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[54] **ROTARY VANE DEVICE WITH IMPROVED SEALS**

[75] Inventor: **Leonard J. Keller**, Sarasota, Fla.

[73] Assignee: **The Keller Corporation**, Dallas, Tex.

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[51] **Int. Cl.** **F01c 1/00;** F01c 19/00; F04c 1/00
[58] **Field of Search** 418/241, 136–138, 418/156, 235

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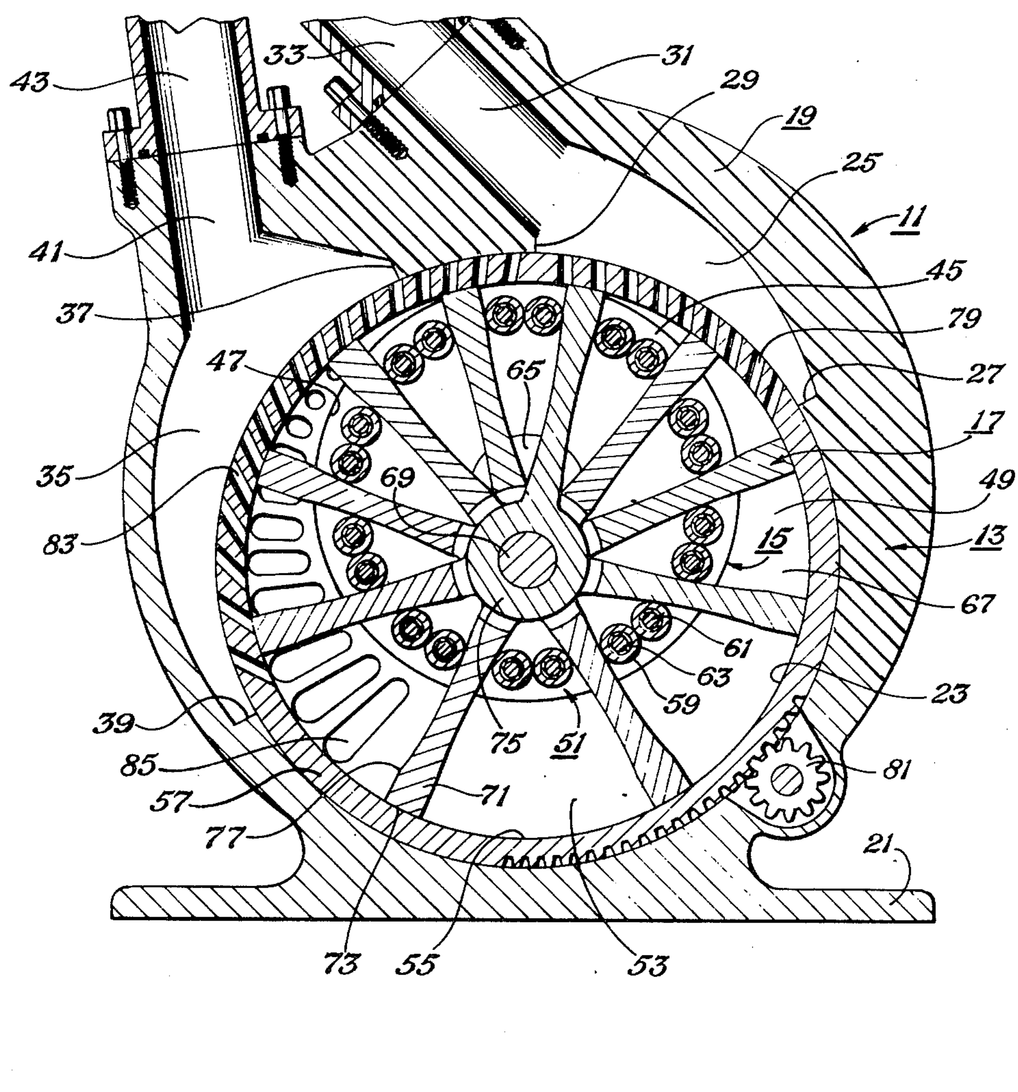
Primary Examiner—C. J. Husar
Assistant Examiner—O. T. Sessions
Attorney, Agent, or Firm—Wofford, Felsman, Fails & Zobal

[57] **ABSTRACT**

An eccentric rotor vane device that may be employed as pumps, blowers (or compressors), engines, or motors, characterized by an improved seal structure; in addition to conventional main chamber; first and second ports communicating with the main chamber; a plurality of annularly related radial vanes, independently pivotal and rotatable about a vane axis within the main chamber; a rotor that is eccentrically mounted with respect to the main chamber; a power delivery shaft connected with the rotor. The improved seal means, in specific embodiments, comprises a plurality of cylindrical rollers that serve as vane guides intermediate each pair of adjacent vanes. The cylindrical rollers adjacent each face of each respective vane engages its lateral face such that a satisfactory seal is made as the roller traverses radially inwardly and outwardly along the lateral face of the vane. Thus, the plurality of rollers serve as at least a part of a piston as well as an interdigitating means for effecting a change in volume of a subchamber defined intermediate the respective vanes, rollers, and interior wall in the main chamber. Also disclosed are improved vane structures for maintaining more nearly perfect seals for long service life.

