United States Patent [19]
Case

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[45] Oct. 15, 1974

[54] ROTARY DEVICE

[76] Inventor: John S. Case, 1150 Gypsy Ln., Towson, Md. 21204

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[21] Appl. No.: 330,188

[52] U.S. Cl. 123/8.47, 123/8.05, 123/8.07, 123/8.13, 123/8.15, 123/8.25, 418/195, 418/196
[51] Int. Cl. F02b 55/14
[58] Field of Search 123/8.41, 8.45, 8.47, 8.49, 123/8.05, 8.07, 8.13, 8.15, 8.19, 8.25, 8.29, 8.43; 418/195; 60/39.61

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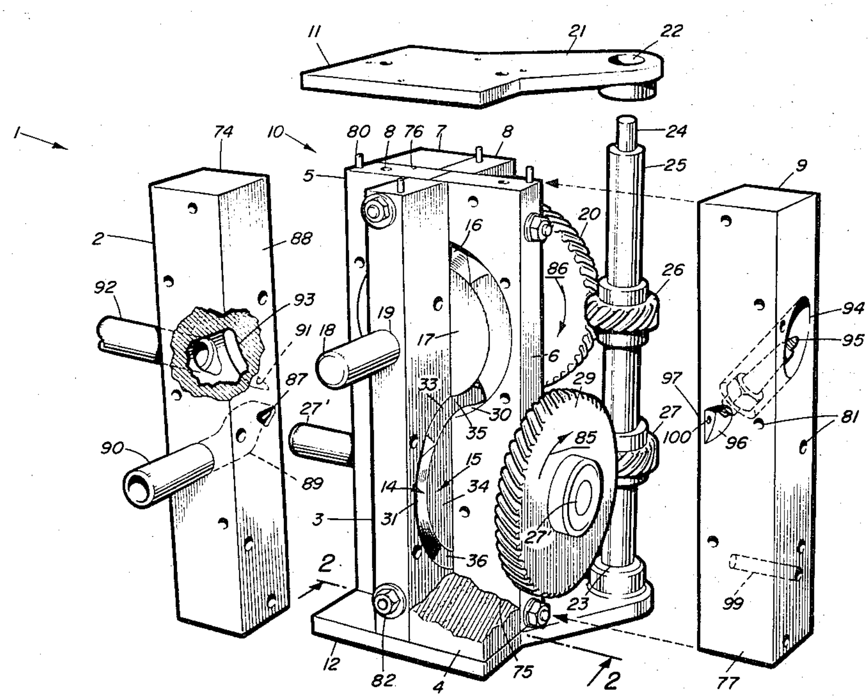
Primary Examiner—Clarence R. Gordon
Attorney, Agent, or Firm—Walter G. Finch

[57] ABSTRACT

A power conversion device which can be used as an internal combustion engine, a fluid pump or a fluid motor. The power conversion device includes at least two intermeshing rotors mounted respectively for rotation in intersecting planes and which rotate in synchronism. Each rotor has an annular piston and the pistons mesh with each other to vary the volume between the pistons to provide the desired action for engine, pump, or motor operation. The rotors are mounted respectively in intersecting casings having annular spaces against which the pistons seal and in which the pistons rotate. The intermeshing of the pistons is such that the leading face of a piston advancing toward a side face of a piston on the other rotor causes compression, exhaust, or discharge whereas a trailing face of a piston moving away from a side face of a piston on the other rotor receives power or causes intake, depending on the cycle of operation of the piston.

