United States Patent [19]

Takacs

[11] **3,791,352**

[45] **Feb. 12, 1974**

[54] ROTARY EXPANSIBLE CHAMBER DEVICE

[76] Inventor: **Andrew Takacs**, 99 Farm Road Cir., Brunswick, N.J. 08816

[22] Filed: **Oct. 25, 1972**

[21] Appl. No.: **300,652**

Related U.S. Application Data

[63] Continuation of Ser. No. 106,351, Jan. 14, 1971, abandoned, which is a continuation-in-part of Ser. No. 854,328, Aug. 28, 1969.

[52] **U.S. Cl.** **123/8.25,** 123/8.43, 418/208

[51] **Int. Cl.** **F02b 53/00**

[58] **Field of Search** 123/8.19, 8.23, 8.25, 8.27, 123/8.29, 8.31, 8.43; 418/196, 208

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Primary Examiner—Manuel A. Antonakas
Attorney, Agent, or Firm—Frederick W. Padden

[57] **ABSTRACT**

A rotary engine comprises a block, a plurality of longitudinally extending cylindrical chambers formed in the block, the longitudinal axes of which are in parallel spaced relation, a rotor disposed in each of the longitudinally extending chambers, each of the rotors having a peripheral surface in substantial surface-to-surface contact with the peripheral surface of at least one other of the rotors, intake and exhaust ports formed in the block for communicating the longitudinally extending chambers with sources of combustible materials and an exhaust system, the intake and exhaust ports of each chamber being covered and uncovered by the rotation of the rotor mounted in the respective chamber, means for interengaging the rotors to control the rotation of each relative to the others, ignition means, means for attaching at least one of the rotors to a means to be driven, and relieved portions formed on each of the rotors for cooperating with the longitudinally extending chambers to define working volumes which are displaceable from being in communication with the inlet ports to being in communication with the ignition means and thereafter to being in communication with the exhaust ports during each combustion cycle of the engine.

33 Claims, 25 Drawing Figures

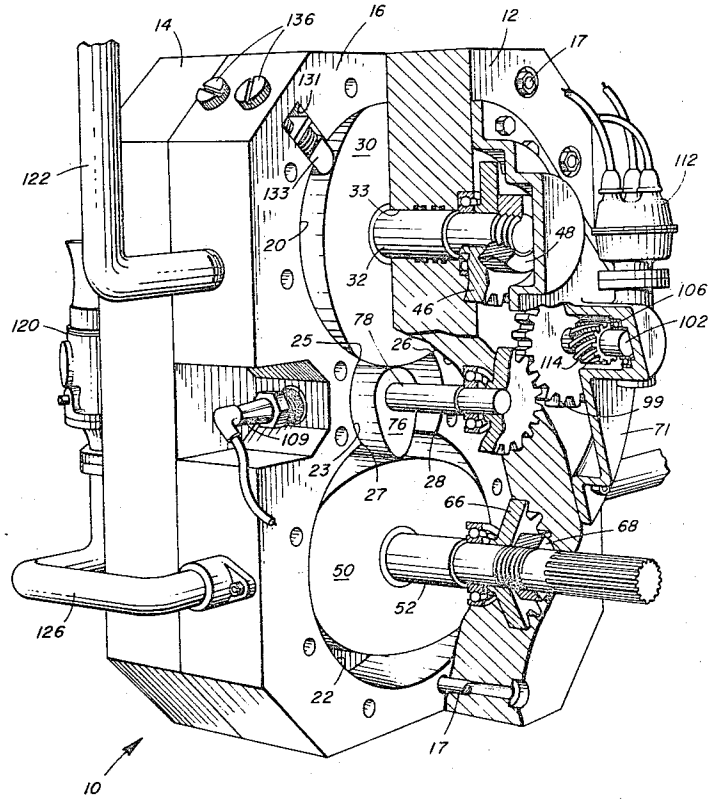
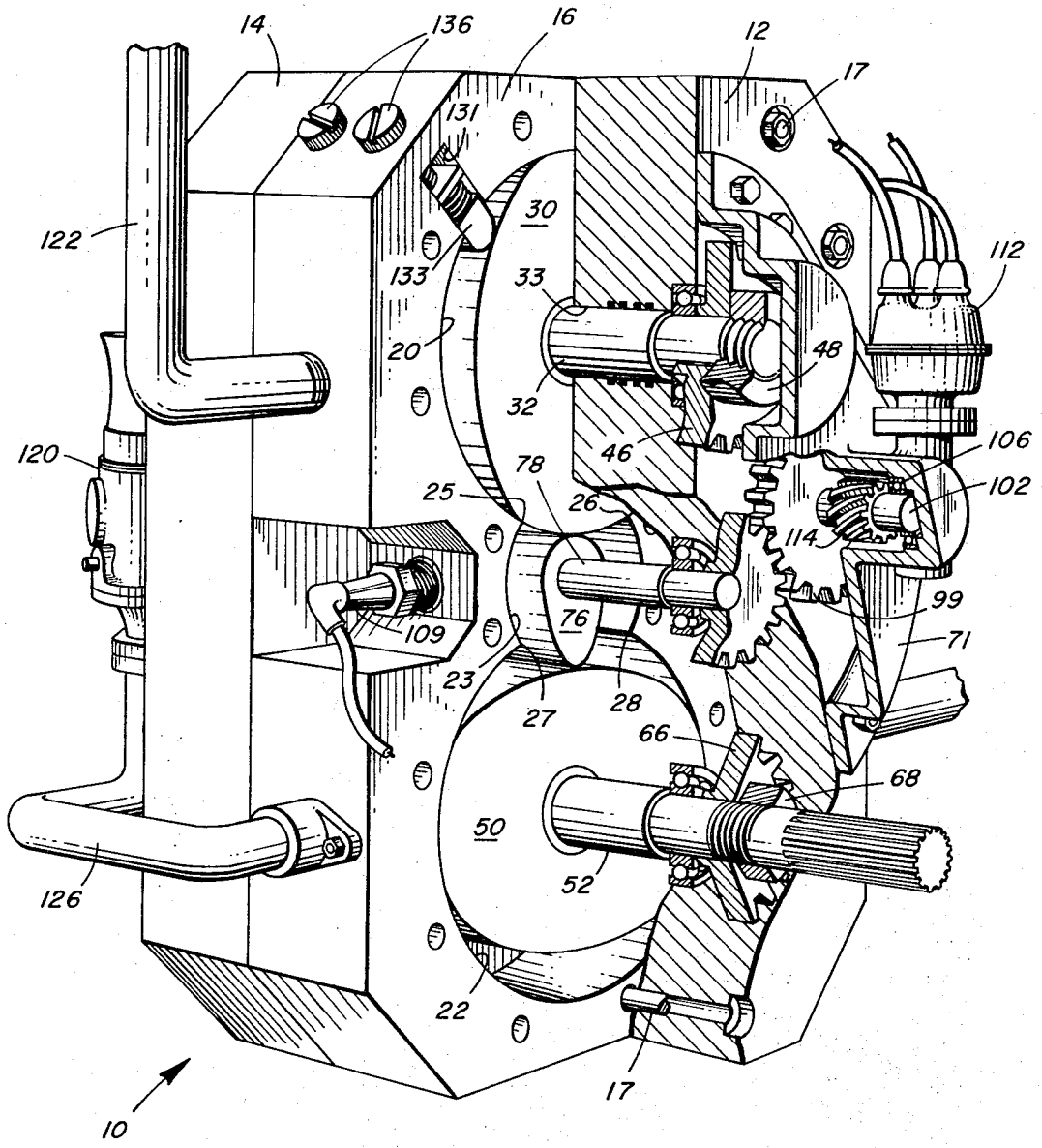