6 Claims, 4 Drawing Figures



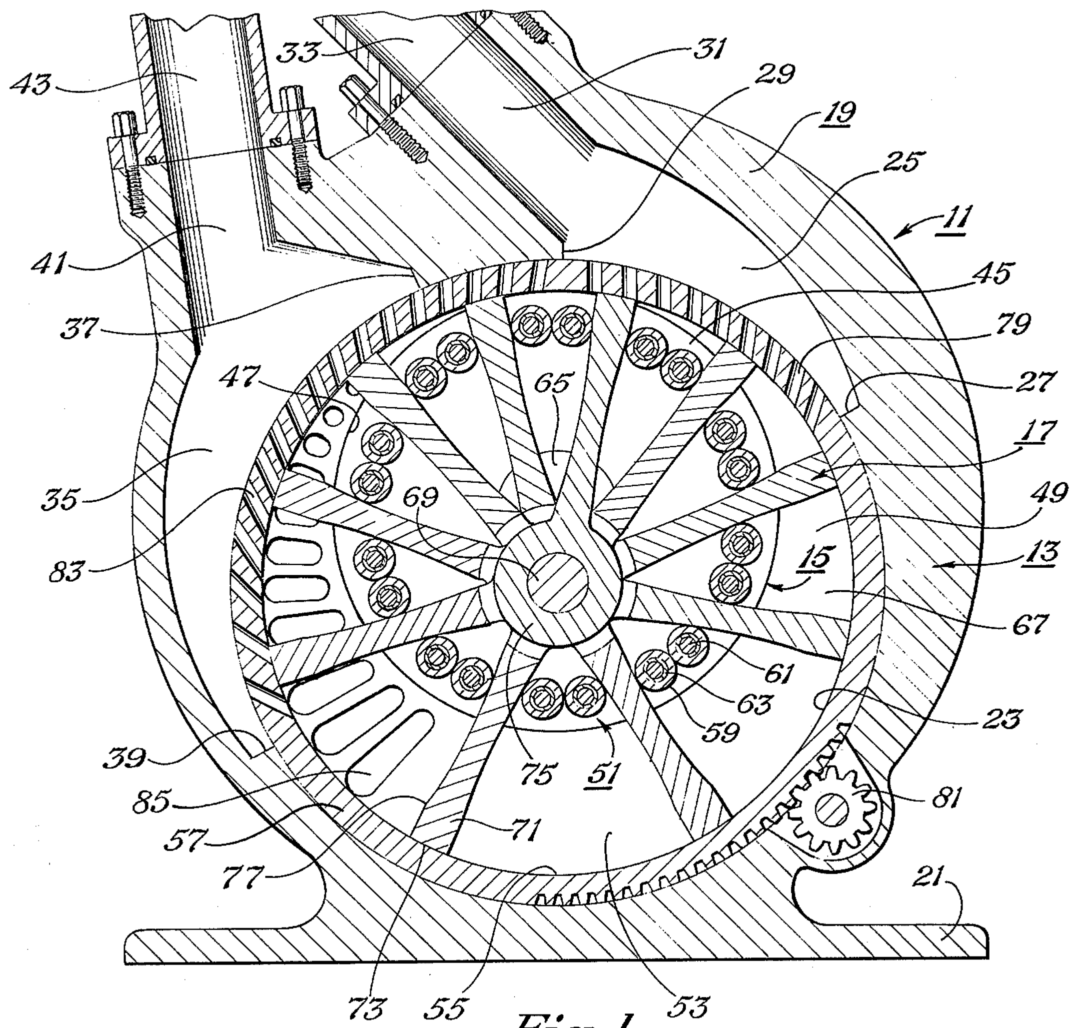

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Fig.1

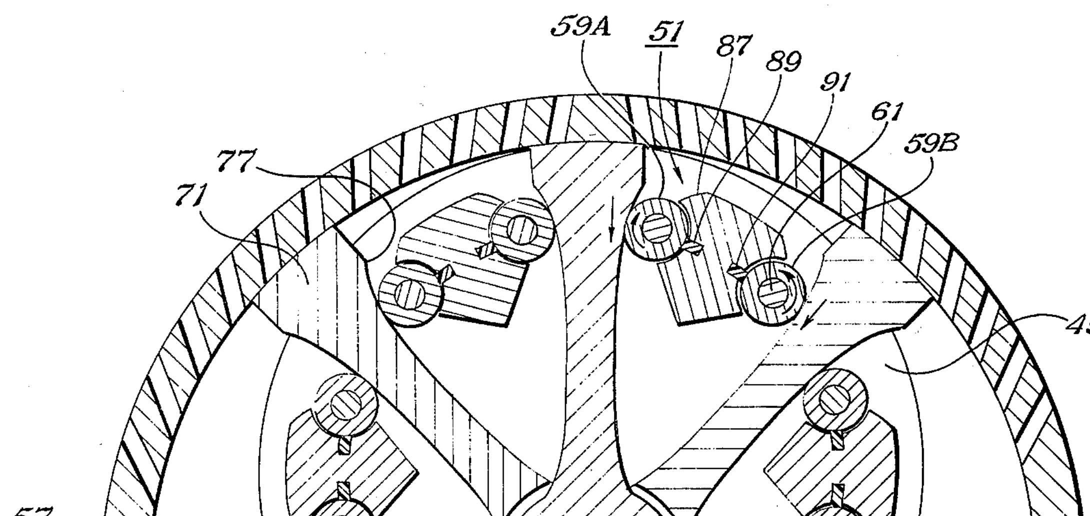
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Fig.2

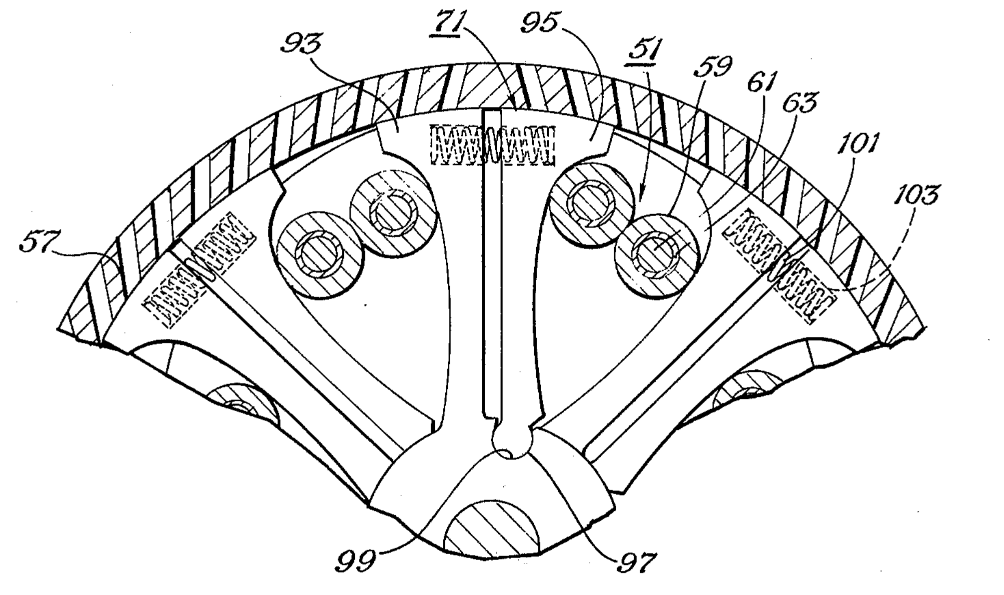

Fig.3

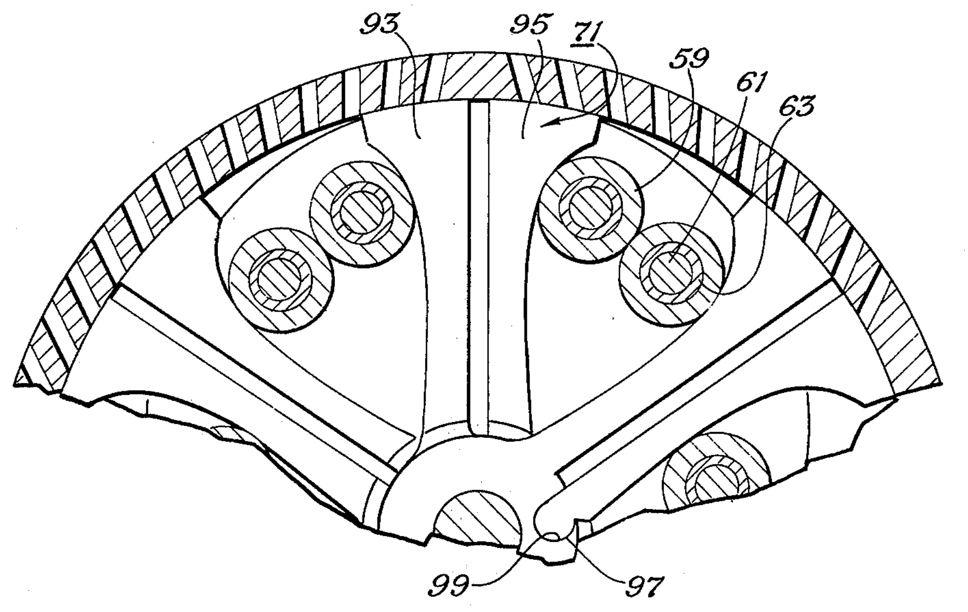

Fig.4

ROTARY VANE DEVICE WITH IMPROVED SEALS

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to an improvement in eccentric rotor, concentric vane devices that may be employed as pumps for pumping incompressible fluids, blowers for compressing and pumping compressible fluids, as engines powered by internal combustion of a fuel using either spark ignition cycle or the diesel cycle, or as motors powered by compressible or partially incompressible fluids.

