Nov. 20, 1962 F. WANKEL ET AL 3,064,880

SEALING ARRANGEMENT FOR ROTARY MECHANISM

Filed Sept. 16, 1958 8 Sheets-Sheet 1

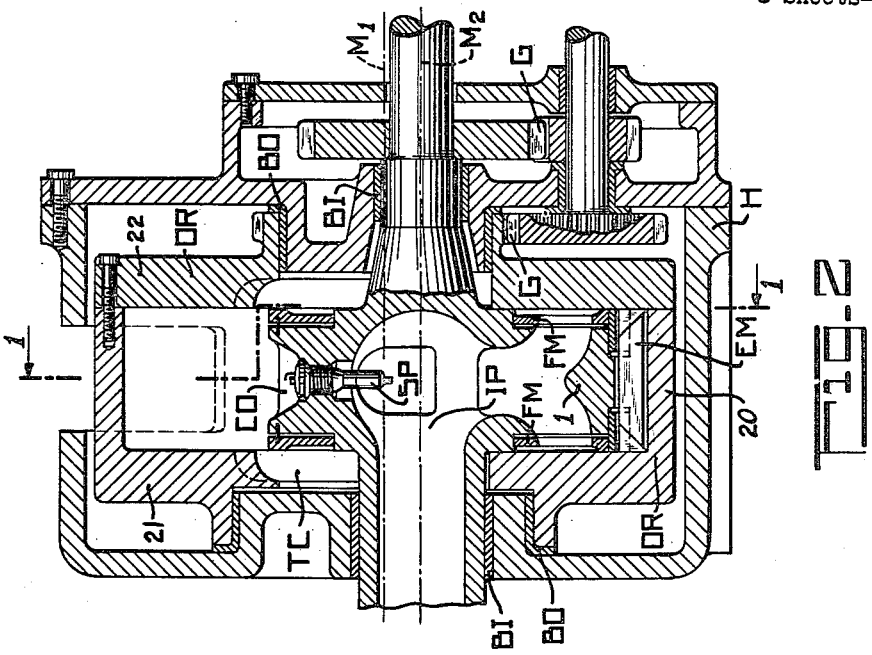

FIG. 2

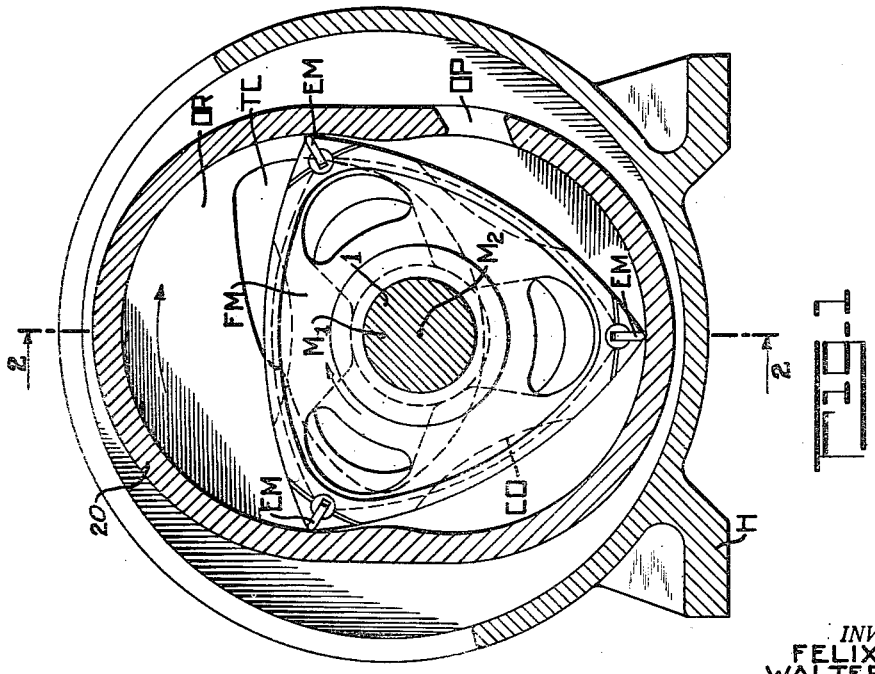

FIG. 1

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SEALING ARRANGEMENT FOR ROTARY MECHANISM

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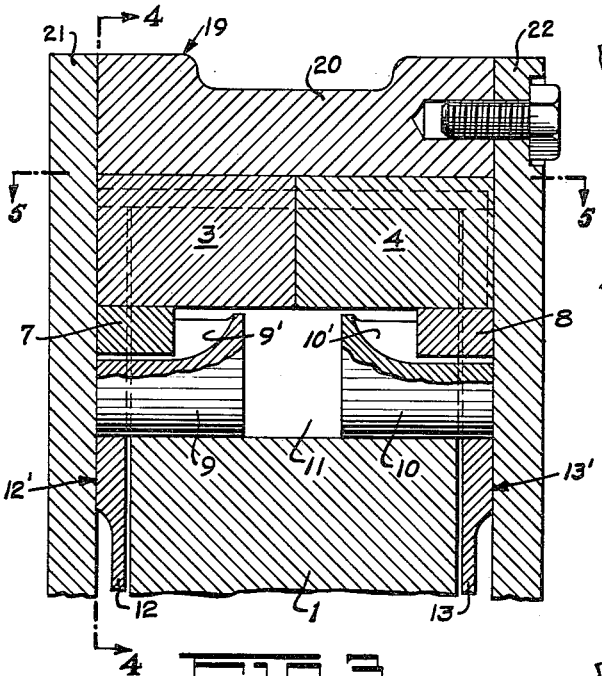