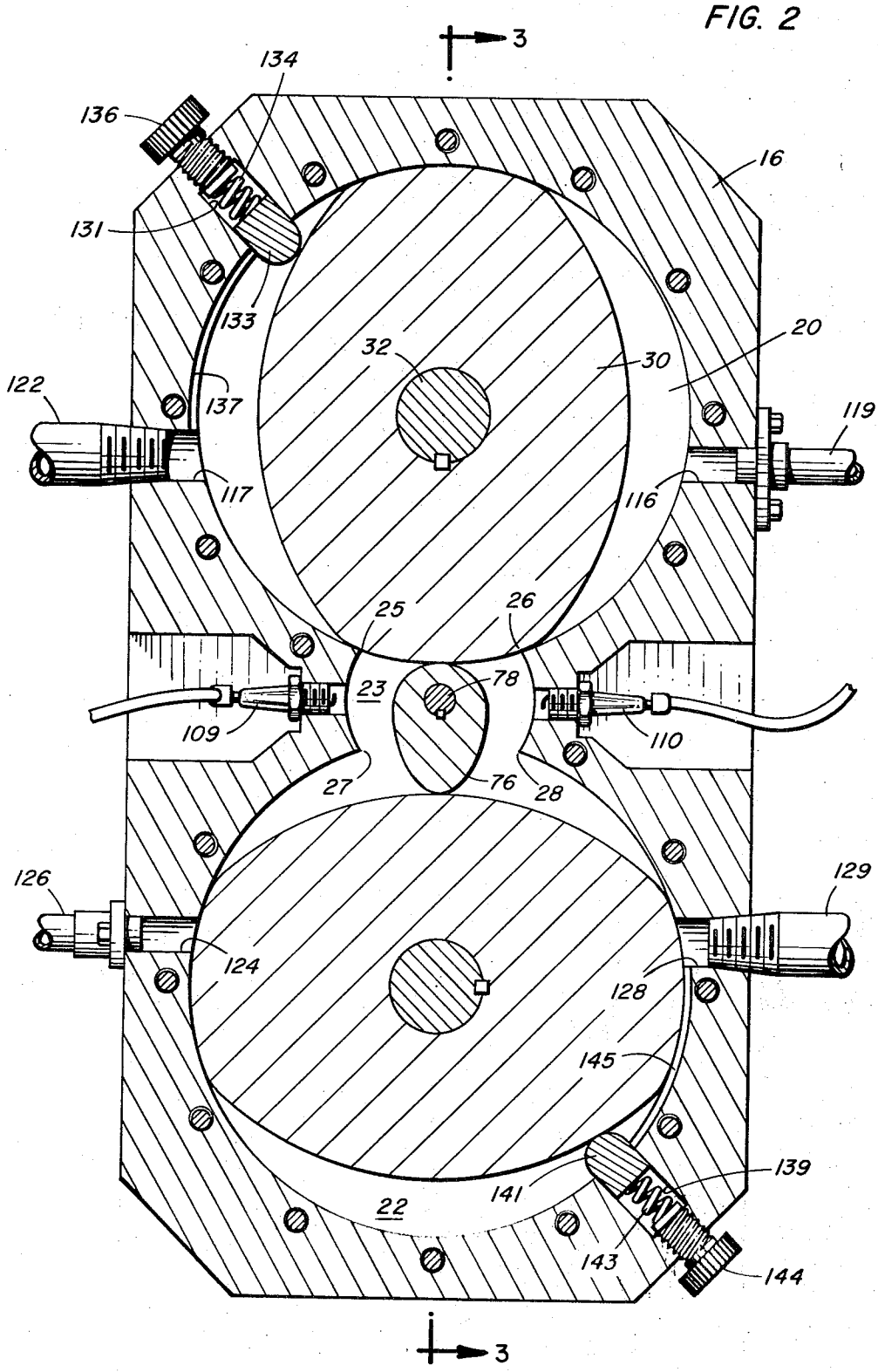
FIG. 1



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ANDREW TAKACS

BY Popper, Bain, Bobis & Gilfillan
ATTORNEYS

FIG. 2


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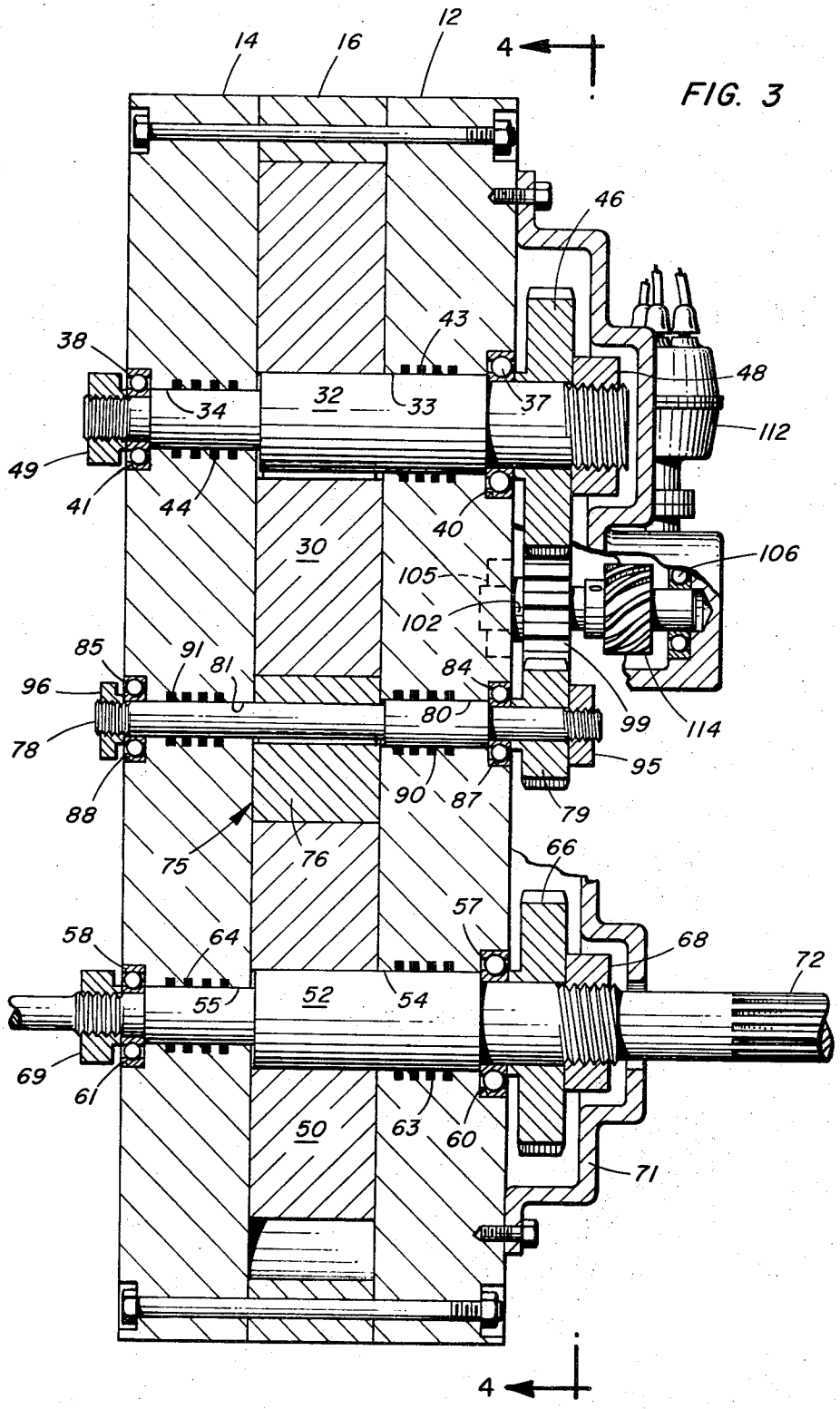

