Sept. 10, 1968 C. JONES 3,400,691

SEAL CONSTRUCTION FOR ROTARY COMBUSTION ENGINES

Filed July 21, 1966 3 Sheets-Sheet 1

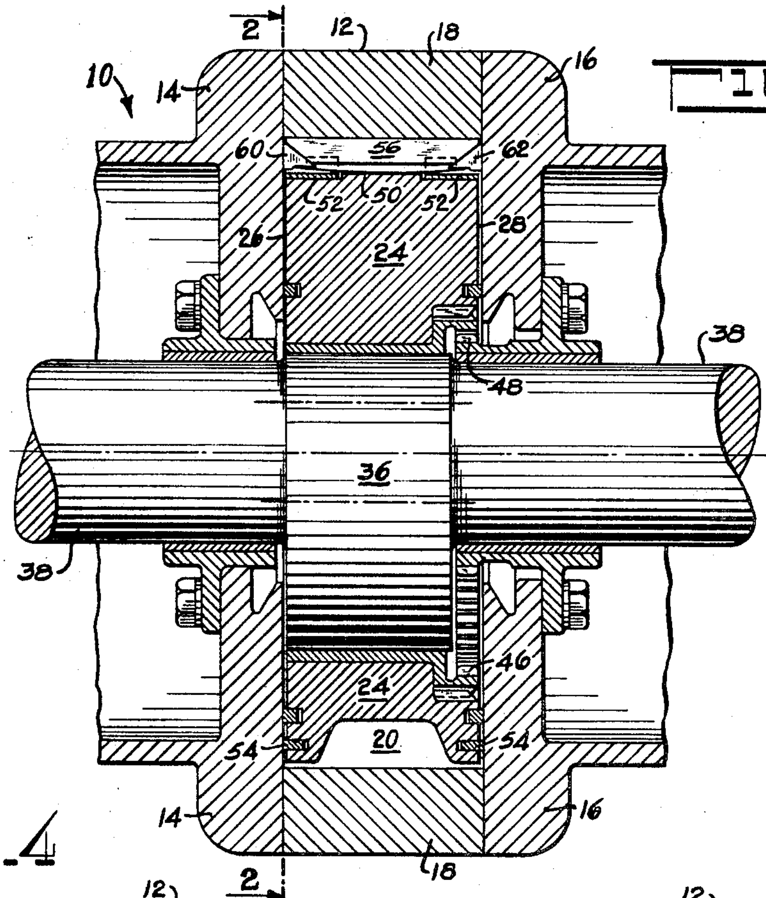
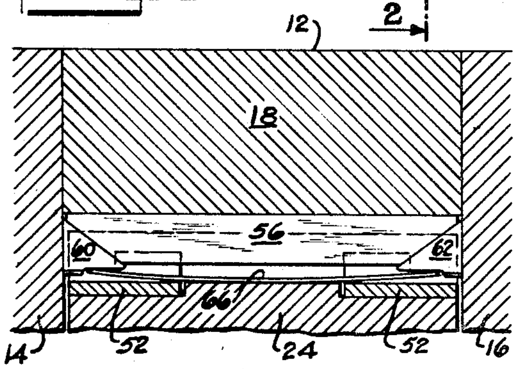