FIG. 3

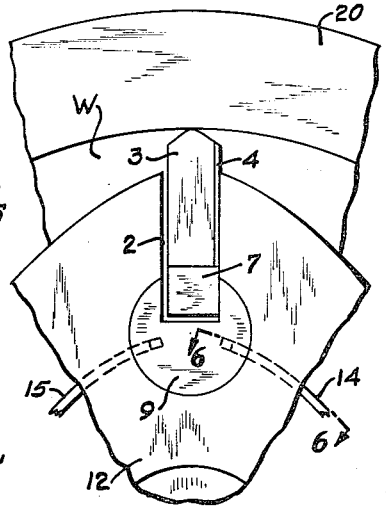

FIG. 4

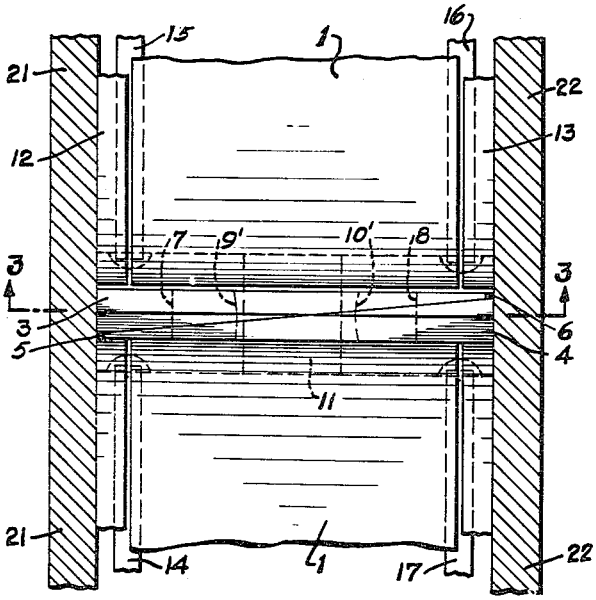

FIG. 5

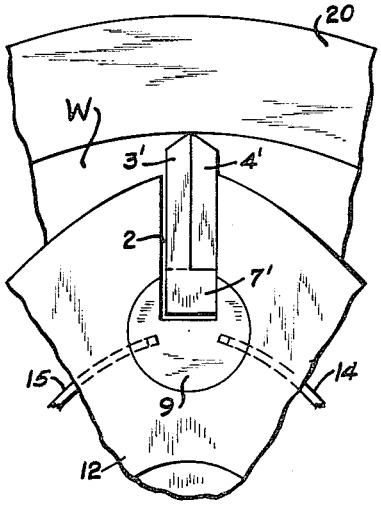

FIG. 9

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SEALING ARRANGEMENT FOR ROTARY MECHANISM

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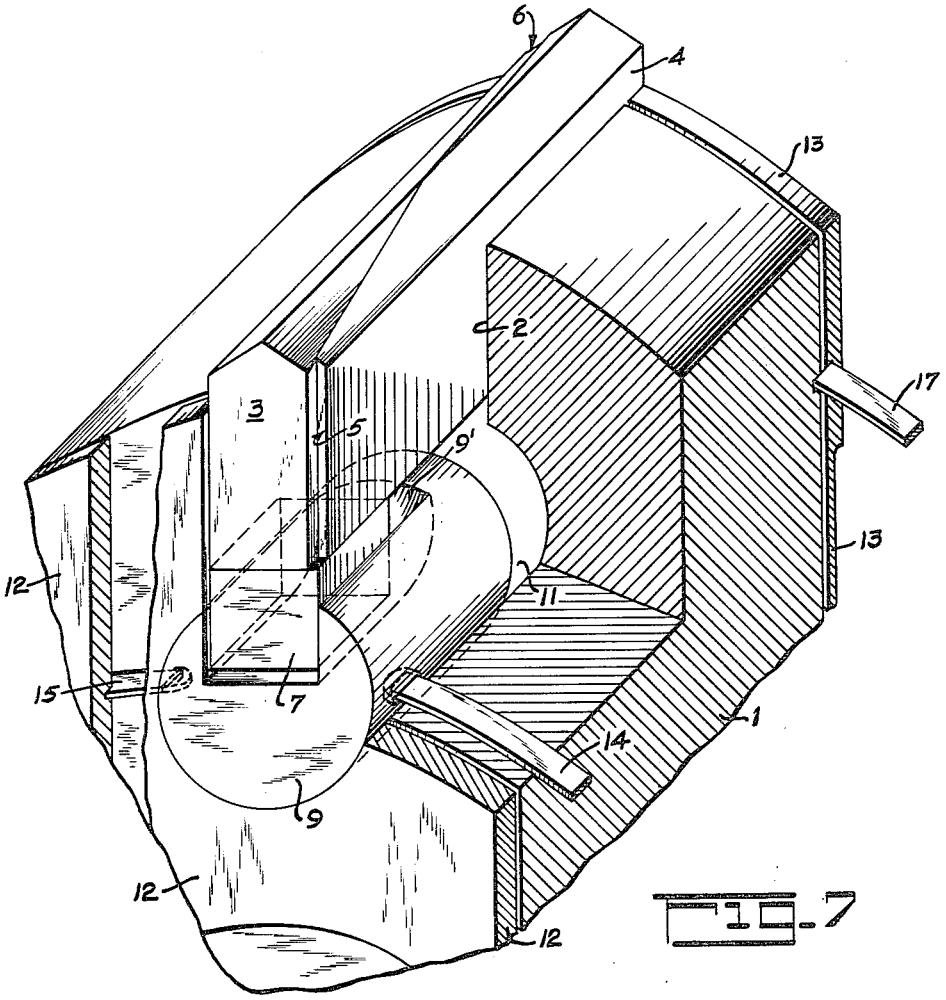

FIG. 7

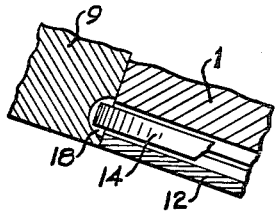

FIG. 6

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SEALING ARRANGEMENT FOR ROTARY MECHANISM

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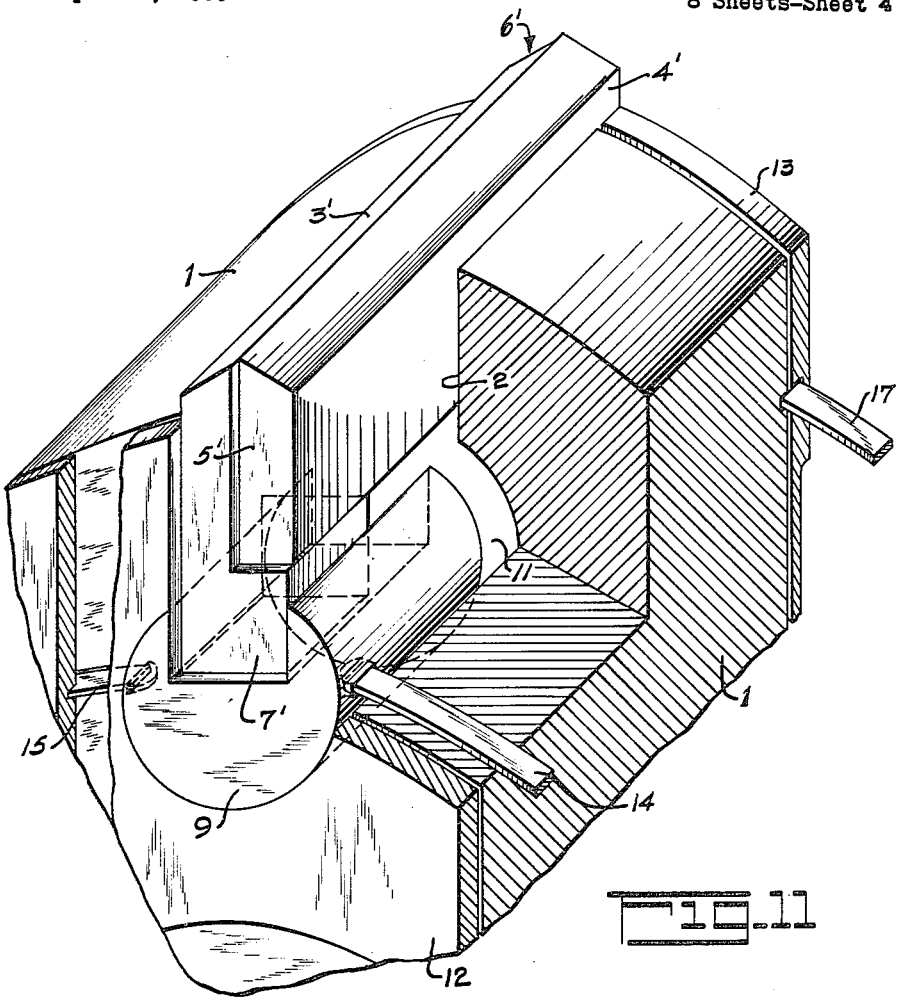

FIG. 11

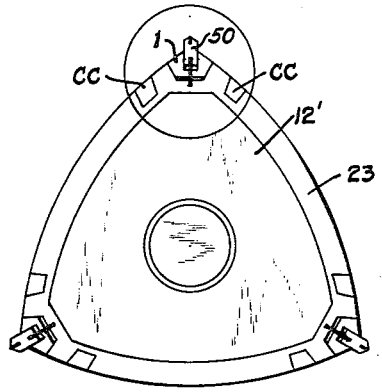

FIG. 12

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SEALING ARRANGEMENT FOR ROTARY MECHANISM

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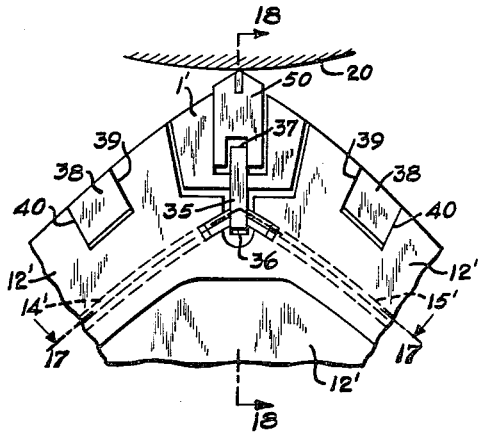