13 Claims, 28 Drawing Figures



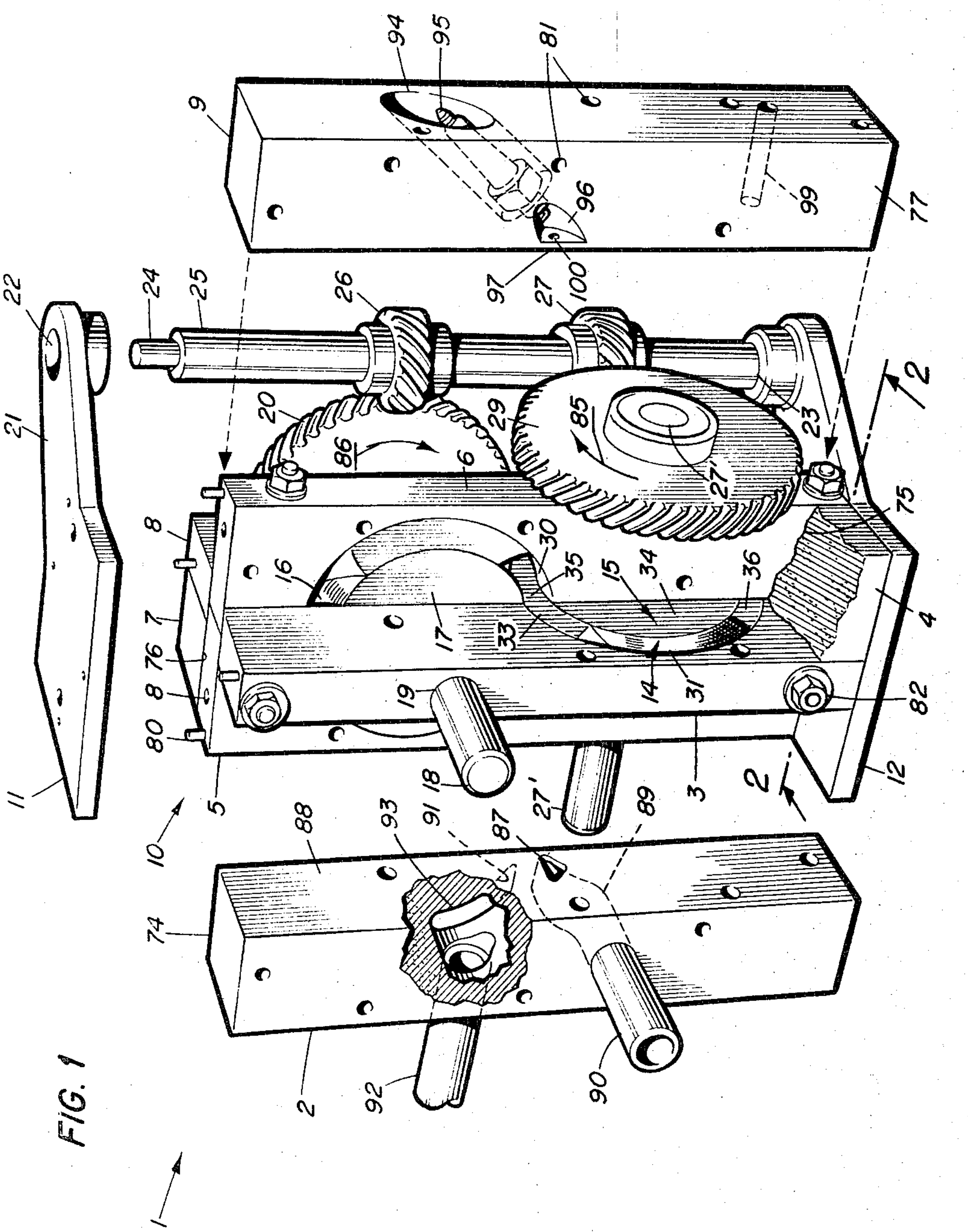


FIG. 1

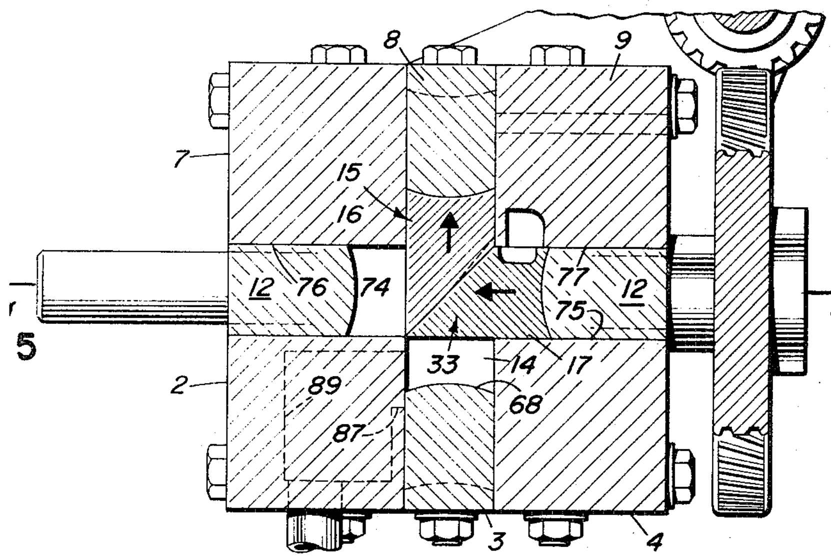

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FIG. 3

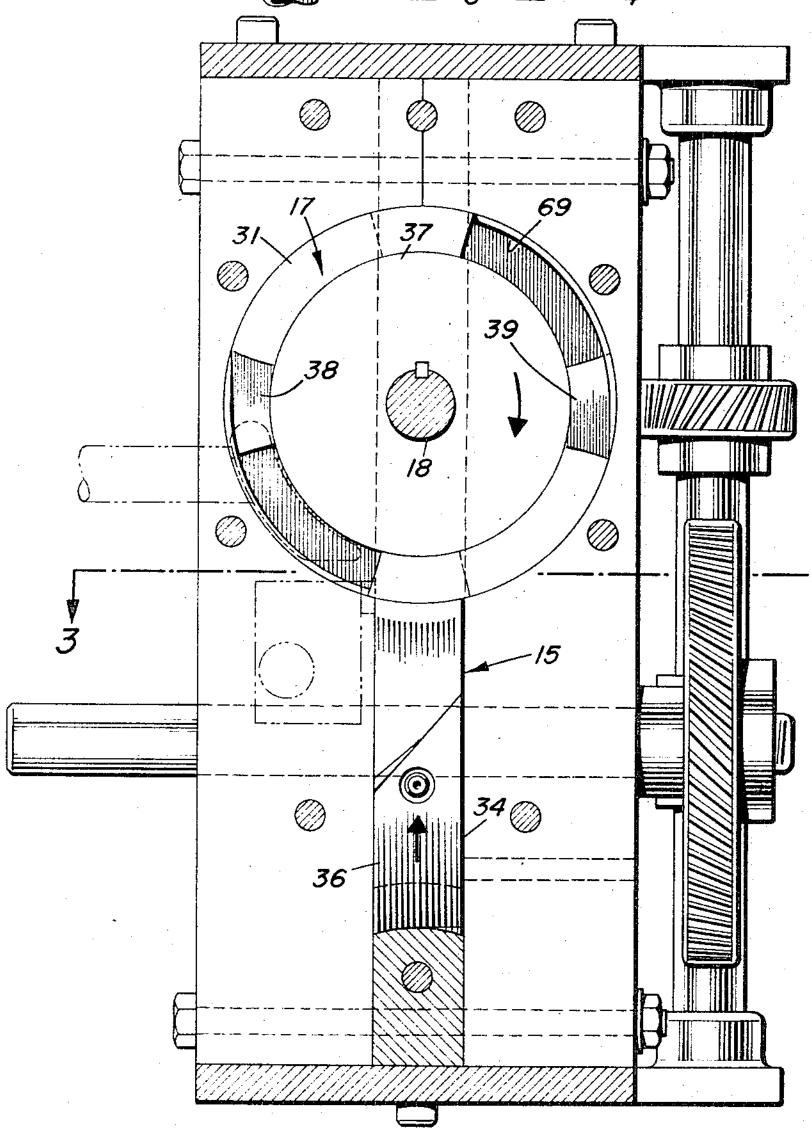
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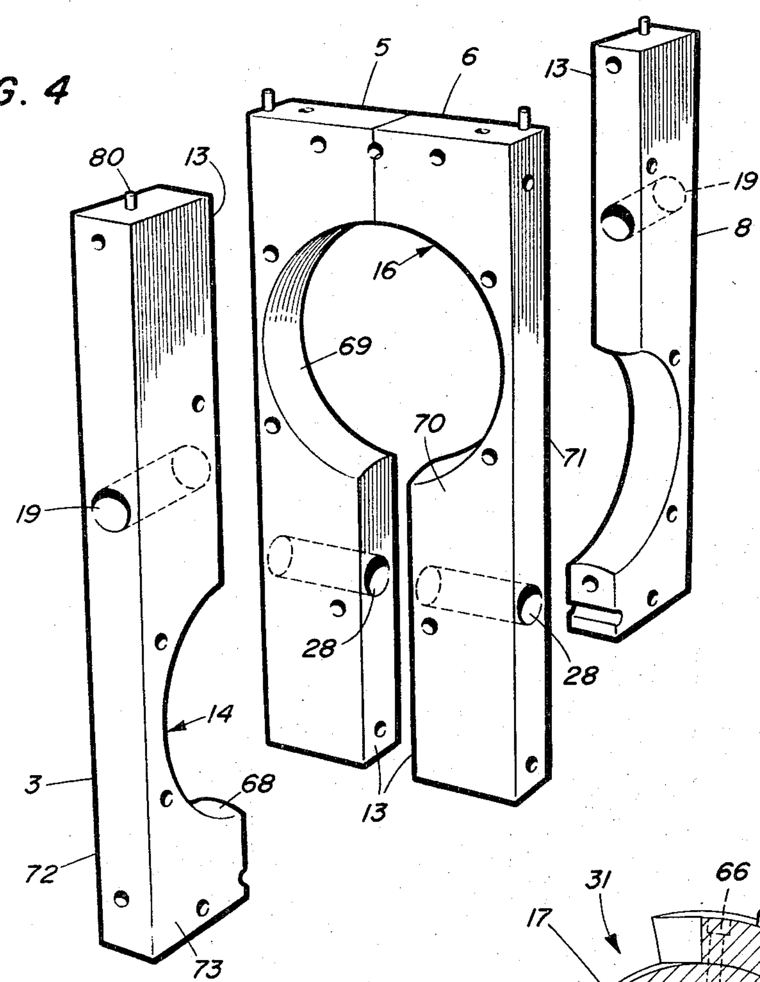
FIG. 2

FIG. 4



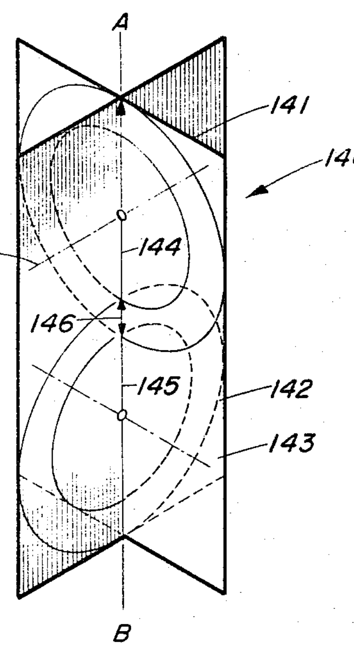


FIG. 19

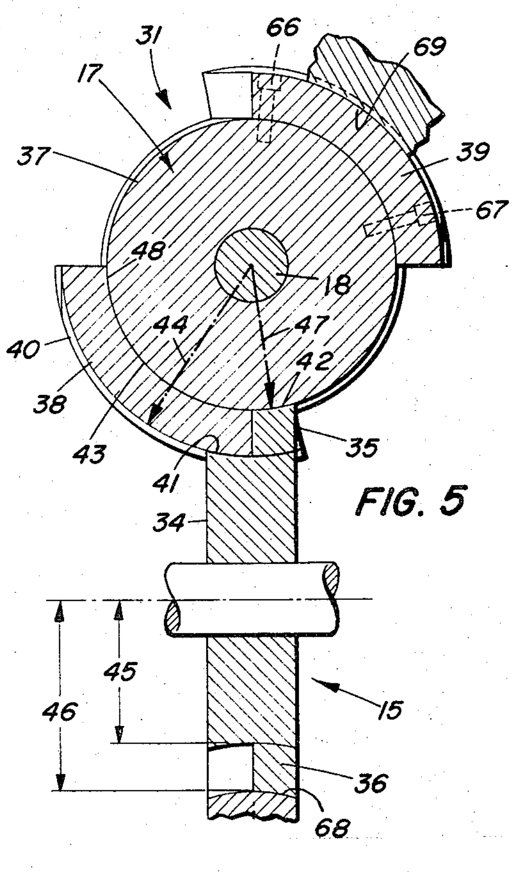


FIG. 5

FIG. 10

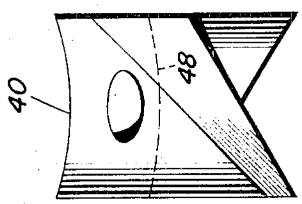


FIG. 7

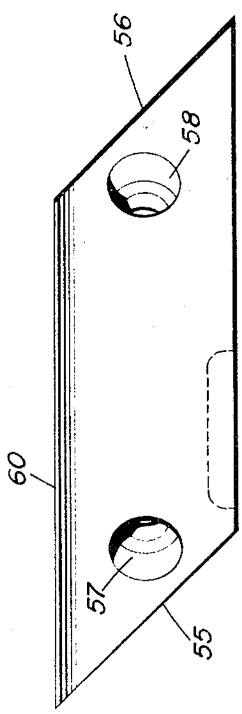


FIG. 6.

