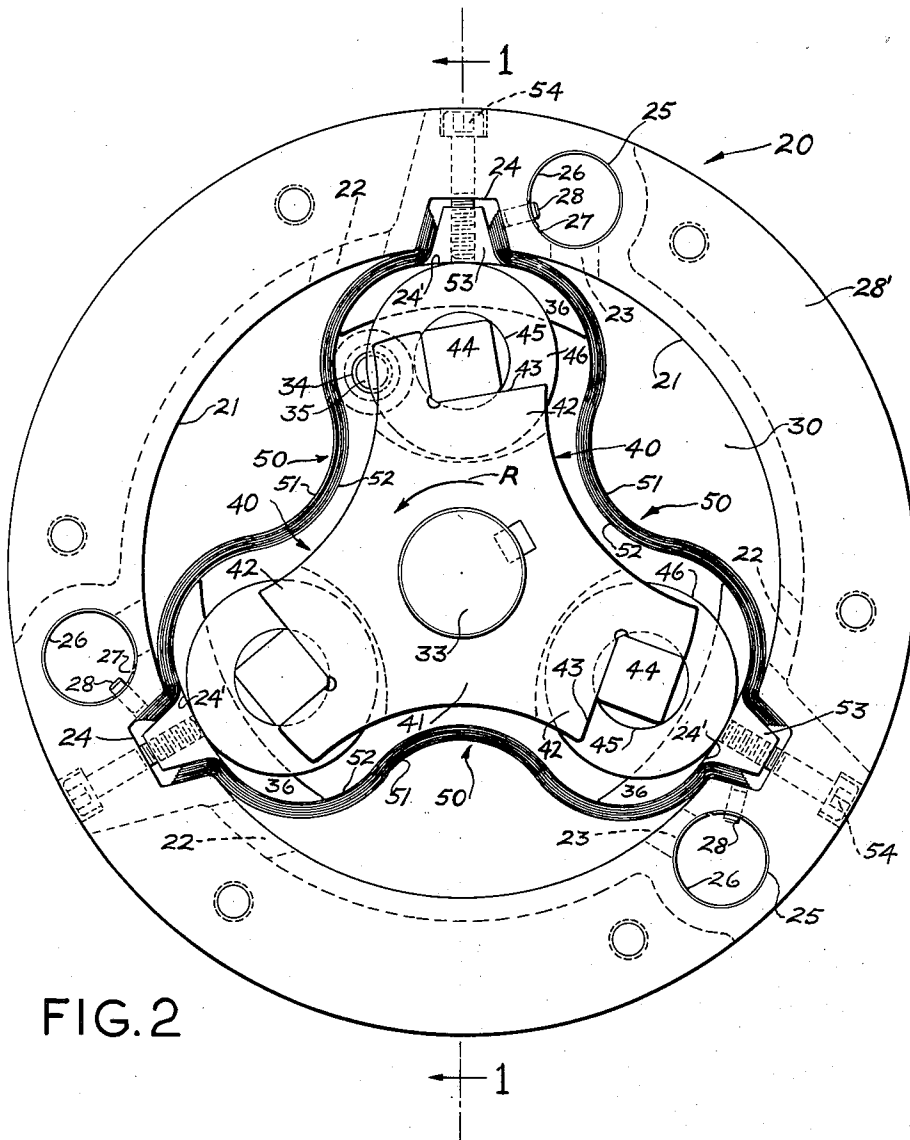


FIG. 2

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ROTARY COMPRESSORS

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This invention relates generally to positive displacement rotary compressors and in particular to that class of rotary compressor mechanism seeking to utilize a flexible band structure element for the compressor function.

The known prior art, extending back some fifty years or so, discloses relatively few compressor mechanisms of this general type and they do not appear to have gained commercial acceptance. It further appears that certain technical difficulties inherent in the problem of using a flexible band element for this purpose, together with the increasing requirement for compressor performance ostensibly beyond the scope of such a mechanism, have long since eliminated it from consideration.

It is a major object of the present invention to provide an improved rotary compressor mechanism of the type referred to that is efficiently adapted for use over a substantially wider range of working fluid densities and pressure ratios than appears to be practicable with any single type of rotary compressor or pump mechanism of present design and manufacture.