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FIG. 3

FIG. 4

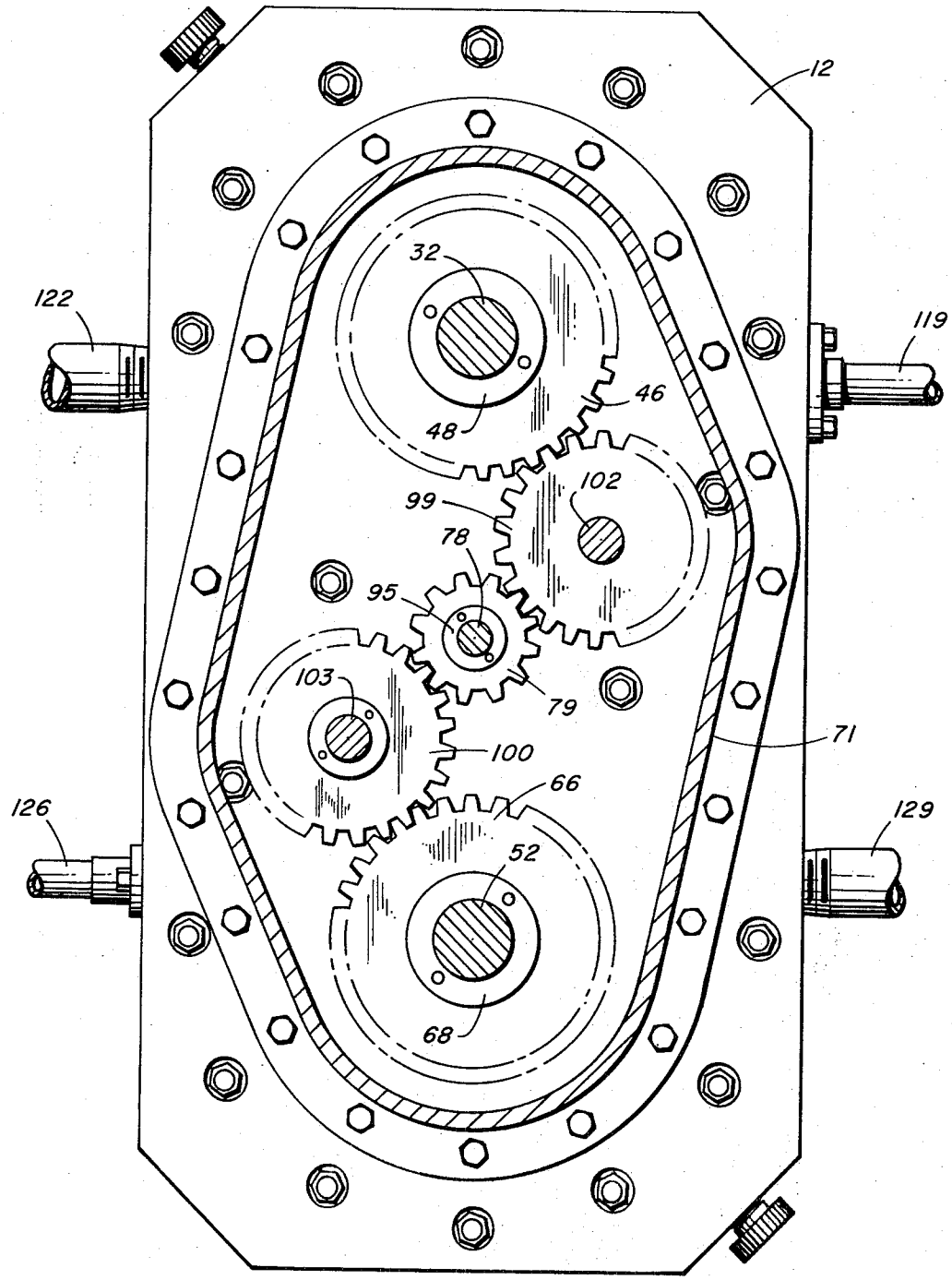


FIG. 5

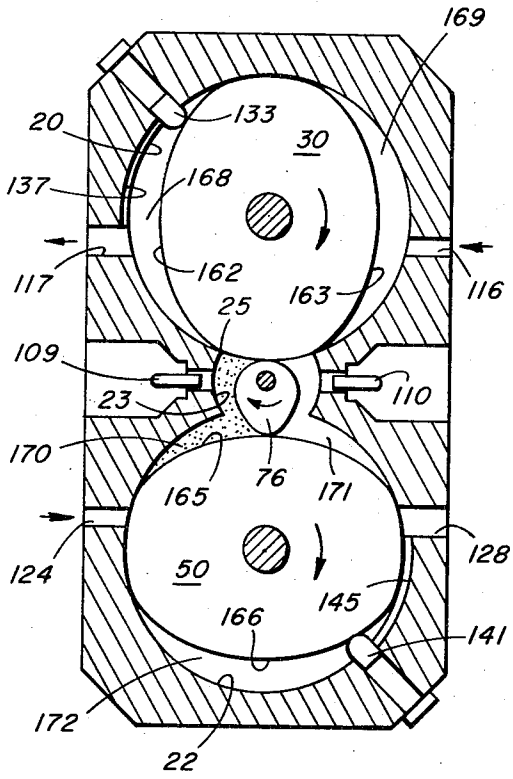


FIG. 6

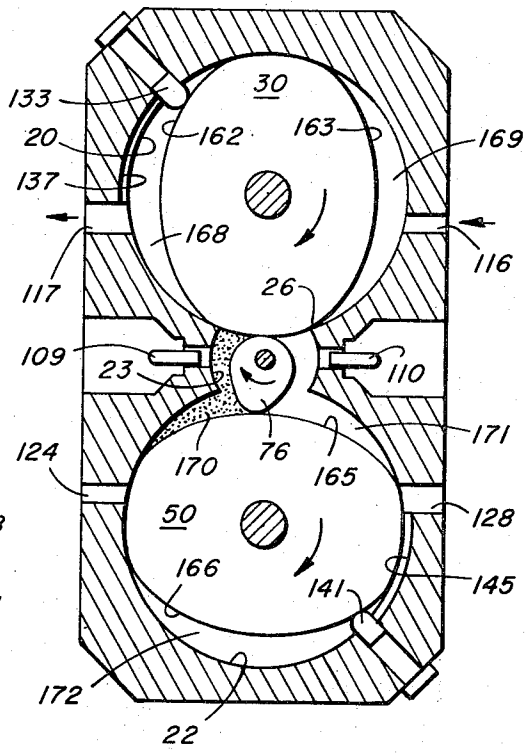


FIG. 7

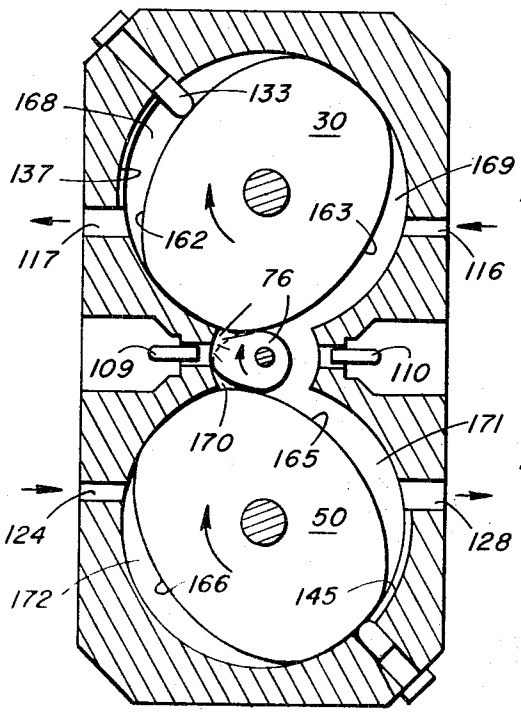


FIG. 8

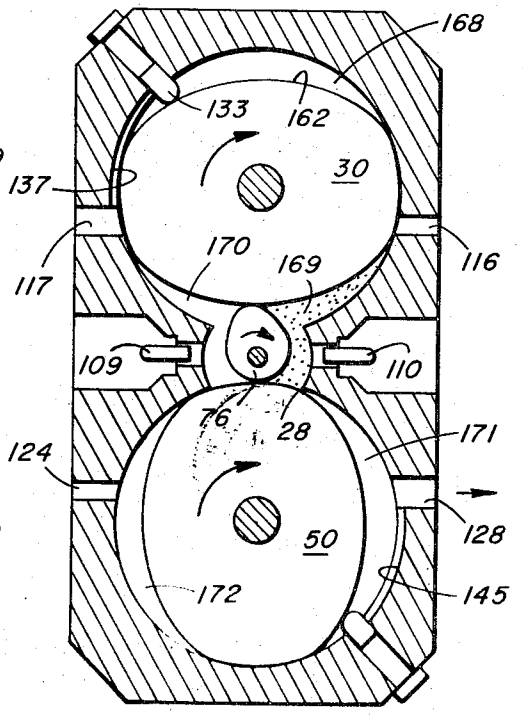


FIG. 9

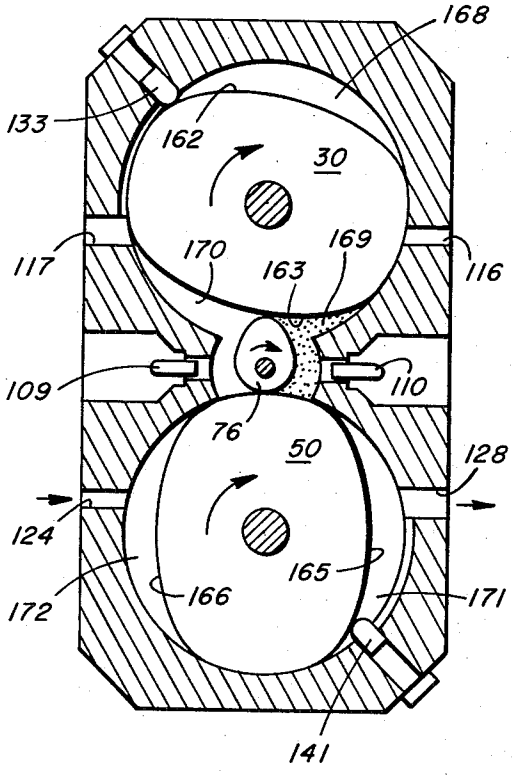

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FIG. 10

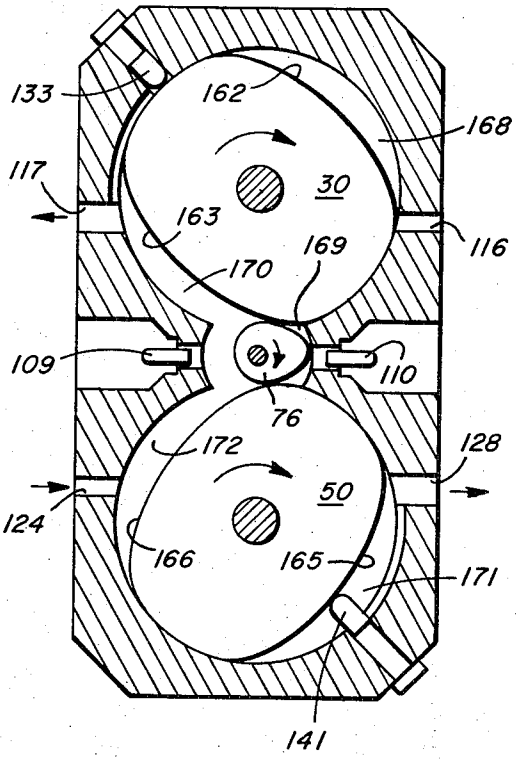

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FIG. 11

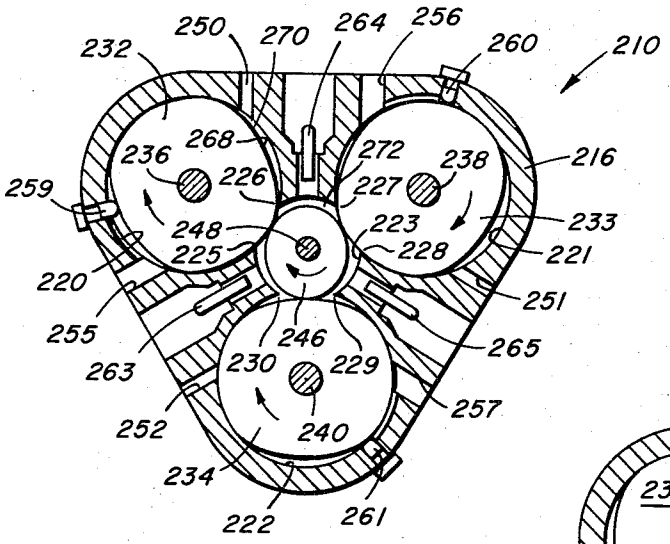


FIG. 12

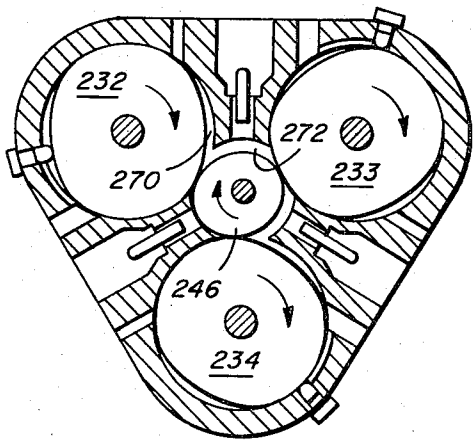


FIG. 13

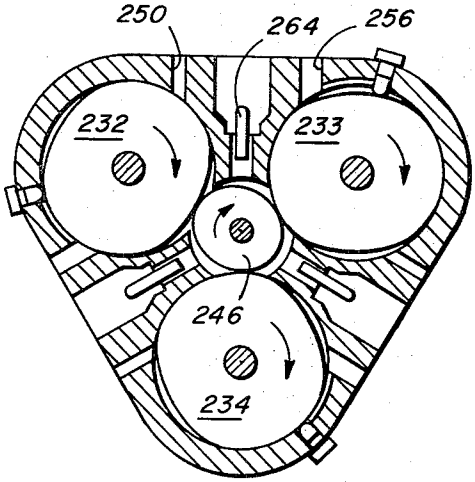


FIG. 14

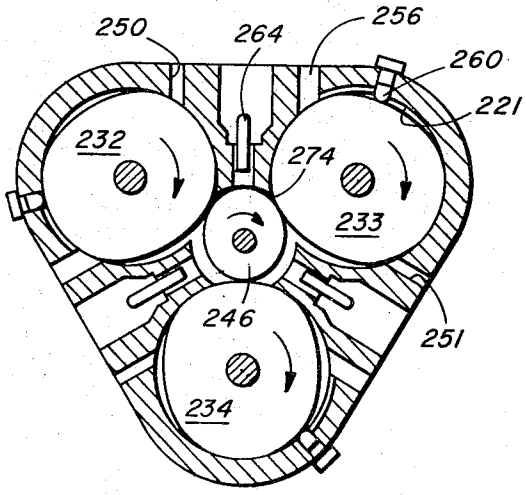


FIG. 15

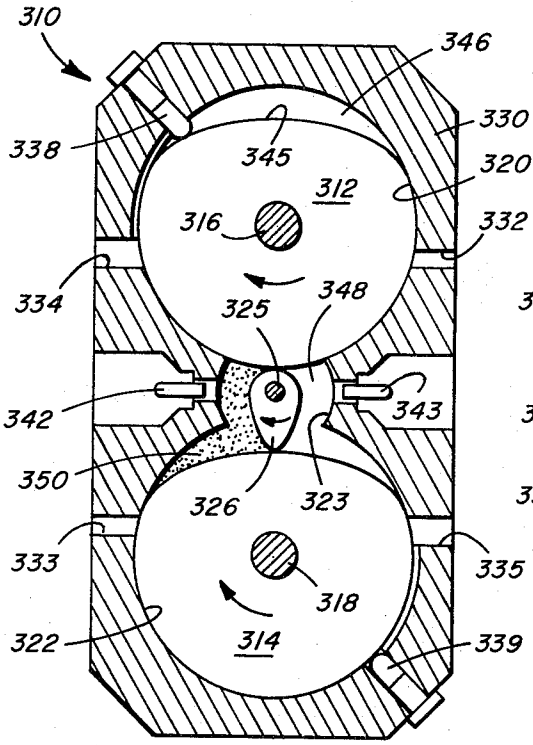


FIG. 16

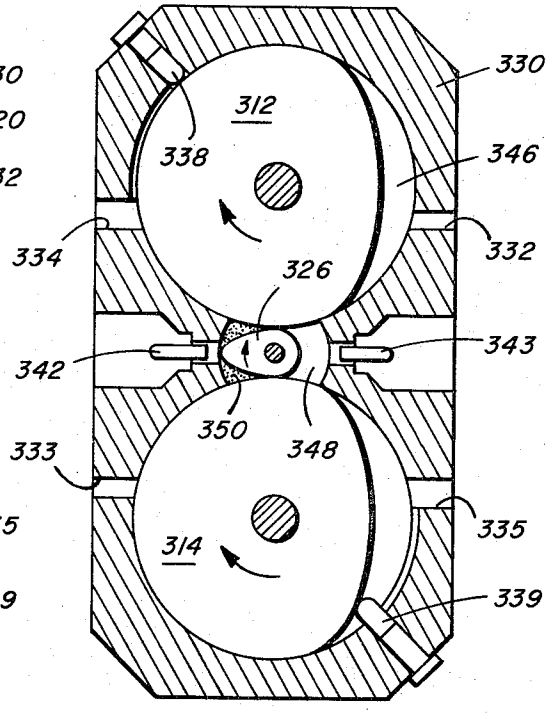


FIG. 17

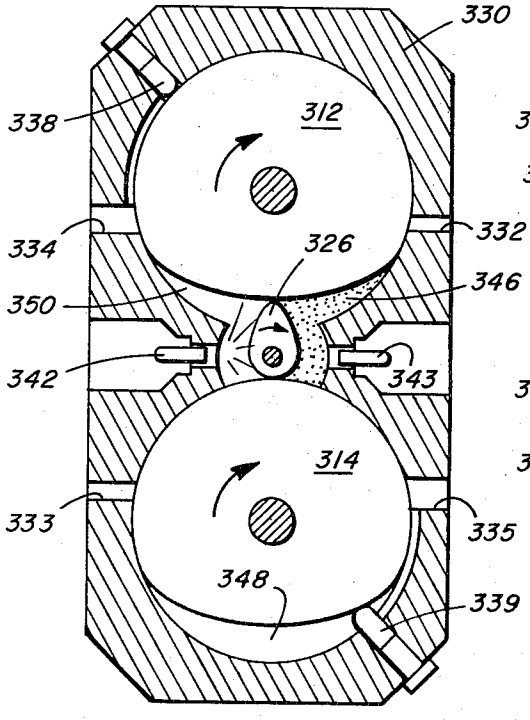


FIG. 18

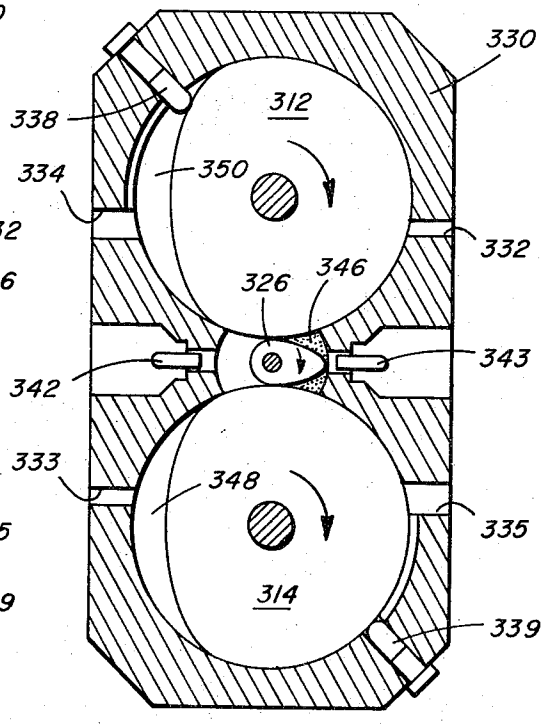


FIG. 19

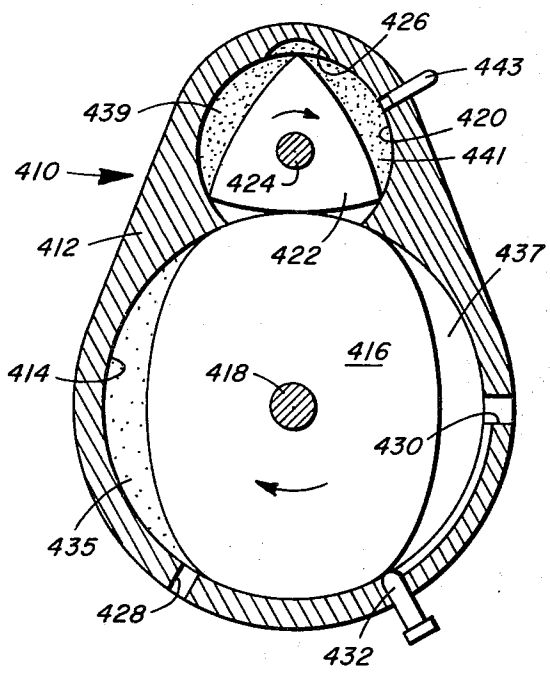


FIG. 20

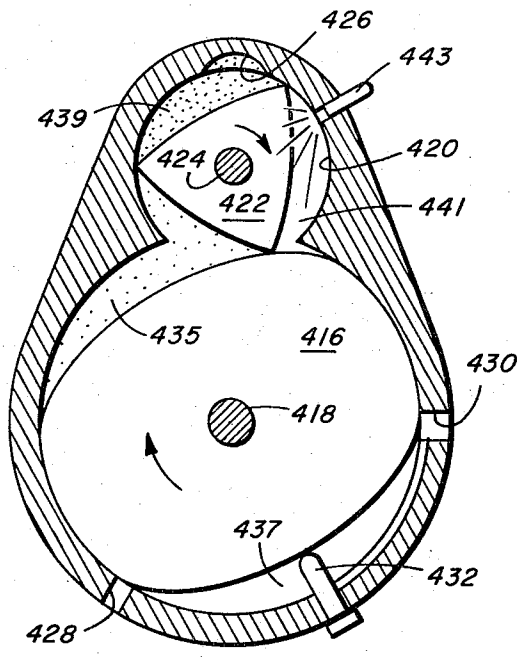


FIG. 21

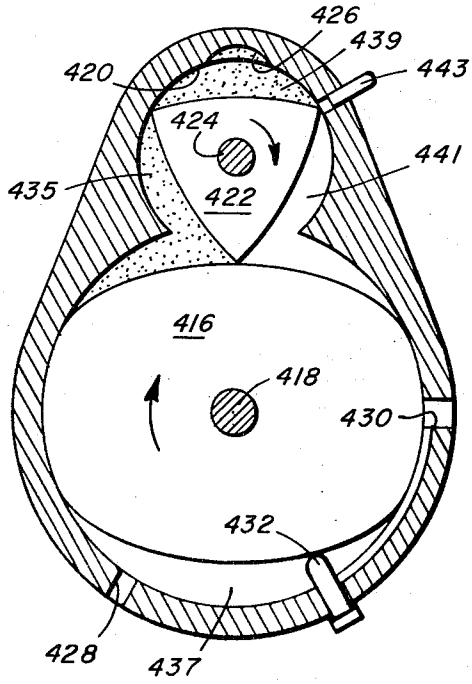


FIG. 22

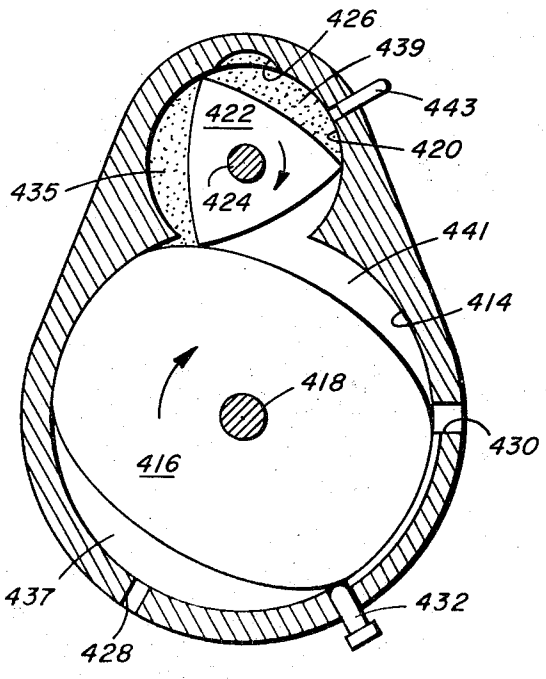


FIG. 23

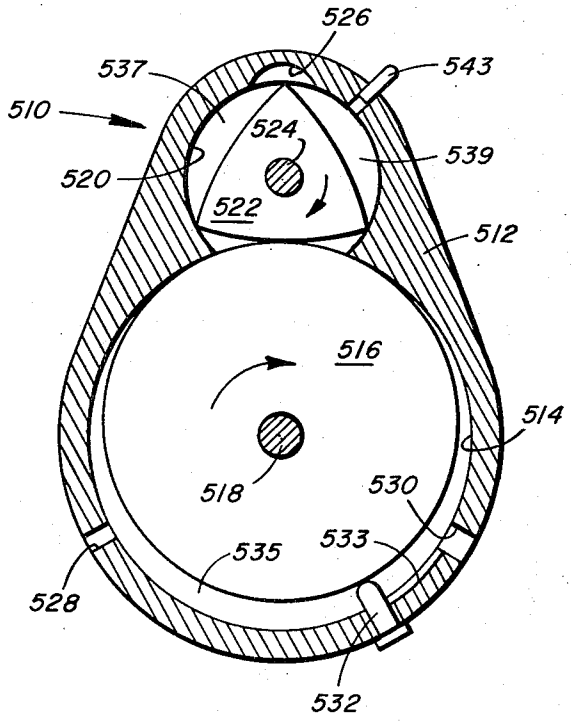


FIG. 24

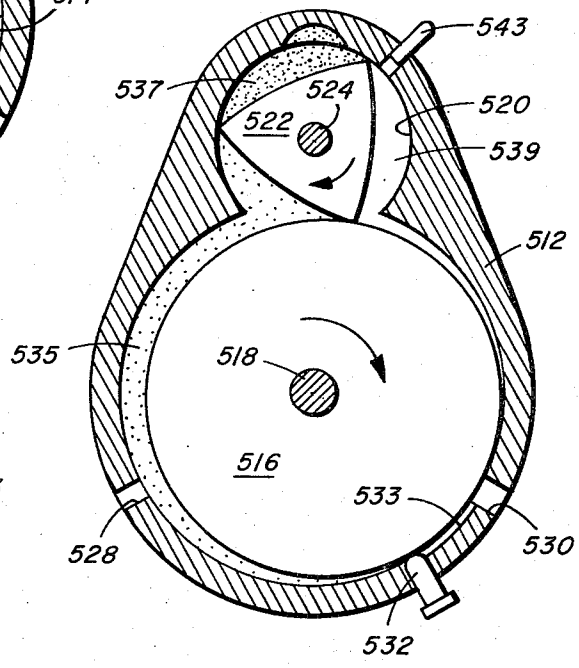
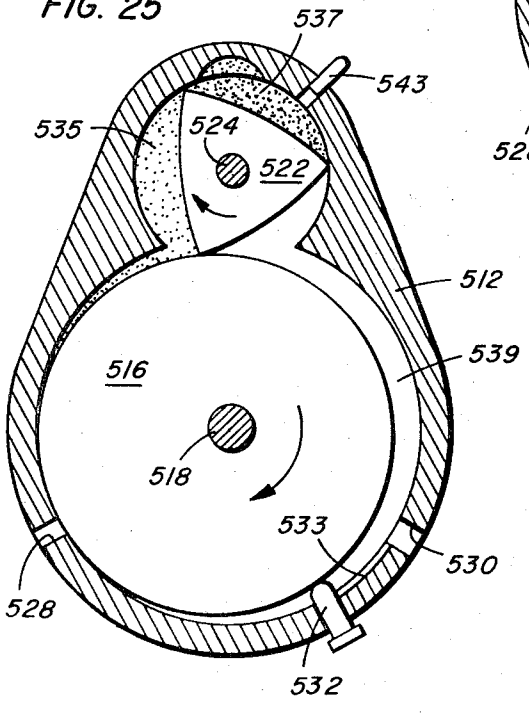


FIG. 25



ROTARY EXPANSIBLE CHAMBER DEVICE

BACKGROUND OF THE INVENTION

This application is a continuation of my copending continuation-in-part for Rotary Engine, Ser. No. 106,351, filed Jan. 14, 1971, and now abandoned which is a continuation-in-part of my application for ROTARY ENGINES, Serial No. 854,328, filed Aug. 28, 1969 and now abandoned. This invention relates generally to expansible chamber devices and particularly relates to rotary internal combustion engines. This invention further relates to rotary heat engines, compressors, motors and pumps.

Those concerned with the design and development of internal combustion engines long have been interested in the direct conversion of combustion energy into rotary motion. The single common most important goal of those directing their attentions to the development of rotary engines has been the desire to eliminate, in smaller internal combustion engines, the occurrence of reciprocating parts with their attendant vibration, wear and overall inefficient operation.

The prior art contains much evidence of activity toward the development of a commercially feasible rotary engine. The engines resulting from this activity, however, have not been sufficiently satisfactory to gain commercial acceptance. Among the problems experienced by prior art engines has been that the combustion of gases coupled with the additive effect of internal engine friction have caused errosion and burning of the sealing faces as well as distortion of the engine components and housing. Additionally, the friction generated by the known arrangement utilized for internal sealing has been sufficiently great to preclude high speed operations. Finally, the combustion gas-flow characteristics of many known engine structures have not been adequate for properly scavenging the exhaust gases, thus reducing the capability of the engine for charge and therewith the engine efficiency.

SUMMARY OF THE INVENTION

Among the objects of the present invention, therefore, are to provide a rotary engine which is subject to less frictional heat and wear than known rotary engines, to provide a rotary engine which can be operated at virtually any speed necessary to accomplish efficient operation, and to provide a rotary engine having a gas flow characteristic which provides for complete scavenging of exhaust gases thereby increasing the charge of combustible mixture per cycle so as to increase the engine efficiency. A further object of the present invention is to provide a rotary engine wherein there are no reciprocating parts.

The foregoing representative objects and others not enumerated are accomplished by the rotary engine of the invention, one embodiment of which may include a block, a plurality of longitudinally extending cylindrical chambers formed in the block, the longitudinal axis of the longitudinally extending chambers being in parallel spaced relation, rotatable means disposed in each of the longitudinally extending chambers, each of the rotatable means having a peripheral surface in substantial surface-to-surface line contact with the peripheral surface of at least one other of the rotatable means, intake and exhaust ports formed in the block and communicating at least one of the chambers with means for

