United States Patent

[11] 3,628,899

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[54] **EXPANSIBLE FLUID ROTARY ENGINE**
18 Claims, 12 Drawing Figs.

[52] **U.S. Cl.** **418/61**
[51] **Int. Cl.** **F01c 1/02**
[50] **Field of Search** .... 91/56, 81, 92; 103/125, 130; 230/145, 150; 123/8 VG, 8, 13 B, 8 JJ, 8 XX; 418/61

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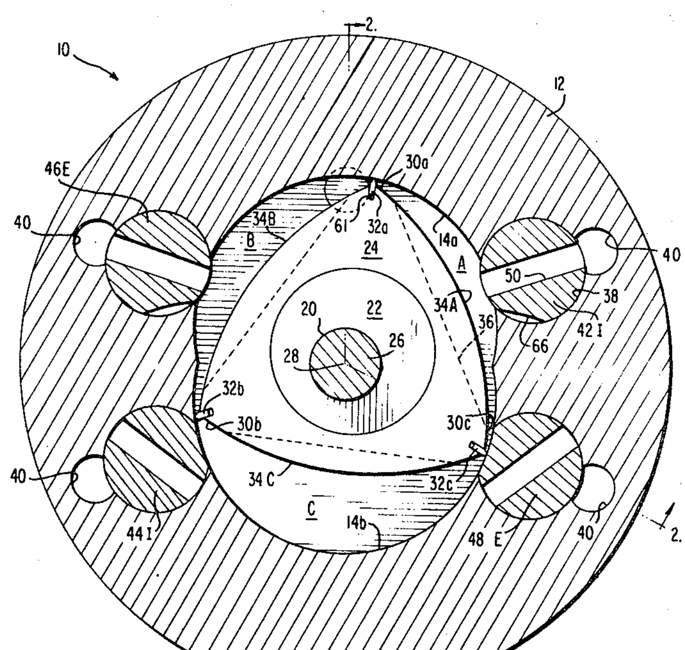
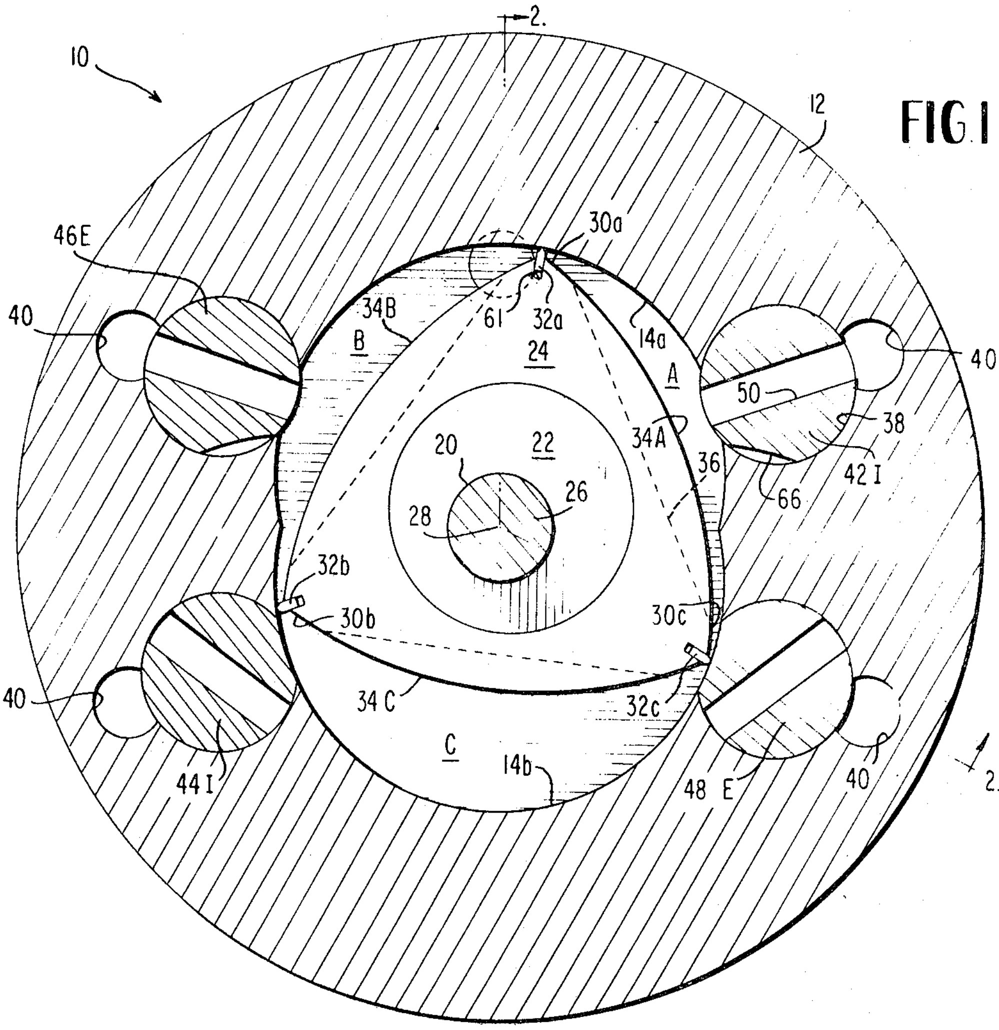
Assistant Examiner—Irwin C. Cohen
Attorney—Le Blanc & Shur

ABSTRACT: The engine comprises a two-lobed housing having an epitrochoidal inner surface in which is mounted a triangular rotor on an eccentric carried by a central driven shaft, the rotor and epitrochoidal surfaces forming variable-volume working chambers. Inlet and exhaust valves are disposed in the housing on opposite sides of the cusps of the epitrochoidal surfaces. A timing mechanism oscillates the valves between open and closed positions to respectively admit expansible fluid into the chambers to rotate the rotor and to exhaust the expanded fluid from the chambers. The valves in their closed positions have surfaces conforming to the lobe surfaces to permit the apex portions of the rotor to sweep past the valves without breaking the seal between adjacent chambers. The valves are timed by a plurality of camshafts coupled to the driven shaft. The rotor can be driven in the reverse direction.




10
12
2.
30a
46E
40
34B
61
32a
14a
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24
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38
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22
34A
42 I
36
66
28
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32b
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34 C
32c
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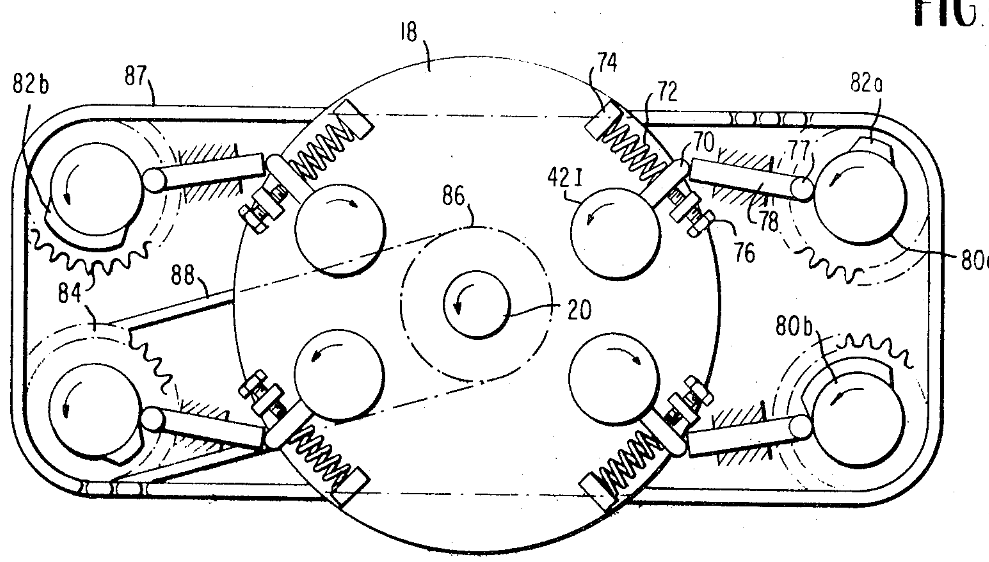
44 I
48 E
40
2.