FIG. 16

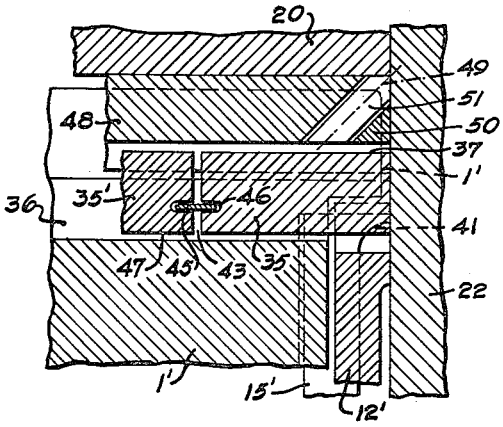

FIG. 18

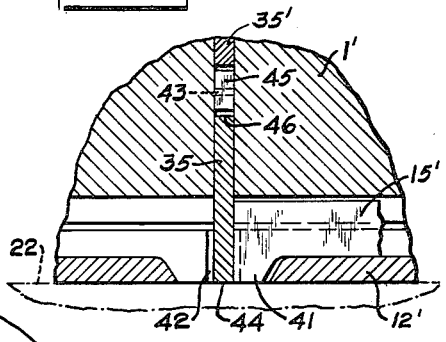

FIG. 17

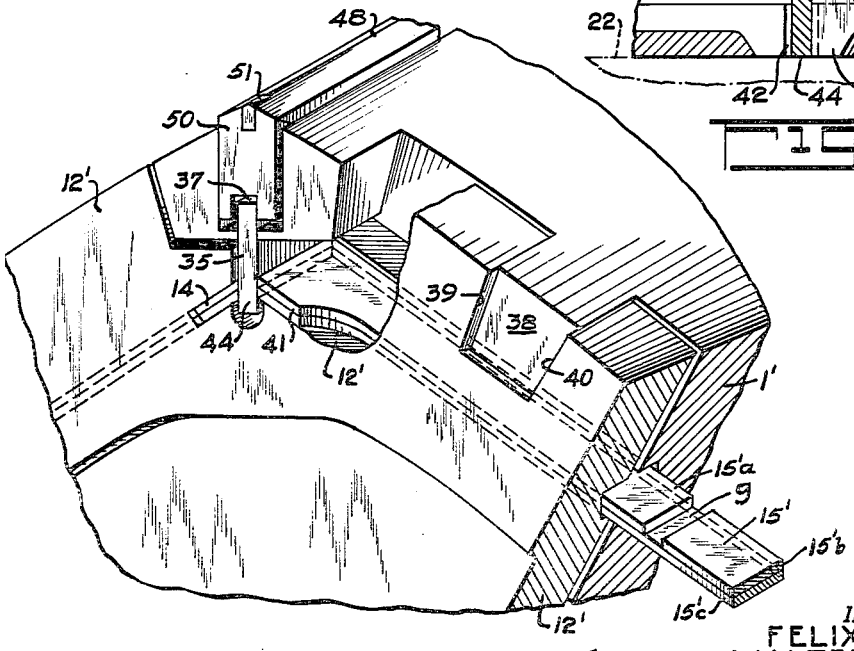

FIG. 19

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SEALING ARRANGEMENT FOR ROTARY MECHANISM

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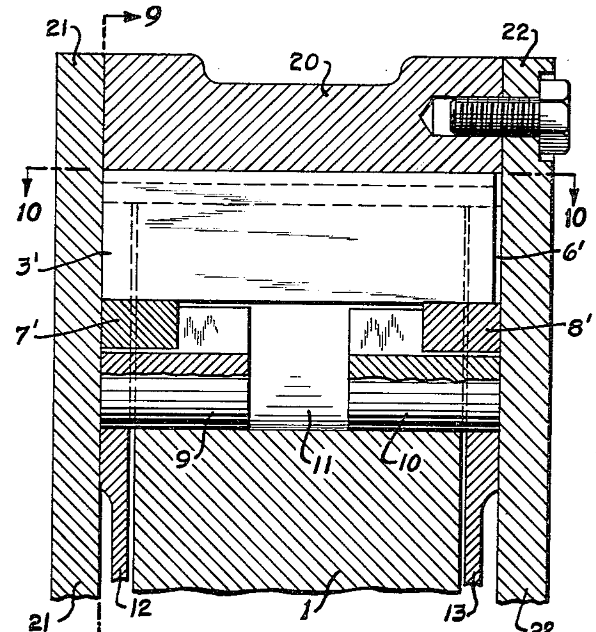

Fig. 8

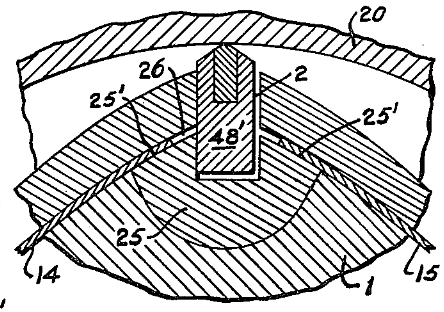

Fig. 13

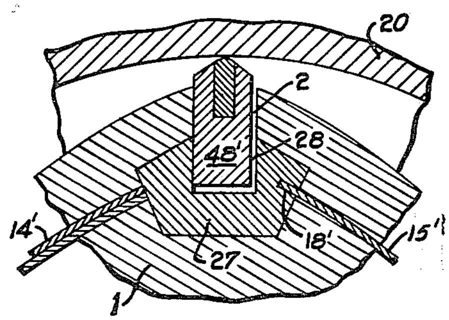

Fig. 14

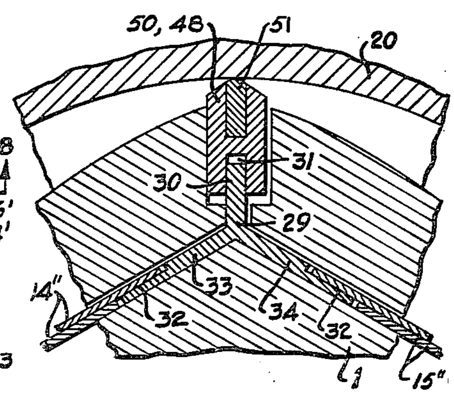

Fig. 15

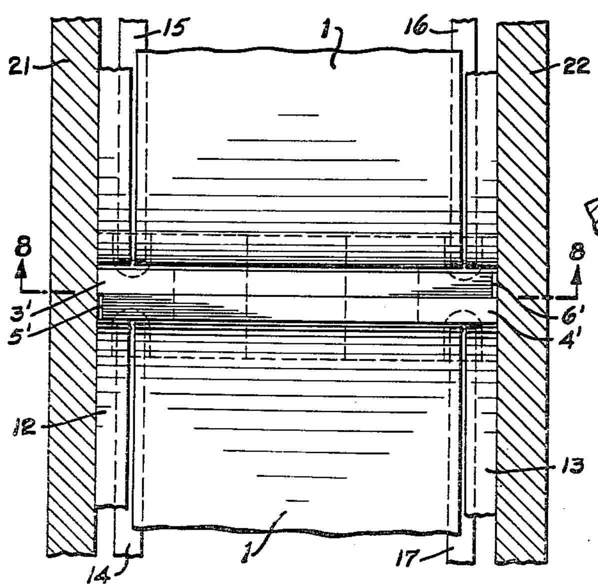

Fig. 10

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SEALING ARRANGEMENT FOR ROTARY MECHANISM

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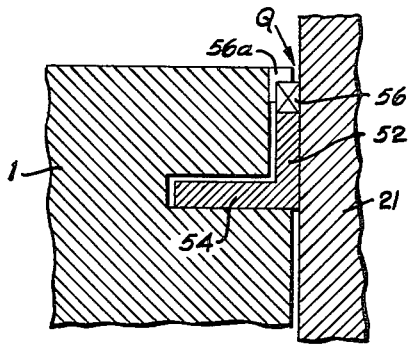

FIG. 20

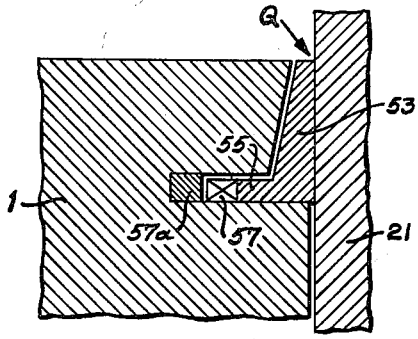

FIG. 21

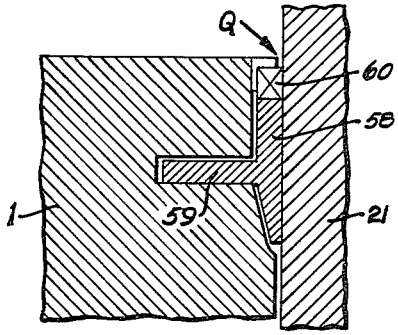

FIG. 22

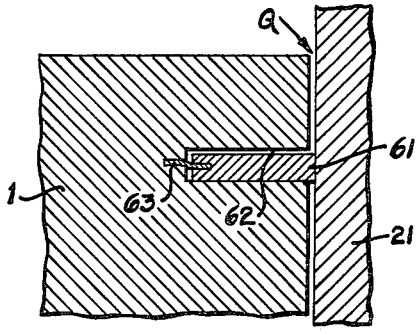

FIG. 23

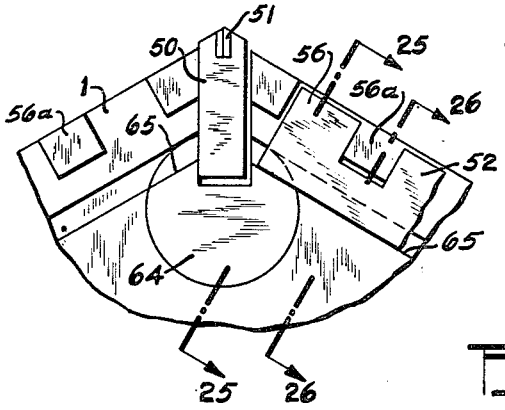

FIG. 24

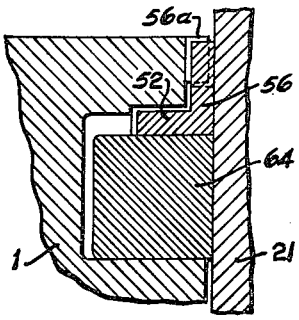

FIG. 25

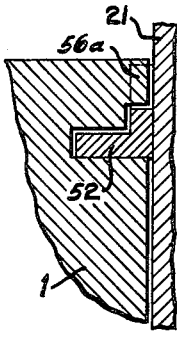

FIG. 26

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SEALING ARRANGEMENT FOR ROTARY MECHANISM

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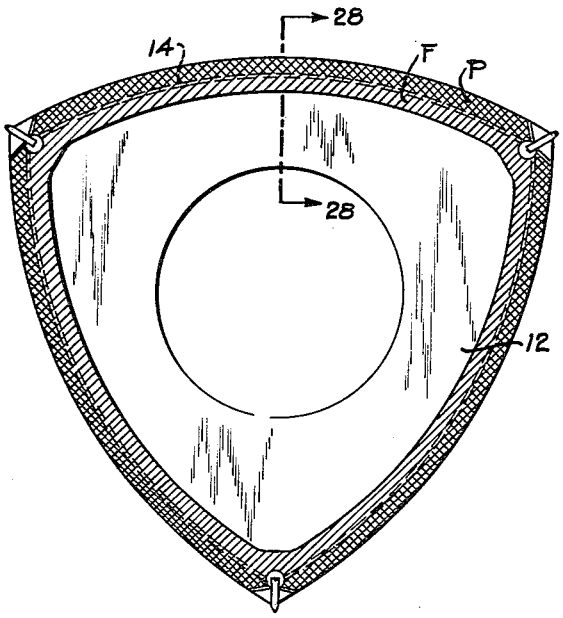