charging the at least one chamber with a combustible mixture and an exhaust system, respectively, the intake and exhaust ports for accommodating the introduction and exhaust of combustion materials and combustion products into and from their associated chambers, and the intake and exhaust ports being selectively covered and uncovered by the rotation of the rotatable means disposed in their respective cylindrical chambers, means for interengaging the rotatable means to control the rotation of each of the rotatable means relative to the others, ignition means, at least one relieved portion on the peripheral surface of each of the rotatable means, the relieved portions cooperating with the longitudinally extending cylindrical chambers to define working volumes, said working volumes being effectively displaced from being in communication with the inlet ports to being in communication with the ignition means and thereafter to being in communication with the exhaust ports during each combustion cycle of the rotary engine, and means for attaching at least one of the rotatable means to a means to be driven.

The rotors and rotor valves have a body of each thickness at their mating surfaces, which thickness is filling with extremely close clearance, the thickness of the chamber cavity, with the only exception being, where either valve(s) or rotor(s), not both, is (are) fitted with running middle or side plates in which case the respective chamber has a cavity thickness to include such plates, said plates having a completely circular curvature and their purpose being mainly to improve cooling and sealing.

BRIEF DESCRIPTION OF THE DRAWINGS

A more complete understanding of the present invention may be had from the following detailed description thereof particularly when read in the light of the accompanying drawings, wherein:

FIG. 1 is a partially cross-sectional, cut-away perspective view of a rotary engine according to the invention;

FIG. 2 is a cross-sectional, elevational view of the engine of FIG. 1;

FIG. 3 is a cross-sectional view through the planes 3—3 of FIG. 2;

FIG. 4 is a cross-sectional, elevational view through the plane 4—4 of FIG. 3;

FIGS. 5–10 are schematic views showing, progressively, the operation of the engine shown in FIGS. 1–4;

FIGS. 11–14 are schematic cross-sectional views of engines similar to the engine of FIGS. 1–4 but having provision for three rotors rather than two rotors;

FIGS. 15–17 are schematic cross-sectional views of an engine similar to the engine of FIGS. 1–4 wherein the rotors are provided with single relieved surfaces rather than two relieved surfaces;

FIGS. 19–22 are schematic cross-sectional views of an engine according to the present invention wherein a single main rotor is utilized in combination with a rotary valve comprising a single rotating lobe; and

FIGS. 23, 24 and 25 show still another embodiment of the present invention, similar to the embodiment of FIGS. 19–22, wherein the main rotor member is generally circular in cross-sectional configuration, the circle being developed about an axis which is offset from the axis of rotation of the rotor member.

DETAILED DESCRIPTION

Referring to FIG. 1, a rotary engine according to the invention is shown and designated generally by the reference numeral 10.

Engine 10 comprises a block having first and second end elements 12 and 14 which are separated by a central element 16, all of the block elements being rigidly secured together by suitable means such as bolts 17. Formed in central block element 16 are upper and lower axially extending cylindrical chambers 20 and 22, respectively. The longitudinal axes of chambers 20 and 22 are parallel and lie in a plane which also contains the longitudinal axis of an intermediate cylindrical chamber 23, which axis is parallel to the longitudinal axes of chambers 20 and 22. The diameter of intermediate chamber 23 is larger than the distance between the peripheries of chambers 20 and 22 thus effecting a communication between chambers 20 and 22 through chamber 23.