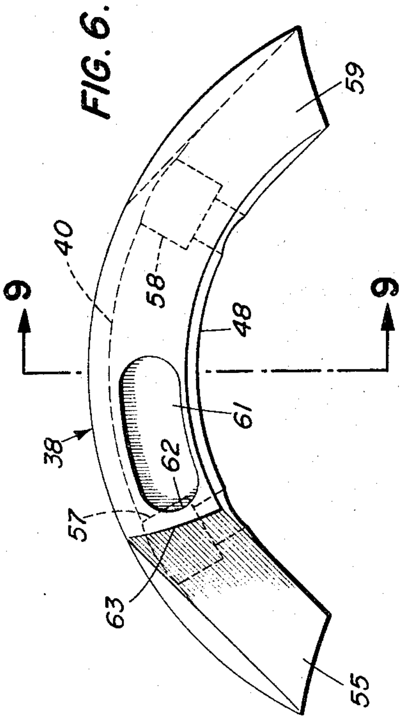


FIG. 8

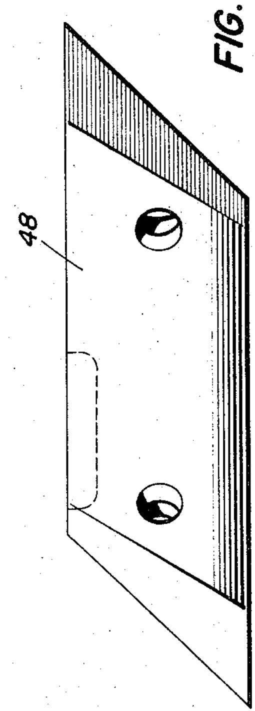
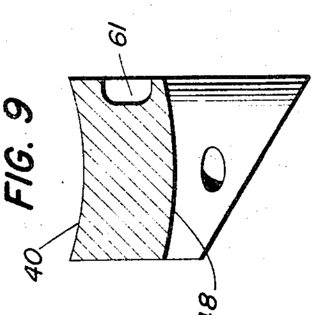