FIG. 27

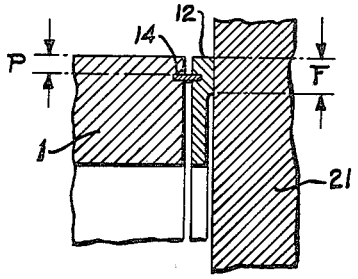

FIG. 28

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United States Patent Office 3,064,880 Patented Nov. 20, 1962

3,064,880
SEALING ARRANGEMENT FOR ROTARY MECHANISM

Felix Wankel, Lindau (Bodensee), Walter Froede, Neckarsulm, Wurttemberg, and Ernst Hoeppner, Lindau (Bodensee), all in Germany, assignors to NSU Motorenwerke Aktiengesellschaft, Neckarsulm, and Wankel G.m.b.H., Lindau (Bodensee), Germany

Filed Sept. 16, 1958, Ser. No. 761,339
Claims priority, application Germany Sept. 19, 1957
33 Claims. (Cl. 230—140)

The present invention relates broadly to the art of rotary mechanisms.

More particularly, this invention relates to a rotary mechanism of the type including relatively rotatable, inner and outer bodies which have cooperating surfaces that during relative movement define variable volume chambers.

Specifically, this invention relates to sealing arrangements for such mechanisms in which high pressure and temperature conditions exist in these chambers either permanently or temporarily, depending on the specific form of the mechanism, that is, whether it is an internal combustion engine, a compressor, or the like.

The seal components in such rotary mechanisms are subjected to centrifugal force, pressure from within the chambers, and wear effect, and these factors initiate deflections, distortions and strains on the sealing components. In addition, temperature conditions initiate expansive and contractive distortions in the mechanism. Therefore, the seal components should have such resiliency as to be able to compensate for such distortions and still be effective in sealing.

Accordingly, the present invention relates to such rotary mechanisms and comprises a sealing arrangement that is an improvement over the sealing means described and claimed in prior filed application Serial No. 654,840, on April 24, 1957, in the name of Felix Wankel and entitled "Seals for Working Spaces of Rotary Piston Engines," now Patent No. 2,880,045.

Therefore, this invention has for a primary object to provide a sealing arrangement for such mechanisms constructed and arranged to provide an effective, continuous line of sealing contact for such chambers.

It is a more specific object of the invention to provide a sealing arrangement for rotary mechanisms of the type set forth, which includes, radially movable edge seal means, axially movable, resilient end seal means and intermediate, axially movable sealing bodies interposed between and in sealing engagement with said edge seal means and said end seal means, respectively, all said seal means and bodies being assisted in maintaining sealing engagement by the pressure conditions in the chambers.

It is a more specific object to provide in a rotary mechanism of the type described which includes an inner rotor having a plurality of axially grooved, apex portions, at least two cooperably shaped, radially movable seal components in each groove, a resilient end seal means carried by said inner rotor adjacent its periphery for sealing relation between the rotor and the adjacent end face of the outer body, and intermediate sealing means associated with the grooves, and in respective sealing relation with the said aforementioned apex seal components and end seal means.

It is a further specific object of the invention to provide said intermediate sealing means with an external configuration adapted to facilitate sealing engagement with said edge seal means and end seal means, respectively.

Consistent with the foregoing object, the invention provides a sealing body with surfaces adapted to make an

overlapping sealing engagement with a component or components of said end seal means.

It is a further object of the invention to provide a sealing arrangement for a rotary mechanism of the type referred to, and in which the inner rotor has a plurality of circumferentially spaced apex portions each having an axial groove extending therethrough, edge sealing means within the grooves including at least two axially movable, sealing components, end face sealing means carried by at least one end face of the inner rotor and having a first sealing surface forming means extending radially of the axis of said inner rotor and a second sealing surface forming means extending parallel to said axis, and an intermediate sealing body operably associated with each groove for axial movement with respect thereto and including surfaces in cooperative sealing relation with said first and said second sealing surface-forming means.

It is an additional specific object to provide said first and second sealing surface-forming means in the form of an integral component having at least two legs, one extending radially of the rotor axis and the other parallel thereto.

Consistent with the immediately aforementioned object, it is a still more specific object of the invention to arrange said integral component in a series of separate segmental components, each extending between adjacent apex portions and in sealing engagement with the intermediate, axially movable sealing body at said adjacent apex portions.

An additional object of the invention is to arrange the various sealing components with relation to the periphery of the rotor and the adjacent end face of the outer body of the rotary mechanism, so that the ratio of surface area of sealing contact with said end face to the surface area subjected to pressure within the chambers is between 2 and 1, whereby to provide an effective seal with minimum frictional wear characteristics.

It is a still further object of the invention to provide a connection between the end face sealing means and the rotor in the form of a toothed coupling which ensures that the end face sealing means remains in phase with the rotation of the rotor, without transferring any load on the intermediate sealing bodies.

In connection with the aforegoing objects, it is to be pointed out that the shape of the intermediate sealing body that is cooperatively related with the radially movable apex sealing components and the axially movable end face sealing components can be varied as desired, so long as effective sealing contact can be maintained between intermediate sealing bodies and that portion of the end face sealing components that extend parallel to the axis of the rotor. Thus, the contact with the said sealing bodies can be in an abutting relation, a tangential-overlapping relation, or a socketed relation.

Further and more specific objects will be apparent from the following description taken in connection with the accompanying drawings illustrating the invention as applied to a rotary internal combustion engine of the type set forth in prior filed U.S. application Serial No. 646,752, filed March 18, 1957, in the names of Felix Wankel and Ernst Hoeppner, and entitled "Rotary Piston Four-Cycle Internal Combustion Engine" and now abandoned, the subject matter of said abandoned application being included in a continuation-in-part application Serial No. 774,517 filed November 17, 1958, and now Patent No. 2,988,065.

In the drawings:

FIGURE 1 is a view partly in elevation and partly in section transversely of the axis of a rotary engine, and illustrating the sealing arrangement of the invention,

FIGURE 2 is a sectional view taken along line 2—2 of FIGURE 1,

FIGURE 3 is a fragmentary longitudinal sectional view on an enlarged scale, taken along line 3—3 of FIGURE 5, and illustrating the sealing components of the invention,

FIGURE 4 is a fragmentary elevational view of the arrangement shown in FIGURE 3, taken along line 4—4 of FIG. 3, as viewed from the left and with the left-hand end wall of the outer element removed,

FIGURE 5 is a view partly in elevation and partly in horizontal section, illustrating the inner element or rotor as viewed from above an apex portion thereof;

FIGURE 6 is a fragmentary cross-sectional view taken along line 6—6 of FIGURE 4;

FIGURE 7 is a fragmentary perspective view of the inner rotor and its associated sealing components shown in FIGURES 3 to 6;

FIGURES 8 to 11 are views respectively similar to FIGURES 3 to 5 and 7, illustrating a modified form of sealing arrangement,

FIGURE 12 is an end elevational view illustrating a modified rotor structure and another modification of the sealing arrangement,

FIGURES 13 to 15 are enlarged fragmentary cross-sectional views illustrating one apex portion of the inner rotor and respectively showing modified forms of the additional or intermediate sealing and coupling bodies of the invention,

FIGURE 16 is an enlarged fragmentary view illustrating a portion of the structure shown in FIGURE 12,

FIGURES 17 and 18 are sectional views taken respectively on lines 17—17 and 18—18 of FIGURE 16,

FIGURE 19 is an enlarged fragmentary perspective view illustrating the modification shown in FIGURES 16 to 18,

FIGURES 20 to 23 are fragmentary longitudinal sectional views taken along lines circumferentially displaced from an apex portion and illustrating modified forms of resilient sealing means interposed between the end face of the rotor and the end wall of the outer body,

FIGURE 24 is a fragmentary end elevational view of an apex portion of a rotor illustrating a modified form of sealing arrangement,

FIGURES 25 and 26 are fragmentary sectional views taken respectively along lines 25—25 and 26—26 of FIGURE 24,

FIGURE 27 is an end elevational view of one end face of the rotor of FIGS. 1 and 2 and diagrammatically illustrating pressure conditions, and

FIGURE 28 is a sectional view taken along the line 28—28 of FIGURE 27.