The intersection of upper chamber 20 with intermediate chamber 23 defines first and second longitudinally extending edges 25 and 26. Similarly, the intersection of intermediate chamber 23 with lower axially extending chamber 22 defines third and fourth longitudinally extending edges 27 and 28, respectively.

Operably disposed within upper cylindrical chamber 20 is a first rotor 30 which is rigidly mounted by a suitable key means on a shaft 32. Referring to FIGS. 1–4, it can be seen that shaft 32 extends through suitable bores 33 and 34 in first and second block elements 12 and 14, respectively, and is supported for rotation by bearings 37 and 38 which are rigidly mounted in suitable annular channels 40 and 41 formed in blocks 12 and 14, respectively.

Leakage of fluid into or out of chamber 20 between shaft 32 and bores 33 and 34 is prevented by seals 43 and 44 which are of known structure and mounted in suitable annular channels formed in the surfaces of bores 33 and 34.

Shaft 32 is relieved at suitable plural positions adjacent its ends to define radially extending shoulders which are useful in axially positioning bearings 37 and 38. The end of shaft 32 adjacent first block 12 also is provided with a relieved portion for rigidly receiving a pinion gear 46, the function of which is discussed in detail below. Additionally, each end of shaft 32 is provided with a threaded section for securely receiving nuts 48 and 49 which cooperate to secure shaft 32 and its related structure in axial position within blocks 12, 14 and 16.

In a manner substantially identical to first rotor 30 in upper cylindrical chamber 20, there is operably disposed within lower cylindrical chamber 22 a second rotor 50 which is rigidly mounted such as by keying to a shaft 52. AS may be best seen in FIGS. 3, shaft 52 extends through suitable bores 54 and 55 in first and second block elements 12 and 14 respectively and is supported for rotation by bearings 57 and 58 which are rigidly mounted in suitable annular channels 60 and 61 formed in blocks 12 and 14, respectively.

Leakage of fluid into or out of lower cylindrical chamber 22 between the surface of shaft 52 and the surfaces of bores 54 and 55 is prevented by seals 63 and 64 which may be any of many known types and which are mounted in suitable annular channels formed in the surfaces of bores 54 and 55.

Shaft 52 is relieved at plural positions adjacent its ends to define radially extending shoulders which are useful in axially positioning bearings 57 and 58. The end of shaft 52 adjacent first block 12 is also provided with a relieved portion for rigidly receiving a gear 66 the function of which is discussed below in detail. Additionally, the surface of shaft 52 adjacent bearing 58 and the surface of shaft 52 adjacent gear 66 are each provided with a threaded section for securely receiving nuts 68 and 69 which cooperate to secure shaft 52 and its related structure in axial position within blocks 12, 14 and 16.

The end of shaft 52 adjacent first block element 12 extends axially away from block element 12 through a gear cover 71 whereupon it is terminated with a splined section 72 adapted for connection to a suitable power takeoff means. The opposite end of shaft 52, i.e. the end adjacent second block element 14, extends beyond block 14 and is adapted for suitable connection to a starter means (not shown), for the engine 10.

Operably disposed within intermediate cylinder 23 is a rotary valve 75 comprising a lobe 76 which is rigidly secured such as by keying to a shaft 78. The longitudinal axis of shaft 78 is parallel and in the same plane with the longitudinal axes of rotors 30 and 50. Additionally, shaft 78 extends through suitable bores 80 and 81 in first and second block elements 12 and 14, respectively, and is supported for rotation by bearings 84 and 85 which are rigidly mounted in suitable annular channels 87 and 88 formed in blocks 12 and 14, respectively.

Leakage of fluid into or out of intermediate chamber 23 between the surface of shaft 78 and the surfaces of bores 80 and 81 is precluded by seals 90 and 91 which may be any of the known types and as shown are mounted in suitable annular channels formed in the surfaces of bores 80 and 81, respectively.

In a manner similar to that discussed above with respect to shafts 32 and 52, shaft 78 is relieved at plural positions adjacent its end to define radially extending shoulders which are useful in axially positioning bearings 84 and 85. The end of shaft 78 adjacent first block 12 is also provided with a relieved portion for rigidly receiving a gear 79, the function of which is discussed in detail below. The axial position of rotary valve 75 is maintained by nuts 95 and 96 which are threadedly secured to the ends of shaft 78 and cooperate not only to maintain shaft 78 and rotary valve 75 in proper axial position but also to axially position the related structure such as gear 79.

With particular reference to FIG. 4, it can be seen that gears 46, 66 and 79 are operably engaged by first and second idler gears 99 and 100. Specifically, idler gear 99 is in meshed engagement with both pinion 46 and with gear 79, and idler gear 100 is in meshed engagement with both gears 79 and gear 66. Idler gears 99 and 100 are rigidly mounted on shafts 102 and 103. Shaft 102 is mounted for rotation in a first bearing 105 which is supported in a suitable annular channel formed in the surface of first block element 12 and a second bearing 106 which is supported in a suitable bore formed in gear cover 71. Similarly, shaft 103 is supported for rotation by a first bearing (not shown) mounted in a suitable annular channel formed in the surface of first block element 12 and a second bearing (not shown) which is mounted in a suitable bore formed in gear cover 71. Thus, caps may be provided

on cover 71 to insure that dirt is excluded from bearings 106 and the corresponding bearing for shaft 103

Gears 46, 66, 79, 99 and 100 may be provided with suitable teeth of any of the known types capable of handling the loads generated by engine 10. With respect to the speed ratios of the respective gears, gears 46 and 66 are equal in effective diameter, whereas in the embodiment shown the effective diameter of gear 79 is one half the effective diameters of gears 46 and 66. Thus, the speed ratio of rotation of gears 46 and 66 is 1:1 and the speed ratio of gears 46 and 66 to gear 79 is 2:1. Gears 99 and 100 are idler gears and as such may be of any suitable diameter.

The central portions of central block elements 16 are relieved to define mounting spaces for first and second spark plugs 109 and 110. These plugs extend radially inwardly through suitable bores in central element 16 toward the axis of rotation of shaft 78 and their ignition gaps are in communication with the interior of intermediate chamber 23 on opposed sides of rotary valve 75. Each of spark plugs 109 and 110 is actuated by a suitable distributor 112 which is operably connected to the electrical system (not shown) associated with the engine 10. Distributor 112 is physically mounted on gear cover 71 and its rotor is driven by a gear 114 formed on the outer end of shaft 102 on which idler gear 99 is mounted.

Extending through the walls of central block element 16 and into upper cylindrical chamber 20 are a first bore 116 and a second bore 117. The first bore 116 defines an intake opening which is suitably connected through a fuel mixture line 119 to a suitable carburetor 120 which may be any of many which are generally known in the art. Second bore 117 defines an exhaust passage which is suitably connected to an exhaust line 122 for carrying the exhaust gases from the engine to a suitable muffler device (not shown).

Disposed generally below exhaust passage 117 is a third bore 124 in central block element 16, which bore defines an intake passage for communicating the interior of lower cylindrical chamber 22 with an intake line 126 extending from carburetor 120. Similarly, disposed under intake passage 116 is a fourth bore 128 which defines an exhaust passage for communicating the interior of lower cylindrical chamber 22 with an exhaust line 129 which, in a manner similar to exhaust line 122, carries exhaust gases from the engine to a suitable muffler means.

Formed in the upper surface of upper cylindrical chamber 20 is a longitudinally extending slot 131 in which is slidably received a divider strip 133. Divider strip 133 is urged out of slot 131 by the action of a spring 134 mounted within the slot behind divider 133. The inner surface 135 of divider 133 is rounded and adapted for surface-to-surface engagement with the peripheral surface of first rotor 30. The force with which the surface 135 of divider strip 133 bears against the surface of first rotor 30 is adjustable by adjusting a pair of set screws 136 which establish compressive load on spring 134. The surface of chamber 20 is relieved between slot 131 and bore 117 to define a channel 137 the purpose of which is discussed below in detail.

Similarly, the lower surface of lower cylindrical chamber 22 is provided with a longitudinally extending slot 139 in which is slidably received a second divider strip 141. A spring 143 is disposed behind second divider strip 141 and adjustable by set screws 144 urges divider strip 141 out of slot 139 and into engagement with the peripheral surface of second rotor 50. In this regard, the inner surface of divider 141 is also rounded to accommodate the surface-to-surface engagement of strip 141 with the surface of rotor 50 during operation of the engine. Slot 139 is in fluid communication with exhaust bore 128 through a channel 145 formed in the surface of chamber 22. As will be discussed below during the description of the operation of engine 10, first and second divider strips 133 and 141 cooperate with rotors 30 and 50 respectively, to define the limits of the intake volumes and exhaust volumes of upper and lower cylindrical chambers 20 and 22 respectively.

It should be noted that no specific means for cooling engine 10 have been disclosed. It will be recognized by those skilled in the art, however, that engine 10 as well as the other embodiments of rotary engines as described in detail below, depending upon the particular size and load characteristics of an engine of this type in use, may be cooled by water systems or air systems or other of the many systems generally known in this art. Additionally, engine 10, as well as the other embodiments of rotary engines disclosed, may be fabricated from any of the many known metals which are suitable for use in this art. In this regard, it should be noted that rotors 30, 50 and lobe 76 are all shapes which require no undercut and as such are capable of being manufactured by basic manufacturing processes and therefore are relatively inexpensive. Because the sectionalization of the volumes defined by cylindrical chambers 20, 22 and 23 within engine 10 is accomplished by the mutual coaction of rotors 30 and 50 and lobe 76 with the surfaces of chambers 20, 22 and 23, the rotor surfaces and chamber surfaces should be machined to provide as little clearance as possible. Clearances of 0.001 inches or less are desirable. However, under certain engine designs, greater clearances may be tolerated.

With respect to the specific design of rotors 30 and 50, and of lobe 76, it can be seen that rotors 30 and 50 are identical, each being provided with opposed arcuate peripheral surfaces and opposed relieved portions. The arcuate surfaces are provided to establish a sealing relationship between the rotors and the surface of the cylindrical chambers so as to prevent the passage of gas between the rotor surface and the chamber surface during operation. Each arcuate surface may be of any length which is greater than the arcuate distance between edges 25 and 26 defined by the intersections of chambers 20 and 23 so as to enable complete isolation of chamber 23 from chamber 20. The degree of relief of the opposed relieved surfaces is dependent upon the desired volume of gas to be worked and the desired compression ratio.

As is evident from FIG. 1, although rotors 30 and 50 are identical, they are operationally positioned so as to have their corresponding diagonals normal to one another. This relationship between the rotors defines the relationship between each of the rotors and lobe 76, the cross-section of which lobe defines a curve which is developed by the rotation of rotors 30 and 50 and the criteria that at all times must the surface of lobe 76 be in substantial line contact with the surface of each of rotors 30 and 50. As was noted above, lobe 76 rotates in the same direction as rotors 30 and 50 but at twice the angular velocity. Thus, each of the relieved portions of rotors 30 and 50 are accommodated to have

continuing substantial surface-to-surface line contact with the surface of lobe 76 and an effective fluid seal from one side to the other side of the lobe is maintained at all times.

Considering now the operation of engine 10, FIGS. 5 through 10 present schematically a complete cycle of the engine which is described below in detail. Referring to FIG. 5, it can be seen that rotor 30 has a first relieved surface 162 and a second relieved surface 163, and similarly that rotor 50 has a first relieved surface 165 and a second relieved surface 166. First relieved surface 162 of rotor 30 cooperates with the surface of upper cylindrical chamber 20 to define a first working volume 168. Second relieved surface 163 of rotor 30 also cooperates with the surface of upper cylindrical chamber 20 to define a second working volume 169. The arcuate surface of rotor 30 cooperates with first relieved surface 165 of rotor 50, the surface of lower cylindrical chamber 22 and lobe 76 to define third and fourth working volumes 170 and 171 respectively. Finally, the second relieved surface 166 of rotor 50 cooperates with the surface of lower cylindrical chamber 22 to define a fifth working volume 172.

The positions of the rotors in FIG. 5 indicate that rotor 30 has just become positioned adjacent longitudinally extending edge 25 to establish a seal between third working volume 170 and first working volume 168. With engine 10 in operation and with the rotors positioned as shown in FIG. 5, first working chamber 168 is being exhausted through bore 117, second working chamber 169 is receiving a properly prepared mixture of fuel and air through bore 116, third working volume 170 has been filled with a charge of combustible fluid and is reducing in size during the compression stage of the cycle, fourth working volume 171 is shown at the substantial completion of an expansion stage and fifth working volume 172 is in the process of being substantially evacuated prior to coming into communication with inlet mixture bore 124. In this regard, it should be noted that as rotors 30 and 50 pass divider strips 133 and 141 respectively, residual exhaust gases which otherwise be trapped behind the divider strips are relieved to exhaust bores 117 and 128 through channels 137 and 145 respectively.