FIG. 1

FIG. 4



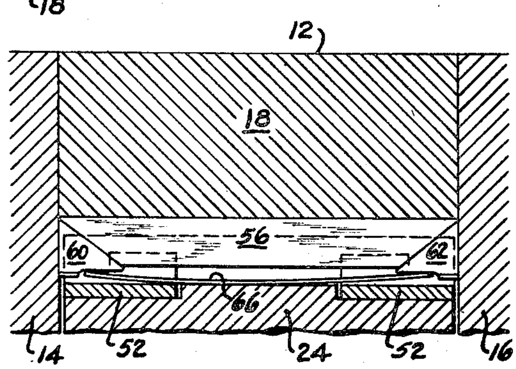


FIG. 5

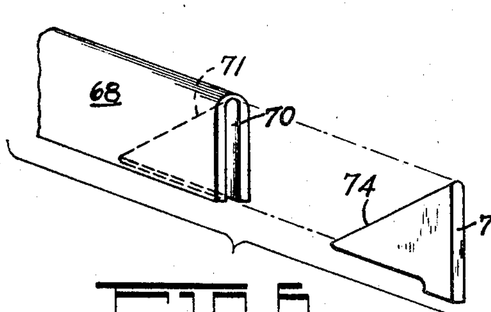


FIG. 6

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SEAL CONSTRUCTION FOR ROTARY COMBUSTION ENGINES

Filed July 21, 1966 3 Sheets-Sheet 2

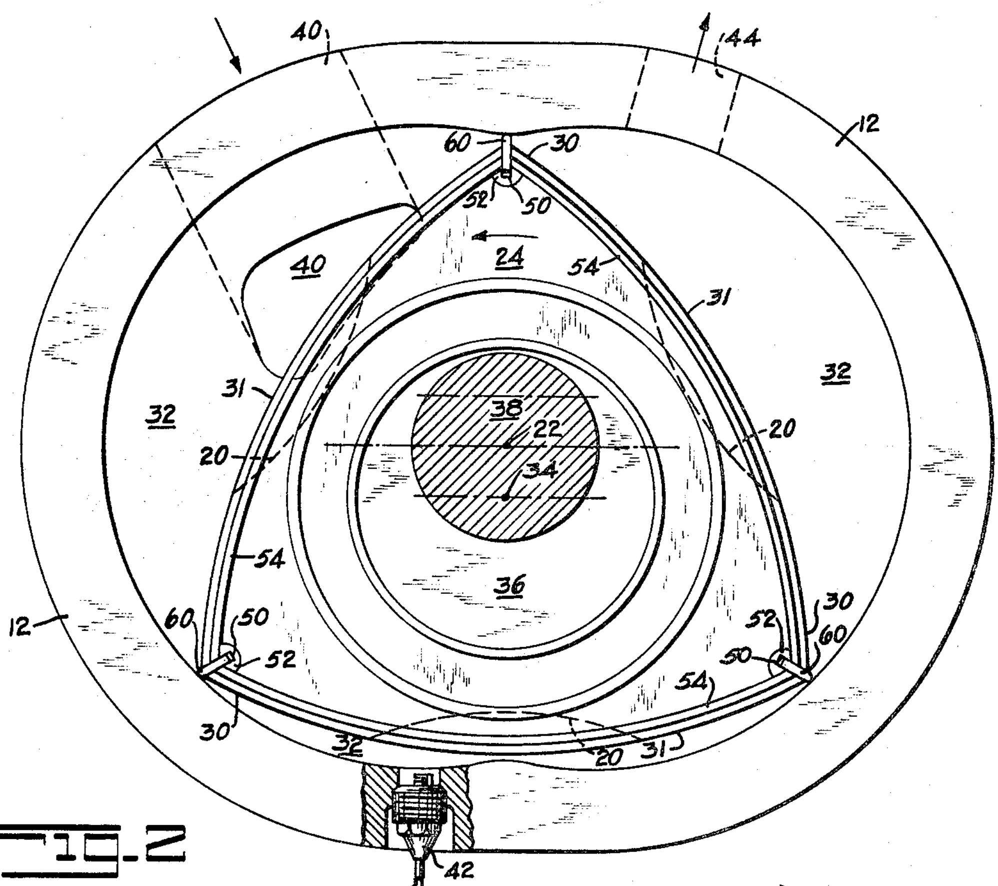

FIG. 2

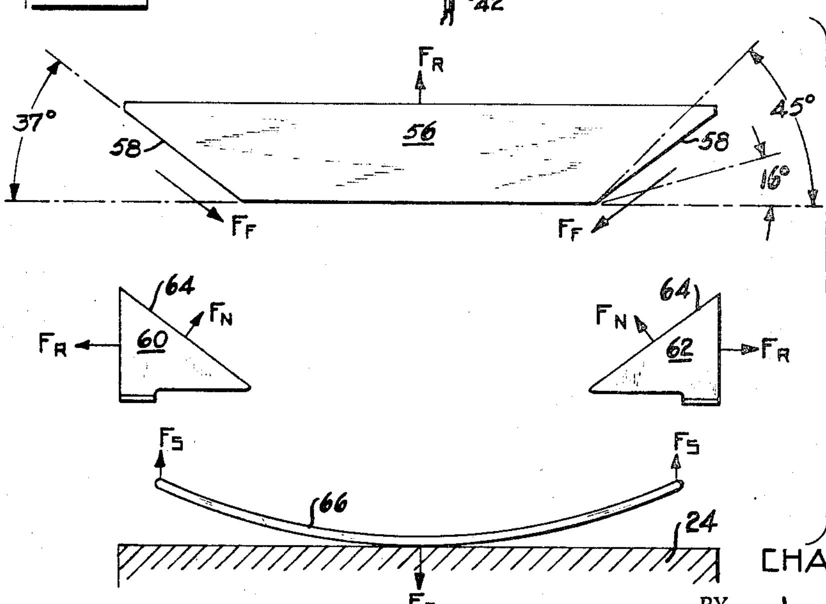

FIG. 3

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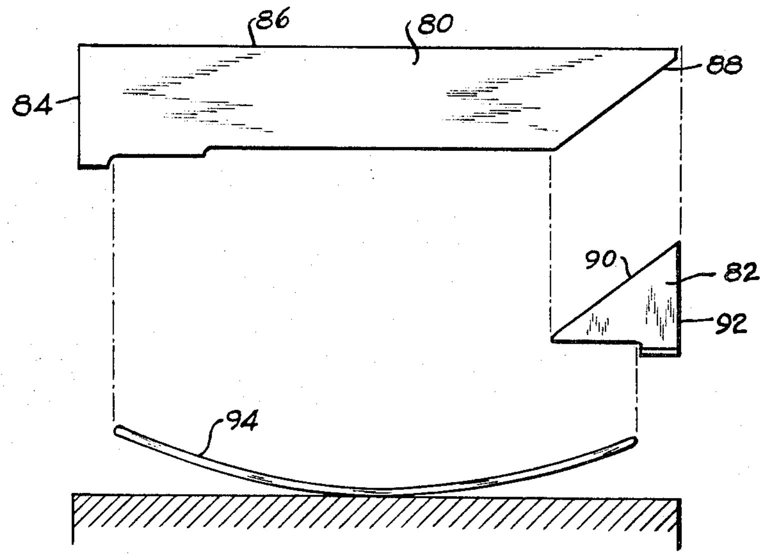

Fig. 7

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3,400,691
SEAL CONSTRUCTION FOR ROTARY COMBUSTION ENGINES

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Continuation-in-part of application Ser. No. 384,056, July 21, 1964. This application July 21, 1966, Ser. No. 575,481

9 Claims. (Cl. 123—8)

ABSTRACT OF THE DISCLOSURE

Rotor apex seal construction for rotary combustion engines, comprising at least a main seal piece and an end seal piece with cooperating inclined faces at the juncture of the main and end pieces, and a spring biasing the end piece substantially radially outwardly of the rotor.