As shown in the drawings, FIGURES 1 and 2, a rotary engine to which the sealing arrangement of the invention is applicable includes a stationary housing H within which is journalled an outer rotary body OR that is hollow, and that has the inner surface of its axially extending wall **20** shaped in the form of a two-lobed epitrochoid and has axially-spaced end walls **21** and **22**. The outer rotor is journalled by suitable bearing BO for rotation about an axis M_1. The inner rotor **1** has its outer axially extending surface shaped with three apex portions, which during operation make sliding contact with the inner surface of the wall **20** of the outer rotor. The inner rotor **1** is journalled by suitable bearings BI for rotation about an axis M_2 that is eccentric of but parallel to the axis M_1 of the outer rotor. Suitable means such as gearing G interconnect the two rotors, so that they rotate in the same direction, shown by the arrows in FIGURE 1, at a fixed speed ratio of 3:2. The facing surfaces of the respective inner and outer rotors define in operation a plurality of variable volume working chambers, the borders of which must be sealed. The inner rotor, in this example, is provided with inlet port means IP, through which a fuel-air mixture is fed to the working chambers. The inner surface of each of the opposite end walls **21**, **22** is provided with a transfer channel TC for directing the fuel mixture into the chambers in accordance with the cycle of operation determined by the phase movement of the inner rotor **1**, the combustion gases discharging from the working chambers through an outlet port shown at OP. Suitable ignition means such as spark plugs SP are disposed in recesses CO, provided in the axially extending surface of the inner rotor between the apex portions thereof.

In connection with this invention, it is to be pointed out that the rotary engine shown is not to be interpreted in a limiting sense. For example, the outer body OR of the engine could be a stationary housing and the inner body **1** a rotor. Likewise, the cooperative facing surfaces of the outer body and rotor can be shaped differently than as shown, as indicated in the said prior filed applications. The invention is further not to be limited to trochoidal shaped components nor to combustion engines, since it is applicable to any rotary mechanism which includes shaped surfaces that define in operation variable volume working chambers, the borders of which must be adequately sealed.

In the example illustrated, each apex portion of the inner rotor accommodates an edge sealing means EM, and each end face of the inner rotor is provided with end face sealing means FM. It should be noted that although, as illustrated, end face sealing means FM are provided at each end face of the rotor it is only essential to provide such end face sealing means at one end face provided the mating surfaces of the other end face of the rotor and the adjacent end wall **21** or **22** are sufficiently flat for good sealing engagement. With this latter arrangement the gas pressure against the rotor end face provided with the end face seal is effective to press the other end face of the rotor into sealing engagement with the adjacent end wall. Therefore, the present invention comprehends an edge sealing means EM at each apex portion of the inner rotor and a face sealing means FM at at least one end face of the inner rotor. The longitudinal dimensions of the inner rotor is therefore subject to variation in size to dependence upon the number of end seal means utilized. It is to be understood, however, that the opposite surfaces of the inner rotor in the direction of its axis always have a dimension therebetween less than the space between the end walls **21**, **22** of the outer rotor.

One form of the sealing means of the invention, generally indicated in FIGURES 1 and 2, is more particularly illustrated in FIGURES 3 to 7, in which the housing H is not shown, and the outer body OR includes the axially-shaped end walls **21**, **22** and an inter-connecting peripheral wall or shell **20**. The inner rotor is shown at **1**, and each apex portion thereof is provided with a groove preferably extending radially inwardly from the edge thereof and extending in an axial direction from one rotor end face to the other. This groove **2** accommodates strip sealing means **3**, **4** constituting one form of edge sealing means. The groove **2** is enlarged at its inner end to accommodate intermediate sealing and coupling bodies that cooperate with the respective edge seals and face seals. The face seals comprise, in the form shown, end plates **12** and **13** that are resilient, so as to be capable of conforming to any deformations that may exist in the end walls **21**, **22** or which may occur during operation of the engine. These end plates are disposed in the space between the opposite end faces of the rotor **1** and the adjacent inner surfaces of end walls **21**, **22**. The space accommodating an end sealing plate **12** or **13** is greater than the thickest part of the end plate in the direction of the axis of the engine, so that these resilient end plates can move axially in response to pressure conditions occurring in the working chambers to apply the sealing faces **12'**, **13'** against the respective end walls of the outer body. In order to bridge the gap be-

tween one end face of rotor 1 and the sealing plate 12, the invention provides a sealing surface forming means extending from apex portion to apex portion comprised in this form by resilient metal strip means 14, 15 accommodated in oppositely facing, axially aligned, similarly shaped grooving in the rotor 1 and end plate 12, respectively. Similar strip means 16, 17 are arranged between the rotor 1 and end plate 13. The inner surfaces of these resilient strip means during operation are pressed into sealing engagement against the surfaces of their accommodating grooving, so as to seal the gap between the rotor and each end plate 12 or 13. To provide a continuous effective sealing line of contact around the periphery of the working chambers, the edge sealing elements 3 and 4 at each apex portion are capable of axial movement, and in this form of the invention are provided with a meeting line of contact that extends substantially diagonally of the groove 2 as viewed from above. Due to the relationship of the meeting line between the edge sealing elements or strips 3, 4 axial movement thereof during operation leaves gaps 5 and 6 at opposite ends of the inner rotor. These gaps must be sealed, and accordingly sealing components in the form of blocks 7 and 8 are mounted for axial movement beneath the opposite ends of sealing strips 3 and 4 to underlie and seal the gaps 5 and 6. To interrelate the edge sealing and end sealing in maintaining the continuous effective sealing line of contact, intermediate sealing and coupling bodies 9 and 10 of simple geometrical configuration are arranged in the enlarged inner portions of grooves 2. In this embodiment these bodies are cylindrical, and have a groove 9', 10' extending inwards from their periphery to accommodate blocks 7 and 8, respectively. The outer end faces of the respective bodies 9, 10 project through cut-out portions or slots in the adjacent end seal plates 12, 13 for sealing engagement with the inner surfaces of the end walls 21, 22 during operation. The gap bridging sealing strip means 14 to 17 make contacting engagement with the bodies 9 and 10. In the form illustrated, as shown in FIGURE 6, the bodies are provided with a notch or recess 18 that accommodates the end of the strips such as 14. This relationship is shown more clearly in FIGURE 7.

It is believed clear, therefore, that during operation gas pressure existing in a working chamber such as W, FIGURE 4, is applied against the side face of sealing strip 3 to press sealing strip 4 against the adjacent face of groove 2, and also to extend the strips 3 and 4 axially to apply their end faces against the inner surfaces of the end walls 21, 22. Gas will pass down inside groove 2 to enter grooves 9', 10' and space 11 between bodies 9 and 10 to effect outward axial movement of both blocks 7 and 8 and bodies 9 and 10, centrifugal force plus gas pressure maintaining sealing contact between the strips 3, 4 and blocks 7, 8. The end plates 12 and 13 are pressed axially outwards by gas pressure applied on that portion thereof radially outwards of the strips 14 to 17, and these strips are applied in sealing engagement against the respective end plate and rotor surfaces, and against the bodies 9, 10.

As clearly disclosed, the intermediate coupling and sealing bodies 9, 10 are located close to the outer edge of each apex means so that the resilient sealing strips such as 14, 15 can likewise be located close to the periphery of the rotor whereby the bodies 9, 10 cannot be projected into the fuel passages such as the transfer channel means TC. The end plates 12, 13 are ported to pass fuel from port means IP to the transfer channels TC.

A modified form of sealing relationship is disclosed in FIGURES 8 to 11. This form of the invention differs only in the relationship of the resilient sealing means disposed in the groove 2 and the means for sealing the space resulting from axial movement of these resilient sealing means. Thus, the sealing strip means that extend parallel to the axis of the rotor 1 and are accommodated in grooves 2 again comprise two separate members 3', 4'. These members meet along a plane that is approximately radial to the axis of rotor 1. Instead of providing separate block elements 7 and 8 to seal the gaps 5', 6' that occur when the strip means 3', 4' move axially apart, the respective strip means are provided at one end with a depending, integral widened portion shown at 7', 8'. The widened portion 7' at one end of the strip means 3' underlies the lower edge of the adjacent end of strip means 4' so as to seal gap 5', whereas the enlarged portion 8' of strip means 4' underlies the adjacent lower surface of strip means 3'. This form of the invention is otherwise similar to the arrangement of FIGURES 3 to 7 and the movement of the parts for sealing is likewise similar.