FIG. 9



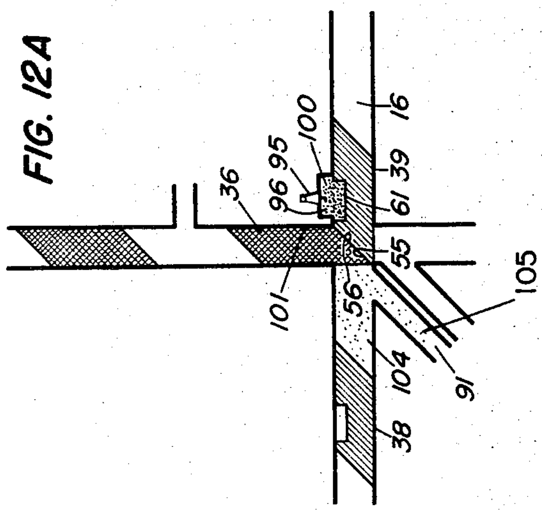


FIG. 12A

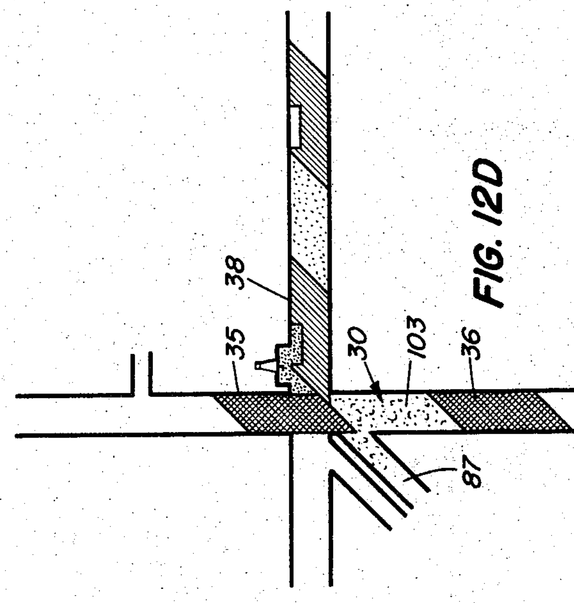


FIG. 12D

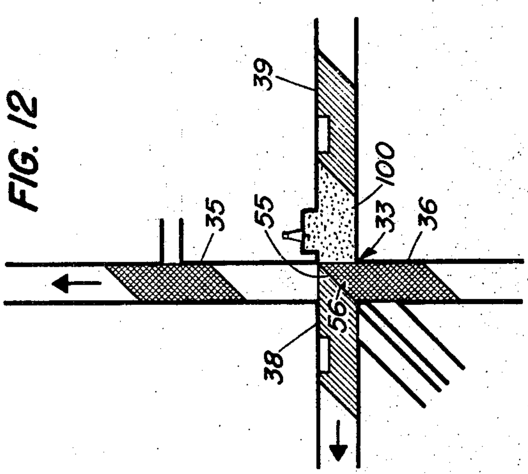


FIG. 12

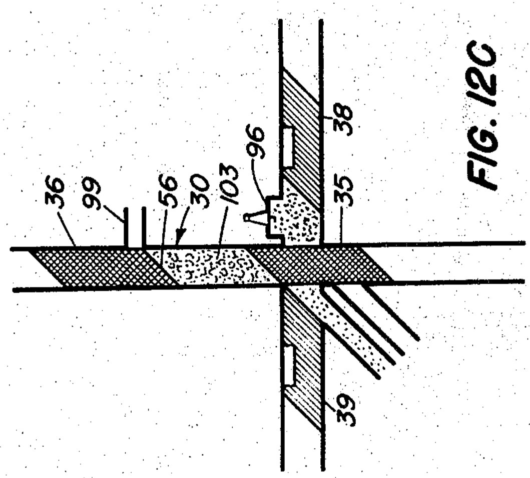


FIG. 12C

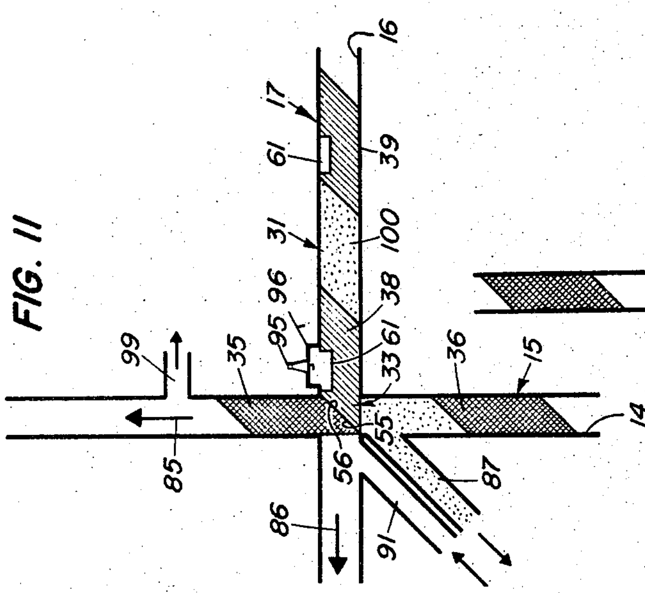


FIG. 11

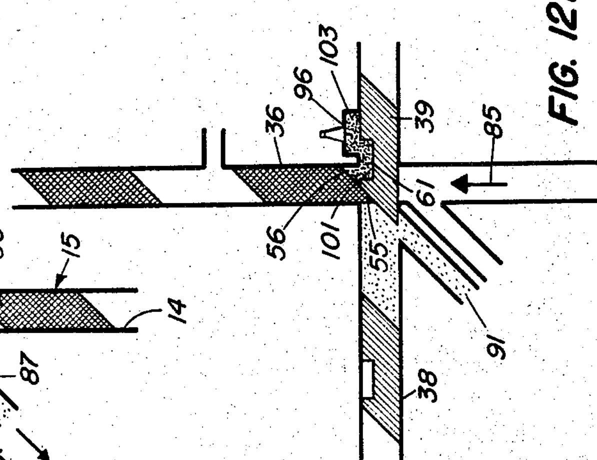


FIG. 12B

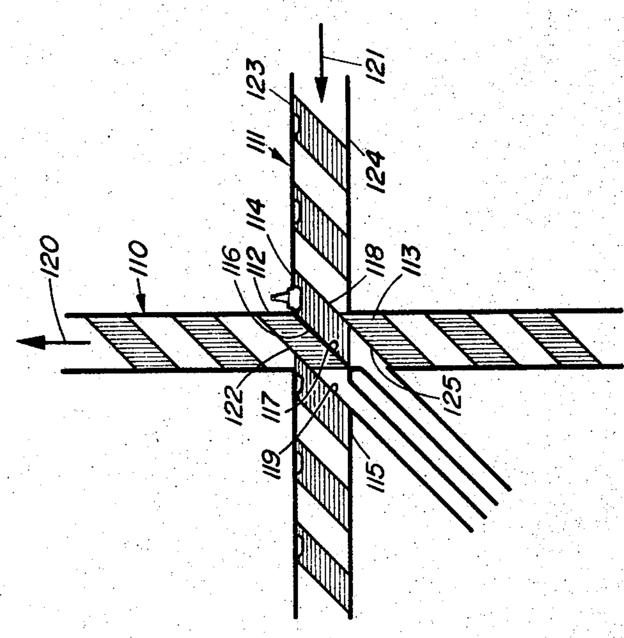


FIG. 15

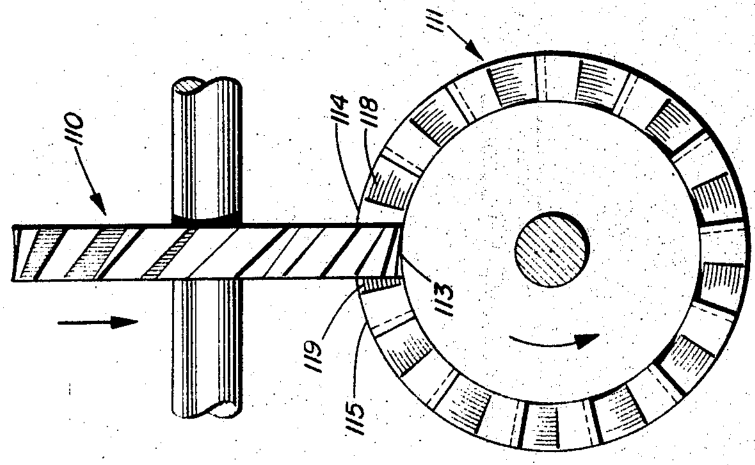


FIG. 14

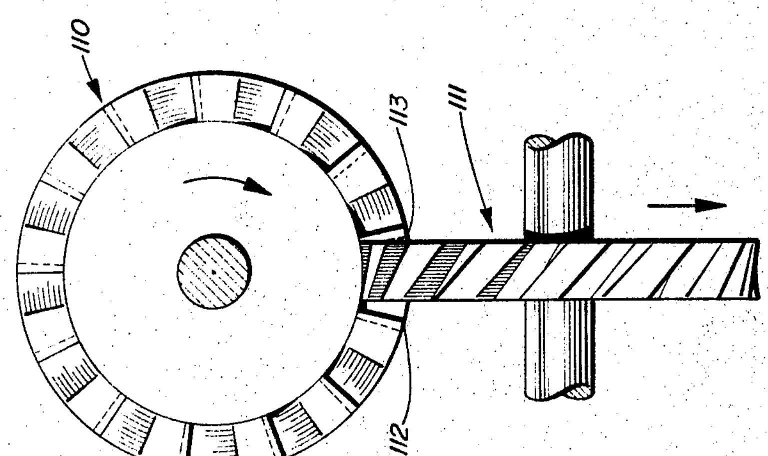


FIG. 13

FIG. 16

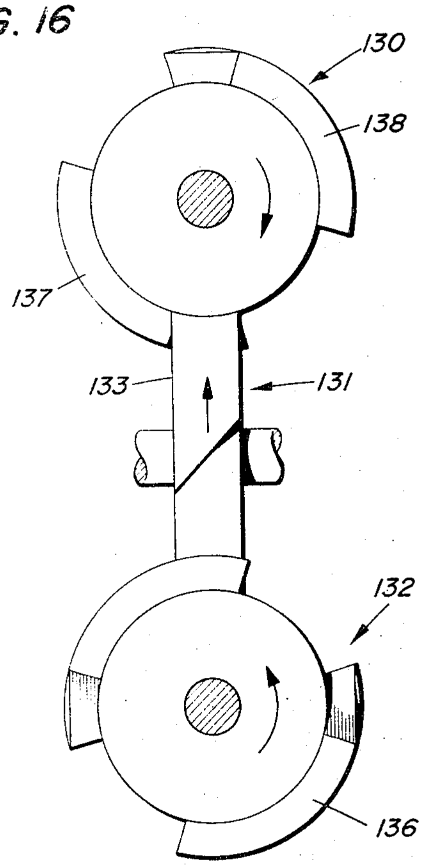
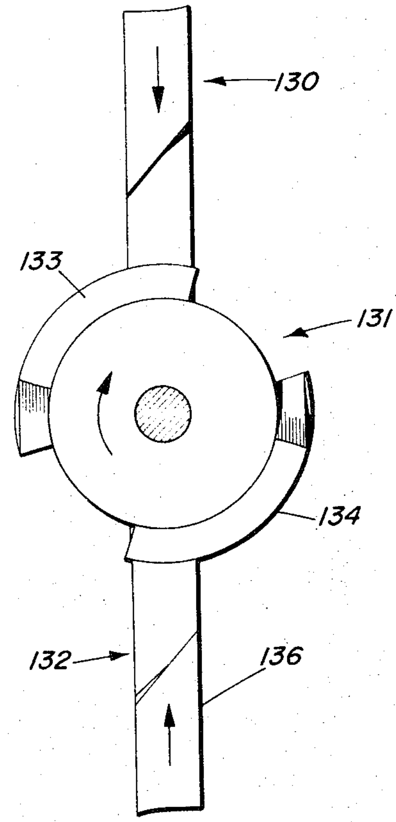


FIG. 17



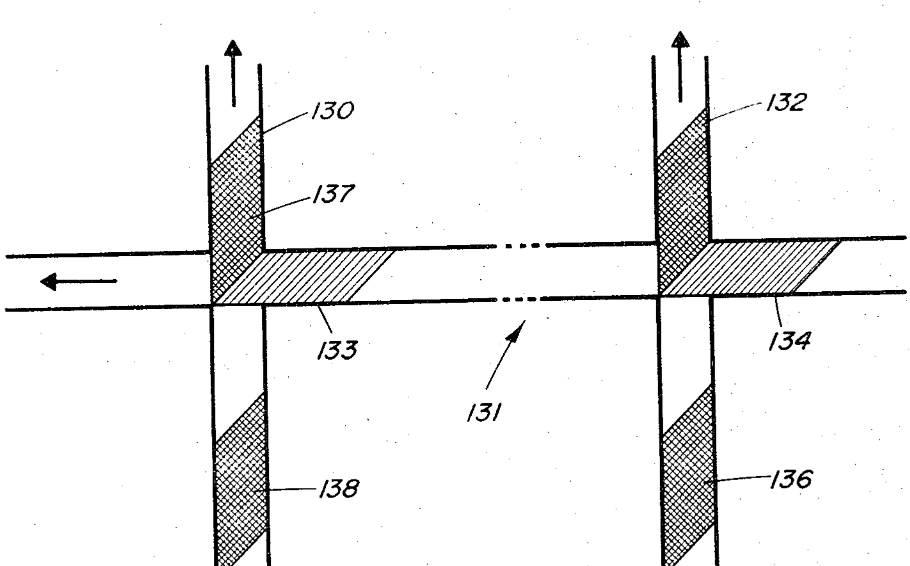


FIG. 18

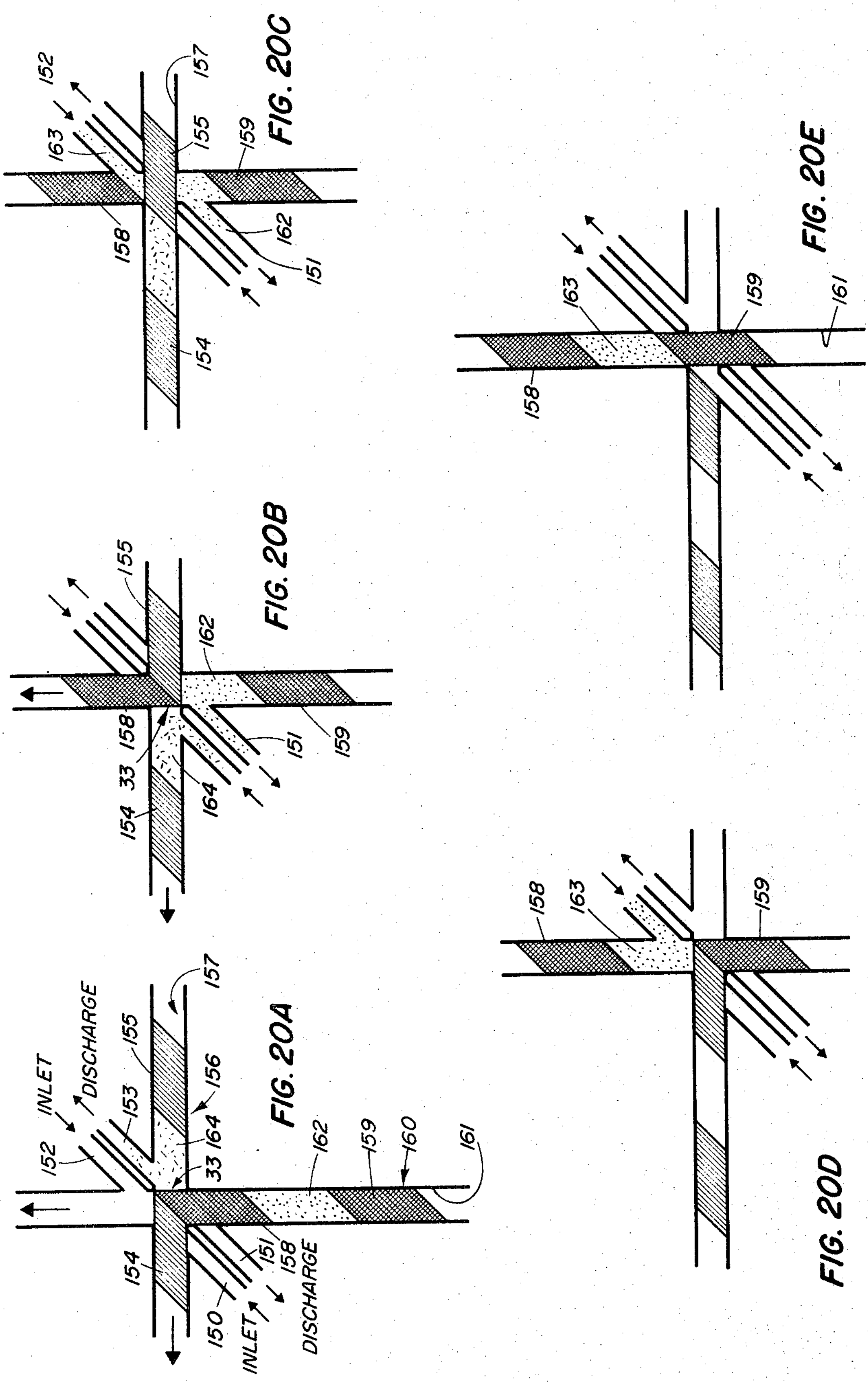


FIG. 20A

FIG. 20B

FIG. 20C

FIG. 20D

FIG. 20E

ROTARY DEVICE

This invention relates generally to a power conversion apparatus, and more particularly to a power conversion device which can be used as an engine, pump, compressor, or fluid motor and which has at least two intermeshing rotors rotating in synchronism to perform the desired function.