This invention relates to rotary combustion engines and in particular is directed to a seal construction for such engines. This application is a continuation in part of applicant's prior application, Ser. No. 384,056 filed July 21, 1964, now abandoned.

The invention is specifically directed to a novel construction of an apex seal member which provides improved sealing efficiency for the working chambers of a rotary combustion engine. In engines of this type combustion takes place in the same region of the outer body which results in variations in the heat input around the periphery of said outer body. These variations in the heat input cause changes in the distance between the end walls of the rotary combustion engine around its periphery which therefore results in variations in the width of the working chambers. In order to effectively seal the working chambers of the rotary combustion engine, a seal means must be provided which can change its dimensions to compensate for the variations in the dimensions in the associated working chamber caused by the temperature differences in the outer body.

While many seal constructions perform satisfactorily during high speed operation, it has been found that during slow speed operation, such as in the idling speed range, or upon starting the engine, particularly when the engine is cold, most of the prior type seal constructions for rotary combustion engines are relatively inefficient and operation of the engine during starting and idling is not always satisfactory. The present invention provides a seal construction which functions to provide more efficient sealing of the working chambers particularly during starting and slow speed operation.

The sealing means of the invention generally comprises a multi-piece apex seal means including a main seal piece having at least one end face inclined from its base toward an associated rotor end face and an end seal piece at the end of the apex seal piece having the inclined end face which end seal piece has an inclined face for mating engagement with the inclined end face of the main seal piece. One form of the invention comprises a three-piece apex seal means in which the main apex seal piece has an inclined end face at each end thereof with a mating end seal piece in sliding engagement therewith. A single-lobed spring means is provided which bears against the bottom groove wall of the rotor which receives the apex seal means and bears against the end seal pieces so that a substantially equal spring force is provided through each end seal piece which force is transmitted through said end pieces to the main seal piece for urging said main seal piece into sealing engagement with the inner surface of the peripheral wall of the outer body. At the same time, the spring force also urges the end pieces to slide along the planes including the inclined end faces of the main seal piece for urging said end seal pieces into sealing engagement with the inner faces of the end walls of the outer body. As will be explained hereinafter, the relationship between the inclined faces of the end seal pieces and the main seal piece as well as the application of the spring force is important for insuring sealing contact between the main seal piece with the inner surface of the peripheral wall and the end seal pieces with the end faces of the end walls as well as insuring sealing contact between the main and end seal pieces, even when the heat input to the housing causes the distance between the end walls to vary. In other words, the seal means of the invention comprises an apex seal construction which is variable in axial width so that the seal means compensates for variations in the dimensions of the working chamber to provide an effective seal means therefor even during starting and low speed operation when compression leakage in the working chambers must be kept to a minimum. It has also been found that the engagement between the main seal piece and the end seal piece serves as a friction damping means for preventing excessive radial movement of the main seal piece and thus aids in reducing seal chatter.

In lieu of the aforesaid three-piece apex seal means, a two-piece apex seal means is now preferred in which only one end of the main apex seal piece has an inclined face for sliding sealing engagement with an end seal piece. As compared to the three-piece apex seal means, such a two-piece apex seal means has numerous advantages. Thus the two-piece apex seal results in less leakage, is more rugged and therefore is less susceptible to breakage, is less expensive and is easier to assemble. What is more significant however is that the two-piece seal appears to have improved dynamic characteristics probably because of the greater frictional resistance to movement of the main seal piece as compared to the frictional resistance to movement of the relatively small end piece. These advantages of the two-piece arrangement have proved to be sufficiently great that it is utilized in all current engine designs of the assignee of this application.

Accordingly, it is one object of the invention to provide a novel and improved multi-piece seal construction for a rotary combustion engine.

Another object of the invention is to provide a novel and improved variable dimension apex seal means for the rotor of a rotary combustion engine.

It is an additional object of the invention to provide a seal means for the working chambers of a rotary combustion engine which seal means provides efficient sealing for the working chambers of the rotary combustion engine for all speed ranges of operation of said rotary combustion engine.

It is still another object of the invention to provide a novel and improved seal means for the working chambers of a rotary combustion engine which seal means is of a multi-part construction and which is capable of varying its axial dimensions to provide effective sealing even for variations in the width of the working chambers of said rotary combustion engine.

It is a further object of the invention to provide a novel and improved multi-piece apex seal construction for a rotary combustion engine wherein the coaction between the elements of said multi-piece seal construction provides efficient sealing of the working chambers of said engine and also provides a friction damping for preventing excessive radial movement of said apex seal construction to minimize seal chattering.

It is still a further object of the invention to provide a novel and improved seal means wherein a spring force is provided for urging the seal means into sealing engagement with the inner surface of the peripheral wall of the housing of said rotary combustion engine and for urging said seal means into sealing engagement with the end faces of the end walls of said housing and wherein said seal means comprises a multi-piece construction which pieces have an angular relationship which serves to control the distribution of the spring force between the pieces of said multi-piece construction.