A further object is to provide such a positive displacement rotary compressor which will operate with high efficiency, in a unit having substantially lower bulk, weight and cost in relation to output than currently available rotary and reciprocating-piston compressor units.

An additional object is to provide such compressor apparatus usable either as a fluid pump or motor, when desired.

Another object is to provide a simple and convenient method of achieving infinitely variable displacement operation in a rotary compressor of the type referred to.

The structural features necessary to accomplish the foregoing objects, and to realize the advantages of this invention implicit therein, are set forth in the following specification and accompanying drawings in which like reference numbers designate like parts and of which

Fig. 1 shows, in axial longitudinal section, an example of a compressor structure embodying this invention substantially as it would appear on the line 1-1 of Fig. 2.

Fig. 2 shows an end view of the compressor taken on line 2-2 of Fig. 1, substantially as it would appear with an end cover plate removed to permit access to the internal parts.

Reference numeral 20 in Figs. 1 and 2 designates a circumferentially flanged cylindrical casing having a cylindrical inner surface 21 with adjacent intake ports 22 and discharge ports 23 angularly disposed in pairs around the inner surface, and axially disposed slots 24 in the casing inner surface between each pair of intake and discharge ports. Since it is desirable to provide means to prevent back flow of a compressed fluid discharge ports 23 preferably embody check valves for this purpose. These may take a variety of forms depending, in part, on the nature of the fluid medium to be compressed. For air and gases, and fluids of relatively low viscosity, such valves may have the simple form disclosed in Fig. 2 in which the compressed medium discharged through the

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ports 23 enters axially extending bores 25 in the casing flanges each bore having a cylindrical tube 26 of resilient sheet metal lining the bore and sealing the ports. A longitudinal slit 27 in the tube adjacent to the port areas enables the tubular portion over the discharge ports to open and close in response to the working pressures and a projecting pin 28 engages the wall of the tube, as shown, to maintain its angular alignment relative to the discharge port areas.

Reference numeral 28' designates integral end flanges of the compressor casing and reference numeral 29 designates supplementary stiffening and cooling flanges. The casing is further provided with removable end plates 30 secured by cap screws 31. Sleeve bearings 32 in the end plates center the coaxial compressor drive shaft 33 and have the added duty of sealing the casing interior at the shaft running clearances. Apertures 34 in the end plates, alternatively closed by cap screws 35 as shown, or open and connected to adjustable inlet valve apparatus of any convenient form, comprise fluid admission ports to an internal compartment of the compressor to optionally permit infinitely variable displacement operation thereof, as will be explained later in describing the method of compressor operation.

A rotary displacer 40, coaxial with the casing, is provided with a hub portion 41 keyed to the drive shaft and with axially spaced radial extensions 42 notched at the outer ends thereof to provide wedge surfaces 43 inclined in the direction of rotation indicated by the arrow R. These wedge surfaces engage the squared ends 44 of shaft members 45 carrying rollers 46 and wedge them radially outwards during rotation of the displacer.

A plurality of flexible band elements each designated by numeral 50 and each having an external and internal band working surface 51 and 52, respectively, are interposed between the rollers 46 and the casing inner surface 21. The band elements preferably are composed of superimposed layers of resilient sheet material such as thin, spring-tempered steel, initially preformed substantially to the curvilinear shape clearly evident in the end view in Fig. 2. The adjacent ends of each such preformed band element are attached to the inner surface of the casing at axially disposed lines comprising the slots 24 between each pair of intake and discharge ports and are securely retained therein by axially extending wedge members 53 held by cap screw 54 and having a wedge surface 24' coextensive with the internal working surface 52 of the band elements. Each band element is given a free circumferential length substantially equal to the circumferential length of the casing inner surface between the lines of attachment thereto and, as shown, the preformed band portions curve freely away from the casing inner surface between the lines of attachment and extend axially between the end cover plates 30 to the closest practical operating clearance therewith at 55. Limitation of the flexural motion and support of the band elements at the lines of attachment is provided by integral end plate projections 36 comprising supporting shoulders extending under the band portions at those points. Such supporting shoulders alternatively may be separately formed and attached to the end plates in the relative position shown and may also be utilized at any axial point between the end plates with the proviso that the rollers be notched to clear them.