Present day piston type internal combustion engines while very highly developed and engineered have an exceedingly great number of parts and are extremely complicated to manufacture, assemble, and service. It is only because of assembly line procedures and mass production techniques that these engines can be manufactured for sale at the existing relatively low prices. The piston type engine has, in addition, significant balancing problems because of the large number of reciprocating parts.

A recently recognized significant disadvantage of the piston type internal combustion engine is the inability of this engine to function properly when equipped with the anti-pollution devices which are presently required. The basic problem is that the piston type engine inherently emits large quantities of pullutants because of the characteristics of the engine.

Recently, the "Wankel" rotory engine was manufactured on a small scale and is presently used by some manufactures because of its lower pollutant emission and its smaller number of parts. Being of the rotary type, the Wankel engine presents fewer balancing problems because of the reciprocating piston engines, but still requires a significant number of parts.

It is a principal object of this invention to provide a power conversion device which can be used as an engine, pump, compressor, or fluid motor, and which has at least two intermeshing rotors rotating in synchronism to perform the desired function.

Another object of this invention is to provide an engine in which there are only a small number of parts and in which the only moving parts rotate so the engine is inherently easy to balance.

Still another object of this invention is to provide an engine which is so arranged that good mixing of the combustible products is obtained with a corresponding reduction of pollutants.

And another object of this invention is to provide an engine which operates at a relatively high compression ratio limited only by the detonation characteristics of the fuel used in the engine.

As previously mentioned, an internal combustion engine is only one of the uses of the power conversion device of this invention.

And still another object of this invention is to provide a device which can also be used as a hydraulic motor, a hydraulic pump, an air compressor, and an air motor. While it is necessary to slightly modify the device for the device to function as a pump, compressor, or fluid engine from its arrangement when used as an internal combustion engine, the modifications are essentially minor so the same basic device can be used for all these purposes.

To provide a rotary device without moving valve parts in which inlet and discharge ports are selectively opened and closed by rotary pistons, these ports requiring no additional valving, is another object of this invention.

To provide in an embodiment of an internal combustion engine, a combustion chamber so arranged that the combustion gases, immediately after combustion, are directed toward a trailing face of a power rotor to drive the rotor in the desired direction, and substantially complete burning of the combustible mixture occurs because of the significant extent of expansion of the combustion gases during the power stroke, is a still further object of this invention.

And to provide high efficiency exhausting of the spent products of combustion when the device is used as an internal combustion engine, is another feature of this invention.

It is still even another object of this invention to provide a new type engine in which there is substantially complete mixing of the air and combustible products prior to compression.

Another important object of this invention is to provide an engine having four cycle operation which provides high efficiency thereof.

The manner in which these and other features of the power conversion device of this invention are attained will now be explained with reference to the accompanying drawings which form a part of this specification and in which:

FIG. **1** is an exploded pictorial view of the power conversion device of this invention showing the device for use as an internal combustion engine;

FIG. **2** is a view in section taken along line **2—2** of FIG. **1**;

FIG. **3** is a view in section taken along line **3—3** of FIG. **2**;

FIG. **4** is an exploded pictorial view of a portion of the casing for the power conversion device;

FIG. **5** is a partial view in section taken along line **5—5** of FIG. **3** with portions of the cylinder and engine block deleted for purposes of clarity;

FIG. **6** is a side view in elevation of a piston of the power conversion device;

FIG. **7** is a top plan view of the piston of FIG. **6**;

FIG. **8** is a bottom plan view of the piston of FIG. **7**;

FIG. **9** is a view in section taken along line **9—9** of FIG. **6**;

FIG. **10** is a front end view of the piston of FIG. **6**;

FIGS. **11** to **12D** show the pistons and cylinders in unrolled flattened form for purposes of explaining the operation of the engine.

FIGS. **13** and **14** are schematics of the piston and rotor relationship to accomplish continuous engagement of the pistons for mutual synchronization;

FIG. **15** shows the piston and rotor relationship of FIGS. **13** and **14** in an unrolled flattened form for purposes of illustrating the operation of the pistons;

FIGS. **16** and **17** are schematics showing the relationship of pistons and rotors when more than two rotors operate together;

FIG. **18** shows the relationship of pistons and rotors of FIGS. **16** and **17** in an unrolled flattened form;

FIG. **19** is a schematic showing the planar relationship of the method for creating the beveled leading and trailing edges of the pistons of FIGS. **6** through **10**; and

FIGS. **20A** through **20E** are schematics of pistons in an unrolled flattened form illustrating the operation of the piston of two rotors when acting as a pump or motor.

Referring now to the drawings in detail and particularly to FIGS. 1–3, a first embodiment of the power conversion device of this invention will now be explained, where the power conversion device takes the form of an internal combustion engine 1. Engine 1 includes a casing which can be of fabricated construction as shown at FIG. 1 and which is comprised of a plurality of casing blocks 2–9 which fit together in the manner shown at FIG. 1 to form a casing 10 for the engine. As shown at FIG. 1 the engine is vertically elongated when in an upright position and also has end plates 11 and 12 which are secured respectively to the opposite ends of casing 10.

The respective blocks 2, 4, 7, and 9 are each of substantially the same external dimensions. The inner or cylinder defining blocks 3 and 8 are identifical to each other and inner blocks 5 and 6 are also identical to each other. The inner blocks 3, 5, 6, and 8 are each identical to each other, blocks 3 and 8 being merely blocks 5 and 6 inverted, as shown at FIG. 4.

Formed in the opposed facing edges of inner blocks 3 and 8 are arcuate cutout portions, each slightly less than a semicircle, and which cooperate to form a cylinder 14 for a power rotor 15, when the blocks are assembled as shown at FIG. 1. Similarly, formed in the facing edges of blocks 5 and 6 are arcuate cutout portions which form a cylinder 16 for an intake or induction rotor 17. It will be apparent with reference to FIG. 4 that blocks 5 and 6 are so formed that there are parallel facing edges 13 at the lower portion of these blocks which are spaced apart a distance precisely the same as the thickness of the blocks 3 and 8. Similarly, blocks 3 and 8 are so formed that their edges 13 are spaced apart by a distance precisely equal to the thickness of the blocks 5 and 6. This permits assembling the blocks so cylinder 16 for intake rotor 17 intersects cylinder 14 for power rotor 15. While the arrangement of FIGS. 1–4 shows the intake rotor 17 above the power rotor 15, it is to be understood that these rotors could be reversed, i.e., the upper rotor could be the power rotor and the lower rotor could be the intake rotor, and that the engine can be oriented as desired without departing from the scope of this invention.

Intake rotor 17 is keyed to a shaft 18 which is journalled in bores 19 of inner blocks 3 and 8, which bores are aligned with each other and with the axis of cylinder 16 when these blocks are assembled. A gear 20 is keyed to one end of shaft 18 so intake rotor 17, shaft 18 and gear 20 rotate in unison. End plates 11 and 12 each have a projecting arm portion 21 in which bearings 22 and 23 are formed, and which bearings are aligned with each other when the end plates are secured to the engine assembly. The bearings 22 and 23 cooperate with the reduced diameter ends 24 of shaft 25 to mount the shaft 25 for rotation about a predetermined vertical axis in the plane of gear 20. Keyed to the shaft 25 is a gear 26 which rotates in a horizontal plane including the axis of shaft 18. Spaced below gear 26 is a second gear 27 which is also keyed to shaft 25 and rotates in a horizontal plane, including the axis of shaft 27'.

Power rotor 15 is keyed to a shaft 27'. Shaft 27' is journalled for rotation in bores 28 of blocks 5 and 6. Bores 28 are aligned with each other as well as with the axis of cylinder 14 of power rotor 15 when the engine is assembled. Keyed to that end of shaft 27' which projects from the engine casing in the same direction as the projecting arms 21 of the upper and lower plates 11 and 12, is a gear 29. Gear 29 rotates in a vertical plane which includes the axis of rotation of shaft 25 and meshes with gear 27. The gears 20 and 29 have the same pitch diameter and the gears 26 and 27 have the same pitch diameter. The gears are each 45° helical gears and cause power rotor 15 to rotate in synchronism with intake rotor 17. While the embodiment of FIG. 1 shows the rotors 15 and 17 to be connected to each other for rotation in synchronism by the external gear train including the gears 20, 26, 27, and 29, an embodiment will subsequently be described in detail which provides for maintaining the rotors in synchronism by means of an internal arrangement.

Cylinders 14 and 16 overlap or intersect at an intersecting space 33 which is common to both cylinders. It is at this intersecting space 33 where the pistons of power rotor 15 and intake rotor 17 intermesh and cooperate with each other to drive the engine 1. This intermeshing arrangement will now be explained.

Power rotor 15 has a generally cylindrical body 34 with parallel side faces. There are a pair of identical power pistons 35 and 36, shown best in FIG. 1, mounted on the periphery of body 34, and there are spaces 30 between the pistons which are substantially identical to the configuration of each piston. Similarly, as shown at FIG. 2, intake rotor 17 has a generally cylindrical body 37 with flat parallel side faces, and projecting pistons 38 and 39 are mounted on the periphery of body 37, with spaces 31 between the pistons which are identical in configuration to the pistons. By virtue of the arrangement of the engine in which the axis of rotation of power rotor 15 is in a plane perpendicular to the axis of intake rotor 17 and because of the gear train which causes the rotors to rotate in synchronism, the pistons of one of the rotors pass alternately through the spaces between pistons of the other rotor. In addition, a piston of one rotor seals against a piston of the other rotor during a portion of its movement through the intersecting space 33.