FIG. 1


18
74
82b
87
72
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42 I
86
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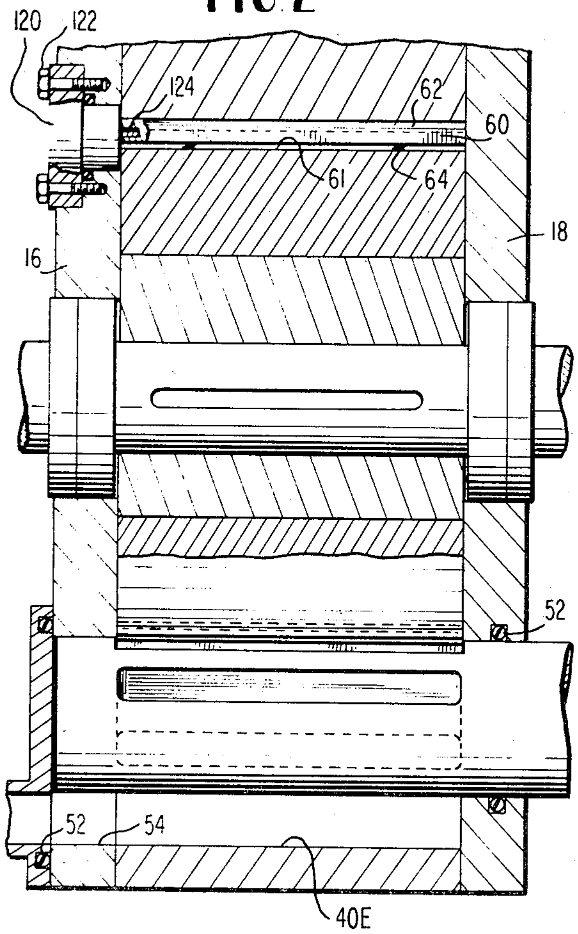
84
88
20
80b