Assembled as thus described it will be observed that the preformed, free-floating band portions constitute a series of angularly disposed external compression spaces of variable volume enclosed between the inner surface of the casing and end plates and the external band working surfaces 51, together with an internal compression space of variable volume enclosed between the end plates and

the internal band working surfaces 52 containing the rotary displacer and roller assembly. It will be further apparent that in the example disclosed this compressor is provided with an equal number of uniformly spaced band and displacer roller elements and rotation of the displacer in the direction indicated by the arrow thereon will result in simultaneous and uniform displacement of all the band elements and simultaneous intake and discharge of a compressed medium through the ports.

While not limited to the symmetrical arrangement of bands and rollers described above and disclosed in the drawings, since it is apparent that more than three separate band portions and a displacer with either an odd or even number of rollers relative to the number of band portions may be utilized, it is considered that three such band and roller assemblies represent a practical minimum and that simultaneous displacement of the band portions conveys desirable operating advantages. These include completely balanced working forces and fluid pressures and negligible bearing loads at the drive shaft. Additional advantages reside in the comparatively large displacement volume thus achieved with each revolution of the shaft and the concomitant ability to provide high compressor output at relatively lower and quieter operating speeds.

Considering now the operating cycle of a compressor constructed as shown and described above, and with particular reference to Fig. 2, it will be seen that rotation of the displacer in the direction indicated will have the immediate effect of wedging the roller shafts and thereby the rollers 46 into firm rolling contact with the internal surface of the band elements, progressively rolling each preformed band length against the inner surface of the casing. The rolling action thus effected is accomplished under high radial wedge pressure and substantially without slip at the casing surface, it being recalled that each band portion is given substantially the same circumferential length as the casing inner surface against which it is rolled by the displacer. As each band portion is rolled against the casing the compression space ahead of each roller contact is progressively reduced in volume and the working fluid contained therein progressively raised to the desired discharge pressure. Coincidentally with the passage of each roller the portions of the bands released by the rollers will recoil to their initial preformed shape by virtue of their inherent spring properties drawing in a fresh charge of the working fluid through the intake ports 22 for a repetition of the cycle. Each compression space is thus filled and the working fluid therein discharged three times during each revolution of the displacer.

The foregoing stipulation that each free band length have substantially the same circumferential length as the casing inner surface against which it operates is an important and novel feature of the present invention and constitutes an essential improvement over prior proposals seeking to utilize such non-rotating band elements in compressor apparatus. This will be apparent when it is considered that if the free lengths of the band elements between the lines of attachment to the casing are substantially longer than the circumferential length of the casing surface against which they are rolled, the extra length will accumulate ahead of the rollers and will be destructively crushed or pinched off as the rollers approach the point of attachment, while if the band elements are substantially shorter, to the point of extending straight between the rollers as usually disclosed in the prior art, there will be destructive frictional slip between band and casing as the rollers approach the point of attachment thereto.

A novel operating feature of this compressor facilitating its efficient performance in the manner described immediately above should be noted at this point. It will be apparent from superficial observation of Fig. 2 that the permissible operating speed of the compressor will be limited by the inertia force of the band elements which

will tend to remain substantially as displaced against the casing inner surface at and above operating speeds at which the spring force of the bands is no longer effective in returning them to the position shown in Fig. 2. To offset this potential performance limiting effect and ensure efficient operation at higher speeds advantage is taken of an internal suction force developed in the space enclosed between the inside surfaces of the band elements and the end plates following outward displacement of the bands. This will be understood when it is observed that the displacer assembly occupies most of the internal clearance space inside the bands when the displacer is in the cyclical position shown in Fig. 2 and that rapid outward displacement of the band elements from this position during normal operation of the compressor results in a substantial enlargement of the internal space and a proportionate reduction of the pressure therein. The internal suction thus produced effectively supplements the working fluid intake pressures and the restoring force in the preformed spring band structure in ensuring full cyclical movement of the bands over a desirably wide range of compressor speeds.