Other objects and advantages of the invention will become apparent upon reading the following detailed description with the accompanying drawings in which:

FIG. 1 is an axial-sectional view of a rotary combustion engine embodying the invention;

FIG. 2 is a sectional view taken along line 2—2 of FIG. 1;

FIG. 3 is an exploded view of the multi-piece seal construction of the invention and illustrating the forces acting between the pieces of said multi-unit construction;

FIG. 4 is a partial sectional view of a rotary combustion engine showing the multi-piece seal construction with the end pieces in one of its variable positions during operation of the rotary combustion engine;

FIG. 5 is a partial sectional view showing the multi-piece seal construction in another of its variable positions during operation of said rotary combustion engine;

FIG. 6 is a perspective view of a portion of a seal construction illustrating another embodiment of the invention; and

FIG. 7 is a view similar to FIG. 3 illustrating a preferred embodiment of the invention.

Referring to the drawings, a rotary internal combustion engine is generally indicated by reference numeral **10**. The engine **10** comprises an outer body **12** having axially-spaced end walls **14** and **16** and a peripheral wall **18** interconnected to form therebetween a cavity **20**. As viewed in FIG. 2, the cavity has a shape which is preferably a multi-lobed shape which may be defined as being basically an epitrochoid. In the specific embodiment illustrated, the cavity has two lobes although the engine is not limited to this specific number.

An inner body or rotor **24** is disposed within the cavity **20** of the outer body **12** with said rotor **24** having axially-spaced end faces **26** and **28** disposed adjacent to the outer body end walls **14** and **16**. The rotor **24** is further provided with a plurality of circumferentially-spaced apex portions **30** which are one more in number than the number of lobes of said cavity **20**. As illustrated, the rotor **24** has three apex portions **30** and the periphery of the rotor has a generally triangular profile. The apex portions **30** are in sealing engagement with the inner surface of the peripheral wall **18** to form a plurality of working chambers **32** between the inner rotor **24** and the outer body **12**, there being three such working chambers **32** illustrated. Each working chamber **32** includes a working face **31** formed between the apex portions **30** of the rotor **24** with each said face forming a substantial part of the combustion space during combustion in said chamber. As further illustrated, the axis **34** of the rotor **24** is offset from and disposed parallel to the axis **22** of the outer body.

In the engine **10** illustrated, the outer body **12** is stationary while the inner rotor **24** is journaled on an eccentric portion **36** of the shaft **38**, said shaft being co-axial with that of the cavity **20** of said outer body. Upon rotation of the inner rotor **24** relative to the outer body **12** the working chambers **32** vary in volume. An intake port **40** is provided in one or both end walls **14** and **16** or in the peripheral wall **18** for admitting air and fuel into the working chambers, a spark plug **42** is provided for igniting the combustible mixture and an exhaust port **44** is provided in the peripheral wall for discharge of the exhaust gases from the working chambers **32**. During engine operation the working chambers **32** have a cycle of operation including the four phases of intake, compression, expansion and exhaust, said phases being similar to

the strokes in a reciprocating-type internal combustion engine having a four-stroke cycle. In order to maintain the relative motion of the rotor **24** relative to the stationary outer body an internal gear **46** is, as illustrated, co-axially secured to the rotor **24** and is disposed in mesh with a fixed gear **48** secured to the outer body, said fixed gear being co-axial with the shaft **38**. It should be understood however, that the outer body **12** as well as the inner body **24** may rotate instead of, as in the embodiment illustrated, only one of said bodies rotating.

As generally explained above, combustion always takes place adjacent one region of the outer body so that this region has a substantially high heat input compared to, for example, the region adjacent the intake port **40**. It will be apparent therefore, that the heat input varies around the periphery of the engine so that there will be a differentiation in the expansion of the engine outer body around its periphery. For this reason, the distance between the end walls, which defines a portion of the working chambers **32**, will vary during engine operation. It is desirable in this case to provide a seal means which may vary its dimensions so that for differences in the dimensions of the working chambers during operation effective sealing will always be provided. This is particularly true during engine starting and at idling or low speed conditions since loss of compression at these times will cause difficulty in starting or roughness in idling. At high speed operation, it has been found that the effectiveness of the sealing between the working chambers **32** is not as critical since the rotor is rotating at substantially higher speeds and therefore there will only be a slight loss of compression during this time due to the time element of the working chambers passing through the cycles of operation. It is during starting of the engine and at low speed operation that other seal means, such as a one piece seal construction, do not provide satisfactory operation because they are not variable in dimension for compensating for the differences in working chamber dimensions during operation. The leakage past the seals is more significant at low speed operation because there is more time, relative to any given phase of the cycle of operation, for the gas, which is being compressed, to leak through a given sized opening. Any such losses during compression result in a loss of available energy. During the compression phase of the working cycle such losses lower the effective compression ratio and volumetric efficiency. During the power or expansion phase these losses reduce the pressure level and thus reduce output work and, in addition, by leaking back into the succeeding compression chamber, the charge in said chamber is diluted with products of combustion which adversely affects engine economy and operation. Tests have indicated that a substantial amount of work of turning the engine over at low speeds is due to the lost work caused by seal leakage. The structure of the present invention minimizes leakage between the working chambers and thus minimizes losses in available energy so that starting at lower cranking speeds is possible and low speed operation is substantially improved.