FIG. 4

FIG. 2



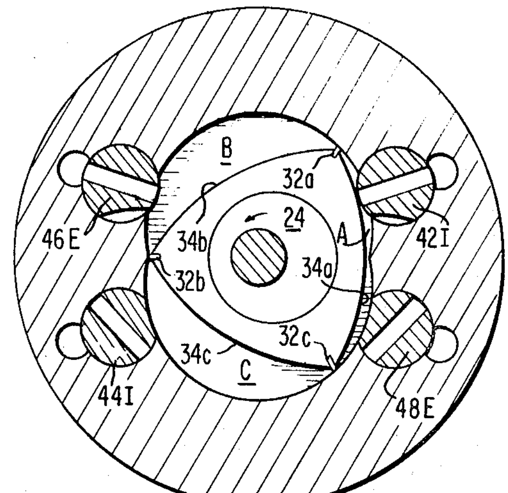


FIG. 3a

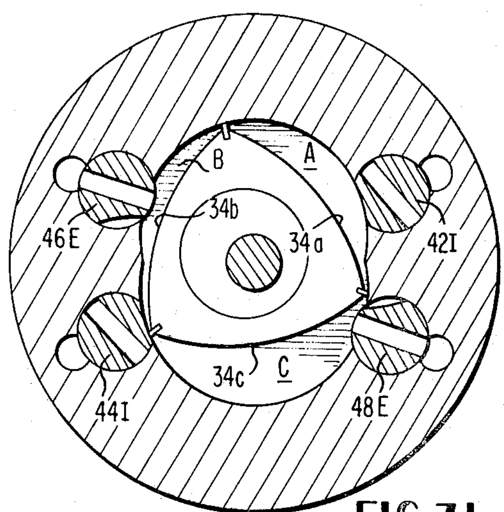


FIG. 3b

FIG. 3c

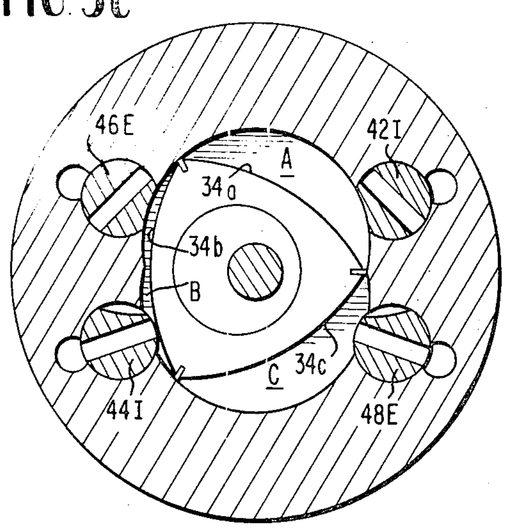


FIG. 3d

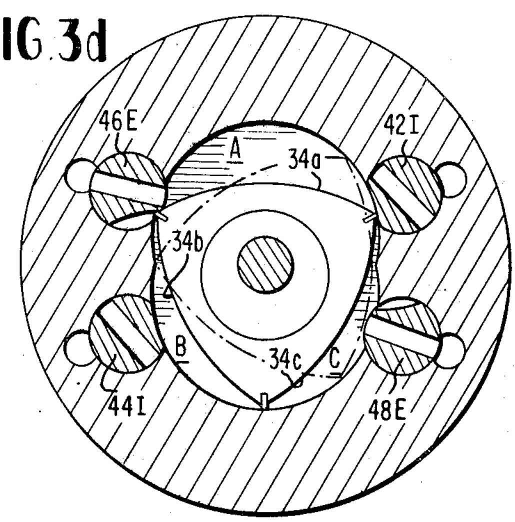


FIG. 5

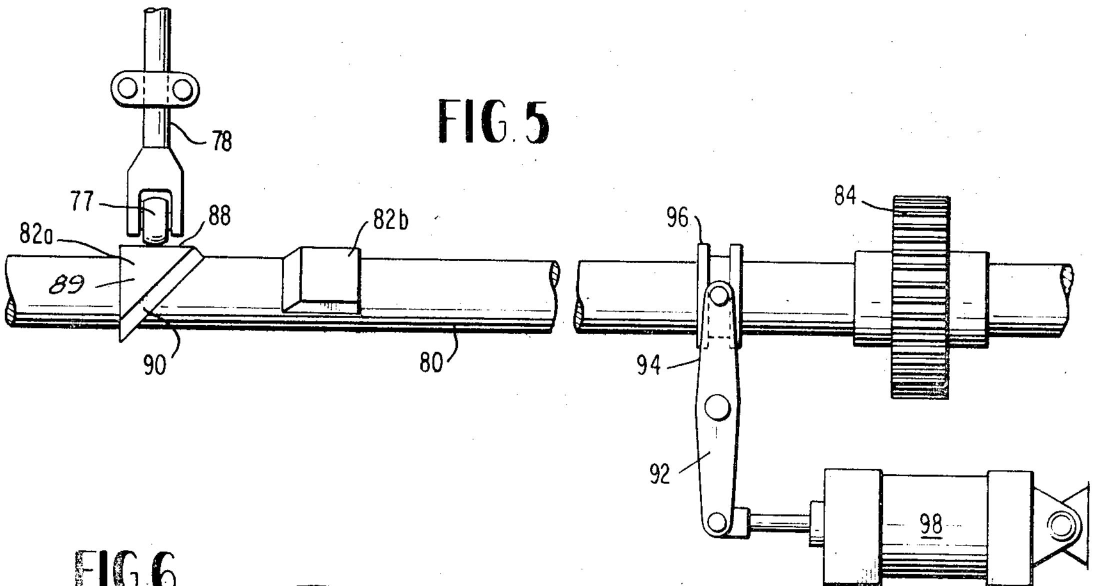


FIG. 6

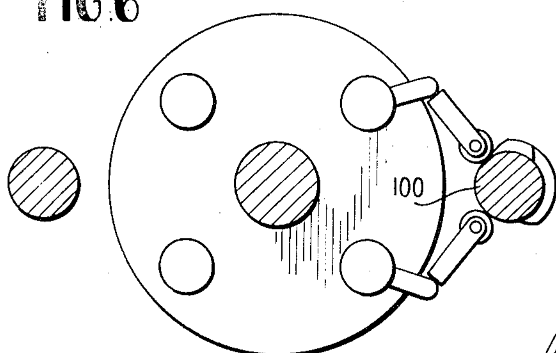


FIG. 8

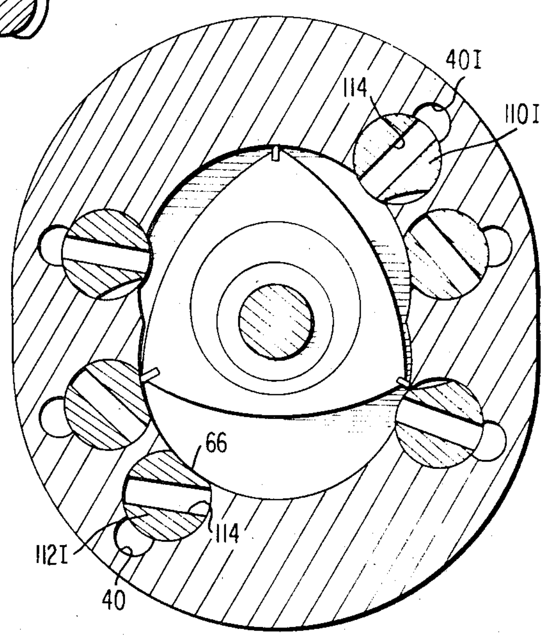
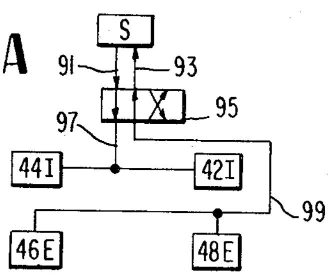


FIG. 5A



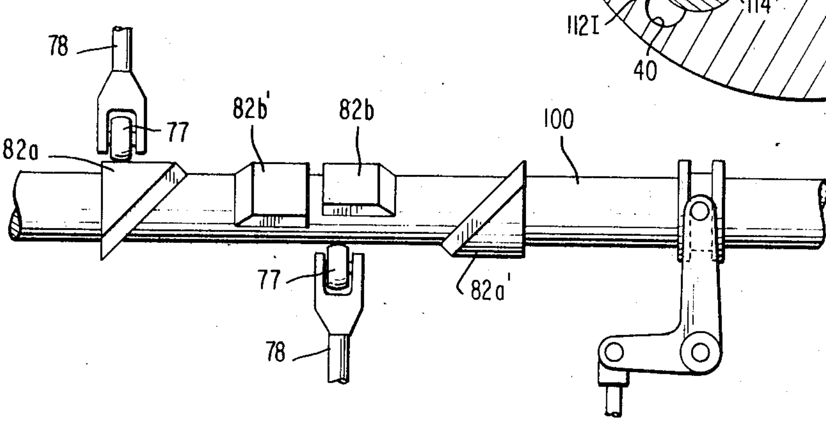


FIG. 7

EXPANSIBLE FLUID ROTARY ENGINE

The present invention relates to a rotary engine and particularly relates to a fluid expansible rotary engine of the type mounting a rotor within an epitrochoidally shaped multilobed housing.

Rotary engines of the type having a multilobed epitrochoidal outer housing and an inner rotor having a plurality of apices equal to one more in number than the number of lobes with the rotor and housing forming variable-volume working chambers have been previously proposed and constructed for use as internal combustion engines and are commonly known as Wankel engines. In such engines having a generally triangular rotor having three apices and rotatable in a two-lobed epitrochoidal housing, there is usually a suction stroke, a compression stroke, an expansion stroke and a discharge stroke, with the shaft making three revolutions for every complete revolution of the rotor. One of the problems associated with internal rotary combustion engines of this type resides in the fact that the inlet and exhaust ports lie in communication with one another at the end of the exhaust stroke and at the beginning of the suction stroke. This overlap causes considerable dilution of the exhaust residuals with consequent reduction in efficiency. Moreover, engines of this type commonly provide apex seals which bear against the surfaces of the epitrochoidal housing. The wear rate on the seals has been extremely high. This has limited the speed and size of the engine. Another disadvantages of these internal combustion rotary engines is the lack of efficient cooling mechanism. The heat, for the most part generated by the combustion gases, is removed through the seals which are naturally small in size and make limited contact with any coolant which could be provided in the engine housing. Lubrication is also a major problem and lubrication oil consumption is high as it is burned and lost.

A rotary engine of the type having a rotor rotatable on an eccentric and within an epitrochoidal-shaped housing, however, has many distinct advantages over the common internal combustion engine by virtue of its unique geometry and configuration. The present invention therefore provides a rotary engine of this geometry and configuration for use with an expansible fluid, such as steam, freon and the like. To provide such expansible fluid rotary engine, inlet and exhaust valves are required and are provided on opposite sides of the cusps separating adjacent lobes of the epitrochoidal multilobed chamber. Operation of these valves requires a controlled opening and closing of these valves such that the expansible fluid can expand to drive the rotor and exhaust. Specifically, the inlet valve must be opened at the end of an exhaust stroke to admit the expansible fluid into a working chamber and then closed to permit the fluid to expand and drive the rotor. The exhaust valve must be timed to open at the end of the expansion stroke and then closed prior to complete evacuation of the exhaust vapors to insure recompression equal to the pressure of the incoming pressure fluid. Additionally, the apex portions of the rotor must make continuous sealing contact with the surfaces of the epitrochoidal chamber to avoid leakage between adjacent chambers. To applicant's knowledge, an expansible fluid rotary engine of this type employing valves which do not break the seal between the rotor and surface of the chamber has not heretofore been proposed or constructed.