2. Description of the Prior Art

Eccentric rotor, concentric vane devices have been known at least since the middle of the 19th century; U.S. Pat. Nos. 43,744 and 83,186 being granted, respectively, in 1864 and 1868 on rotary steam engines. Subsequently, there has been at least eighteen different United States patents issued on similar structures for one or more of the uses delineated hereinbefore. Yet, not a single one of the patented devices, insofar as I am aware, has achieved widespread commercial use. The failure to be widely useful is generally conceded to be due to lack of having a satisfactory seal between the vanes and the vane follower, or vane guide, portion of the rotor that interdigitates the vanes. The seal means attempted before my invention have either allowed too much leakage to be practical or have imposed too much frictional resistance to movement to allow the machines sufficient mechanical efficiency to be practical. The early attempts; the intermediate attempts, such as exemplified by U.S. Pat. No. 2,129,431; and very recent attempts, such as delineated in U.S. Pat. No. 3,572,985, employed semi-cylindrical seal members slidably engaging each side of planar vanes as they slid radially inwardly and outwardly along the vanes. Other patents, such as U.S. Pat. No. 2,022,209, described employing a seal having a knife-like edge that engaged planar vanes, attempting to seal as it moved radially inwardly and outwardly along the vanes. None effected the desired satisfactory seal. In my U.S. Pat. No. 3,748,068, I delineated an improved seal structure that solved the problems of the prior art; including the art cited in that patent. With experience in different embodiments, alternative seal structures have been found to be equally efficacious and provide unobvious advantages over the prior art. For example, it has been found desirable to provide independent rolling friction intermediate respective rollers contiguous respective vane faces for effecting a low frictional drag and long life.

Accordingly, it is an object of this invention to provide an eccentric rotor vane device that obviates the disadvantages of the prior art structure.

Specifically, it is an object of this invention to provide an eccentric rotor vane device having an improved seal between the interdigitating portion of the rotor and adjacent vanes throughout the full 360 (°) of rotation of the rotor such that the interdigitating portion can operate as a piston, as well as a vane guide and employ rolling friction intermediate a roller contiguous each adjacent face of each vane; regardless of whether the rotor vane device is being employed as a pump, blower, engine or motor.

It is also an object of this invention to provide a rotor vane device having the same advantages as delineated in U.S. Pat. No. 3,748,068 and still provide the foregoing objects.

These and other objects will become apparent from the descriptive matter hereinafter, particularly when taken in conjunction with the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a partial cross sectional view from the side of one embodiment of this invention.

FIG. **2** is a partial cross sectional view from the side showing a sleeve serving as an internal wall in the main chamber, rotor, vanes, vane guides, and the respective seals therebetween in accordance with another embodiment of this invention.

FIG. **3** is a partial cross sectional view from the side showing a sleeve, rotor, vanes, vane guides, and the respective seals therebetween in accordance with another embodiment of this invention.

FIG. **4** is a partial cross sectional view from the side showing a sleeve, rotor, vanes, vane guides and the respective seals therebetween in accordance with still another embodiment of this invention.

DESCRIPTION OF PREFERRED EMBODIMENTS

Referring to FIG. **1**, there is illustrated one embodiment of this invention in the form of a motor **11**, or eccentric rotor, concentric vane motor device. The motor **11** comprises a stator **13**; a rotor, or rotor assembly, **15**; and a vane assembly **17**. The motor **11** is described in detail in my copending patent application entitled "Rotor Vane Motor Device", Ser. No. 227,393, filed Feb. 18, 1972, now Pat. No. 3,797,975; and the descriptive matter contained therein is embodied by reference herein for complete description of the construction and operation of the motor. In that application, the motor described was a variable torque, vairable power motor employing the improved seals described in my aforementioned U.S. Pat. No. 3,748,068; and having improved torque and power control means. The descriptive matter of U.S. Pat. No. 3,748,068 is also incorporated herein by reference. In view of the aforementioned U.S. Pat. No. 3,748,068 and the patent application Ser. No. 227,393, now U.S. Pat. No. 3,797,975, the following abbreviated description is believed adequate and is afforded merely for the convenience of the reader to prevent having to refer to the delineated patent and patent application.