For engine 1 to operate efficiently it is necessary that each piston form a gas tight seal with the cylinder in which it rotates, and it is also necessary for each piston to form a gas tight seal with the body of the other rotor when a piston passes through the space between pistons of the other rotor. For example, a close essentially gas tight seal is required between the outer periphery 40 of pistons 38 and 39 and the peripheral surface 41 of body 34 of power rotor 15 as shown best in FIG. 5. Similarly, it is also necessary to have a gas tight seal between the outer periphery 42 of pistons 35 and 36 and the peripheral surface 43 of body 37 of the rotor 17 as illustrated in FIG. 5.

To obtain a substantial surface type seal between surface 41 of body 34 and peripheral surface 40 of pistons 38 and 39, the surface 41 is transversely concave and of a radius 44 corresponding to the radius of rotor 17 as measured to peripheral surface 40 of pistons 38 and 39 as shown in FIG. 5.

In addition, peripheral surface 40 of pistons 38 and 39 has a transverse concave curvature with a radius 45 equal to the radius of body 34 of rotor 15, as indicated in FIG. 5. This enables mounting rotors 15 and 17 on their respective axes with surfaces 40 of pistons 38 and 39 in sliding subtantial surface engagement with peripheral surface 41 of body 34 when these pistons pass through the spaces 30 between the pistons 35 and 36 of rotor 15. Similarly, peripheral surface 43 of body 37 has a transverse concave curvature of the same radius as the radius 46 of rotor 15 as measured to peripheral surface 42 of pistons 35 and 36. In addition, peripheral surface 42 of the pistons 35 and 36 is transversely concave and of a radius of curvature the same as the radius 47 of body 37.

For ease of manufacture, pistons 35, 36, 38, and 39 are separately formed and are then secured to the respective bodies 34 and 37. The rotors 15 and 17 can also be formed with the pistons integral with the respective bodies 34 and 37.

The construction of the pistons will now be explained in detail with reference to FIGS. 7–11. Initially, it can be pointed out that where the rotors 15 and 17 are of the same diameter, as is the case with the embodiment of the engine shown at FIG. 1, pistons 35, 36, 38, and 39 are essentially identical except for a minor difference which will subsequently be pointed out. As shown at FIG. 6 for piston 38, each piston takes the form of a segment slightly greater than 90° in circumferential extent. (This relationship only applies where there are two pistons for each rotor.) The outer peripheral surface 40 is transversely concave for the reasons previously explained. The inside peripheral surface 48 has a radius 47, the same as body 37 as shown at FIG. 5, and is also transversely convex so the surface 48 mates the concave surface 43 of body 37.

Each piston, as shown at FIGS. 6–10 for the piston 38, has a beveled leading edge or face 55 and also has a beveled trailing edge or face 56. As shown at FIG. 7, the leading face 55 and trailing face 56 are cut generally in the same direction so the piston has generally a parallelogram type appearance as viewed from above. Formed in the body of the piston are counterbores 57 and 58 which lie along axes that meet at the axis of rotation of the rotor body on which the piston is mounted. The piston has side faces 59 and 60, shown in FIGS. 6 and 7, which can be flat and parallel to each other where the side faces of the cylinders in which the piston rotates are flat as is the case with the cylinders 14 and 16.

Formed in side face 59 of piston 38 is a combustion recess 61 which takes the form of a depression which opens through side face 59 but is otherwise closed. Recess 61 has its leading edge 62 closely adjacent to but spaced from the juncture line 63 at the intersection of side face 59 with leading face 55 of the piston. The function of recess 61 is to provide for one component of a combustion chamber and to communicate combustion pressures to the trailing face of a power piston.

The only essential difference between pistons 35 and 36 of power rotor 15 and pistons 38 and 39 of intake rotor 17 is that the pistons 35 and 36 do not have the combustion chamber recess 61 described for piston 38, but piston 39 does have this recess.

As shown at FIGS. 5 and 6, piston 38 is secured to body 37 of intake rotor 17 by bolts 66 and 67 the heads of which are recessed relative to peripheral surface 40 of the piston. Piston 39 is similarly secured to body 37, and pistons 35 and 36 are secured to body 34 in the same manner.

Peripheral wall 68 of cylinder 14 has a convex transverse curvature, as shown at FIGS. 4 and 5, which conforms to the concave curvature of surfaces 42 of pistons 35, 36. The radius of this transverse curvature is the same as the radius 47 of body 37 to provide a substantial area of contact between pistons 35 and 36 and the peripheral wall 68 to prevent leakage of combustion gases between the outside surface of the pistons and the cylinder wall. Similarly, the peripheral wall 69 of cylinder 16 is of convex transverse curvature to conform to the concave curvature of the surfaces 40 of pistons 38 and 39. This convex curvature has a radius equal to the radius 45 of body 34 of rotor 15.

While the relationship between the several transverse concave and convex curvatures have been explained with reference to rotors 15 and 17 of the same diameter having the same number of pistons thereon, these relationships also apply where for example, power rotor 15 has a diameter twice the diameter of intake rotor 17, in which instance the power rotor will have four pistons rather than two and these pistons will intermesh with the spaces 31 between the two pistons of the intake rotor.

The sides 70 and 71 of blocks 5 and 6 in which cylinder 16 is formed are flat and parallel and the sides 72 and 73 of blocks 3 and 8 are also flat and parallel. The side openings of cylinder 16 are closed by the flat faces 13 of the blocks 3 and 8 which abut surfaces 70 and 71, and surfaces 74–77 of the respective blocks 2,4, 7 and 9 complete the sidewalls for cylinder 16 as shown in FIG. 1. Walls 74 and 75 are flush with the wall 13 of block 3 and walls 76 and 77 are flush with the wall 13 of block 8 so the sides of cylinder 16 are flat and paralle. The sides of cylinder 14 are similarly flat and parallel.

Since the body 37 has flat parallel sides and the sides of pistons 38 and 39 are also flat, parallel and flush with the sides of body 37, the entire rotor has flat parallel side faces. The rotor 17 has a transverse size to be a close fit in cylinder 16 so there is a minimum of leakage between the sides of the cylinders and the sides of the pistons and body 37.

Suitable high temperature resistant seals can be provided between the sides of body 37 and the sides of cylinder 16 as well as between the pistons 38 and 39 and both the sides of the cylinder and its peripheral surface 69. The arrangement for pistons 35 and 36 and the body 34 of power rotor 15 is the same as explained above with regard to intake rotor 17.

As is evident from the explanation above, it is necessary for the several casing blocks 2–9 to precisely fit relative to each other. In addition, it is necessary for the end plates 11 and 12 to be in precise positional relation relative to shaft 25. These precise positional relationships are provided during assembly of the engine by the strategic use of locating pins 80 which cooperate with suitable openings 81 formed in the several blocks to permit positioning the blocks in their required precise positions relative to each other. The engine when assembled is secured together with bolts such as bolts 82 which firmly hold the blocks in their respective positions.

As shown at FIG. 1, power rotor 15 rotates in the direction of arrow 85 which is clockwise as viewed from the gear end of shaft 27', and intake rotor 17 rotates in the direction of arrow 86, which is counterclockwise as view from the gear end of shaft 18. As shown in FIGS. 1 and 3, an exhaust port 87 formed in block 2 opens through side face 88 of the block and coummunicates with cylinder 14 at a location spaced only slightly from the intersecting space 33 of cylinders 14 and 16.

Communicating with port **87** is a passage **89** which is connected to exhaust pipe **90.** Also formed in block **2** is a curved elongate intake port **91** which opens through wall **74** of the block and communicates with an intake pipe **92** through a passage **93** in block **2.** Intake port **91** commmunicates with cylinder **16** at a location only slightly spaced from intersecting space **33** of the cylinders. An additional exhaust port **99** can be formed in block **9,** this port communicating with cylinder **14** at a location spaced from intersecting space **33.**

Formed in block **9** is a spark plug receiving openings **94** which receives a spark plug **95** threaded into its lower end. When in this position, the electrode of the spark plug **95** communicates with a combustion recess **96** formed in wall **77** of block **9.** Recess **96** terminates in spaced relation to surface **97** of block **9.** The recess communicates with cylinder **16** at a location spaced only slightly from the intersecting space **33** of the cylinders **14** and **16.**

By virtue of the direction of rotation of rotor **17,** it will be apparent that combustion recess **96** is slightly ahead of intersecting space **33** in the direction of travel of rotor **17,** intake port **91** is slightly downstream of the intersecting space **33** in the direction of travel of rotor **17,** and exhaust port **87** is slightly upstream of the intersecting space **33** in the direction of travel of power rotor **15.**

The operation of engine **1** of FIGS. **1** to **10** will now be described briefly with reference to FIGS. **11–12D.** As shown at FIG. **11,** pistons **38** and **39** of the intake rotor **17** move through cylinder **16.** The movement is in the direction of arrow **86.** Pistons **35** and **36** of power rotor **15** move through cylinder **14** in the direction of arrow **85.** Communicating with cylinder **14** at a location immediately ahead of intersecting space **33** is the exhaust port **87** and communicating with cylinder **16** at a location immediately downstream from intersecting space **33** is the inlet port **91.** There is a combustion recess **61** in the side wall of each of the pistons **38** and **39,** combustion recess **96** is shown communicating with cylinder **16,** and spark plug **95** is positioned in the recess. FIG. **11** also shows an additional exhaust port **99** communicating with cylinder **15** at a location substantially downstream from the intersecting space **33** of the cylinders.