To accomplish the foregoing, the present invention provides a rotary engine having the previously described geometry and configuration and including cylindrically shaped oscillating inlet and exhaust valves having slots extending diametrically therethrough. In the open position of each inlet valve, the slot provides communication between an associated variable-volume working chamber and a source of expansible fluid under pressure. In the valve open position of each exhaust valve, the slot provides communication between the working chamber containing the expanded fluid and reservoir. Portions of the valves, when open, extend through the chamber surface and project into the working chamber. In order to permit the apex seals on the rotor to sweep about the epitrochoidal surface without breaking the seal between adjacent chambers, an arcuate axially extending cutout is formed in the cylindrical surface of the valve to correspond and conform to the shape of lobed surface of the epitrochoidal shaped housing. The cutout is circumferentially spaced from the slot about the cylindrical valve member. In this fashion, the valve can be rotated to a closed position with the arcuate cutout forming an unbroken continuation of the surface of the epitrochoidal chamber whereby the apex seals on the rotor sweep past the arcuate portion without leakage between adjacent chambers.

A timing mechanism is provided to oscillate the cylindrical valves between open and closed positions whereby the expansible fluid can be admitted and exhausted in synchronism with the rotor cycle. To this end, camshafts, coupled to the engine output or driven shaft carry cam surfaces which cooperate with push rods, which, in turn engage spring-biased levers carried by the cylindrical valves whereby the axial displacement of the push rods cause the levers to oscillate the valves between open and closed positions.

As a further feature hereof, the period of fluid admission is adjustable to facilitate engine starting. To this end, the cam surface on the camshaft is cut away at an angle. By axially displacing the camshaft, the cam surface is selectively positioned to a greater or lesser circumferential extent below the push rod associated with the inlet valve whereby the inlet valve may be held open for a selected period of time.

It is a further feature of the present invention that the engine can be run in the reverse direction. To accomplish this, each of the camshafts carries a pair of cam surfaces. For operating the engine in one direction, the camshafts are axially displaced such that one of the cam surfaces is engageable with the push rods operating the associated inlet or exhaust valves in a manner to permit operation in one direction. By axially displacing the camshafts to locate the second cam surface below the associated push rods, the timing of the valves can be reversed to permit rotation of the rotor in the opposite rotary direction. That is to say, the valves employed as inlet and exhaust valves for rotating the rotor in one direction can be employed as exhaust and inlet valves respectively for rotating the rotor in the opposite direction.

Accordingly, it is a primary object of the present invention to provide a novel, improved expansible fluid rotary engine.

It is another object of the present invention to provide a novel, improved expansible fluid rotary engine of the type having a multilobed epitrochoidal housing mounting a rotor having multiple apices one more in number then the number of lobes.

It is still another object of the present invention to provide an expansible fluid rotary engine having inlet and exhaust valves conforming in the closed position to the inner surfaces of the epitrochoidally shaped rotor housing to preclude leaking between adjacent variable-volume working chambers.

It is a further object of the present invention to provide an expansible fluid rotary engine having inlet and exhaust valves having surfaces conforming to the epitrochoidally shaped surface together with a timing mechanism for locating such surfaces as to permit passage of the apex seals thereby without breaking the seal between adjacent working chambers.

It is a still further object of the present invention to provide an expansible fluid reversible rotary engine.

It is a still further object of the present invention to provide an expansible fluid rotary engine of the type mounting a rotor for rotation within an epitrochoidally shaped housing and having valves for admitting fluid under pressure into the working chambers and exhausting expanded fluid from the chambers wherein the period of fluid admission can be selectively controlled particularly to facilitate engine starting.

These and further objects and advantages of the present invention will become more apparent upon reference to the following specification, appended claims and drawings wherein:

FIG. 1 is a cross-sectional view of an expansible fluid rotary engine constructed in accordance with the present invention;

FIG. 2 is a cross-sectional view thereof taken generally about on line 2—2 in FIG. 1;

FIG. 3a—3d are reduced cross-sectional views similar to FIG. 1 illustrating the rotor in various operating positions:

FIG. 4 is an end elevational view of a timing mechanism employed with the expansible fluid rotary engine hereof;

FIG. 5 is a fragmentary elevational view of a timing camshaft employed with the engine hereof;

FIG. 5a is a schematic illustration of an expansible fluid circuit for operating the engine in a reverse direction;

FIG. 6 is a schematic end elevation view of a further form of timing mechanism employed with the engine hereof;

FIG. 7 is a fragmentary elevational view of the timing mechanism illustrated in FIG. 6; and

FIG. 8 is a cross-sectional view of an expansible fluid rotary engine constructed in accordance with the present invention and having a mixed pressure operation.

Referring now to the drawings, particularly to FIG. 1, there is illustrated, in a cross section transverse to the engine axis, a trochoidal-type rotary engine, generally designated 10, having an outer body comprising a two-lobed peripheral housing 12 with a basically epitrochoidal inner surface 14 defining lobes 14a and 14b and a pair of end walls 16 and 18 as seen in FIG. 2. A shaft 20 extends longitudinally through the engine housing 10 and is suitably journaled in end walls 16 and 18. Shaft 20 carries an eccentric portion 22 which is received in a rotor 24, the eccentric 22 serving as a crank as the rotor 24 rotates. Suitable gear teeth, not shown, on the rotor and housing are provided whereby the rotor 24 transmits its rotary motion about the offset axis 26 of eccentric 22 thereby to rotate shaft 20 as in conventional engines having the foregoing configuration. Rotor 24 is generally triangular in outline as viewed in an axial direction having three apex portions 30a, 30b and 30c each carrying an apex seal 32a, 32b and 32c. The seals 32 of rotor 24 define, with portions of the inner epitrochoidal surfaces 14 and the arcuate surfaces 34A, 34B, and 34C of the rotor 24 three variable-volume working chambers A, B and C. Cutout portions 36 are recessed from each of the surfaces 34 for the transfer of expansible fluid across the cusps of the epitrochoidal-shaped chamber. The housing 12 may be formed of a casting or the like.