Since the foregoing paragraph describes how the automatically produced cyclical pressure difference in the space inside the bands is utilized to accelerate their return to the initial position shown in Fig. 2, the method of achieving infinitely variable displacement operation of this compressor can be inferred therefrom. As noted earlier the apertures 34 in the end plates, shown provisionally closed by cap screws, can be utilized to admit through any convenient regulating valve means a fluid counterpressure against the internal band surfaces 52 to supplement their inertia force and limit their inward displacement by infinitely small increments, and thus, the output of the compressor. Conversely, connection of the same apertures to an external suction source such as an internal combustion engine intake manifold, can be utilized to supplement the internal suction following outward displacement of the band elements as described above and ensure their maximum inward cyclical movement at still higher operating speeds.

Operation of this compressor as a motor is accomplished by arranging a plurality of angularly phased coaxial compressor assemblies of the type disclosed, or, for the same total axial length two such half length coaxial assemblies, arranged out of phase to facilitate starting from the dead-center motor position shown in Fig. 2, the required phasing in this case being equal to half the angle of rotation for the compressor cycle. Arranged thus, coaxial motor assemblies are functionally separated from each other by flat disc partitions similar to the end plates and it can be noted that this compressor structure is conveniently adapted to such arrangement with little or no modification of the basic design. Operating as a motor the supply of driving medium enters the intake ports 22 and exhausts through the discharge ports 23. The check valves 26 may be omitted with this method of operation.

As affecting operating efficiency and general utility of this compressor, leakage conditions at the necessary working clearances and arrangements for lubrication, where required, will be noted. In most compressors the working clearances, and therefore the leakage areas, remain substantially constant throughout the compression cycle and leakage tends to increase with operating pressure. The compressor of the present invention has the favorable characteristic that the only operating clearance at which leakage can occur is at the free edges of the band at the end plates and that the leakage area at these locations is inversely proportional to the displacement, reducing substantially to zero at maximum displacement and discharge pressure. A further favorable characteristic is that since in normal operation there is always a certain residual amount of working fluid in the internal compression space occupied by the displacer assembly, rotation of the latter

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generates a centrifugally induced fluid counterpressure against the internal surfaces of the band and at the edge clearance, which is of value in holding potential leakage to a minimum.

The requirement for operation with effective sealing of the working clearances without free lubrication in the compression spaces is ordinarily difficult, if not impossible, of attainment in positive displacement compressors of high capacity. Lubrication in the compression spaces of the present compressor, other than by a dry lubricating film initially applied to the band rolling and end plate contacts, is not required. Lubrication of the drive shaft and displacer roller shaft journal bearings is satisfactorily accomplished with use of the well known oil-impregnated porous metal bearing material for those parts, the rollers 46 being fabricated from a solid cylinder of such material if desired. Where higher loads and speeds than can be handled by such material are in question, sealed anti-friction bearings can be utilized for the drive shaft and displacer rollers. Lubrication of the slight interlaminary motion of the flexible band structure where the latter is composed of a number of superimposed layers of sheet material, as disclosed, can be met by dry lubricant coatings applied before assembling the bands in the casing, such initial application of lubricant being effective for the life of the band. It may be pertinent to note at this point that the band elements are conveniently renewable in service by simply removing an end plate and loosening cap screws 54 sufficiently to release the ends of the bands at the wedge members 53.

Adaptation of the compressor of this invention for a wide range of working fluid densities and pressure ratios, requires only that the materials of construction be selected for specific performance requirements and the parts properly proportioned for the working stresses. Analysis, thickness and finish of material for the flexible band components, for example, will be largely determined by the size of the unit and the cyclical loads to which the band is subjected in operation. The desired compression ratio will determine the number of superimposed layers and the resulting total thickness of the band. Bands for operation at relatively low pressures and high displacer speeds will be relatively light in weight and composed of only one or two thicknesses of material. Higher pressures and proportionately lower operating speeds will utilize a relatively heavy, multi-layer band structure.

No particular arrangement for manifolding the compressor intake and discharge passages has been specified since, as is well known, the requirements for this purpose vary widely in practice. It is important, however, that the compressor design be economically adapted to a variety of manifold arrangements. As will be apparent in the present disclosure, intake and discharge ducts can be either integral with the end plates or separately applied and can embody a single intake and discharge port each serving a plurality of passages at one or both end plates of the compressor.

These various structural and utilization features are cited to emphasize that the compressor of this invention is not limited to the specific embodiment shown herein by way of example and that numerous such modifications are well within the province of this disclosure and the appended claims.