As shown at FIG. **11,** the leading face **55** of piston **38** is in sealing engagement with the trailing face **56** of piston **35.** As will subsequently be explained in detail, these leading and trailing faces **55** and **56** engage and seal against each other when pistons of both rotors are in the intersecting space **33** of the cylinders.

Shown in one of the spaces **31** between pistons **38** and **39** of intake rotor **17** is a combustible charge **100.** This charge **100** was previously received through the intake port **91** when the space **31** was in communication with the intake port.

At FIG. **12,** pistons **38** and **39** have advanced and pistons **35** and **36** have also advanced so the leading edge **55** of piston **36** engages the trailing edge **56** of piston **38.** The engagement of the pistons with subsequent sealing along the faces **55** and **56** occurs during the initial engagement of leading face **55** with trailing face **56** so the combustible mixture **100** is partially compressed as a result of the decrease in volume resulting from the front portion of piston **36** entering the intersecting space **33** between pistons **38** and **39.**

As pistons **36** and **39** advance further to the position of FIG. **12A,** all the combustible mixture **100** is now confined in the opposed recesses **61** and **96.** What transpired during the movement of piston **39** from the position of FIG. **12** to the position of FIG. **12A** is that combustion recess **61** was in communication with the space ahead of leading face **55** of the piston through the spark plug recess **96** while the charge **100** was compressed as a result of movement of the piston **39** toward the piston **36** which completely closed the intersecting space **33** of the cylinders.

As a result, the charge **100** was compressed and forced around the edge **101** of the piston into the opposed recesses **61** and **96.** During communication of recesses **61** and **96,** charge **100** was ignited by the spark plug **95** at an appropriate time.

By virtue of this arrangement of the opposed recesses **61** and **96,** there is possible for a short period of time, constant volume type combustion of the charge **100** in these opposed recesses. As shown at FIG. **12B** lip **101** has moved to a position where recess **61** communicates with the space behind trailing face **56** of piston **36.** However, leading face **55** of piston **39** at this position of the pistons still seals against the trailing face **56** so the effect of the now ignited charge **103** on the trailing face **56** is to drive piston **36** in the direction of arrow **85** and thereby impart power to rotor **15.**

This expansion of the charge **103** occurs quite rapidly and as a result of the configuration of recess **61,** is wholly in a direction toward the trailing face **56** of piston **36.**

It has been found that the time that recess **61** is in the position of FIG. **12B** where the recess commmunicates with spark plug recess **96** is sufficient for the combustion gases **103** to pass into the space behind trailing face **56** of piston **36** and obtain substantial driving force on this piston. By virtue of the continued sealing engagement between leading face **55** of piston **39** and trailing face **56** of piston **36,** virtually all the combustion gases **103** are contained in the space **30** between pistons **35** and **36** as shown in FIG. **12C.**

Additional exhaust port **99** is so located that when the trailing edge **56** of piston **36** passes port **99,** the exhaust gases **103** exhaust so the pressure within space **30** is substantially atmospheric. The final exhausting of combustion gases **103** occurs through exhaust port **87** as shown at FIG. **12D.** In this position of the pistons, the remaining portion of the combustion gases **103** are driven out of space **30** as a result of the decrease in volume of the space **30** when piston **38** crosses in front of piston **36.** Ultimately, a position of the pistons is reached as shown at FIG. **11** where all the residual exhaust has been driven through port **87.**

With reference to FIG. **12,** as charge **100** is being compressed, piston **38** moves from the position of FIG. **12** to the position of FIG. **12A** while piston **36** extends across interesecting space **33.** As a result, a low pressure region is formed in the space **104** behind piston **38,** and this space is in communication with inlet port **91.** As a result, a new charge **105** is drawn into cylinder **16** in the space **104** behind piston **38.** It will be noted with reference to FIG. **12B** that piston **39** has almost closed inlet port **91** when the pistons are in the position of FIG. **12B.**

Where the engine has rotors **15** and **17** each with two pistons, there are two intakes and combustions during each revolution of the rotors. The engine, however, operates on a four cycle principal but requires no moving valves but merely ports such as the ports **87** and **91**, and if desired, the additional port **99** for exhaust. The pistons themselves open and close these ports at the proper time during operation of the engine. As a result, the number of moving parts in the engine is substantially less than that of existing engines. The elimination of moving valves results from the relative locations of the intake and exhaust ports relative to the intersecting space **33** between cylinders **14** and **16**.

There are several advantages to locating the intake port **91** immediately downstream from the intersecting space **33** between the cylinders. One advantage obtained is that the new charge **105**, shown in FIG. 12A, which is drawn into the space **104** behind the cylinder **38**, as shown at FIG. 12A, subsequently functions to cool the leading edge **55** of the piston **39** when this piston reaches the position shown in FIG. 12B. At the same time, the charge is preheated as a result of the heat transferred from this leading face **55** of piston **39**. In addition, since the charge **105** is in the space between the pistons **38** and **39** for approximately 270° of rotation of these pistons, the charge is well mixed even before compression begins as shown at FIG. **12** As a result of compressing the well mixed charge, ignition occurs in a uniform and predictable manner when spark plug **95** is energized.

A second embodiment of the power conversion devise of this invention and which does not require the external gearing including the gears **20, 26, 27,** and **29** of the first embodiment will now be described. This second embodiment has particular utility where small size is required and where external gears for maintaining the rotors in synchronism are deemed undesirable.

In this second embodiment of the power conversion device as shown at FIGS. **13** and **14**, the rotors **110** and **111** are arranged in the manner shown for the first embodiment, and both rotors can be of the same diameter. Where the rotors are of the same diameter each rotor has an equal number of pistons such as the pistons **112** and **113** on the rotor **110** and the pistons **114** and **115** on the rotor **111**. Each of the pistons have the same 45° angle leading and trailing faces previously explained for the pistons of the embodiment of FIG. **1**. A significant difference between the embodiments of the power conversion devices is, however, that the embodiment of the power conversion device of FIGS. **13** and **14** has pistons which are of a length as measured between the leading and trailing faces which is shorter than the width between their side faces. In addition, the distance between the pistons is the same as the length of the space between pistons on other rotor or very slightly smaller other rotor to provide running clearance.

FIG. **13**, and its orthographically projected side view FIG. **14**, illustrates generally the above described second embodiment. For a fuller understanding of the relationship between the elements of the rotors reference is made to the unrolled schematic showing of FIG. **15** wherein rotors **110** and **111** rotate in the direction of the respective arrows **120** and **121**.

Pistons **112** and **113** on rotor **110** are in mesh respectively with pistons **114** and **115** of the rotor **111**. In addition to the broad engagement between the trailing face **117** of piston **112** and the leading face **116** of piston **114**, it can be noted that the trailing face **119** of departing piston **115** still engages the leading face **122** of piston **112** for a while after the leading face **125** of advancing piston **113** has come into engagement with trailing face **118** of piston **114**.

By virtue of this arrangement, a piston of one rotor is always between adjacent pistons of the other rotor, and, as a result, the pistons themselves function as gearing to maintain the rotors in rotating synchronism. Such gearing as provided by the pistons in this embodiment eliminates the need for the external gearing required in the embodiment of the power conversion device **1** of FIGS. **1–10** where the length of each piston is greater than the width between its side faces.

It is to be observed with particularity with regard to piston **114**, that this piston has a circumferential extent as measured between its leading face **116** and its trailing face **118** which is less than the width of the pistons as measured between their side faces **123** and **124**.

A similar relationship exists with regard to rotor **110**, by virtue of this arrangement, a piston on one rotor such as the piston **114** on the rotor **111** will always be in mesh with two pistons on the other rotor.

The advantage of the embodiment of the power conversion device of FIGS. **13–15** is the absence of the external gearing used in the embodiment of the power conversion device **1** of FIGS. **1–10**. By examination of external gearing, compression and expansion pressures are directly absorbed by the pistons to maintain close contact and more accurate register of the pistons.

While two embodiments of means for maintaining synchronization of the rotors has been shown and described, it is to be understood that other means can be employed.

A third embodiment of the power conversion device of this invention will now be described. In the third embodiment, with reference to FIGS. **16–17**, there are three rotors **130–132** each having two pistons mounted thereon. This arrangement is quite similar to the embodiment of the power conversion device **1**, of FIGS. **1** to **10** in that the rotors **130** and **131** cooperate in a manner like the rotors **17** and **15** respectively, but in addition, there is a third rotor **132** mounted for rotation about an axis parallel to the axis of rotation of rotor **130** which intermeshes with the rotor **131**.

As shown at FIGS. **16–17**, rotor **131** has pistons **133** and **134** equally spaced apart circumferentially and these pistons **133** and **134** alternately mesh with the pistons **135** and **136** of rotor **132** and pistons **137** and **138** of rotor **130**.