To provide for operation as an expansible fluid engine, a plurality of longitudinally extending bores 38 are formed through housing 12. A pair of bores 38 are provided on opposite sides of each epitrochoidal surface 14 and on opposite sides of each cusp. The bores 38 are formed such that portions of their peripheries open through the surfaces 14a and 14b of the epitrochoidal chamber and form slots therein. Longitudinally extending reduced diameter bores or passages 40 are also formed through housing 12, outwardly of and in communication with bores 38. A pair of cylindrically expansible fluid inlet valves 42I and 44I are provided in diametrically opposed bores 38 and a pair of similar cylindrical exhaust valves 46E and 48E are provided in the other pair of diametrically opposed bores 38. Thus, an inlet and an exhaust valve are provided on opposite sides of each of the cusps. Each of the valves 42I, 44I, 46E and 48E is provided with a through diametrically extending slot 50. Valves 42I, 44I, 46E and 48E are suitably mounted for rotation in end walls 16 and 18 and are provided with suitable seals, indicated at 52 in FIG. 2. It will be appreciated that the passages 40 and the slots 50 are arranged such that when the valves 42I, 44I, 46E and 48E are rotated to positions wherein the slots 50 open into chambers A, B and C, the opposite ends of the slots open into the axially extending cylindrical passages. The passages 40 associated with the inlet valves 42I and 44I communicate through an aperture, not shown, in end wall 16 with a source of expansible fluid under pressure. The passages 40 associated with the exhaust valves 46E and 48E communicate through an aperture 54, as seen in FIG. 2, formed in end wall 16, the aperture 54 preferably communicating with a fluid reservoir, not shown. Accordingly, when the valves 42I and 46E are disposed in the positions illustrated in FIG. 1, expansible fluid under pressure is admitted from passage 40 through the slot 50 in valve 42I into working chamber A, while the expansible fluid in working chamber B is exhausted therefrom through the slot 50 in valve 46E into its associated passage 40. It will be appreciated that communication through these valves to their associated passages 40 is precluded when they are rotated to valve positions exemplified by the positions of closed valves 44I and 48E in FIG. 1.

As described hereinafter in detail, rotor 24 rotates within the epitrochoidal chamber with the seals 32 sweeping along the epitrochoidal surfaces 14a and 14b in continuous sealing-engagement therewith. Each seal 32 is disposed in a recess 61 formed in the associated apex portions 30 of the rotor 29 and comprises, as seen in FIG. 2, an elongated strip including a main body 60 formed by a very lightweight metal and having a tip 62 formed of a plastic material such as nylon or teflon. The tip material provides a wearing surface bearing against the inner walls 14a and 14b of the epitrochoidal chamber. As seen in FIG. 2, a plurality of helical springs 64 are located between each seal strip and the base of its associated recess 61 whereby seal strips 32 are biased outwardly into constant sealing engagement with the epitrochoidal surfaces 14a and 14.

As the rotor seals 32 must lie in continuous contact with the surface of the epitrochoidal chamber as the rotor rotates within the housing 12, it is otherwise that the contour of the chamber remain unbroken as otherwise the seals would be ineffective to preclude communication between adjacent working chambers. It is, accordingly, a particular feature of the present invention that the valves 42I, 44I, 46E and 48E are specifically configured such that, when these valves lie in a valve closed position, they form with the adjacent epitrochoidal surfaces 14a and 14b a smooth, continuous and unbroken surface. This permits the apex seals to remain in sealing engagement with the walls of the epitrochoidal chamber even as the seals sweep past the valves. To this end, each of the cylindrical valve members 42I, 44I, 46E and 48E is provided with an arcuate cutout portion 66 extending axially along its periphery and corresponding in curvature to and forming a continuation of the curvature of the associated epitrochoidal surfaces 14a and 14b. Thus, surfaces 66 complement the epitrochoidal surfaces 14a and 14b when the valves are disposed in a closed position, i.e., the valves 44I and 48E in FIG. 1, whereby the apex seals 62 remain in constant sealing engagement along the surface 14a and 14b as they sweep past the slots accommodating the valves and formed through the chamber wall.

The movement of rotor 24 within the chamber and the timed movement of the valves will now be described, the timing mechanism for the valves being described hereinafter. When the rotor 24 lies in the position illustrated in FIG. 3a, valves 42I and 46E are open and valves 44I and 48E are closed. Valve 42I accordingly admits expansible fluid under pressure from associated passage 40 into chamber A, the latter being defined between the rotor surface 34A and the wall portion of surface 14a and 14b between apex seals 32a and 32c. Valve 46E is open permitting chamber B to exhaust through the valve into its associated passage 40, chamber B being defined between the rotor surface 34b and the wall portion of surfaces 14a and 14b between the apex seals 32a and 32b. Valves 44I and 48E have just closed and the chamber C defined by rotor surface 34c and the portion of surfaces 14a and 14b between apex seals 32b and 32c contains expansible fluid admitted from its associated passage 40 when valve 44I was open. The fluid in chamber C expands to drive rotor 24 in a counterclockwise direction thereby also driving output shaft 20 in a counterclockwise direction. When the rotor has advanced to the position illustrated in FIG. 3b, the period of fluid admission in chamber A is complete and the valve 42I has rotated to a closed position. Note that, in the movement of rotor 24 from the position illustrated in FIG. 3a to the position illustrated in FIG. 3b, the apex seal 32c has swept past the arcuate surface 66 of the valve 48E and seal 32b bears on the surface 66 of valve 44I, each without breaking its sealing engagement with the wall of the epitrochoidal chamber. The valve 46E remains in the open position exhausting chamber B. The valve 48E has rotated to an open position exhausting chamber C. In this rotor position, rotor 24 is driven by the expansion of the fluid in chamber A with the rotor obtaining the position illustrated in FIG. 3*c*. In this position, the valve 46E has rotated to a closed position and the valve 44I has rotated to an open position to admit fluid into chamber B. Chamber C continues to exhaust the fluid through the open valve 48E. The expansion in chamber A continues to rotate rotor 24 in a counterclockwise direction. In FIG. 3*d*, the apex seal 32*a* has swept past the valve 46E and the latter has rotated to an open position to exhaust the expansible fluid from chamber A into its associated exhaust passage 40. The valve 44I has rotated to the illustrated closed position with the period of admission of expansible fluid into chamber B being complete. The valve 48E remains open and continues to exhaust the fluid from chamber C. The rotor has thus advanced 90° from the rotor position of FIG. 3*a* to the rotor position illustrated in FIG. 3*d*. It will be noted that as soon as fluid expansion in one of the chambers is complete and begins to exhaust, expansion in a second chamber is initiated and power is thereby continuously provided for rotating the rotor.

It will be appreciated that cylindrical valves 42I, 44I, 46E and 48E oscillate about their longitudinal axes between positions admitting fluid into and exhausting fluid from the working chambers and positions wherein the arcuate surfaces 66 form continuations of epitrochoidal surfaces 14*a* and 14*b*. To obtain this oscillatory motion in a timed sequence, i.e., to open and close the valves at the proper points in the operating cycle, a timing mechanism is provided and illustrated in FIGS. 4 and 5. In FIG. 4, the cylindrical valves extend through the end wall 18 of the engine housing and carry lever arms 70. Springs 72 engage between lugs 74 fixed to the engine housing and the lever arms 70 thereby biasing the valves into normally closed positions. Levers 70 bear against adjusting screws 76 in the valve closed positions. Push rods 78 are slidably carried by the housing and engage the ends of associated levers 70, the opposite ends of push rods 78 carrying rollers 77 for bearing against associated camshafts 80. Each camshaft 80 mounts a pair of projecting cams 82*a* and 82*b* at axially spaced positions therealong. The camshafts 80*a* associated with inlet valves 42I and 44I carry cams 82*a* and 82*b* as illustrated in FIG. 5, while the camshafts 80*b* associated with the exhaust valves 46E and 48E carry cams 82*a* and 82*b* in an axially reversed position, not shown. That is to say, each cam 82*a* on camshafts 80*b* is located in the position occupied by cam 82*b* in FIG. 5 while each cam 82*b* on camshafts 80*b* is located in the position occupied by cam 82*a* in FIG. 5. Cams 82*a* and 82*b* are normally associated with the inlet and exhaust valves respectively. The camshafts 80 are slidably carried by the engine housing, by means not shown, and carry sprockets 84 splined to the camshafts 80. An external portion of the driven shaft 20 mounts a similar sprocket 86 in FIG. 4 and a drive chain 88 connects between the drive sprocket 86 and the driven sprocket 84. A chain drive 87 encompasses the four sprockets 84 whereby the camshafts are driven in a time relation to the driven shaft 20.