The stator **13** includes a main body member **19** having a base or mounting bracket **21.** The main body member **19** has peripherally disposed circular flanges (not shown) for affixing cap members at each side of the motor **11**, or each end of a main chamber. A longitudinal cylindrical cavity **23** is formed in the inner face of the main body member **19** and includes a main chamber. An inlet port **25** is formed in the inner face of the main body member **19** and extends from the medial top, or 0°, position thereof for about 50° clockwise. The inlet port **25** has its leading and trailing edges **27** and **29** extending longitudinally for the full length of the main body member **19** for providing maximum flow area. The inlet port **25** communicates via passageway **31** in main body member **19** with a collar **33** to facilitate connecting an inlet of motor **11** with a high pressure source of working fluid, as described in detail in Ser. No. 227,393, now U.S. Pat. No. 3,797,975. Similarly formed in the inner face of the main body member **19** is an exhaust, or discharge, port **35.** The discharge sliding engagement with the sleeve **57** such that it forms a satisfactory seal for confining the fluid in the respective subchambers **53** on either side thereof. The seals intermediate the vanes **71** and the sleeve **57** have not been particularly critical because the differential pressure between adjacent subchambers **53** is not inordinately high and because the centrifugal force on the vanes **71** tends to retain sufficient sealing engagement between the respective vane ends **73** and sleeve **57.** Any type of seal appropriate to the vane ends **73** may be employed, as described in the aforementioned Ser. No. 227,393 now U.S. Pat. No. 3,797,975 and U.S. Pat. No. 3,748,068. The radially exterior end **73** of the respective vanes may be formed as desired to minimize the volume in the subchamber defined between the radially outermost ends of adjacent vanes. For example, the vanes **71** may have arcuate intruding shoulders to more closely fit the respective plurality of cylindrical rollers **59** of the rotor assembly **15** to reduce the volume to near zero.

As described in detail in Ser. No. 227,393 now U.S. Pat. No. 3,797,975, each of the vanes **71** has integrally formed with the inner radial end thereof at least one annular knuckle **75** that conformingly engages the axle pin **69.** The knucles **75** of respective vanes **71** are axially offset relative to each other along the axle pin **69** and are stacked on the axle pin with their confronting faces in sliding engagement to permit the relative interdigitating, or rocking, of the vanes **71** about the axle pin **69.** It will be appreciated that; as specifically illustrated in the aforementioned U.S. Pat. No. 3,748,068; the vane central knuckle is twice as wide as ordinary and disposed intermediate the adjacent knuckles on either side. If desired, the vanes may have the respective knuckles disposed at one-half of the axle pin **69** plus the thickness of one knuckle and intermesh such that the use of the wide central knuckle is obviated. Any other method of supporting the vanes that will allow the interdigitating thereof may be employed. Since the vanes are accelerated and decelerated during rotation, however, symmetrical arrangement of the knuckles with respect to a transverse plane through the vane's center is preferable.

The respective vanes **71** have lateral faces **77** that are concaved inwardly toward the central plane of the vane such that the respective followers, or vane guides, **51** are maintained in substantially uniform sealing engagement with the vane lateral faces **77** as the vane guides **51** traverse radially inwardly and outwardly therealong during rotation of the rotor assembly **15.** By substantially uniform sealing engagement is meant an engagement such that a satisfactory seal is maintained intermediate the respective vane guides **51** and the vanes **71** so that the vane guides **51** can serve as pistons as well as interdigitating means as they traverse radially inwardly and outwardly along the respective vanes **71.**

As is well recognized, what is satisfactory sealing engagement will vary depending upon the application, or use; which determines several pertinent factors. These factors include the size of the unit, the differential pressure across a vane guide **51** from the subchamber to the interior of the rotor assembly **15,** the total pressure of the fluid being handled in the subchamber and the efficiency desired. To illustrate, I have found that as much as 0.010 inch clearance may be tolerated between the vane guides **51** and the vane lateral faces **77** with large motors such as may be employed with low pressure steam. For example, with low pressure steam that may be emitted from geothermal wells, the motor device may have dimensions as large as 30 inches in length by 36 inches in diameter; or larger, if used on individual steam wells. On the other hand, when employing the motor with a low entrophy fluid flowing therethrough, I have found it preferable that a clearance of less than 0.005 inch; for example, about 0.001–0.003 inch; be employed between the surfaces of the vane guides **51** and the vane lateral faces **77.** Lighter motors may be only about 4 inches in length and 6 inches in diameter, yet develope enough power to operate a small automobile.