In the construction of the present invention, the working chambers **32** are sealed by providing a novel apex seal construction, which will be explained in greater detail hereinafter, in a groove **50** formed in each apex portion **30** of the rotor **24** with said apex seal means running from one end face **26** to the other end face **28** of the rotor in a direction parallel to the rotor axis. The apex seal means in each apex portion **30** of the rotor seals the working chambers in the circumferential direction between the respective apex portions **30** and cooperates with an intermediate seal means **52** and side face seal means **54** to complete the sealing of each working chamber **32** between the inner surface of the peripheral wall and the end walls of the outer body. No invention is alleged in the particular construction of the intermediate seal structures **52** and the side face seal means **54** and their related cooperation with the apex seal means and reference may be made, for example, to U.S. Patent 3,033,180 issued to Max Bentele on May 8, 1962, for a more detailed description of the intermediate and side face seal means.

The apex seal means, to which the present invention is directed, comprises a main seal piece 56 which extends from one end face of one end wall of the outer body 12 to the end face of the opposite end wall at the narrowest spacing between said end walls and is disposed so as to be in sealing engagement with the inner surface of the peripheral wall 18. As illustrated in FIGS. 3–5, the main seal piece preferably has inclined end faces 58, which as shown in particular in FIG. 3, are inclined to the engine axis in a direction toward an associated rotor end face and which pass substantially through each radially outward corner of the main seal piece 56. In order not to have sharp edges at the seal corners of the main seal piece 56 and to increase the structural strength of the seal construction the angular end faces 58 pass slightly below the radially outward corners of the main seal piece 56 so that the end faces are slightly squared off, as shown in FIGS. 3, 4 and 5. It should be understood however, that this feature has been exaggerated in said figures for ease and clarity of illustration and that the faces 58 preferably pass as close to the corners as possible while still providing a surface which will not have unduly poor wearing qualities. A pair of end seal pieces 60 and 62 are disposed in the seal grooves 50 for sealing engagement with the main seal piece 56 and the end faces of the end walls 14 and 16. The end seal pieces 60 and 62 have inclined faces 64 which are cut so as to mate with the inclined end faces 58 and 64 of the main seal piece so that the end seal pieces 60 and 62 may slide along said inclined end faces 58 in order to vary the width of the apex seal means. As can be seen in FIGS. 4 and 5, the main seal piece 56 and the end seal pieces 60 and 62 have a substantial portion extending radially outwardly beyond the rotor 24 or in other words these seal pieces project radially outwardly beyond the seal groove 50. It is therefore necessary to insure that sealing contact is maintained between the main seal piece 56 and the end seal pieces 60 and 62 as well as between the seal pieces and the outer body since a portion of the mating surfaces of the respective seal pieces also projects beyond the seal groove 50. It will be apparent that, if these seal pieces are not maintained in sealing engagement, a substantial amount of leakage at the mating surfaces will occur.

A single-lobed curved leaf spring 66 is provided which spring is disposed so as to provide a spring force against the bottom or radially inward side of each of the end pieces 60 and 62, respectively, with the bottom portion thereof bearing against the bottom of the groove 50. It is important to the invention that the major force provided by the spring means passes through the end pieces 60 and 62 and not also directly through the main seal piece 56 so that the greatest radial spring force provided for the main seal piece 56 must pass through said end seal pieces 60 and 62. This insures that there will be sealing engagement between the inclined end faces 58 of the main seal piece 56 and the inclined faces 64 of the end seal pieces 60 and 62 even during relative movement between said pieces.

In order to maintain substantially equal linear intensity of sealing pressure on both the end walls and inner surface of the peripheral wall and to provide for relative movement between the main seal piece 56 and the end seal pieces 60 and 62, the slope angle of the plane including the mating surfaces 58 and 64 of the seal pieces must be controlled in order to insure proper distribution of the spring force between the main and side seal pieces. Referring to FIG. 3, there is shown therein the forces acting on the respective seal pieces and the relationship of the slope of the plane including the mating surfaces 64 and 58. It should be understood however, that other forces are also present which act on the seal pieces, such as for example the friction force between the spring 66 and the seal pieces 60 and 62, and the friction force between the inner faces of the end walls 14 and 16 and the associated side faces of the seal pieces 60 and 62. Also, due to varying housing widths and radial motion caused by bearing clearances, thermal distortions, machining tolerances, etc. the seal movement will at times reverse which will cause a reversal of some of the forces illustrated in FIG. 3. The forces and their respective directions of action illustrated in FIG. 3 are shown only for purposes of explaining the determination of the slope angle of the plane including the mating surfaces 58 and 64 and the forces affecting the linear intensity of sealing pressure at the sealing surfaces between the seal elements and the housing. As illustrated in FIG. 3, it will be seen that the spring force provides a substantially radial force F_s at the base of the side seal pieces 60 and 62 which is transferred to the main seal piece 56 substantially as a normal force F_n at the mating surfaces 58 and 64. Resisting the relative movement of the main seal piece 56 and the side seal piece 60 and 62 is a friction force F_f with the resultant movement of the individual seal pieces being shown as a force F_r. With the specific seal configuration illustrated, in order to determine the proper slope angle of the plane including the mating surfaces 58 and 64 for insuring equal linear intensity of sealing pressure, it has been found that for materials having a maximum coefficient of friction of 0.15 the slope angle will vary from the horizontal, that is from the base of the seal piece 56 between the angles of substantially 16° to 45°. Preferably however, the materials are chosen so that the coefficient of friction ranges from 0.09 to 0.135 which therefore dictates a slope angle ranging between 30° and 40° and more specifically it is preferred to choose materials having an average coefficient of friction of 0.125 with a slope angle of 37°. By using the above values, it has been found that the sealing pressure expressed in pounds/inch of seal length is substantially equal at the sealing surfaces including those between the main seal piece and the inner surface of the peripheral wall and the end faces of the end walls and the side pieces 60 and 62. Since the single-lobed spring 66 bears solely against the side seal pieces 60 and 62, the main seal piece 56 will be urged into sealing engagement with the inner surface of the peripheral wall with a force which is directed through said side seal pieces and sealing engagement between said side seal pieces 60 and 62 at the mating surfaces 58 and 64 will always be maintained. Due to the cooperation of the single-lobed spring with the multi-piece construction of the invention, it is not necessary to use filling pieces or inserts between the mating surfaces of the seal pieces, such as that required in the multi-piece seal construction shown in U.S. Patent 3,064,880.