As seen in FIG. 5, the cams 82*a* are substantially triangular in shape having a base surface portion 89 and a hypotenuse surface 90 for reasons noted hereinafter. Thus, as the respective camshafts 80*a* rotate, the rollers 77 on the end of push rods 78 associated with the inlet valves engage cams 82*a* and ride up base surfaces 89 and over the cams to displace the push rods. This, in turn displaces levers 70 thereby pivoting the associated inlet valve. As the camshafts 80*a* continue to rotate, the rollers on push rods 78 drop off the cam surfaces 90 back onto the camshafts 80*a* whereby springs 72 pivot levers 70 and the associated valves in the opposite direction into the normally closed valve positions. It will be appreciated that the camshafts 80*b* and cams 82*b* associated with the exhaust valves operate in a like manner with the cams 82*b* similarly causing displacement of the exhaust rods and levers corresponding oscillation of the exhaust valves is effected. It will, of course, be appreciated that the camshafts are initially positioned such that the cams are disposed in various circumferential positions in relation to the associated push rods whereby the proper timing cycle is effected.

To vary the period of admission of expansible fluid into the working chambers through the valves 42I and 44I, as for example, to provide an increase period of admission during the initial starting of the engine, cams 82*a* are triangular in shape, as previously described. Thus, by axially shifting the cams 82*a* with respect to the push rods 78, the period in which the cams 82*a* displace the push rods and hence maintain the inlet valves in an open position can be varied. To this end, and for reasons set forth below, each of the camshafts 80 is axially displaceable by means of a pivoted actuating lever 92 which has a yoke portion 94 engageable with a collar 96 carried on camshaft 80. The opposite end of the lever 92 is reciprocated by means of a fluid-actuated cylinder 98. Accordingly, to extend the period of admission, the fluid-actuated piston is extended to pivot lever 92 in a clockwise direction as seen in FIG. 5 thereby to displace camshaft 80 to the right. By thus displacing camshaft 80, a circumferentially greater surface of cam 82*a* is disposed below roller 77 whereby the associated inlet valve is maintained in an open position for an extended period of time. This is particularly desirable during starting torque with the period of admission being curtailed or shortened by axially displacing the camshaft 80 to the left as seen in FIG. 5 as the rotor begins to turn. It will be further appreciated that by displacing the camshaft 80*a* to the left such that the cam 82*a* lies beyond the roller 77, the inlet valves would be maintained in their normally closed positions whereby the engine would stop. The cams 82*b* associated with the exhaust valves are rectangular in shape about camshafts 80 whereby axial displacement of the latter to vary the period of admission has no effect on the period during which the exhaust valves remain open. It will be appreciated that the cylinders 98 can be operated, as by suitable valving, not shown, to jointly advance and retract the camshafts 80.

By providing inlet and exhaust valves of approximately the same size, the engine can be operated such that the rotor rotates in a reverse direction. To accomplish this, each camshaft 80 is shifted axially in a like direction such that the cam surfaces 82*a* underlying the push rods 78 associated with the inlet valves and the cam surfaces 82*b*, underlying the push rods 78 normally associated with the exhaust valves, are moved to inoperative positions with the cams 82*a* on shafts 80*b* and the cams 82*b* on shafts 80*a* being moved to positions underlying the push rods 78. In this manner, the timing action for the valves would be reversed, that is, the valves 42I and 44I become the exhaust valves and the valves 46E and 48E become the expansible fluid admission valves. Suitable valving, for example, the valving arrangement shown in FIG. 5*a*, is provided to provide the expansible fluid under pressure to the passages 40 associated with valves 46E and 48E and to exhaust the fluid from the passages 40 associated with the valves 42I and 44I. In FIG. 5*a*, a closed cycle operation is shown with the expansible fluid source being indicated at S. The supply and exhaust conduits indicated at 91 and 93 respectively communicate through a four-way two-position valve 95. In the illustrated valve position, the fluid is supplied through valve 95 to the valves 42I and 44I via passages 40, and conduit 97. The exhaust fluid is returned to the source S via passage 99 from the valves 46E and 48E. By shifting valve 95 to the left as seen in FIG. 5*a* the fluid is supplied to the valves 46E and 48E via conduit 99 and the exhaust fluid is returned to the source S via conduit 97. In this manner, the expansible fluid can be selectively provided to valves 42I, 44I or 46E, 48E as desired with the expanded fluid being returned through the other set of valves. Thus, simply by axially shifting the camshafts 80 and shifting valves 95, the engine can be run such that the rotor rotates in either direction.

The foregoing timing arrangement has been described with respect to a four-camshaft arrangement with one camshaft operating each valve. With reference to FIGS. 6 and 7, it will be seen that the timing arrangement can be accomplished with two camshafts. To this end, a pair of triangularly shaped cams **82***a* and **82***a'* are spaced along a single camshaft **100**. Similarly, a pair of cam surfaces **82***b* and **82***b'* are spaced one from the other between the cam surfaces **82***a* and **82***b'*. It will be appreciated that, in this form, the levers **78** associated with the inlet and exhaust valves on each side of the engine housing are axially offset one from the other such that the roller **77** associated with the push rod of the inlet valves rides on the cam surface **82***a* and roller **77** associated with the push rod **78** of the exhaust valve rides on the cam surface **82***b*.

The position of the camshaft **100** illustrated in FIG. 7 corresponds to the position of the rotor **24** illustrated in FIG. 3*a*. That is to say, the inlet valve **42I** is open as it has been pivoted by the displacement of push rod **78** riding on the cam **82***a*. As seen in FIG. 7, the push rod **78** associated with the exhaust **48E** rides on camshaft **100** whereby the valve lies in its normally closed position. Upon further rotation of the camshaft **100**, the camshaft **82***a* rotates beyond lever **78***a* whereby the spring **72** biases lever **70** against screw **76** thereby to pivot inlet valve cylinder **42I** back to its normally closed position illustrated in FIG. 3*b*. Simultaneously, the cam surface **82***b* will have rotated to a position below the push rod **78** associated with valve **48E** to thereby open the valve as illustrated in FIG. 3*b*. A camshaft **100** of this type is provided on each side of the engine housing.

As in the camshaft arrangement illustrated in FIG. 5, the camshafts **100** of the embodiments of FIGS. 6 and 7 can be axially displaced to both alter the period of admission of expansible fluid into the working chambers as previously described and also to reverse the function of the admission and exhaust valves, i.e., to operate the admission valves **42I** and **44I** as exhaust valves and to operate the exhaust valves **46E** and **48E** as admission valves thereby to reverse the engine. This is accomplished by axially displacing both camshafts **100** to the left as seen in FIG. 7 such that the left hand push rod **78** engages the cam **82***b'* and the other right-hand push rod **78** engages the cam **82***a'*.