I claim:

1. In a rotary compressor, a casing including end plates and having a cylindrical inner surface with adjacent intake and discharge ports angularly disposed in pairs around said surface, a rotary displacer coaxial with said casing, and a plurality of laminated spring band elements interposed between the casing inner surface and said displacer and attached to the casing inner surface at axially disposed lines between each pair of ports, each of said band elements having an external and an internal working surface and being movable away from said casing inner surface between the lines of attachment thereto and the

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end plates to form an external compression space of variable volume between said inner surface and the band element and an internal compression space of variable volume enclosed between the internal surfaces of said band elements and said end plates, the movable portions of said band elements having a free circumferential length substantially equal to the circumferential length of the casing inner surface between said lines of attachment and the portions of said band elements adjacent to said lines of attachment being initially performed to curve freely away from said inner surface, said rotary displacer having a plurality of wedge-mounted and angularly spaced rollers in radially wedged rolling contact with said internal surface of the band elements.

2. In a rotary compressor, a casing including end plates and having a cylindrical inner surface and with adjacent intake and discharge ports angularly disposed in pairs around said surface, a like plurality of laminated spring band elements each having an external and an internal working surface and being attached to said inner surface at lines between each pair of ports, each of said band elements having a circumferential length substantially equal to the circumferential length of said inner surface between said lines of attachment and each being preformed to curve freely away from said surface between the lines of attachment to provide external compression spaces of variable volume between said inner surface and said end plates and the external surface of the band elements and an internal compression space of variable volume between the internal surfaces of the band elements and said end plates, a rotary displacer coaxial with said casing and having wedge-mounted rollers in radially wedged contact with the internal surfaces of the band elements to effect cyclical displacement thereof, and means for infinitely variable control of the output of said compressor through regulation of said cyclic displacement comprising admission ports to said internal compression space for admission to a fluid counterpressure.

3. In a rotary compressor, a casing including end plates and having a cylindrical inner surface with adjacent intake and discharge ports angularly disposed in pairs around said surface, a rotary displacer coaxial with said casing and having a plurality of wedge-mounted rollers parallel to the axis of the casing, and a plurality of flexible band elements comprising layers of resilient sheet material interposed between the inner surface of the casing and the rollers and extending axially between said end plates, said band elements being attached to the casing at lines between adjacent ports and having free edges with minimum clearance at said end plates, said band elements being preformed to curve freely away from said inner surface between said lines of attachment and having a free circumferential length substantially equal to the circumferential length of said inner surface between said lines of attachment and said rollers being in radially wedged rolling contact with the internal surface of said band elements to effect simultaneous cyclical displacement thereof.

4. In a rotary compressor, a circumferentially flanged casing including end plates and having a cylindrical inner surface with adjacent intake and discharge ports angularly disposed in pairs around said surface, a rotary displacer coaxial with said casing and having angularly spaced rollers parallel to the axis thereof, and superimposed layers of resilient sheet material interposed between the inner surface of the casing and the rollers and extending between the end plates, said layers being attached to said inner surface at lines between adjacent ports and being preformed to curve away from said surface and comprise movable layer portions having free edges with minimum contact clearance at said end plates and between said lines of attachment, each of said movable portions having a free circumferential length substantially equal to the circumferential length of the inner surface between said lines of attachment, and each of said discharge ports com-

prising an axially disposed bore extending through the casing flanges and having a cylindrical tube of resilient sheet material lining said bore and sealing said discharge ports, said tube having a longitudinal slit adjacent to said ports to permit a tubular portion over said ports to lift in response to discharge pressures.

5. In a rotary compressor, a casing including end plates and having a cylindrical inner surface with adjacent intake and discharge ports angularly disposed in pairs around said surface, a rotary displacer coaxial with said casing and having a plurality of angularly spaced wedge-mounted rollers parallel to the axis of said casing, and a plurality of flexible band elements comprising superimposed layers of resilient sheet material interposed between the inner surface of the casing and the rollers and attached to the casing at lines between adjacent ports, the edges of the band elements being in free contact with said end plates, said band elements being preformed to curve freely away from said inner surface between said lines of attachment and having a free circumferential length substantially equal to the circumferential length of the casing inner surface between said lines of attachment, said rollers being arranged for radially wedged rolling contact with the internal surface of said band elements to effect cyclical displacement thereof.