In FIG. 4 there is shown a partial sectional view of a rotary combustion engine embodying the seal construction of the invention with the seal construction being illustrated as passing through a heated portion of the outer housing. As can be seen therein, the main seal piece 56, which is constructed so as to be wide enough for mating engagement with the inner faces of the end walls 14 and 16 at the narrowest spacing therebetween, does not extend entirely across the width of said end walls at the heated portion of the outer housing. As explained above, this is due to the fact that the heat input in this region causes the rotor housing width to vary during engine operation. It will therefore be apparent that, if a one-piece seal construction were used in this situation, there would be a substantial loss of compression between the one-piece seal and the end walls 14 and 16 due to the increase in axial width of the housing relative to the apex seal. However, due to the fact that the present seal construction allows for a variation in the dimensions of the seal construction, there will be very little leakage between the working chambers. During rotation of the rotor, as the apex portion 30 of the rotor reaches a portion of the housing which is acted upon by a relatively high heat input, the spring **66** acting on the seal pieces **60** and **62** causes said seal pieces **60** and **62** to slide along the mating surfaces **58** and **64** to move said seal pieces axially outwardly to compensate for the increase in axial width of the spacing between said end walls **14** and **16**. At the same time, the spring **66** maintains the seal pieces **60** and **62** in tight mating engagement at the surfaces **58** and **64** so that no leakage will be present between the main seal piece **56** and the end seal pieces **60** and **62**. As also explained above, the spring force exerted through said seal pieces **60** and **62** passes through said seal pieces **60** and **62** to urge the main seal piece **56** into sealing engagement with the inner surface of the peripheral wall **18**. Thus, during starting of the engine, particularly when the engine is cold, or during low-speed operation, there will be little loss of compression between the working chambers.

In FIG. 5, which is a view similar to FIG. 4 but showing the rotor in a position with respect to the housing wherein the housing is relatively cool, it will be seen that the end seal pieces **60** and **62** have moved inwardly or toward each other along the mating surfaces **58** and **64** since in this position the width between the end walls **14** and **16** has not substantially increased due to the relatively low heat input in this area of the outer body. Since the mating plane between the seal pieces **56**, **60** and **62** passes substantially through the corners of the main seal piece **56**, which main seal piece **56** will now be in sealing engagement with the inner faces of the end walls **14** and **16**, there will be little, if any, blowby or loss of compression between the working chambers. Thus, it will be apparent that the seal construction of the invention will provide efficient sealing between the working chambers **32** of the rotary combustion engine of the invention and there will be little loss of compression or blowby between the working chambers because of the relative movement of the seal pieces **56**, **60** and **62** even during substantial relative axial movement of the end seal pieces **60** and **62**. It will be apparent that this would not be the case, if the mating plane did not pass substantially through the corners of the main seal piece **56** or if the axial width of the main seal piece **56** were not chosen as described. For example, if the mating planes pass substantially below the corners of the main seal piece **56** or through the side faces below the corners, when the end seal pieces **60** and **62** were caused to move to compensate for increased axial width of the working chambers there would be substantial spacing between the main seal piece and the end faces of the end walls **14** and **16** which would increase the loss of compression between the working chambers and would not serve to carry out the purpose of the invention.

With the construction of the present invention the cranking speed required for starting the engine has been substantially reduced and a substantial reduction in idling speeds has also been possible without accompanying roughness in engine performance at reduced speeds. It should also be noted, as stated above, that effective sealing is provided by the seal construction of the present invention without the use of additional shims or other construction for insuring that no leakage is present between the pieces **56**, **60** and **62** at their mating surfaces **58** and **64** which constructions were required in some other multipiece seal embodiments. The combination shown by the present invention of the main seal piece **56**, the end seal pieces **60** and **62** and the arrangement of the single-lobed spring **66** serves to provide a seal construction where effective sealing is always maintained at the inner surface of the peripheral wall **18** and the end faces of the end walls **14** and **16** as well as at the seal piece mating surfaces **58** and **64**. With the values of the coefficient of friction and the slope angles of the mating plane chosen as described above, it has also been found that the end seal pieces may be moved relatively freely for compensating for variations in the dimensions of the combustion chamber while at the same time maintaining effective sealing.