Expansible fluid is then provided the passages **40** associated with valves **46E** and **48E** by shifting the valve **95** as previously described. Thus, in both timing mechanism, the camshafts can be axially shifted to both alter the period of admission and to reverse the engine.

It will be appreciated of course that a suitable interlock, not shown, can be provided between the valve **95** and the camshaft action such that one cannot be actuated without the other.

It is a specific feature hereof that the expandible fluid rotary engine hereof can also be employed as a mixed pressure engine. That is to say, expansible fluid at two different pressures from two different sources, can be utilized simultaneously in the same engine. To accomplish this and referring now to FIG,. **8**, there are provided two additional valves, an inlet valve **11oI** and an inlet valve **112I** lying closely adjacent and beyond the inlet valve **42I** and **44I**, respectively. These valves are identical in construction to the valves previously described and include diametrically extending slots **50** and arcuate surface portions **66** conforming to the walls of the epitrochoidal chamber. The passages **40** associated with valves **110I** and **112I** lie in communication with an expansible fluid source, not shown, at a pressure lower than the pressure of the fluid supplied to the passages **40** associated with inlet valves **42I** and **44I**. The valves **110I** and **112I** are timed such that they remain in a closed position when the high-pressure expansible fluid in the chambers defined in part by the arcuate surfaces **60** of the valves **110I** and **112I** is expanding after having been admitted through the valves **42I** and **44I** respectively. That is to say, the valves **110I** and **112I** are maintained in a closed position while the high-pressure fluid is first admitted into the associated working chamber as previously described. The high-pressure fluid inlet valve is then closed by the previously described timing mechanism. When the pressure in the working chamber is reduced to a pressure substantially equal to or less than that of the lower pressure expansible fluid in passage **40**, the valve **110I** and **112I**, as the case may be, opens to admit the lower pressure expansible fluid and then immediately closes. In this fashion, the expansible fluid in the chamber will continue to expand and rotate rotor **24** in a like direction as in the previous embodiments. The timing mechanism for the valves **110I** and **112I** can be identical to the single-camshaft timing devices illustrated in FIG. **5**. The cams associated with mixed pressure operating camshafts are reduced in circumferential extent in comparison with the cam surfaces **82***a* whereby the period of admission for the lower pressure inlet valves **110I** and **112I** would be substantially reduced.

A further feature of the present invention provides for ready inspection and replacement of the apex seals at the apex portions of the rotor when necessary without dismantling the engine. As noted previously, the wear on these seals is much less than the wear associated with apex seals in internal combustion engines. However, over long periods of engine operation, the seals should be replaced. To this end, a plurality of end covers **120**, seen in FIG. **2**, are provided about end wall **16** and suitably secured thereto the bolts **122** one end cover would be sufficient. These end covers preferably comprise material iron or steel plugs with seal of neoprene or such plugs having inner faces which lie flush with the inner surfaces of end plate **16**. To inspect the apex seals, the covers are removed and the rotor turned until the seals line up with the inspection openings. A tapped hole **124** is provided in the end of the apex seals whereby a bolt or screw can be threaded into the tapped hole and the seal including the springs withdrawn from apex recesses **61**. Thus, the seals can be inspected and replaced without dismantling the end pieces or plates.

Should the rotor stop in a position wherein the fluid inlet valves are fully closed, as illustrated in FIG. 3*b*, the engine could not be started. To start the engine, a compound rotor comprising a pair or rotors on a common shaft can be provided, as schematically illustrated in FIG. 3*d*. The rotors are angularly offset one from the other, preferably at 45°, whereby at least one of the inlet valves of one of the rotors would lie in a position to admit fluid into the working chamber and thereby drive the compounded rotor assembly.

While the expansible fluid rotary engine has been described with respect to a two-lobed chamber and a triangular rotor, it will be appreciated that the rotary engine hereof can be employed in a multilobed epitrochoidal housing mounting a rotor having one more side than the number of lobes. Particularly, the present invention can be employed with a three-lobe epitrochoidal housing mounting a substantially square rotor. In this and other configurations, exhaust valves are mounted on opposite sides of the cusps of the epitrochoidal chamber. Similar timing arrangements could be there employed, for example, utilizing a single camshaft for each valve or one camshaft for a pair of inlet and exhaust valves.

In use of the present invention, a closed cycle can be employed utilizing freon 12 as the expansible fluid. Expansible fluids such as hexafleurobenzine or freon 12 as well as other fluids which are expansible from a high to a low pressure such as steam can also be employed. Also, it will be appreciated that the present invention could be employed as a pump or blower, if desired.

What is claimed and desired to be secured by United States Letters Patent is:

1. A rotary mechanism utilizing a fluid comprising: an outer body having a cavity, an inner body received within said outer body cavity, means including a shaft for mounting said inner body within said outer body cavity for relative rotation therein with the axis of said inner body being laterally spaced from and parallel to the axis of said outer body cavity and said shaft, said inner and outer bodies having respectively facing outer and inner peripheral surfaces defining a plurality of variable-volume working chambers, the inner peripheral surfaces of said outer body cavity having a multilobed epitrochoidal shape with said lobes being equally spaced about the axis of

said outer body cavity, the outer peripheral surfaces of said inner body including a plurality of apex portions spaced circumferentially about the inner body axis and engageable with the inner peripheral surfaces of said outer body cavity to form seals between adjacent working chambers, said apex portions being one more in number than the number of said lobes, first and second valves carried by said outer body and spaced one from the other about the inner surface of said outer body cavity, said valves opening through the inner peripheral surface of said outer body into said cavity, each of said valves including a member movable between open and closed positions to provide communication therethrough with said cavity in said valve open position, each of said members in said closed portion having a surface forming a continuation of the epitrochoidal shape of the lobes of the inner surface of said outer body to permit the apex portions of said inner body to sweep past in continuous sealing engagement therewith as said inner body rotates about the outer body cavity, means for supplying the fluid to said first valve for admission into said working chambers when said first member lies in said open position, and timing means for selectively moving said first and second members to said open position to respectively admit fluid into and exhaust the fluid from said chambers and to said closed position to permit movement of said apex portions past the continuing surfaces of said members without field leakage between adjacent chambers.

2. A mechanism according to claim 1 wherein said first and second valves are spaced about the surface of one of said lobes, third and fourth valves spaced one from the other about the surface of a second lobe and opening through the surface thereof into said cavity, each of said third and fourth valves including a member movable between open and closed positions to provide communication therethrough with said cavity in said valve open position, each of said third and fourth members in said valve closed position having a surface forming a continuation of the epitrochoidal shape of said second lobe surface to permit the apex portions of said inner body to sweep past in continuous sealing engagement therewith as said inner body rotates about the outer body cavity, means for supplying the fluid to said third valve for admission into said working chambers when said third member lies in said open position, and timing means for selectively moving said third and fourth members to said open position to respectively admit the fluid into and exhaust the fluid from said chambers and to said closed position to permit movement of said apex portions past the continuing surfaces of said members without fluid leakage between adjacent chambers.