The improved seal means of this invention, as described hereinbelow, makes practical the eccentric rotor, concentric vane motor of this invention, that has all of the advantages of the invention of U.S. Pat. No. 3,748,068 and the aforementioned Ser. No. 227,393 now U.S. Pat. No. 3,797,975. This improved seal preferably employs a plurality that is an even number of cylindrical rollers **59** intermediate each pair of adjacent vanes **71.** By this structure, each of the rollers **59** engages respective lateral faces **77** of the vane contiguous therewith, as well as engage the surface of any adjacent cylindrical roller **59** with rolling friction. Thus, reduced friction is effected for more efficient operation. Moreover, there is substantially no wear and the wear is evenly apportioned, because of the rolling interconnection between contiguous surfaces, the rolling of contiguous surfaces being in the same direction, or compatible rather than opposite, for still less friction. Consequently, the improved seal means is durable and trouble-free, the cylindrical rollers rolling along the vane faces and in contact with each other.

As noted in U.S. Pat. No. 3,748,068 and Ser. No. 227,393 now U.S. Pat. No. 3,797,975, I have attempted to delineate, through mathematical experts and computer computations, the exact definition of the concavity of the lateral faces **77** but have not been successful to date. The concavity can be delineated graphically, employing a scale that is larger than actual size. I have developed an empirical formula by trigonometry which is close also. In practice, I have found exact mathematical delineation to be unnecessary. Instead, I employ a grinding jig with grinding rollers to duplicate the physical relationships and dimensions employed in a particular motor device **11.** Specifically, the grinding of the vane faces is effected by repeatedly moving the vanes and sized grinding rollers through 360° as the vanes are moved by the rotor assembly **15,** with increasing distances of eccentricity up to the eccentricity actually employed in the motor device **11.** By increasing distances of eccentrically is meant the increasing moving apart, with successive revolutions, of the shaft of the vane axle pin **69** and the axis of the shaft of the grinder rollers that is equivalent to the axis of the shaft of the rotor assembly **15,** as described in Ser. No. 227,393 now U.S. Pat. No. 3,797,975. In this way, I get exact initial engagement and do not have to worry about the clearance. Once a particular vane contour, or concavity, has been established for a particular motor, it may be reproduced by conventional methods of copying.

In the above referenced Ser. No. 227,393 now U.S. Pat. No. 3,797,975, there was described an integral adjusting flow through and torque control means for controlling torque output of the motor **11** so that it could be operated without requiring a throttle and the throttle-caused losses in efficiency. That does not comprise a part of this invention, per se, and need not be described in detail herein. It is sufficient to note that the flow through and torque control means comprises the torque control sleeve **57**, delineated hereinbefore, that is conformingly disposed interiorly of the longitudinal cylindrical cavity **23**. The torque sleeve **57** mates with and telescopes within the cavity **23** and rotatably and slidably engages the inside face of the cavity to permit angular adjustment of the torque control sleeve **57**. The torque control sleeve has at least an inlet aperture in the form of a first set of longitudinally extending slots **79**. The inlet slots **79** communicate between the interior of the vane assembly cavity **67** and the inlet port **25**. It is sufficient to note in the abbreviated description herein that advancing of the torque control sleeve by suitable gear **81** will increase the effective flow area through the inlet apertures until the inlet aperture is at a maximum. On the other hand, the torque control sleeve **57** may be retarded or rotated in a second direction opposite the first direction to decrease the effective flow area of the inlet aperture and inlet port. The degree of retardation may be sufficient to completely close off the inlet port or to effect a reduced flow of fluid through the motor. The respective means for controlling the gear **87** is described in detail in Ser. No. 227,393 now U.S. Pat. No. 3,797,975 and is not shown or described herein.

Also, the use of discharge slots **83** to control the discharge independently for reducing losses from over expansion or under expansion of a working fluid flowing through the motor **11** was described in detail in Ser. No. 227,393 now U.S. Pat. No. 3,797,975.

In operation, a fluid will enter through the inlet passageway **31** and inlet port **25**, entering into the respective subchambers **53** at their minimum volume position near the top. The point of entry may be controlled by the torque control sleeve **57**. The fluid is preferably an expansible fluid that will do work as it expands to effect rotation of the respective vanes and act against the respective vane guides, or plurality rollers **59**, serving as a piston. This forces rotation of the rotor assembly and the work output shaft as the fluid expands to the maximum position near the bottom. Shortly past the bottom, the fluid will be vented through a second set of discharge apertures **85** in the annularly disposed plates **49**, or through the discharge slots **83** and discharge port **35**, depending upon which are set earlier by the respective torque control means. Thus, as each subchamber is rotated, the fluid contained therein is allowed to do work and deliver power from the motor **11** before the fluid is begun to be discharged in its fully expanded condition directly to the pressure existing in the discharge passageway **41**, without any throttle control losses. The respective sealing surfaces on the respective plurality of rollers **59** remain contiguous and in sealing engagement with a rolling action to minimize friction and wear.