FIGURE 12 illustrates in end elevation a modified form of rotor 1 which includes a modified sealing arrangement also shown in the detail views of FIGS. 16, 17, 18 and 19. In this form of the invention, at each apex portion of the rotor there is a projecting portion 1' that extends axially beyond the end face of the rotor to provide metal to metal contact between rotor 1 and the edge sealing means along substantially the entire length of said sealing means to improve heat transfer especially from the end face portions of the edge seal means to the inner body. Further, to connect each sealing plate with the rotor during rotation, a claw coupling arrangement indicated generally at CC is provided on each side of each apex and adjacent the same. This claw coupling arrangement for an end sealing plate includes toothed portions or projections 38 extending axially from the adjacent end face of the rotor and notches in said end plate having circumferentially spaced edges 39, 40, see FIGURE 16, into which the projections 38 fit. This claw coupling arrangement prevents relative rotation between rotor 1 and the end sealing plates. In this form of the invention the sealing means is more clearly shown in FIGURES 16 to 18. Each apex portion is provided with a groove extending inwardly from its outer edge and extending in a direction parallel to the rotor axis from one face to the other of the rotor to accommodate sealing strip means including a first part 48 and a pair of triangular shaped parts 50 disposed at opposite ends of said first part 48, each triangular part 50 having an inclined surface indicated by the line 49 and facing a similarly inclined surface on the adjacent end of the part 48 with each said inclined surface having a groove between its sides and running from one end to the other of said surface and facing the corresponding groove in the other of said surfaces, and a filling piece 51 is inserted in said facing grooves to bridge the junction of said inclined surfaces. The outer end of the insert piece 51 has one face for sealing against the adjacent end wall of the outer body and another face for sealing against the peripheral wall 20 of the outer body. It is clear, therefore, that relative axial movement, responsive to gas pressure conditions, can be imparted to the edge sealing components 48, 50 and 51 while still maintaining an effective continuous sealing line of contact with the surfaces of the outer body. The intermediate coupling and sealing bodies are of modified form and include a strip means 35, 35' of rectangular cross section accommodated in a groove 36 extending axially of the inner body or rotor 1 and a groove 37 extending inwardly from the undersurface of sealing strip components 48 and 50. To bridge the gap 43 between these sealing bodies 35, 35' resilient metal strips 45 are interposed in oppositely facing similarly shaped grooves 46 in each of these intermediate bodies. As in the forms described previously, the end plates are mounted for axial movement with respect to the adjacent rotor end faces and resilient sealing means 14', 15' bridge the gap between the end plates and the rotor body and are disposed in grooving formed in these components. As clearly shown in FIGURES

16 and 17, the ends of these last-mentioned resilient strip means that are adjacent the intermediate coupling and sealing bodies such as 35 are widened or enlarged as shown at 41 and extend through a cut-out or slot formed in the sealing plate 12 so that centrifugal force can maintain adequate sealing contact between the end faces of the resilient strip means 14', 15' and the intermediate body 35. The intermediate body part 35 has an end face 44 that seals against the inner surface of end wall 22. In FIGURE 17 the resilient sealing strip means between the rotor body and the end plate, similar to strip means 15' is not shown in the grooving to the left of body 35 so that the clearance space 42 between the intermediate body 35 and the grooving cut in the sealing plate 12 to accommodate this body 35 is visible.

FIGURE 19 is a perspective view clearly illustrating the relationship of FIGURES 16 to 18.

In connection with the arrangement shown in FIGURES 16 to 19, the strip means 14', 15' extending from the intermediate sealing body 35 adjacent one apex portion to the intermediate sealing body at the next apex portion are of laminar, overlapped construction so that the abutting sealing contact along the widened edge 41 will be maintained independent of differences in total lengths of the strips 14', 15' in relation to the peripheral extent of the grooving accommodating these strips. In other words each strip means such as 15' in FIGURE 19 has two lamina, each lamina having two parts such as 15'*a* and 15'*b* which can move relatively apart toward the respective apex portions due to centrifugal force. This movement leaves a gap *g* which is covered by the subjacent lamina part 15'*c*. The same relationship of parts exists near the next adjacent apex portion. Thus, the gaps between the two parts of each lamina are always overlapped by the other lamina.

It is to be pointed out that the intermediate body that is in cooperative sealing relation with the end face sealing means and the edge sealing means can have modified cross-sectional shapes. Thus, FIGURE 13 illustrates an arrangement in which the edge sealing means 48' is accommodated in a groove 2 formed in the edge of the rotor 1 and the end face of the rotor has a groove to accommodate sealing strips such as 14, 15. The enlarged portion of the groove 2 instead of being circular is shaped to accommodate an intermediate coupling and sealing body 25 having strip contacting surfaces 25' that extend approximately parallel to the outer face portions of the rotor 2 on opposite sides of the apex. The resilient strips 14 and 15 bear against the surfaces 25' in tangential contact leaving a clearance space 26 at the ends of the axial grooving. The edge strip means 48' is of course constructed of two or more parts so as to provide for axial movement of these parts as in the aforedescribed modifications.

In FIGURE 14 the intermediate body is shaped as shown at 27, and has a pentagonal cross section. The outer surface of this intermediate body is provided with a groove 28 that accommodates the edge sealing strip means 48'. The metal strips 14, 15 are again accommodated in axially extending grooving provided in the end face of the rotor and the adjacent end face of the sealing plate so arranged relative to the intermediate bodies 27 that the ends of strip means 14 of laminar construction as set forth above abut the intermediate bodies 27 along a line parallel to the axis of the rotor 1, whereas the strip means 15 is accommodated in a groove or socket 18' extending inwardly from the opposite end face of the bodies 27 at right angles to said opposite end face.

FIGURE 15 illustrates a modification in which the edge sealing means is similar to that shown in FIGURES 16 to 18 and the intermediate body 29 is of inverted Y shape and includes three legs 30, 33, and 34. The outwardly projecting leg 30 is accommodated in a groove 31 formed in the undersurface of the edge sealing strip means 50, 48 while the legs 33 and 34 are accommodated in the axially extending grooving provided in the end face of the rotor and the adjacent end face of the seal plate for receiving the metal strip means. In this case the metal strip means 14'' and 15'' are in double-ply relationship so that one portion thereof overlaps the gaps at the ends of the legs 33, 34 as shown at 32. The outer surfaces of the legs 33, 34 are cutaway to permit this overlap.

The aforedescribed modifications include in all cases end face sealing means that comprise a first sealing surface forming means in the form of the end plate or plates that is movable axially of the rotor 1 and a second sealing surface forming means comprised by the resilient strip means such as 14, 15 that bridge the gap between the rotor 1 and the end plates and which strip means move transversely of the axis of the rotor. The invention further contemplates an arrangement in which these two sealing surface forming means are combined in one component structural member, which has one surface to seal against the end wall 21 of the outer body and another surface which seals against the rotor body 1. FIGURE 20 illustrates an embodiment in which the end face sealing means is a resilient strip that is angle-shaped in cross section including one leg 52 that applies against the inner face of end wall 21 in response to axial movement and another leg 54 accommodated in an axially extending groove directed inwardly from the end face of rotor 1. Thus, as indicated by arrow Q the angle-shaped sealing strip means 52 will seal against the inner surface of the end wall 21 and the inner face of the groove in the rotor and thus bridge the gap between the rotor and end wall. Claw coupling means are likewise employed in this relationship as diagrammatically indicated at 56.

FIGURE 21 illustrates a variant of the structure in FIGURE 20 in which the angle-shaped sealing strip means 53 is coupled to the rotor body by a claw coupling means 57 including teeth formed on the axially extending leg of the sealing strip means and cooperating teeth formed on a segment 57*a* that is positioned in the grooving in the rotor 1 and extending from apex portion to apex portion.

FIGURE 22 illustrates a further modification in which the resilient end face sealing strip means is T-shaped in cross section, has claw coupling teeth 60 on its outer leg and the intermediate leg or section 59 is accommodated in the axial grooving in the rotor 1.

FIGURE 23 illustrates a further modification in which the end face sealing means 61 are in the form of a rectangular section, segmental strip means accommodated in an axially extending grooving 62 disposed between the apex portions of the rotor 1. Resilient metal strip means 63 are arranged between the strip means 61 and the rotor body and accommodated in axially extending grooves as shown.

In each of the aforegoing modifications in FIGURES 20 to 23 it is to be understood that the respective resilient strips means, 52, 53, 58 and 61 extend between successive apex portions, and that they are in sealing contact with an intermediate sealing and coupling body in each apex portion and the respective coupling bodies are in sealing contact with the edge strip means as previously described. This relationship is more clearly illustrated in FIGURES 24 to 26 illustrating a cross-sectional relationship similar to that shown in FIGURE 20. In FIGURE 24 the intermediate connecting body 64 has surfaces 65 which contact the undersurface of the toothed angle-shaped, in this instance segmental sealing strip elements 52. The teeth on the strip elements are denoted at 56 and the notches between the teeth accommodate projections 56*a* extending axially of rotor 1. The edge seal can be of the type shown in FIGURES 16 to 18. FIGURES 25 and 26 respectively illustrate the sealing relation between the intermediate coupling and sealing body 64 and the sealing strip 52 and the adjacent end face of the end wall 21 as well as the sealing relation be-

tween the resilient strip means 52 and the grooving in the rotor body 1 accommodating these strip means.

It is believed clear that the shape of the bodies 64 can be varied so long as there are surfaces such as 65 permitting tangential contact with the undersurface of the sealing strip means 52.