6. In a rotary compressor, a casing including end plates and having a cylindrical inner surface and adjacent intake and discharge ports angularly disposed in pairs around said surface, a rotary displacer coaxial with said casing, and a plurality of laminated spring band elements interposed between the casing inner surface and said displacer, each of said band elements having a plurality of fixed and a plurality of free edges and having an external and an internal working surface, said fixed edges being in wedged attachment to the casing inner surface at axially disposed lines between said adjacent ports and said free edges being in contact with said end plates, said band elements being preformed to curve freely away from said inner surface and comprise movable band portions between the lines of attachment, the external working surface of said movable portions being substantially equal in circumferential length to the circumferential length of the casing inner surface between the lines of attachment, said wedged attachment comprising axially disposed wedge members having a working surface coextensive with the internal working surface of said band elements, and said rotary displacer having a plurality of wedge-mounted rollers in radially wedged rolling contact with said internal working surface.

7. In a rotary compressor, a casing including end plates and having a cylindrical inner surface with adjacent intake and discharge ports angularly disposed in pairs around said surface, a rotary displacer coaxial with said casing and having angularly spaced rollers parallel to the axis thereof and superimposed layers of resilient sheet material interposed between the inner surface of the casing and the rollers and extending between the end plates, said layers being attached to said inner surface at lines between adjacent ports and being preformed to curve away from said surface and comprise movable layer portions having free edges with minimum contact clearance at said end plates and between said lines of attachment, each movable portion having a free circumferential length substantially equal to the circumferential length of the inner surface between said lines of attachment, and said end plates having projections thereof comprising supporting shoulders extending under said superimposed layers at said lines of attachment.

8. In a rotary compressor, a casing including end plates and having a cylindrical inner surface with adjacent intake and discharge ports angularly disposed in pairs around said surface, a rotary displacer coaxial with said casing and having a plurality of angularly spaced rollers parallel to the axis of said casing, and a plurality of band elements comprising freely superimposed layers of resilient sheet material interposed between the inner surfaces of the casing and the rollers and attached to the casing at lines between adjacent ports, each of said band elements being initially sprung away from said inner surface between said lines of attachment and having free edges with minimum contact clearance at said end plates and each having a free circumferential length substantially equal to the circumferential length of said inner surface between said lines of attachment.

9. In a rotary compressor, a casing having end plates and a cylindrical inner surface and having axially extending slots between adjacent intake and discharge ports angularly disposed in pairs around said surface, a rotary displacer coaxial with said casing and having a plurality of angularly spaced rollers parallel to the axis thereof, and portions of resilient sheet material interposed between the inner surface of the casing and the rollers in wedged attachment to the casing at said slots the edges of said sheet material being in free contact with the end plates and, each of said portions having a free circumferential length substantially equal to the circumferential length of the casing inner surface between said slots.

10. In a rotary compressor, a casing having a cylindrical inner surface and adjacent intake and discharge ports disposed in pairs around said surface, a rotary displacer coaxial with said casing having a hub portion with radially extended wedge surfaces, a plurality of rollers parallel to the axis of said casing each having a shaft engaging said wedge surfaces, and superimposed layers of resilient sheet material each having a plurality of fixed edges and a plurality of free edges interposed between said surface and the rollers, said fixed edges being attached to said surface at lines between adjacent ports and said layers curving freely away from said inner surface between the lines of attachment and having a free circumferential length substantially equal to the circumferential length of the surface between said lines, each of said rollers being in radially wedged rolling contact with the layers.

11. In a rotary compressor, a casing having a cylindrical inner surface and a plurality of adjacent pairs of intake and discharge ports angularly spaced around said surface, a like plurality of superimposed layers of resilient sheet material each having a plurality of fixed and free edge portions, said fixed edge portions being attached to said surface at lines between adjacent ports and movable away therefrom between said lines, each movable portion having a circumferential length substantially equal to the circumferential length of the surface between said lines, and a rotary displacer coaxial with said casing having a like plurality of equiangularly spaced rollers in radially wedged rolling contact with said sheet material.

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