Another embodiment of this invention is illustrated in FIG. **2**. Therein, only a portion of the torque control sleeve **57** is illustrated since the environment is the same as described hereinbefore with respect to FIG. **1**. As illustrated in FIG. **2**, each respective vane guide **51** comprises two cylindrical rollers **59**A and **59**B that are affixed by their respective shafts **61** to the circular plates **45**, similarly as described hereinbefore. As illustrated in FIG. **2**, however, the respective plurality of rollers **59**A and **59**B are not contiguous each other, but are contiguous an intermediate member **87**. Specifically, the respective cylindrical rollers **59**A and **59**B engage the respective seals **89** and **91** that are sealingly engaged in recesses in the coextensive and longitudinally extending intermediate member **87**. Expressed otherwise, the intermediate member **87** extends coextensive with the respective rollers **59**A and **59**B longitudinally of the rotor assembly **15** and is sealingly affixed to the circular plates **45**, similarly as are the shafts **61** of the rollers.

As illustrated, the respective vanes **71** have their vane lateral faces **77** contoured to maintain the desired sealing engagement with the surfaces of the respective rollers **59**A and **59**B, as described hereinbefore with respect to the lateral faces **77** of the vanes **71**. Otherwise, the structure of the vanes, with their axle pin **69**; the vane assembly **17**; the rotor assembly **15**; the main body member **19** and the respective inlet and discharge ports **25** and **35** are the same and the operation is the same as described with respect to the embodiment of FIG. **1**.

Thus, it can be seen that in the embodiment of FIG. **2**, the respective rollers **59**A and **59**B engage their respective contiguous vane lateral faces **77** with a rolling action as the vane guides **51** move radially inwardly and outwardly along the vanes **71**. This rolling action attains the desired lowered friction and reduced wear, similarly as described hereinbefore with respect to the embodiment of FIG. **1**. If desired, the intermediate memberr **87** may have a plurality of roller bearings for sealingly engaging the rolling surface of the respective cylindrical rollers **59**A and **59**B, instead of or in addition to the respective seals **89** and **91**.

Still another embodiment of the invention is illustrated in FIGS. **3** and **4**. In FIG. **3**, the same embodiment about the torque sleeve **57** is employed as described with respect to FIG. **1**. Similarly, the same cylindrical rollers **59** are employed as the vane guides **51**, as described with respect to FIG. **1**. In the embodiments of FIGS. **3** and **4**, however, each vane **71** comprises first and second members **93** and **95** that are biased toward their respective contiguous rollers **59** for maintaining the satisfactory sealing engagement therewith. Respective first and second members may comprise simply a bifurcated end of an integral vane in which the physical properties of the material of which the vane is made biases the first and second members toward their respective rollers **59**. As illustrated, however, the second member **95** is pivotally mounted such that its radially outermost end is biased away from the radially outermost end of the first member **93**. The pivotal mounting may comprise simply a quasi-cylindrical head **97** that is embedded in a suitable slot **99** in the main body of the vane, with or without an inherent bias being effected. On the other hand, one or both of the first and second members may be sealingly mounted on a fulcrum shaft if desired. Sealing of the quasi-cylindrical head in a conforming slot **99** is more easily effected. It is apparent, however, that the use of a vane **71** having a bifurcated end forming the first and second members **93** and **95** automatically effects sealing and overcomes the problem with sealing, although it is relatively expensive to form the slot intermediate the bifurcated members.

In the embodiment of FIG. **3**, the first and second members have a spring member **101** seated in respective recesses 103 and biasing the radially outermost ends of the respective vanes 71 toward their respective contiguous rollers 59.

In the embodiment of FIG. 4, the space intermediate the respective first and second members 93 and 95 is filled with a compressible material for effecting the biasing of the radially outermost ends of the vanes 71 toward their respective contiguous rollers 59. As illustrated, the compressible material is the compressible fluid that is being flowed through the motor 11, FIG. 1. If desired, the compressible material may be a resilient material such as the elastomeric materials like rubber. The elastomeric material should be resistant to the fluid being flowed through the motor. For example, the synthetic rubbers like Neoprene or Buna N, may be employed satisfactorily.

The embodiments of FIGS. 3 and 4 operate similarly as described hereinbefore with respect to the embodiments of FIGS. 1 and 2. It is noteworthy, however, that good sealing contact is made because of the flexibility and the biasing of the bifurcated first and second members toward their respective contiguous rollers 59. The resulting compressive force exerted on the contiguous rollers 59 also assists in maintaining sealing contact between the respective surfaces of the rollers as wear develops between the respective shafts and inserts 61 and 63.

The operation of the motor 11 as a pump or air compressor is described in the hereinbefore referenced U.S. Pat. No. 3,748,068 and that descriptive matter need not be repeated herein.

The materials of construction ordinarily employed in this art may be employed herein and no exotic new materials are necessary. The structural strength and the wearing properties of the materials that interface together will be chosen appropriate to the application. For example, in certain applications it may be possible to employ plastics to reduce the friction as they interface with adjacent metallic components. In general, we have been working with the most deleterious types of materials, such as steam, and have employed noncorrodable metals in those surfaces in contact with such materials, or fluids.