In FIG. 6 there is shown another embodiment of the invention which operates in the same manner as the embodiment described above. In the embodiment of FIG. 6 the main apex seal member **68** is provided with a cutout portion **70** which portion **70** is cut so as to have an inclined face **71** which is substantially identical to the inclined face **58** in the above described embodiment. An end seal piece **72** is provided with said end seal piece **72** being substantially identical to one of the end seal pieces **60** or **62** of the prior embodiment, which end seal piece **72** has an inclined face **74** for sliding engagement with the inclined face of the main seal piece **68**. It will be apparent that the inclined seal face **74** is constructed so it has to fit into the groove **70** in the main seal piece **68** with the inclined face **74** thereof being in sliding, mating engagement with the inclined end face **71** of said main seal piece **68**. With this construction, the main seal piece **68** provides a sheath-like cover over the end seal piece **72** which makes the composite structure more durable since the mating surfaces of the respective seal pieces are not as exposed, as in the previous embodiment, so that there will be less likelihood of breakage particularly at the corners and mating surfaces of their respective seal pieces. Thus, the structure of the embodiment in FIG. 6 may be used for more heavy duty applications and where increased structural strength of the seal structure is desired. It will be understood that the seal construction and embodiment of FIG. 6 operates in the same manner as the prior described embodiment.

FIG. 7 discloses a further embodiment of the invention in which a two-piece apex seal means replaces the three-piece apex seal means of the embodiments of FIGS. 1–5 and 6 in each rotor apex groove **50**. FIG. 7 is similar to FIG. 3 except that in FIG. 7 the apex seal means has only one end seal piece, the other end seal piece in effect being integral with the main seal piece.

With the arrangement of FIG. 7, each apex seal means has a two-piece construction comprising a main seal piece **80** (corresponding to the main seal piece **56** of FIG. 3) and only a single end seal piece **82** (corresponding to end seal piece **60** or **62** of FIG. 3). One end face **84** of the main seal piece **80** is disposed at right angles to the outer seal edge **86** of said main seal piece for sealing engagement with the adjacent end wall **14** or **16** and the other end of said main seal piece as an inclined face **88** which makes an acute angle with said outer edge **86**. The single end seal piece **82** of each said two-piece apex seal means has a shape which is generally that of a right triangle with its long face **90** slidingly and sealingly engaging the inclined face **88** of the associated main seal piece **80**. A second face **92** of said end seal piece **82** is disposed at right angles to the outer edge **86** of the main seal piece for sealing engagement with the other end wall **14** or **16**. A spring **94** (corresponding to the spring **66** of FIG. 3) is disposed under each two-piece apex seal means and comprises a single-lobed curved leaf-type spring having only its two ends contacting the apex seal means so that one end contacts and exerts a radially outward force on the single end seal piece **82** and the other end contacts and exerts a radially outward force on the end of the main seal piece **80** remote from the end seal piece **82**, the mid portion of the spring **94** bearing against the bottom of the rotor groove receiving said apex seal means.

Compared to the previously described three-piece apex seal construction, the two-piece apex seal means **80** and **82** obviously is simpler and therefore less expensive. Also, elimination of the acute corner at one end of each main apex seal piece **80** makes this piece more rugged and therefore less likely to break than the main apex seal **56** of FIG. 3. Furthermore, by in effect making one of the end seal pieces **60** to **62** integral with one end of the main seal piece, leakage across that end of each main seal piece, during engine operation, is reduced. What is even more important is that the two-piece apex seal means appears to have improved dynamic stability probably because of the greater frictional resistance to movement of the main seal piece **80** compared to the frictional resistance to movement of the relatively small end seal piece which is eliminated by the two-piece seal construction. Because of its advantages said two-piece apex seal means has replaced the three-piece seal arrangement in current rotary combustion engine designs of applicant's assignee.

While I have described my invention in detail in its preferred embodiment, it will be obvious to those skilled in the art, after understanding my invention, that various changes and modifications may be made therein without departing from the spirit or scope thereof. For example, the invention is not intended to be limited to a three-piece seal construction and the invention may be embodied in a two-piece construction with the main seal piece having only one sloping end face and only one end seal piece being provided. In such an embodiment it would of course be understood that the spring means would include means for insuring sufficient spring force to maintain the one end seal piece and the main seal piece in sealing engagement with each other. I aim in the appended claims to cover all such modifications.

I claim as my invention:

1. A sealing arrangement for the working chambers of a rotary combustion engine comprising an outer body having axially-spaced end walls interconnected with a peripheral wall to form a cavity therebetween; a rotor received within said cavity and having axially-spaced end faces adjacent to said end walls and a plurality of circumferentially-spaced apex portions for sealing engagement with the inner surface of said peripheral wall to form a plurality of working chambers between said rotor and said peripheral wall which upon relative rotation between said rotor and said outer body vary in volume; and means for igniting a combustible mixture in said working chambers adjacent one region of said outer body so that the heat input in said region causes variations in the size of said working chambers; said sealing arrangement comprising a multi-piece seal construction disposed in a groove in each apex portion of said rotor, said multi-piece seal construction including a main seal piece extending from one end face of said rotor to the other end face of said rotor and disposed in said rotor apex portion for sealing engagement with the inner surface of said peripheral wall, said main seal piece having an inclined face at each end thereof with each said inclined face inclining from the base of said main seal piece in a direction toward an associated rotor end face and passing substantially through its radially outward corner radially outwardly of the rotor, and said multi-piece seal construction further including an end piece disposed at each end of said main seal piece for sealing engagement with said end walls, and each said end piece having an inclined face disposed for sliding sealing engagement with the inclined end face of said main seal piece so that each said end piece is movable relative to said main seal piece along their engaged inclined faces; and spring means in engagement solely with said rotor and said end pieces for exerting a radial outward force against said main seal piece through said end pieces and for urging said end pieces to slide along said inclined faces relative to said main seal piece such that said multi-piece seal construction may increase its axial dimension with increases in the axial dimension of said working chambers.