The immediately aforementioned FIGURES 23 to 26 all relate to arrangements in which the end face sealing means is comprised by separate resilient strips extending between the respective apex portions of the rotor and in sealing relation at the apex portions with the intermediate coupling and sealing bodies, which are in turn in sealing relation with the edge strip sealing means, so that a continuous seal is provided around the end face of the rotor and an effective continuous sealing line of contact is obtained. With regard to the area of sealing contact between the inner surface of the end wall or walls of the outer body and the axially movable end face sealing components carried by the rotor, the relationship between the surface area in contact with the end wall of the outer body and the surface area under pressure of the gas within the chambers is important. The engagement of the end face sealing means against the inner surface of the end wall or walls of the outer body is effected by the pressure of the gas within the working chambers. This pressure is effective on the surface area of the strip means engaging the end wall of the outer body. A hydrostatic counterpressure is built up within this surface area of contact which varies depending on the accuracy of the respective faces in engagement and on the degree of lubrication between these faces. A surface area of sealing contact that is small in relation to the surface area of the axially movable end seal components that are subjected to the pressure from the gases in the chambers is effective but establishes high specific pressures with the consequent risk of rapid wear. Therefore, the ratio between the surface area contacting the inner surfaces of the outer body end walls and the surface area acted on by the gas pressure must be so related as to obtain an effective sealing contact while minimizing wear possibilities. It has been discovered that this ratio of surface area should lie withn the range of 2 and 1 in order to provide an effective and long lived seal. FIGURES 27 and 28 illustrate this relationship as applied to an end plate sealing element 12. The area under pressure is denoted by the reference character P whereas the area in contact with the inner surface of end wall 21 is denoted by the reference character F. As shown in these figures the surface area F of contact against end wall 21 is approximately double the surface area P that is subjected to gas pressure.

It is to be pointed out that the resiliency of the component parts that constitute the several forms of edge seal means is comparable to the working conditions for piston rings.

Further, the dimensions of the edge seal components, while exaggerated in the drawings are small as regards their width and thickness. As an example the total width of an edge seal means in one embodiment of an engine whose outer body has a major axis approximately 10 inches long is about 2 mm. A much larger engine can utilize the same width of seal components and thus provide for increased resiliency.

What is claimed is:

1. A sealing arrangement for the working chambers of a rotary mechanism including an outer body having axially-spaced end walls and a peripheral wall interconnecting said end walls to form a cavity therebetween; and an inner body received within said cavity and having axially-spaced end faces disposed adjacent to and having continuous sealing cooperation with said end walls and also having a plurality of circumferentially-spaced apex portions each extending from one end face to the other and having continuous sealing cooperation with the inner surface of said peripheral wall to form a plurality of working chambers between said inner body and peripheral wall which vary upon relative rotation of said inner and outer bodies; said sealing arrangement comprising radially-movable edge seal means carried by said inner body at each of its said apex portions with said edge seal means having peripheral-wall-engaging seal faces along their radially outer edges and having end-wall-engaging seal faces at their ends; end face sealing means carried by said inner body at an end face thereof and including axially movable means having end-wall-engaging seal faces; and a plurality of axially-movable intermediate sealing bodies carried by said inner body at said last-mentioned end face thereof, there being one such intermediate sealing body at each apex portion of said inner body, each said intermediate sealing body being disposed radially inwardly of the radially outermost part of its associated apex portion and having sealing cooperation with the adjacent edge seal means and with adjacent portions of said end face sealing means throughout relative movement of said inner and outer bodies.

2. A sealing arrangement as claimed in claim 1 and in which each said edge seal means is axially extendible and comprises at least two radially-movable seal members.

3. A sealing arrangement as claimed in claim 2 wherein said apex portions have axially extending grooves therein extending inwards from the outer periphery of the inner body and shaped to accommodate both said edge seal means and said intermediate sealing bodies, said end face sealing means including a portion on each side of each apex portion having a surface extending parallel to the axis of said inner body and socketed therein for sealing engagement with said inner body and said intermediate sealing bodies, each sealing member of said edge seal means having an axial extent less than the distance between said end walls and having adjacent surfaces meeting along a plane passing transversely through the associated groove at an acute angle to the base of the groove.

4. A sealing arrangement as claim in claim 3 in which said plane extends from the base of the groove outwardly towards the said end face, said adjacent surfaces having oppositely directed grooves therein, and sealing insert means in such grooves.

5. A sealing arrangement as claimed in claim 2 wherein said apex portions have axially extending grooves therein extending inwards from the outer periphery of the inner body and shaped to accommodate both said edge seal means and said intermediate sealing bodies, said end face sealing means including a portion on each side of each apex portion having a surface extending parallel to the axis of said inner body and socketed therein for sealing engagement with said inner body and said intermediate sealing bodies, each said intermediate sealing body having a groove therein extending radially inwards from its outer periphery, said sealing members being accommodated within said last-mentioned groove, each sealing member having an axial extent less than the distance between said end walls and having abutting side surfaces and means operatively associated with the sealing members and having an extent transversely of the groove in the sealing body corresponding to the combined extent in the same direction of said sealing members and disposed between the base of the groove in the sealing body and said sealing members, and said last-mentioned means having an upper surface bridging the gap along the adjacent end wall of the hollow body that forms upon axial movement of the sealing members.

6. A sealing arrangement as claimed in claim 5 in which said last-mentioned means is integral with one of said sealing members.

7. A sealing arrangement as claimed in claim 2 wherein said apex portions have axially extending grooves therein extending inwards from the outer periphery of the inner body and shaped to accommodate both said edge seal means and said intermediate sealing bodies, said end face sealing means including a portion on each side of each

apex portion having a surface extending parallel to the axis of said inner body and socketed therein for sealing engagement with said inner body and said intermediate sealing bodies, each sealing member of the edge seal means having an axial extent less than the distance between said end walls and having side surfaces meeting along an approximately radial plane passing through the axis of the inner body.

8. A sealing arrangement as claimed in claim 2 wherein said apex portions have axially extending grooves therein extending inwards from the outer periphery of the inner body and shaped to accommodate both said edge seal means and said intermediate sealing bodies, said end face sealing means including a portion on each side of each apex portion having a surface extending parallel to the axis of said inner body and socketed therein for sealing engagement with said inner body and said intermediate sealing bodies, each sealing member of said edge seal means having an axial extent less than the distance between said end walls and having side surfaces meeting along a plane extending approximately diagonally of the groove.

9. A sealing arrangement as claimed in claim 2 wherein said apex portions have axially extending grooves therein extending inwards from the outer periphery of the inner body and shaped to accommodate both said edge seal means and said intermediate sealing bodies, said end face sealing means including a portion on each side of each apex portion having a surface extending parallel to the axis of said inner body and socketed therein for sealing engagement with said inner body and said intermediate sealing bodies, each said intermediate sealing body having a groove therein extending radially inwards from its outer periphery, said sealing members being accommodated with said last-mentioned groove, each sealing member having an axial extent less than the distance between said end walls and having abutting side surfaces and means operatively associated with the sealing members and having an extent transversely of the groove in the sealing body corresponding to the combined extent in the same direction of said sealing members and disposed between the base of the groove in the sealing body and said sealing members, and said last-mentioned means comprising a separate sealing body underlying both said sealing members.

10. A sealing arrangement as claimed in claim 1 wherein said apex portions have axially extending grooves therein extending inwards from the outer periphery of the inner body and shaped to accommodate both said edge seal means and said intermediate sealing bodies, said end face sealing means including a segmental portion on each side of each apex portion having a surface extending parallel to the axis of said inner body and socketed therein for sealing engagement with said inner body, and said intermediate sealing bodies having surfaces in sealing relation with the adjacent ends of said segmental portions.

11. A sealing arrangement as claimed in claim 1 wherein said apex portions have axially extending grooves therein extending inwards from the outer periphery of the rotor and shaped to accommodate both said edge seal means and said intermediate sealing bodies, said end face sealing means including a segmental portion on each side of each apex portion having a surface extending parallel to the axis of said rotor and socketed therein for sealing engagement with said rotor and said intermediate sealing bodies having surfaces in overlapping sealing engagement with the adjacent ends of said segmental portions.

12. A sealing arrangement as claimed in claim 1 wherein said apex portions have axially extending grooves therein extending inwards from the outer periphery of the inner body and shaped to accommodate both said edge seal means and said intermediate sealing bodies, said end face sealing means including a segmental portion on each side of each apex portion having a surface extending parallel to the axis of said inner body and socketed therein for sealing engagement with said inner body, said intermediate sealing bodies having surfaces in abutting sealing relation with the adjacent ends of said segmental portions, each segmental portion being of laminar construction with each lamina having two parts that are movable relatively apart toward adjacent apex portions due to centrifugal force, said sealing bodies being abutted by the outer ends of each part and the adjacent inner ends of the parts on one lamina being overlapped by one part in the next lamina.

13. A sealing arrangement as claimed in claim 1 wherein said apex portions have axially extending grooves therein extending inwards from the outer periphery of the inner body and shaped to accommodate both said edge seal means and said intermediate sealing bodies, said end face sealing means including a segmental portion on each side of each apex portion having a surface extending parallel to the axis of said inner body and socketed therein for sealing engagement with said inner body, and said intermediate sealing bodies having sockets therein on each side of the associated apex portion accommodating in sealing engagement the ends of said segmental portions.

14. A sealing arrangement as claimed in claim 1 wherein said apex portions have axially extending grooves therein extending inwards from the outer periphery of the inner body and shaped to accommodate both said edge seal means and said intermediate sealing bodies, said end face sealing means including a portion on each side of each apex portion having a surface extending parallel to the axis of said inner body and socketed therein for sealing engagement with said inner body and said intermediate sealing bodies, and one of said sealing bodies and edge seal means having a radially extending groove therein and the other of said sealing body and edge seal means having at least a portion fittting within said groove.