Referring to FIG. 6, it can be seen that the rotors have rotated a few degrees more clockwise and rotor 50 is positioned such that first relieved surface 165 thereof has advanced to a point adjacent exhaust bore 128 thus marking the completion of the expansion cycle for fourth working chamber 171. In this regard, it should be noted that the arcuate surface of rotor 30 is still positioned substantially adjacent second longitudinally extending edge 26 so as to establish a sealing relationship therewith and prevent the communication of gas between secomd working volume 169 and fourth working volume 171. This, combined with the fact that exhaust bore 128 is of larger size than inlet bore 116 permits the relief of pressure within fourth working volume 171 prior to communication thereof through second working volume 169 with inlet bore 116 so as to prevent a backfire of the apparatus through inlet bore 116.

With respect to the remaining working volumes as shown in FIG. 6, first working volume 168 is continuing to be exhausted through exhaust bore 117, third working volume 170 is continuing to diminish in size whereby to compress the combustible mixture contained therein, and fifth working volume 172 is substantially completely evacuated. In this regard, it should be noted that evacuation in accordance with the present invention is accomplished by the cooperation of divider strips 133 and 141 with the surfaces of rotors 30 and 50, respectively. More specifically, referring to FIGS. 5 and 6, as rotor 50 turns clockwise within lower cylindrical chamber 22, exhaust gases between divider strip 141 and exhaust bore 128 are prevented from passing divider strip 141 by the substantially surface-to-surface contact between divider strip 141 and the surface of rotor 50. Thus, as rotor 50 continues to rotate clockwise, the volume of fifth working volume 172 becomes greater thereby causing a vacuum to be induced therein. Ultimately, this evacuated space will communicate with a source of combustible gas through inlet bore 124 and because of the preestablished vacuum therein, the intake of fuel mixture into the engine will be expedited.

As the engine rotors rotate from the positions shown in FIG. 6 to the position shown in FIG. 7, it can be seen initially with respect to first working volume 168 that exhaust of expended gases therefrom is continuing. Second and fourth working volumes 169 and 171 have been placed in communication and thus, a unidirectional flow of gas is established from inlet bore 116 through working volumes 169 and 171 and out exhaust bore 128. This unidirectional flow facilitates the removal of all spent gases from the apparatus thereby improving the efficiency of the engine and its capability for clean running. By comparison, third working volume 170 has diminished to its maximum compression point and at substantially this time the compressed fuel mixture is ignited and expansion commences. Concurrently, fifth working volume 172 has come into communication with inlet bore 124 thereby facilitating the intake of fuel mixture through bore 124.

As the rotation of the rotors continues from the positions shown in FIG. 7 to the positions shown in FIG. 8, it can be seen that first working volume 168 leaves communication with exhaust bore 117 and is in the process of being evacuated by the cooperation of divider strip 133 with relieved surface 162 in the manner discussed above with respect to fifth working volume 172. Additionally, the arcuate surface of rotor 50 has come into sealing position with respect to fourth longitudinally extending edge 28 thereby isolating second working volume 169 from fourth working volume 171 and commencing the compression stage of the cycle for second working volume 169. Third working volume 170 continues in the expansion stage of the cycle, fourth working volume 171 continues in the exhaust stage of the cycle, and fifth working volume 172 continues in the intake stage of the cycle.

Still continued rotation of the rotors from the positions shown in FIG. 8 to the positions shown in FIG. 9 causes first working volume 168 to be continued to be evacuated by the cooperation of divider strip 133 and surface-to-surface engagement with the first relieved surface 162 of rotor 30.

Second working volume 169 continues in its compression stage of the cycle while third working volume 170 is just completing the expansion stage of its cycle and commencing the exhaust stage. In this regard, it should be noted again that exhaust bore 117 is sized or positioned in such a manner as to permit the communication of third working volume 170 with exhaust bore

117 prior to the communication of third working volume 170 with fifth working volume 172 as continued rotation of the rotors takes place. This pre-communication of third working volume 170 with exhaust bore 117 permits the relief of gaseous pressure from third working volume 170 and prevents backfire as discussed above. Finally, fourth working volume 171 continues in its exhaust stage.

Rotation of the rotors from the positions shown in FIG. 9 to the positions shown in FIG. 10 causes a full communication between third and fifth working volumes 170 and 172 so as to generate a flow of fluid through inlet bore 124, fifth working volume 172 and third working volume 170 out of exhaust bore 117 whereby to urge these volumes of engine 10 of all spent gases. First working volume 168 has just finished complete evacuation and is coming into communication with inlet bore 116 whereby to be charged with fuel. Second working volume 169 is approaching its fully compressed state and is ready for ignition and fourth working volume 171 is continuing in the exhaust stage of its cycle.

It can be seen from the foregoing, therefore, that for each complete rotation of rotors 30 and 50, four full power strokes occur. Additionally, the efficiency of the combustion is relatively high because of the purging action of the unilateral flow of intake and exhaust gases which occurs when adjacent working volumes are in communication through intermediate cylindrical chamber 23. In this regard, it will be recognized by those skilled in the art that this engine is typical of most rotary engines and operates at very high speeds. Thus, although the operation of the engine has been described in a step-by-step fashion, it will be recognized that each of the steps occurs in a very short period of time and thus loses its individuality to contribute to the smoothly flowing operation of the engine.

A second embodiment of engine according to the invention is shown schematically in FIGS. 11 through 14. This embodiment is substantially the same in construction as the embodiment discussed above with respect to FIGS. 1–10, except for the fact that the engine, designated generally by the reference numeral 210 is provided with three major rotors rather than the two disclosed with respect to the prior embodiment.

Considering engine 210 in detail, therefore, and with reference to FIGS. 11–14 which show engine 210 schematically, an engine block 216 is shown to be provided with first, second and third longitudinally, coaxially extending cylindrical chambers 220, 221 and 222, respectively. The longitudinal axis of chambers 220, 221 and 222 are symmetrically spaced about the central longitudinal axis of block 216 which defines the longitudinal axis of an intermediate longitudinally extending cylindrical chamber 223 which is in communication with each of chambers 220, 221 and 222.

The inner section of first chamber 220 with intermediate chamber 223 defines first and second longitudinally extending edges 225 and 226. Similarly, the inner section of second and third cylindrical chambers 221 and 222 define third, fourth, fifth and sixth longitudinally extending edges 227–230, respectively.

Operably disposed within each of cylindrical chambers 220, 221 and 222 are first, second and third rotors 232, 233 and 234 each respective rotor being rigidly mounted for rotation on the shafts 236, 238 and 240.

Operably disposed within intermediate cylinder 223 is a two lobe rotary valve 246 which is rigidly secured such as by keying to a shaft 248. The longitudinal axis of shaft 248 is parallel with the longitudinal axes of rotors 232, 233 and 234.

Each of cylindrical chambers 220, 221 and 222 is provided with an inlet bore, 250, 251 and 252 respectively, which is connected to a fuel line in communication with a suitable source of combustible mixtures such as a carburetor (not shown). Similarly, each of cylindrical chambers 220, 221 and 222 is provided with an exhaust bore, 255, 256 and 257 respectively, which is in communication with a suitable exhaust system (not shown).

In the same manner as discussed above with respect to the embodiment of FIGS. 1–10, each of cylindrical chambers 220, 221 and 222 is provided with a longitudinally extending slot for receiving a spring loaded divider strip, the strips being shown in FIGS. 11–14 as 259, 260 and 261 respectively. The surfaces of chambers 220, 221 and 222 are each provided with a channel 276, 277 and 278 respectively, which communicate the strip-containing slots with exhaust bores 255, 256 and 257. Additionally, suitable bores are provided in block 216 to accommodate the mounting therein of spark plugs 263, 264 and 265 which are operably connected to a suitable source of ignition energy such as a distributor.

Although the embodiment of engine shown in FIGS. 11–14 is shown only schematically, it will be recognized by those skilled in the art that the engine may be structured in the basic manner discussed above with respect to the embodiment of FIGS. 1–10. More specifically, an engine 210 would be provided with end block sections or their equivalent, bearing means for rotatably supporting the shafts, gear means or the like for interconnecting the rotors and the centrally disposed rotary valve, starter means, ignition means, means for connecting the engine to a load such as a splined output shaft and means for cooling the engine during operation. The only basic difference is that the means for interlocking the rotors and the shaft 248 of the rotary valve would be gear means or the like sized to provide rotation of valve 246 at twice the speed of each of rotors 232, 233 and 234.

Considering now the operating cycle of the three-rotor engine 210, it can be seen from the FIGS. that the rotors 232, 233 and 234 and valve 246 cooperate with the longitudinally extending cylindrical chambers 220, 221, 222 and 223 to form working volumes in the same manner as was discussed above with respect to the embodiment of FIGS. 1–10. In this regard, the operation of this embodiment of the engine is substantially the same as discussed with respect to the embodiment of FIGS. 1–10 with the exception that there is one additional primary rotor. Thus, considering the operation of the engine in terms of a single working cycle and referring to FIG. 11, a first relieved surface 268 of rotor 232 cooperates with the inner surface of chamber 220 to define a working volume 270. Similarly, the surfaces of rotors 232 and 233 cooperate with the surface of valve 246 and the surface of intermediate chamber 223 to define a second working volume 272. In the stage of the cycle shown in FIG. 11, the arcuate surface of rotor 232 is in close proximity to longitudinally extending edge 226 thereby establishing a seal for preventing the flow of gases between first working volume 270 and

second working volume 272. First working volume 270 is in communication with intake bore 250 and is filled to capacity with a combustible mixture of fuel and air. Continued rotation of the rotors from the positions shown in FIG. 11 to the positions shown in FIG. 12 causes communication of first working volume 270 with second working volume 272. The establishment of this communication marks the commencement of the compression stage of the engine cycle which continues as the rotors rotate through the positions shown in FIG. 13 to the positions shown in FIG. 14, whereupon spark plug 264 ignites the mixture to commence the expansion or power stage of the cycle.

The surfaces of rotor 233, cylindrical chamber 221 and lobe 246 cooperate to define a third working volume 274 (FIG. 14) in which the expansion of the ignited gases takes place. This expansion continues until rotor 233 has rotated sufficiently to place third working volume 274 in communication with exhaust bore 256 thus relieving the vent exhaust gases to the exhaust system. Still further rotation of rotor 233 causes third working volume 274 to pass by divider strip 260 whereby to create a vacuum therein in preparation for being placed in communication with inlet bore 251 to repeat the cycle once again.

The combustion cycle described above with respect to working chambers 270, 272 and 274 is typical of the operation which continues throughout each of the chambers of engine 210. Thus, it can be seen that this operation is substantially the same as that described above with respect to the embodiment of FIGS. 1–10 in that it provides the advantages of uni-directional flow of gases through the engine and the attendant purging capabilities and also provides for six expansion phases for each single rotation of the main rotors.

Rotary engine 310 is exactly the same structurally as the embodiment discussed above in detail with respect to FIGS. 1–10 with two exceptions, viz. each of the main rotors has a single relieved surface rather than plural relieved surfaces and the rotary valve is geared to rotate at the same angular speed as the main rotors rather than at twice the speed as provided for in engine 10.

Considering the structure of engine 310 briefly, upper and lower main rotors 312 and 314 are mounted on shafts 316 and 318 for rotation within upper and lower longitudinally axially extending cylindrical chambers 320 and 322, respectively. Cylindrical chambers 320 and 322 are in communication through an intermediate longitudinally axially extending cylindrical chamber 323, the longitudinal axis of which is parallel to and contained in the same plane as the longitudinal axis of chambers 320 and 322. Mounted on an axially extending shaft 325 for rotation within intermediate chamber 323 is rotary valve comprising a lobe 326, the surface of which is configured to define a substantially surface-to-surface line contact with the surfaces of each of rotors 312 and 314 at all times during operation of the engine 310.

Cylindrical chambers 320, 322 and 323 are formed in a block member 330, it being understood that the complete engine 310 requires end blocks or equivalent closures when fully assembled. Also formed in block member 330 are intake and exhaust bores 332, 333, 334 and 335, one intake and one in exhaust bore communicating with chambers 320 and 322. Additionally, block 330 is provided with longitudinally extending slots, one formed in the surface of each chamber 320 and 322, in which slots are received spring loaded divider strips 338 and 339. The surfaces of chambers 320 and 322 are each relieved to provide channels extending between the respective slots for divider strips 338 and 339 and exhaust bores 334 and 335. Disposed in communication with intermediate chamber 323 through suitable bores in block 330 are first and second ignition means 342 and 343 which may be spark plugs or the like.