2. A sealing arrangement as recited in claim **1** wherein said spring means comprises a single-lobed curved leaf spring disposed in each rotor apex groove with the lobe portion thereof bearing against the base of said groove and the ends thereof bearing against the base portion of each said end piece so that said single-lobed spring exerts a direct spring force only on the end pieces of said multi-piece seal construction.

3. A sealing arrangement as recited in claim **1** wherein said main seal piece has an inclined groove cut in each end thereof with one wall of each said groove forming said inclined faces of said main seal piece and each said end seal piece being disposed so that a substantial portion thereof lies within a groove in said main seal piece.

4. A sealing arrangement for the working chambers of a rotary combustion engine comprising an outer body having axially-spaced parallel end walls interconnected with a peripheral wall to form a cavity therebetween; a rotor received within said cavity and having axially-spaced end faces adjacent to said end walls and a plurality of circumferentially-spaced apex portions for engagement with the inner surface of said peripheral wall to form a plurality of working chambers between said rotor and said peripheral wall which upon relative rotation between said rotor and said outer body vary in volume; intake means in one region of said outer body for supplying air to said working chambers for combustion adjacent a second region of said outer body so that the heat input to said outer body varies between said first and second outer body regions and produces differences in the axial distance between said end walls; said sealing arrangement comprising a multi-piece seal construction including a first seal piece disposed in a groove in each apex portion of said rotor with at least the outer edge of said first seal piece extending substantially from one end face of the rotor to the other and at least one end of said first seal piece having an end face inclined to the outer edge of the first seal piece such that the width of the first seal piece between the radially inner portion of said end faces is less than that of said outer edge; at least one second seal piece also being disposed in a groove in each apex portion of said rotor for sealing engagement with an outer body end wall with said second seal piece having an inclined face disposed in sliding mating engagement with the inclined face of said first seal piece for permitting relative movement between said first and second seal pieces and said mating inclined surfaces of said seal pieces including a line which passes substantially through a radially outward corner of said radial first seal piece adjacent said one axial end thereof and radially outwardly of the rotor; and a single-lobed curved leaf-spring means for each said multi-piece seal construction and disposed so as to engage only the ends of said multi-piece seal construction so that one end thereof exerts a radially outward spring force through said second seal piece for urging said first and second seal pieces in a radial direction and for producing relative movement therebetween such that said multi-piece seal construction may vary its axial dimensions for differences in the axial distance between said outer body end walls while maintaining sealing contact between said first and second seal pieces of said multi-piece seal construction.

5. A sealing arrangement as recited in claim **4** wherein said main seal piece and said end seal pieces are composed of materials having a maximum coefficient of friction of 0.15 and said inclined end face has a slope substantially between the angles of 16° to 45°.

6. A sealing arrangement as recited in claim **5** wherein the coefficient of friction of said materials preferably averages 0.125 and said slope angle is 37°.

7. A sealing arrangement as recited in claim **4** wherein said first seal piece includes a groove formed in one end thereof with said one inclined face comprising one wall of said groove and said second seal piece being substantially disposed within said first seal piece groove so that said first seal piece forms a sheath around a substantial portion of said second seal piece.

8. A sealing arrangement for the working chambers of a rotary combustion engine comprising an outer body having axially-spaced parallel end walls interconnected with a peripheral wall to form a cavity therebetween; a rotor received within said cavity and having axially-spaced end faces adjacent to said end walls and a plurality of circumferentially-spaced apex portions for engagement with the inner surface of said peripheral wall to form a plurality of working chambers between said rotor and said peripheral wall which upon relative rotation between said rotor and said outer body vary in volume; intake means in one region of said outer body for supplying air to said working chambers for combustion adjacent a second region of said outer body so that the heat input to said outer body varies between said first and second outer body regions and produces differences in the axial distance between said end walls; said sealing arrangement comprising a two-piece seal means for each rotor apex portion with each two-piece apex seal means disposed in a rotor apex portion groove running from one rotor end face to the other, each said two-piece apex seal means comprising a main seal piece and a single end seal piece, each said main piece having an outer seal edge extending substantially from one outer body end wall to the other for sealing engagement with the outer body peripheral wall and having an end face at one end disposed at right angles to said outer seal edge for sealing engagement with the adjacent end wall of the outer body and also having an inclined end face at the other end, making an acute angle with said outer edge, the single end seal piece of

each two-piece seal means having a generally triangular shape with one face disposed in sliding engagement with the inclined end face of the associated main seal piece and with a second face disposed at right angles to the outer edge of said main seal piece for sealing engagement with the adjacent end wall of said outer body, and a single-lobed curved leaf spring for each two-piece seal means disposed in the rotor groove for said seal means between said seal means and bottom of said groove with the ends only of the leaf spring contacting the apex seal means such that one end contacts and exerts a radially outward force on said end seal piece and the other end contacts and exerts a radially outward force on the end of the main seal piece remote from said end seal piece.

9. A sealing arrangement as recited in claim **8** wherein the end seal piece of each two-piece apex seal means extends radially outwardly beyond the rotor.

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