15. A sealing arrangement as claimed in claim 1 wherein said apex portions have axially extending grooves therein extending inwards from the outer periphery of the inner body and shaped to accommodate both said edge seal means and said intermediate sealing bodies, said end face sealing means including a portion on each side of each apex portion having a surface extending parallel to the axis of said inner body and socketed therein for sealing engagement with said inner body and said intermediate sealing bodies, each said sealing body having a groove therein extending radially inwards from its outer periphery and the adjacent edge seal means being socketed within said groove.

16. A sealing arrangement as claimed in claim 1 wherein said apex portions have axially extending grooves therein extending inwards from the outer periphery of the inner body and shaped to accommodate both said edge seal means and said intermediate sealing bodies, said end face sealing means including a portion on each side of each apex portion having a surface extending parallel to the axis of said inner body and socketed therein for sealing engagement with said inner body and said intermediate sealing bodies, each said edge seal means having a groove therein extending radially outwards from its inner periphery and the adjacent intermediate sealing body having a portion fitting within said last-mentioned groove.

17. A sealing arrangement as claimed in claim 1 wherein said apex portions have axially extending grooves therein extending inwards from the outer periphery of the rotor and shaped to accommodate both said edge seal means and said intermediate sealing bodies, said end face sealing means including a segmental portion on each side of each apex portion having a surface extending parallel to the axis of said rotor and socketed therein for sealing engagement with said rotor and said intermediate sealing bodies, said end face sealing means also having a cut-out to accommodate said bodies, each said edge seal means having a groove therein extending radially outwards from its inner periphery with the adjacent intermediate sealing body having a portion fitting within said last-mentioned

groove, and said segmental portions comprising resilient strip means having portions extending parallel to the inner body axis, disposed radially inwardly of the adjacent edge seal means and bridging the space between said intermediate sealing bodies and the edges of the cut-outs.

18. A sealing arrangement as claimed in claim 1 and in which each said intermediate sealing body has an end-wall-engaging seal face.

19. A sealing arrangement as claimed in claim 1 in which said apex portions have axially extending grooves therein accommodating said edge seal means and said intermediate sealing bodies.

20. A sealing arrangement as claimed in claim 1 and in which said intermediate sealing bodies each have an axially extending groove therein accommodating their associated edge seal means.

21. A sealing arrangement for the working chambers of a rotary mechanism including an outer body having spaced end walls and a peripheral wall interconnecting said end walls to define between said walls a cavity having an axis along which the end walls are spaced, and an inner body received within said outer body cavity for relative rotation with respect to the outer body with the axis of the inner body being laterally spaced from, but parallel to, the axis of the outer body cavity, said inner body having axially-spaced end faces disposed adjacent to and having continuous sealing cooperation with said end walls and having an outer surface with a plurality of circumferentially-spaced apex portions each extending from one end face to the other and having continuous sealing cooperation with the inner surface of said peripheral wall to form a plurality of working chambers between said inner body and peripheral wall, each of said working chambers extending from one apex portion of the inner body to an adjacent apex portion and varying in volume upon relative rotation of said inner and outer bodies; said sealing arrangement comprising radially-movable edge seal means carried by and extending along each of said apex portions within a groove in said apex portion extending from one end face to the other of the inner body, said edge seal means having peripheral-wall-engaging seal faces along their radially outer edges and having end-wall-engaging seal faces at their ends; a plurality of seal strips received within grooves in an end face of said inner body, there being one such end face seal strip for and extending between each pair of adjacent apex portions with each of said seal strips being movable in a direction parallel to the axis of the inner body and having an end-wall-engaging seal face; and a plurality of intermediate seal members carried by said inner body, there being one such intermediate seal member in and at an end of each said apex portion groove for sealing engagement with the adjacent end of an edge seal means and with the adjacent ends of a pair of end face seal strips, each said intermediate seal member being disposed radially inwardly of the outermost part of its associated apex portion and being movable in a direction parallel to the axis of the inner body and having an end-wall-engaging seal face.

22. A sealing arrangement as recited in claim 21 in which each apex grove has an enlarged bottom portion within which an associated intermediate seal member is received and each said intermediate seal member has a slot in its radially outer side within which the radially inner edge of the associated apex seal means is received.

23. A sealing arrangement as recited in claim 22 in which each end face sealing strip has a leg portion extending axially into the associated end face groove and has another portion extending laterally from the outer end of said leg portion and having said end-wall-engaging seal face.

24. A sealing arrangement as recited in claim 21 and including means on said inner body engageable with said end face seal strips to prevent movement of said seal strips along their respective grooves.

25. A sealing arrangement as claimed in claim 21 and in which end of each face seal strip overlaps a portion of the adjacent intermediate seal member for sealing engagement therewith.

26. A sealing arrangement for the variable volume chambers of a rotary mechanism comprising relatively rotatable elements including a hollow body having axially spaced end walls and an axially extending peripheral wall, a rotor mounted within said hollow body and having axially spaced end faces having continuous sealing cooperation with said end walls and a peripheral outer surface, said rotor having an axial extent less than the distance between said end walls, the inner surface of said peripheral wall and said peripheral outer surface having cooperatively shaped facing surfaces to generate a plurality of said variable volume working chambers upon relative rotation of said elements, said facing surfaces including a plurality of apex means on said rotor spaced circumferentially about the axis thereof and having continuous sealing cooperation with said peripheral wall, said sealing arrangement comprising an edge seal means comprising an axially extendable radially movable seal including at least two cooperating members associated with each apex means, each apex means having a groove therein extending radially inwards from and axially along the periphery thereof, each groove accommodating said cooperating members, at least one end face of said rotor having axially extending grooving disposed inwardly of but adjacent said peripheral outer surface, segmental sealing sections extending between adjacent apex portions and accommodated in said grooving, an axially movable intermediate sealing body disposed in each groove, said segmental sections having ends in sealing contact with adjacent sealing bodies, end-wall-engaging sealing means interconnected with said segmental sections, each of said cooperating members of each edge seal means being in sealing engagement with the intermediate sealing body in the associated groove, and each intermediate sealing body and at least one of said at least two cooperating members having an end-wall-engaging seal face.

27. A sealing arrangement as claimed in claim 26 in which said end-wall-engaging sealing means is integrally interconnected with said segmental sealing sections.

28. A sealing arrangement as claimed in claim 26 in which said end-wall-engaging sealing means is integrally interconnected with said segmental sealing sections and said interconnected segmental sections and means are rectangular in cross section.

29. A sealing arrangement as claimed in claim 26, and in which the ratio of the area of the end-wall-engaging seal surface of said end-wall-engaging sealing means to the area of said sealing means subjected to pressure from within said chambers is between 2 and 1.

30. A sealing arrangement as claimed in claim 26 including end-wall-engaging sealing means having a cut-out therein adjacent each apex portion, said end of the rotor having an axial projection disposed in each cut-out.

31. A sealing arrangement as claimed in claim 26 in which said end-wall-engaging sealing means has a cut-out in the periphery accommodating said intermediate sealing body, said end-wall-engaging sealing means also having a cut-out disposed on each side of said intermediate sealing body in alignment with said axially extending grooving and the ends of said segmental sections having an axially widened portion disposed in said last-mentioned cut-outs and having an end face sealing against said end wall.

32. A sealing arrangement for the working chambers of a rotary mechanism including an outer body having axially-spaced end walls and a peripheral wall interconnecting said end walls to form a cavity therebetween; and an inner body received within said cavity and having axially-spaced end faces disposed adjacent to and having continuous sealing cooperation with said end walls and also having a plurality of circumferentially-spaced apex portions, each extending from one end face to the other and having continuous sealing cooperation with the inner surface of said peripheral wall to form a plurality of work-

ing chambers between said inner body and peripheral wall which vary upon relative rotation of said inner and outer bodies; said sealing arrangement comprising apex seal means carried by said inner body at each of its said apex portions with said apex seal means having radially movable edge seal portions with peripheral-wall-engaging seal faces along their radially outer edges and also having end wall seal portions with end-wall-engaging seal faces; end face sealing means carried by said inner body at an end face thereof and including axially movable means having end-wall-engaging seal faces; and a plurality of axially-movable intermediate sealing bodies carried by said inner body at said last-mentioned end face thereof, there being one such intermediate sealing body at each apex portion of said inner body, each said intermediate sealing body being disposed radially inwardly of the radially outermost part of its associated apex portion and having sealing cooperation with the adjacent apex seal means and with the adjacent portions of said end face sealing means, and said apex seal means, said end face sealing means and the intermediate sealing bodies providing a continuous seal engagement between said inner and outer bodies to seal said working chambers from each other and from the surrounding atmosphere throughout relative movement of said inner and outer bodies.

33. A sealing arrangement as claimed in claim 32 in which the apex seal means and the end face sealing means are disposed in grooves in the inner body and the intermediate sealing body seals off communication between respective grooves.

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