The arrangement of the embodiment of the power conversion device of FIGS. **16–17** can be used as a motor by providing suitable inlet ports communicating with the cylinder for rotor **131** such that there are two intakes per revolution, in which instance the rotor **131** would be the intake rotor and rotors **130** and **132** in this instance would each be power rotors. The relationships of the parts as illustrated in FIGS. **11–12D** being the same, the combustible mixture drawn in by the intake rotor **131** would be compressed and ignited four times for each revolution of the rotor **131**.

Alternatively, the embodiment of the power conversion device of FIGS. **16–17** could be used as a pump or compressor where the rotors **130** are each both intake and discharge rotors and the rotor **133** is merely an idler rotor which provides for sealing at the faces of the pistons to provide for compression by the rotors **130** and **132**.

The leading face **55** and trailing face **56** of each piston, such as piston **38** of FIG. **6**, is not a plane surface, but is instead a curved or warped surface to obtain substantial surface to surface contact between a leading face of a piston on one rotor and the trailing face of a piston on the other rotor. With reference to FIG. **19** there is shown schematically a rotor **140** rotatable in a plane **141** and which meshes with a rotor **142** rotatable in a plane **143.** Rotor **140** has an imaginary radius **144** which is common to an imaginary radius **145** of the rotor **142** in the region **146** which is common to the pistons of each rotor. If the radius **144** is rotated about its axis **147,** at an angular velocity equal to the angular velocity of advance of the rotor **142,** a geometrical surface will be formed on rotor **142** which closely approximates the geometrical surface of the leading and trailing faces of each piston of the power conversion device of this invention.

Hence, while the precise curvature of these leading and trailing faces of the pistons is not known, the configuration of these surfaces approximates the surface formed by a line passing through the geometric center of each rotor and perpendicular to the axis of each of the rotors and which is rotated about one of the axes at the same angular velocity (or where the rotors are of different sizes, at the same linear speed) as the angular velocity of rotation of the rotor about the other axis. Since both the leading and trailing faces of each piston are at an angle of 45° to the axis of rotation of a rotor, each take the form of a 45° angle helix so that the surfaces of a leading face are in substantial engagement with the surfaces of a trailing face when any two pistons are in engagement with each other during operation of the power conversion device.

The operation of the power conversion device as a pump will now be explained with reference to FIGS. **20A–20E**. It will be observed by comparing FIGS. **20A–20E** with FIGS. **12–12E** that only slight modification is required for the power conversion device to operate as a pump, or alternatively, as a fluid engine. As shown at FIG. **20A**, there is an inlet **150** and a discharge **151** positioned in the same positions as the respective intake and exhaust ports **91** and **87** of the embodiment of the power conversion device of FIGS. **1–12D**, where the power conversion device is used as a internal combustion engine.

In addition, at the other side of the common or intersecting space **33** there is an additional inlet **152** and an additional discharge **153,** in the embodiment of the power conversion device of FIGS. **20A–20E**. There are pistons **154** and **155** of a rotor **156** which rotates in a cylinder **157.** In addition, there are pistons **158** and **159** on a rotor **160** which rotates in a cylinder **161.**

As shown at FIGS. **20A** and **20B**, a fluid **162** previously in the space between pistons **158** and **159** is being compressed by the continued advance of the piston **159** against the side face of piston **155** which now seals against piston **158** at the crossover intersecting space **33** such that the fluid **162** is forced out through discharge **151.**

Slightly after the piston **158** leaves engagement with the piston **155,** a low pressure region is created behind the piston **158** as a result of its movement such that an additional charge **163** of fluid is drawn through inlet **152** into the space behind the piston **158.** Simultaneously, piston **159** continues to expel fluid **162** through the discharge port **151** as shown at FIG. **20C**.

The continued intake or induction steps are shown at FIGS. **20D** and **20E** where it is ultimately noted in FIG. **20E** that the fluid **163** is in the space between the pistons **158** and **159.** At the same time that the rotor **160** is compressing the charges **162** and the rotor **156** goes through induction.

As piston **159** of rotor **160** is compressing fluid **162,** inlet port **150** is uncovered and fluid **164** is drawn into the space behind the piston **154.** The fluid remains trapped between the pistons **154** and **155** until these pistons again reach the position of FIG. **20A** where the fluid **164** is expelled through discharge **153,** and substantial compression is obtained.

It is to be noted again that in the embodiment of the power conversion device or pump of FIGS. **20A–20E**, it is the side faces of the pistons which open and close the inlet and discharge ports, and that no valves separate from the mere ports **150–153** are required. It may, in some instances, be desirable to install check valves on discharges **153** and **151** to prevent reverse flow into the engine until the pressure within the cylinders exceeds the back pressure in a reservoir (not shown) into which the fluid is expelled.

While several preferred embodiments of the power conversion device of this invention have been shown and described, it is to be understood that numerous changes can be made without departing from the scope of this invention as set forth herein and specified in the appended claims.

What is claimed is:

1. A power conversion device, comprising, a casing; an intake rotor and a power rotor intermeshing with each other and mounted respectively for rotation in intersecting planes within the casing; each of the rotors including a piston projecting from each rotor, the piston having a beveled leading edge, a beveled trailing edge, and side faces joining the leading and trailing edges; the leading and trailing edges of the pistons engaging and sealing against each other during rotation of the rotors; the casing mounting the rotors for rotation in close fitting relation to the side faces of the pistons, the casing including first and second circumferential spaces intersecting at the intermeshing region of the rotors; a combustion chamber defined in part by a first recess in a wall of the first circumferential space of the casing and at a location adjacent to but spaced from the location of intersection of the circumferential spaces, and defined in part by a second recess in a side face of the piston of the intake rotor at a location adjacent to but spaced from the leading edge of the intake rotor piston, said second recess being between the leading and trailing edges of the piston; the second recess of the intake rotor piston opposing the first recess in the wall of the casing during at least a portion of each revolution of the intake rotor and communicating combustion pressures in the first recess to the second circumferential space in a direction toward the trailing edge of the power piston; whereby, pressures from combustion within the power conversion device are directed away from the leading edge of the intake piston.

2. A power conversion device according to claim **1** wherein the beveled leading and trailing edges of the several pistons are each surfaces; sufaces; and the surfaces are in substantial surface to surface sealing engagement during at least a portion of each revolution of the rotors.

3. A power conversion device according to claim 2 wherein the intersecting planes in which the intake and power rotors rotate are perpendicular to each other; and the leading and trailing edges of the pistons are 45° angle helical surfaces.

4. A power conversion device according to claim 1 wherein said second recess of the combustion chamber is wholly within the side face of the piston of the intake rotor and is isolated from the leading edge of the piston.

5. A power conversion device according to claim 1 wherein an exhaust port communicates with said second circumferential space at a location immediately ahead of the intermeshing region of the rotors; and an inlet port communicates with the first circumferential space at a location immediately following the intermeshing region of the rotors.

6. A power conversion device according to claim 5 wherein an additional exhaust port communicates with the second circumferential space at a location spaced from the intermeshing region of the rotors by a distance approximating the length of a piston as measured between its leading and trailing edges.

7. A power conversion device according to claim 6 wherein the inlet port, exhaust port, and additional exhaust port are periodically closed by side faces of the rotor pistons.

8. A power conversion device according to claim 1 wherein the engine further includes means connecting the rotors together for rotation in synchronism.

9. A power conversion device according to claim 8 wherein the means connecting the rotors for rotation in synchronism includes a gear train externally of the casing.

10. A rotary energy conversion device according to claim 6 wherein the casing further includes additional circumferential space intersecting the first circumferential space at a location spaced from the intersection of the first and second circumferential spaces; additional rotors mounted for rotation in the additional circumferential space, the additional rotors having a piston like the aforementioned pistons intermeshing with the pistons of the first rotor at the intersection of the first and additional circumferential spaces.

11. A rotary energy conversion device according to claim 10 wherein the first and additional rotors are mounted for rotation in the same plane, with the axes of rotation of the rotors are parallel.

12. A rotary energy conversion device according to claim 11 wherein an additional inlet communicates with the first circumferential space at a location immediately beyond the location of engagement of the first piston with the additional piston; and an additional outlet communicates with the additional circumferential space at a location immediately ahead of the location of engagement of the first and additional pistons.

13. A power conversion device, comprising a casing; an intake rotor and power rotor intermeshing with each other and mounted respectively for rotation in intersecting planes and respectively within first and second circumferential spaces in the casing; the first and second circumferential spaces intersecting at the intermeshing region of the rotors; each of the rotors including a piston projecting therefrom; a combustion chamber defined in part by a first recess in a wall of the first circumferential space of the casing and at a location spaced from the location of intersection of the circumferential spaces, and defined in part by a second recess in the piston of the intake rotor, the second recess of the intake rotor piston opposing the first recess in the wall of the casing during at lest a portion of each revolution of the intake rotor and communicating combustion pressures in the first recess to the second circumferential space in a direction toward the power piston; whereby, pressures from combustion within the power conversion device are directed away from the intake piston.

* * * * *

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,841,276 Dated October 15, 1974

Inventor(s) John S. Case

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 12, line 64, after "each" delete "surfaces; surfaces;" and insert -- helical surfaces; --.

Column 14, line 32, the word "lest" should read -- least --.

Signed and sealed this 17th day of December 1974.

(SEAL)
Attest:

McCOY M. GIBSON JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents

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