Considering now the operation of rotary engine 310, it can be seen from FIG. 15 that upper rotor 312 is provided with a relieved surface 345 which cooperates with the surface of upper cylindrical chamber 320 to define a first working volume 346. Similarly, lower rotor 314 is provided with a relieved surface 348 which cooperates with the surfaces of lower cylindrical chamber 322 the surfaces of intermediate cylindrical chamber 323 and the surface of valve 326 to define second and third working volumes 348 and 350, respectively.

Because the combustion cycle in working volumes 346, 348 and 350 is exactly the same as that described above with respect to the working volumes of rotary engine 10, it suffices with respect to the detailed description of the operation of rotary engine 310 to describe the stages of the combustion cycle in which each of the working volumes 346, 348 and 350 appears in FIGS. 15–18. Thus, in FIG. 15, first working volume 346 is substantially at the completion of its exhaust and evacuation stage, second working volume 348 is nearing the completion of its expansion stage and third working volume 350 is nearing the completion of its compression stage.

In FIG. 16, the rotors have rotated 90° in a clockwise direction and first working volume 346 is shown during its intake stage, second working volume 348 is shown during its exhaust stage, and third working volume 350 is shown at its substantially maximum compression point which corresponds approximately to the time of ignition. In this regard, it will be recognized by those having skill in this art that the instant of ignition can be varied in accordance with the proper tuning of the engine.

In FIG. 17, the rotors have rotated an additional 90° clockwise from the positions shown in FIG. 16 and first working volume 346 is shown immediately after the completion of its intake phase and at the beginning of its compression stage. Second working volume 348 is shown substantially at the completion of its exhaust and evacuation stages and third working volume 350 is shown during its expansion stage. Finally, with respect to FIG. 18, first working volume 346 is shown at the substantial completion of its compression stage, second working volume 348 is shown during its intake stage and third working volume 350 is shown during its exhaust stage. It can be seen, therefore, that rotary engine 310 is substantially the same engine as that discussed above with respect to FIGS. 1–10 with the exception that rather than four combustion cycles for each full rotation of the rotors, there occurs only two.

The embodiment of rotary engine disclosed in FIGS. 19–22 and designated generally by the reference numeral 410 is different from the prior embodiments because it has only a single major rotor. The basic construction of engine 410 is the same as that discussed

above with respect to the prior embodiments to the extent that similar end cover, bearings, gearing and carburetion and distributor arrangements may be utilized.

Considering the structure of engine 410 briefly, a block member 412 is provided with a first longitudinally extending cylindrical chamber 414 wherein is mounted a rotor 416 for rotation with a shaft 418. First chamber 414 is in communication with a second longitudinally extending cylindrical chamber 420 wherein there is mounted a three lobe rotary valve 422 for rotation with the shaft 424. Shafts 418 and 424 are connected through external gearing (now shown) which is sized to provide for rotation of valve 422 at two thirds the speed of rotor 416. In this regard, the cross-sectional configuration of valve 422 is designed to provide for substantial surface-to-surface line contact between the valve lobes and rotor 416 at all times during the operation of engine 410.

Formed in the upper surface of cylindrical chamber 420 is a relieved channel 426 the function of which is discussed below with respect to the operation of engine 410. Extending through the wall of block member 412 is an intake bore 428 for communicating the interior of chamber 414 with a suitable source of combustible mixture, e.g. a carburetor, and an exhaust bore 430 which communicates the interior of chamber 414 with a suitable exhaust system for exhaust gases. Also formed in the surface of chamber 414 is a longitudinally extending slot in which is mounted a spring-loaded divider strip 432. In the same manner as was discussed above with respect to the other embodiments, divider strip 432 is spring loaded in such a manner as to be in surface-to-surface engagement with the surface of rotor 416 at all times during operation of the engine 410. Further, exhaust bore 430 and the seat containing divider strip 432 are in communication through a channel formed in the surface of chamber 414.

Ignition of the combustible mixture in engine 410 is accomplished by an ignition means such as spark plug 443 which is electrically connected to a suitable source of energy such as a distributor or the like.

Considering therefore the operation of engine 410, it can be seen that rotor 416 cooperates with the surface of chamber 414, the surface of lobe 422 and a portion of the surface of chamber 420 to define a first working volume 435 and a second working volume 437. Additionally, lobe 422 cooperates with the inner surface of cylindrical chamber 420 to define a third working volume 439 and a fourth working volume 441. As is evident from FIG. 19, working volumes 439 and 441 are in communication through relieved channel 426.

Thus, referring to FIG. 19, first working volume 435 is in the intake stage of the combustion cycle, working volumes 439 and 441 are in communication and in the high compression phase of the cycle just prior to ignition, and fourth working volume 437 is in the exhaust phase of the cycle. A rotor 416 and lobe 422 rotate from the positions shown in FIG. 19 to the positions shown in FIG 20, fourth working volume 441 becomes isolated from third working volume 439, and at approximately this point in the stage, spark plug 443 is actuated to ignite the combustible mixture contained within working volume 441 and commence the expansion phase of the combustion cycle. Additionally, the surface of rotor 416 has covered intake bore 428, thus signifying the end of the intake stage of the combustion cycle for first working volume 435 and the commencement of the compression stage. Similarly, second working volume 437 is completing the exhaust and evacuation stages of its combustion cycle.

Continued rotation of rotor 416 and lobe 422 from the positions shown in FIGS. 20 to the positions shown in FIG. 21 causes further compression of the combustible mixture in first working chamber 435, places intake bore 428 in communication with second working volume 437 and continues with the expansion stage of the cycle of fourth working volume 441. It should be noted that during the period of rotation of lobe 422 between the position shown in FIG. 20 and the position shown in FIG. 21, no particular operation is being accomplished by or performed on the combustible mixture contained within third working volume 439.

Continued rotation of rotor 416 and lobe 422 from the positions shown in FIG. 21 to the positions shown in FIG. 22 cause continued compression of the combustible mixture in first working volume 435, permit further intake of combustible mixture into second working volume 437, causes the exhaust bore 430 to be uncovered thereby terminating the expansion stage of the combustion cycle for the combustion products in fourth working volume 441 and continues the movement of the combustible mixture in third working volume 439. The rotation of rotor 416 and lobe 422 continues hereafter until the rotor and lobe positions as shown in FIG. 19 are reached and the cycle continues in this manner.

Thus, it can be seen with respect to the embodiment of rotary engine 410 that by properly controlling the speed of rotation of lobe 422 in cojunction with the speed of rotation of rotor 416, the above described advantages of providing a continuous throughput of combustible gases and a uni-directional flow of gases from the intake through the exhaust enables combustion a higher degree of efficiency and with better control.

A yet further embodiment of a rotary engine according to the present invention is disclosed in FIGS. 23–25 and designated generally by reference numeral 510. The construction of engine 510 is substantially the same as that discussed above with respect to rotary engine 410 with the exception that the rotor of engine 510 is circular in cross-sectional configuration and mounted for eccentric rotation and the rotary valve lobe operates at one third of the angular velocity of the main rotor.

Considering the structure of engine 510 briefly, a block number 512 is provided with a first longitudinally extending cylindrical chamber 514 wherein is mounted a rotor 516 for rotation on a shaft 518. First chamber 514 is in communication with a second longitudinally extending cylindrical chamber 520 wherein there is mounted a three lobe rotary valve 522 for rotation with a shaft 524. Shafts 518 and 524 are connected through external gearing (not shown) which is sized to provide for rotation of valve 522 at one third the speed of rotor 516. In this regard, the cross-sectional configuration of valve 522 is designed to provide for substantial surface-to-surface line contact between the lobe surfaces of valve 522 and rotor 516 at all times during operation of the engine 510.

Formed in the upper surface of cylindrical chamber 520 is a relieved channel 526 the function of which is discussed below with respect to the operation of this engine. Extending through the wall of block member

512 is an intake bore 528 for communicating the interior of chamber 514 with a suitable source of combustible mixture, e.g. a carburetor, and an exhaust bore 530 which communicate the interior of chamber 514 with a suitable exhaust system for exhaust gases. Also formed in the surface of chamber 514 between intake bore 528 and exhaust bore 530 is a longitudinally extending slot in which is mounted a spring loaded divider strip 532. In the same manner as was discussed above with respect to the prior described embodiments, divider strip 532 is spring loaded in such a manner as to be in surface-to-surface engagement with the surface of rotor 516 at all times during the operation of engine 510. Further, exhaust bore 530 and the slot containing divider strip 532 are in communication through a channel 533 formed in the surface of chamber 514.

A bore is formed in the wall of block member 512 to be in communication with the interior of second chamber 520 and to provide for the mounting therein of a suitable ignition means such as a spark plug 543. The positioning of spark plug 543 should be angularly spaced clockwise from relieved channel 526 so as to permit the timing of ignition at a point in the cycle which is subsequent to the passage of the apex of a lobe of valve 522 to preclude the promulgation of combustion in a counterclockwise direction.

Considering therefore the operation of rotary engine 510, it can be seen from FIGS. 23–25 that rotor 516 and valve 522 cooperate with the inner surfaces of longitudinally extending cylindrical chambers 514 and 520 to define first, second and third working volumes 535, 537 and 539 respectively. With particular reference to FIG. 23, first working volume 535 has one portion in the intake phase of the combustion cycle and another portion, i.e. that portion disposed counter-clockwise from divider strip 532 in the exhaust phase of the combustion cycle. Second working volume 537 is in communication with third working volume 539 through channel 526 to provide compressed combustion gases to third working volume 539 just prior to ignition which occurs selectively after the apex of a lobe of valve 522 passes the clockwise edge of channel 526 as seen in FIG. 23. Rotation of the valve and rotor from the positions shown in FIG 23 to the positions shown in FIG. 24 causes rotor 516 to cover exhaust bore 530 thus marking the completion of the exhaust phase for first working volume 535 except for that portion of the spent gases which flow through channel 533 from the area of divider strip 532 to exhaust bore 530, causes second working volume 537 to be isolated from third working volume 539 by the sealing action of the apex of valve 522 with the inner surface of cylindrical chamber 520 and places third working volume 539 into the expansion phase of the combustion cycle.

The continued rotation of lobe 522 and rotor 516 from the positions shown in FIG. 24 to the positions shown in FIG. 25 causes the covering of intake bore 528 thereby completing the intake stage of the combustion cycle for first working volume 535, causes clockwise displacement of second working volume 537 in anticipation of its communication with first working volume 535 for purposes of preparing for ignition and uncovers exhaust bore 530 to commence the exhaust stage of the combustion cycle for working volume 539.

Rotary engine 510 thus provides in a rotary engine of the eccentric rotor type the advantage of unidirectional flow of gases through the engine from the intake to the exhaust stages of the combustion cycle. As will be recognized by those skilled in this art, the imbalance created by a single eccentric rotor can be offset by providing an additional engine stage with the rotor disposed 180° out of phase with rotor 516. Similarly, plural additional stages or opposed counterweight can be utilized to accomplish the same balancing effect.

It will also be recognized by those skilled in the art that although the disclosed embodiments have been charged with combustion materials through a carburetion means, other combustion material charging approaches may be utilized, e.g. fuel injection.

The above described embodiments of rotary engines will be recognized as providing a rotary engine design which is unique, which provides advantages over prior art devices and which, because of the elimination of undercuts and the like in the engine members provides for economic and speedy manufacture.

Although five embodiments of rotary engines according to the invention have been disclosed in detail above, it is considered to be manifest that many modifications thereto can be made without departing from the spirit and scope of this invention.