It is noteworthy that when the device is employed as an air compressor, or blower, similarly as described in U.S. Pat. No. 3,748,068, it has many advantages that are not found in the ordinary blowers. For example, in centrifugal blower embodiments, there is no problem of balancing; since the rotor assembly 15 may be run with up to several pounds out-of-balance mass in the larger sizes. This is in contrast to only a few ounces, or less of imbalance that is tolerable in conventional blowers. For example, I have designed a large diameter unit to serve as a centrifugal blower that will deliver up to five million standard cubic feet per minute of air for use in magneto hydrodynamics applications. There is no conventional blower that can presently supply this amount of air. The use of rolling friction with the improved plurality of cylindrical rollers enables employing large size units without intolerable friction.

From the foregoing, it can be seen that a highly efficient positive displacement device is provided that finally achieves all of the advantages heretofore known but not practically achieveable because of the difficulty with seals intermediate the rotor assembly and the vanes. Specifically, this invention provides a rotor vane device that achieves the objects delineated hereinbefore and obviates the disadvantages of the prior art devices. Its size and weight are unbelieveably more compact and lighter than conventional air compressors. The use of roller vane guides, with the attendant rolling friction, effects a long-wearing, trouble-free seal that is an important advance in the technology to improve our ecology. The rotor vane device also makes practical an essentially nonpolluting engine that may be used as an expander in an external combustion Rankine cycle system.

Moreover, as disclosed in U.S. Pat. No. 3,748,068, the large changes in volume of the subchambers allow unusually large variation in compression ratios when the rotor vane device is employed as an engine.

Also, the numerous advantages of the motor 11 are described in the above reference Ser. No. 227,393 now U.S. Pat. No. 3,797,975. These numerous and lengthy advantages are not repeated herein, although this invention also provides these same advantages over the art prior to the above described Ser. No. 227,393 now U.S. Pat. No. 3,797,975.

A wide variety of other embodiments employing the basic improved seal are feasible. Only a few of the different embodiments are implicit and explicit in the descriptive matter hereinbefore. It would be virtually impossible to catalogue all of the embodiments. Hence, although this invention has been described with a certain degree of particularity, it is understood that the present disclosure has been made only by way of example and that numerous changes in the details of construction and the combination and arrangement of parts may be resorted to without departing from the spirit and the scope of this invention.

What is claimed is:

1. In an eccentric rotor vane device having:

a. a main chamber having a substantially cylindrical interior surface;

b. first and second ports spaced around and communicating with said main chamber;

c. a plurality of annularly related radial vanes, independently pivotal and rotatable within said main chamber about a vane axis therewithin; said vanes occupying substantially the total radial distance from said axis to said interior surface of said main chamber;

d. a rotor that is eccentrically mounted with respect to said main chamber and rotatable about a rotor axis spaced from said vane axis; said rotor having follower means for interdigitating said vanes and effecting a change in volume of a subchamber intermediate respective said vanes as said rotor and said vanes are rotated within said main chamber; each subchamber being delineated by a pair of confronting vane faces and a corresponding follower means between said vane faces and said main chamber interior surface and varying from a minimum volume at a radially outermost position of said follower means with respect to said vane axis, said minimum volume position being referred to as the 0° position, to a maximum volume at the radially innermost position of said follower means, referred to as the 180° position; and

e. power delivery shaft connected with said rotor for delivering power in association therewith; the improvement comprising an improved seal means intermediate said vanes and said follower means in which:

f. each follower means is disposed intermediate adjacent said respective vanes and comprises a plurality of rotatably-mounted cylindrical rollers extending longitudinally of said rotor; each said roller having respective vane engaging surface; said plurality of said rollers intermediate adjacent vanes being contiguous each other; and

g. said vanes have lateral faces that are concaved inwardly toward the central plane of the vane such that said follower means is maintained in substantially uniform sealing engagement with said vane lateral faces as said follower means traverse inwardly and outwardly therealong during rotation of said rotor such that a satisfactory seal is maintained intermediate said follower means and said vanes so that said follower means can serve as a piston as well as an interdigitating means; and each said roller contiguous a lateral face of a vane engages said vane face with rolling friction for reduced friction and long life.

2. The device of claim **1** wherein said plurality of rollers intermediate adjacent vanes is an even number of rollers such that said rollers engage said vanes and each other with rolling friction.

3. The device of claim **1** wherein each said vane comprises first and second vane members that are biased toward their respective contiguous rollers for maintaining satisfactory sealing contact therebetween.

4. The device of claim **3** wherein said first and second vane members have a spring member disposed therebetween for effecting the biasing.

5. The device of claim **3** wherein said first and second vane members have a compressible material disposed therebetween for effecting the biasing.

6. The device of claim **5** wherein said compressible material is a compressible fluid.

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