3. A mechanism according to claim 2 including means coupling said timing means to said shaft whereby said valves are movable between open and closed positions in accordance with rotary position of said inner body in said outer body cavity, said members being carried by said outer body for rotation about axes generally parallel to the axis of rotation of said inner body and said shaft, each of said members including a passage opening into said cavity when said valves lie in open position, each of the continuing surfaces of said members being spaced circumferentially about said member from passage opening.

4. A mechanism according to claim 1 wherein each of said apex portions has a recess, a seal strip disposed in said recess and a spring carried within said recesses for continuously biasing said seal strip outwardly into engagement with the inner surface of said outer body and the continuing surfaces of said members as said inner body rotates within said cavity.

5. A mechanism according to claim 4 wherein said outer body includes an end wall having an opening in transverse alignment with the path transcribed by said seal strips as said inner body rotates within said cavity and a member releasably secured in said opening to provide access through said outer body to said seal strip.

6. A mechanism according to claim 1 including means coupling said timing means to said shaft whereby said valves are movable between open and closed positions in accordance with the rotary position of said inner body in said outer body cavity.

7. A mechanism according to claim 1 wherein said members are carried by said outer body for rotation about axes generally parallel to the axis of rotation of said inner body and said shaft, each of said members including a passage opening into said cavity when said valve lies in the open position, each of the continuing surfaces of said members being spaced circumferentially about said member from said passage opening.

8. A mechanism according to claim 1 wherein said mechanism comprises a fluid expansible rotary engine, means for supplying expansible fluid under pressure to said first valve for admission into said working chambers when said first valve lies in said open position to thereby rotate said inner body in one direction, and means for receiving the fluid issuing from said working chambers through said second valve when said second valve lies in said open position.

9. A mechanism according to claim 8 including means for selectively varying the period of fluid admission into said working chambers.

10. A mechanism according to claim 8 including means for supplying expansible fluid under pressure to said second valve for admitting of fluid into said working chambers when said second valve lies in the open position to thereby rotate said rotor in the opposite direction, means for receiving fluid issuing from said working chambers through said first valve when said first valve lies in said open position and means for adjusting said timing means to provide for movement of said first and second members to said open position to respectively exhaust and admit the fluid from said chamber.

11. A mechanism according to claim 1 wherein said cavity comprises two lobes and said inner body comprises a generally triangular shaped rotor.

12. A mechanism according to claim 11 wherein said first and second valves are spaced about the surface of one of said lobes, third and fourth valves spaced one from the other about the surface of a second lobe and opening through the surface thereof into said cavity, each of said third and fourth valves including a member movable between open and closed positions to provide communication therethrough with said cavity in said valve open position, each of said third and fourth members in said valve closed position having a surface forming a continuation of the epitrochodial shape of said second lobe surface to permit the apex portions of said inner body to sweep past in sealing engagement therewith as said inner body rotates about the outer body cavity, means for supplying the fluid to said third valve for admission into said working chambers when said third member lies in said open position, and timing means for selectively moving said third and fourth members to said open position to respectively admit the fluid into and exhaust the fluid from said chambers and to said closed position to permit movement of said apex portions past the continuing surfaces of said members without breaking fluid leakage between adjacent chambers.

13. A mechanism according to claim 12 wherein said timing means includes means for oscillating said valves between said open and closed positions.

14. A mechanism according to claim 12 wherein said timing means include a camshaft carrying a cam, means coupling said camshaft to said first-mentioned shaft to rotate said camshaft, a cam follower engageable with said cam, and means coupling said cam follower and at least one of said valves to oscillate said one valve in response to rotation of said camshaft.

15. A mechanism according to claim 1 wherein said first and second valves are spaced on opposite sides of a cusp formed by said epitrochoidally shaped cavity.

16. A rotary mechanism utilizing a fluid comprising: an outer body having a cavity, an inner body received within said outer body cavity, means including a shaft for mounting said inner body within said outer body cavity for relative rotation therein with the axis of said inner body being laterally spaced from and parallel to the axis of said outer body cavity and said shaft, said inner and outer bodies having respectively facing

outer and inner peripheral surfaces defining a plurality of variable-volume working chambers, the inner peripheral surfaces of said outer body cavity being multilobed with said lobes being equally spaced about the axis of said outer body cavity, the outer peripheral surfaces of said inner body including a plurality of apex portions spaced circumferentially about the inner body axis and engageable with the inner peripheral surfaces of said outer body cavity to form seals between adjacent working chambers, said apex portions being one more in number than the number of said lobes, first and second valves carried by said outer body and spaced one from the other about the inner surface of one of said lobes, third and fourth valves carried by said outer body and spaced one from the other about the inner surface of a second lobe, said first and second valves and said third and fourth valves being spaced from the end cusps of said first and second lobes respectively, said valves opening through the inner surface of said outer body into said cavity each of said valves including a member movable between open and closed positions to provide selective communication therethrough with said cavity, means for supplying the fluid to said first and third valves for admission into said working chambers when said first and third members lie in said open position, and timing means for selectively moving said first and second members to said open position to respectively admit fluid into and exhaust the fluid from the adjacent chambers formed in part by said one lobal surface and to said closed position, said timing means including means for selectively moving said third and fourth members to said open position to respectively admit fluid into and exhaust the fluid from the adjacent chambers formed in part by said second lobal surface and to said closed position.

17. A rotary mechanism according to claim **16** wherein each of said members in said closed position has a surface forming a continuation of the shape of the respective lobal surfaces of the inner surface of said outer body to permit the apex portions of said inner body to sweep past in sealing engagement therewith as said inner body rotates about the outer body cavity.

18. A rotary mechanism according to claim **16** wherein each of said members in said closed position has a surface forming a portion of the surface defining the associated variable-volume working chamber, the apex portions of said inner body forming a seal with said member along the surface thereof as said apex portions sweep past said member when said inner body rotates about the outer body cavity.

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,628 899 Dated December 21, 1971

Inventor(s) Leslie C George

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

In Col. 1, line 27, "disadvantages" should read --disadvantage--

In Col. 2, line 22, "of" should read --for--.

In Col. 4, line 15, "by" should read --of--; in line 25, "otherwise" should read --essential--; line 45, "surface" should read --surfaces--; line 56, "portion of surface" should read --portions of surfaces--; lines 59-60, "portion" should read --portions--.

In Col. 5, line 75, "exhaust" should read --associated--.

In Col. 6, line 17, "reciprocated" should read --selectively reciprocated--; line 25, "starting torque" should read --starting in order to give the engine maximum starting torque--; line 72, "valves" should read --valve--.

In Col. 7, line 19, "camshaft" should read --cam--; line 50, "expandible" should read --expansible--; line 57, "valve 42I and 44I" should read --valves 42I and 44I--.

In Col. 8, line 3, "and" should be --or--;

line 25, "surfaces" should read --surface--; line 56, "freon 12" should read --freon 21--.

In Col. 9, lines 13-14, Claim 1, "portion" should read --position--; line 25, Claim 1, "field" should read --fluid--; line 59, Claim 3. "from" should read --from said--.

In Col. 10, line 61, Claim 14, "include" should read --includes--.

Signed and sealed this 18th day of July 1972.

(SEAL)
Attest:

EDWARD M.FLETCHER, JR.
Attesting Officer

ROBERT GOTTSCHALK
Commissioner of Patents