I claim:

1. A rotary internal combustion engine comprising:

a block;

a first longitudinally extending cylindrical chamber formed in said block;

a second longitudinally extending cylindrical chamber formed in said block, the longitudinal axis of said second chamber being parallel to and spaced from the longitudinal axis of said first chamber;

a third longitudinally extending chamber formed in said block, the longitudinal axis of said third chamber being parallel to and disposed centrally of the longitudinal axes of said first and second chambers, said axes of said first and second chambers being disposed symmetrically about said axis of said third chamber and equidistant therefrom, said third chamber having a diameter to overlap said first and second chambers for placing said first, second and third chambers in mutual communication;

a first rotor operably co-axially disposed within said first chamber, said first rotor comprising a generally cylindrical member having a diameter substantially equal to the inside diameter of said first chamber, and at least one relieved portion on the surface thereof for cooperating with at least said first chamber to define a working volume;

a second rotor operably co-axially disposed within said second chamber, said second rotor comprising a generally cylindrical member having a diameter substantially equal to the inside diameter of said second chamber, and at least one relieved portion on the surface thereof for cooperating with at least said second chamber to define a working volume;

said first and second rotors operationally positioned in said first and second chambers with the axis of said relieved portions thereof substantially normal to each other;

a third rotor operably co-axially disposed within said third chamber, said third rotor comprising a lobe member, said lobe member defining a surface for

providing a substantial surface-to-surface line contact with the surfaces of said first and second rotors at all times during rotation of said rotors;

intake means for introducing a charge of combustible material into at least one of said first and and second chambers;

exhaust means for exhausting combustion products from at least one of said first and second chambers;

ignition means for igniting said combustible material within said block;

each said working volume, under the control of the rotation of said first, second and third rotors being effectively displaced from being in communication with said ignition means and thereafter to being in communication with said exhaust means during the combustion cycle of said rotary engine; and

means for interengaging said first, second and third rotors to control their relative rotation in the same rotational direction.

2. A rotary engine according to claim 1 and further including means for evacuating said working volumes after each has been in communication with said exhaust port and prior to each coming into communication with said inlet ports.

3. A rotary engine according to claim 2 wherein said means for evacuating cooperates with said rotatable means to force gases from said working volumes through said exhaust ports.

4. A rotary engine according to claim 1 wherein said block comprises at least a first end element, a second end element and at least one central element, and said longitudinally extending cylindrical chambers are formed in said central element.

5. A rotary engine according to claim 4 wherein said intake and exhaust ports comprise passages extending through the wall of said central element into at least one of said chambers.

6. A rotary engine according to claim 2 wherein said means for evacuating said working volumes comprises a longitudinally extending slot formed in the surface of said at least one of said cylindrical chambers, a divider strip reciprocably received within said slot, and means for resiliently urging said divider strip into surface-to-surface engagement with the rotatable means in said at least one of said cylindrical chambers.

7. A rotary internal combustion engine comprising:

a block;

a first longitudinally extending cylindrical chamber formed in said block;

a second longitudinally extending cylindrical chamber formed in said block, the longitudinal axis of said second chamber being parallel to and spaced from the longitudinal axis of said first chamber;

a third longitudinally extending cylindrical chamber formed in said block, the longitudinal axis of said third chamber being parallel to and disposed between the longitudinal axis of said first and second chambers, said third chamber being disposed between and overlapping said first and second chambers in mutual communication;

a first rotor operably co-axially disposed within said first chamber, said first rotor comprising a generally cylindrical member having a diameter substantially equal to the inside diameter of said first chamber, and at least one relieved portion on the surface thereof to define a working volume;

a second rotor operably co-axially disposed within said second chamber, said second rotor comprising a generally cylindrical member having a diameter substantially equal to the inside diameter of said second chamber, and at least one relieved portion on the surface thereof to define a working volume;

a third rotor operably co-axially disposed within said third chamber, said third rotor comprising a lobe member defining a surface for providing a substantial surface-to surface line contact with the surfaces of both said first and second rotors at all times during the rotation of said rotors;

intake means for introducing a combustible mixture into at least one of said first and second chambers;

exhaust means for exhausting combustion products from at least the other of said first and second chambers;

ignition means for igniting said combustible mixture within said block;

means for interengaging said first, second and third rotors to control their relative rotation in the same rotational direction;

means for attaching said rotors to a means to be driven; and

means controlled by said first and second rotors and formed in said blocks for evacuating said working volumes after each has been in communication with said exhaust means and prior to each coming into communication with said intake means.

8. A rotary internal combustion engine according to claim 7 wherein said block comprises a first end element, a second end element and at least one central element, and wherein said first, second and third longitudinally extending cylindrical chambers are formed in said at least one central element.

9. A rotary internal combustion engine according to claim 7 wherein said intake means and said exhaust means comprise passages extending through said block into said first and second chambers.

10. A rotary internal combustion engine according to claim 8 wherein said intake means and said exhaust means comprise passages formed in said central element of said block and extending into said first and second chambers.

11. A rotary engine according to claim 7 wherein said means for evacuating cooperates with said rotors to force gases from said working volumes through said exhaust means.

12. A rotary internal combustion engine according to claim 7 wherein said means for evacuating comprises:

a longitudinally extending slot formed in the surface of said at least the other of said first and second chambers;

a divider strip reciprocably received within said slot; and

means for resiliently urging said divider strip into surface-to-surface engagement with the rotor in said one of said first and second chambers.

13. A rotary internal combustion engine according to claim 7 wherein said ignition means is disposed to initiate combustion of said combustible vapor within said third chamber.

14. A rotary internal combustion engine according to claim 9 wherein said passages defining said intake means and said exhaust means are covered and uncovered by said first and second rotors during their rotation within said first and second chambers, respectively, said covering and uncovering of said passages defining a valving operation.

15. A rotary internal combustion engine according to claim 7 wherein said first, second and third rotors are shaped such that tangents to the surfaces of the rotors along their lines of substantial contact do not intersect the structure of the contacting rotors. second and third rotors cooperate with said first, second and third longitudinally extending cylindrical chambers to define working volumes, said working volumes being effectively displaced from being in communication with said passage defining said intake means to being in communication with said ignition means and thereafter to being in communication with said passage defining said exhaust means during each combustion cycle of said rotary engine.

16. A rotary internal combustion engine according to claim 7 wherein no tangent to the surface of any of said first, second or third rotors intersects the structure of the rotor to which it is tangent.

17. A rotary internal combustion engine according to claim 7 wherein said relieved portion on the surfaces of said first,

18. A rotary internal combustion engine comprising:

a block;

a first longitudinally extending cylindrical chamber formed in said block;

a second longitudinally extending cylindrical chamber formed in said block, the longitudinal axis of said second chamber being parallel to and spaced from the longitudinal axis of said first chamber;

a third longitudinally extending cylindrical chamber formed in said block, the longitudinal axis of said third chamber being parallel to and spaced from the longitudinal axes of said first and second chambers;

a fourth longitudinally extending chamber formed in said block, the longitudinal axis of said fourth chamber being parallel to and disposed centrally of the longitudinal axes of said first, second and third chambers, said axes of said second and third chambers being disposed symmetrically about said axis of said fourth chamber and equidistant therefrom, said fourth chamber being sufficiently large in diameter to overlap said first, second and third chambers for placing said first, second, third and fourth chambers in mutual communication;

a first rotor operably co-axially disposed within said first chamber, said first rotor comprising a generally cylindrical member having a diameter substantially equal to the inside diameter of said first chamber, and at least one relieved portion on the surface thereof for cooperating with at least said first chamber to define a working volume;

a second rotor operably co-axially disposed within said second chamber, said second rotor comprising a generally cylindrical member having a diameter substantially equal to the inside diameter of said second chamber, and at least one relieved portion on the surface thereof for cooperating with at least said second chamber to define a working volume;

a third rotor operably co-axially disposed within said third chamber, said third rotor comprising a generally cylindrical member having a diameter substantially equal to the inside diameter of said third chamber, and at least one relieved portion on the surface thereof for cooperating with at least said third chamber to define a working volume;

a fourth rotor operably co-axially disposed within said fourth chamber, said fourth rotor comprising a lobe member rigidly mounted on a shaft for rotation therewith, said lobe member defining a surface for providing a substantial surface-to-surface line contact with the surfaces of said first, second and third rotors at all times during the rotation of said rotors;

intake means for introducing a charge of combustible material into at least one of said first, second and third chambers;

exhaust means from exhausting combustion products from at least one of said first, second and third chambers;

ignition means for igniting said combustible material within said block;

each said working volume being effectively displaced from being in communication with said intake means to being in communication with said ignition means and thereafter to being in communication with said exhaust means during the combustion cycle of said rotary engine;

means for interengaging said first, second, third and fourth rotors to control their relative rotation; and

means for attaching said rotors to a means to be driven.

19. A rotary internal combustion engine according to claim 18 wherein said intake means and said exhaust means comprise passages extending through said block into said first, second and third chambers.

20. A rotary internal combustion engine according to claim 19 wherein said ignition means is disposed to initiate combustion of said combustible mixture within said fourth chamber.

21. A rotary internal combustion engine according to claim 19 wherein said passages defining said intake means and said exhaust means are covered and uncovered by said first, second and third rotors during their rotation within said first, second, and third chambers, respectively, said covering and uncovering of said passages defining a valving operation.

22. A rotary engine according to claim 18 and further including means for evacuating said working volumes after each has been in communication with said exhaust port and prior to each coming into communication with said inlet ports.

23. A rotary engine according to claim 22 wherein said means for evacuating cooperates with said rotatable means to force gases from said working volumes through said exhaust ports.

24. A rotary engine according to claim 22 wherein said means for evacuating said working volumes comprises a longitudinally extending slot formed in the surface of said at least one of said cylindrical chambers, a divider strip reciprocably received within said slot, and means for resiliently urging said divider strip into sur-

face-to-surface engagement with the rotatable means in said at least one of said cylindrical chambers.

25. A rotary expansible chamber device comprising

a block,

at least one intake and at least one discharge port formed in said block,

a plurality of longitudinally extending substantially cylindrical rotor chambers formed in said block,

at least one longitudinally extending communication chamber formed in said block and having an opening between each of at least two of said rotor chambers for mutual communication therebetween,

the longitudinal axes of said rotor and communication chambers being spaced in parallel relation,

a rotor operably disposed in each of said rotor chambers, each said rotor comprising at least one cylindrical lobe member having a diameter substantially equal apart from minimal clearance to the inside diameter of a cylindrical part of said rotor chamber in which said each rotor is disposed and at least one relieved portion on the surface thereof for cooperating with at least said last mentioned rotor chamber to define a working volume,

a rotary valve operably disposed in each of said at least one communication chamber, said rotary valve having a peripheral surface in line-to-line contact apart from minimal clearance with said peripheral surfaces of said rotors disposed in each of said at least two rotor chambers, said line-to-line contact existing substantially throughout each revolution of said rotors,

said rotors and each said rotary valve rotating in the same rotational direction,

each said rotary valve rotating at a rotational speed other than less than the rotational speed of said rotors,

and said at least one rotary valve and said rotors disposed in said at least two rotor chambers are operationally phased such that at least one variable volume compression chamber and at least one variable volume expansion chamber occur substantially simultaneously during a part of each revolution of said rotary valve, said each one of said variable volume compression or expansion chamber is defined by a part of a peripheral surface of a cylindrical lobe member of one of said last-mentioned rotors, a part of a relieved portion of another of said last-mentioned rotors, a part of the peripheral surfaces of said last-mentioned rotary valve, inner wall surfaces of said communication chamber in which said last mentioned rotary valve is disposed, and inner wall surfaces of said rotor chamber in in which said other rotor is disposed.

26. The invention of claim 25 wherein said lobe member of each one of said rotors has a surface extending peripherally for substantially covering a predetermined portion of said opening between said communication chamber and said chamber within which said one of said rotors is disposed.

27. The invention of claim 25 wherein each said rotary valve is rotatable at the same rotational speed as said rotors.

28. The invention of claim 25 wherein each said rotary valve is rotatable at twice the rotational speed of said rotors.

29. The invention of claim 28 wherein each of said rotors has two said relieved portions operationally disposed in said block with axes normal to two respective relieved portions of another of said rotors.

30. The invention of claim 25 further comprising

intake means for introducing a combustible mixture into at least one of said chambers,

ignition means for igniting said combustible material within said block,

and means controlled by said rotors and formed in said block for evacuating each said working volume after each has been in communication with said discharge port and prior to each coming into communication with said intake port.

31. The invention of claim 25 wherein said inner wall surfaces of each of said chambers in which said rotors are disposed comprises end surface segments contiguous to end surface segments of inner wall surfaces of said communication chamber and at said opening for forming sealing surface edges for separating said variable volume compression and expansion chambers.

32. The invention of claim 31 wherein said sealing surface edges coact with said peripherally extending surface of said lobe member of a respective one of said rotors for sealing said variable volume compression and expansion chambers during a covering of said opening between said communication chamber and said rotor chamber in which said last-mentioned one of said rotors is disposed.

33. The invention of claim 25 wherein said rotary valve comprises first and second side surfaces and further comprising circular plates fitted to said side surfaces of said rotary valve and disposed within said block.

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