Feb. 28, 1956 G. E. MALLINCKRODT 2,736,328

ROTARY MACHINE

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FIG. 1.

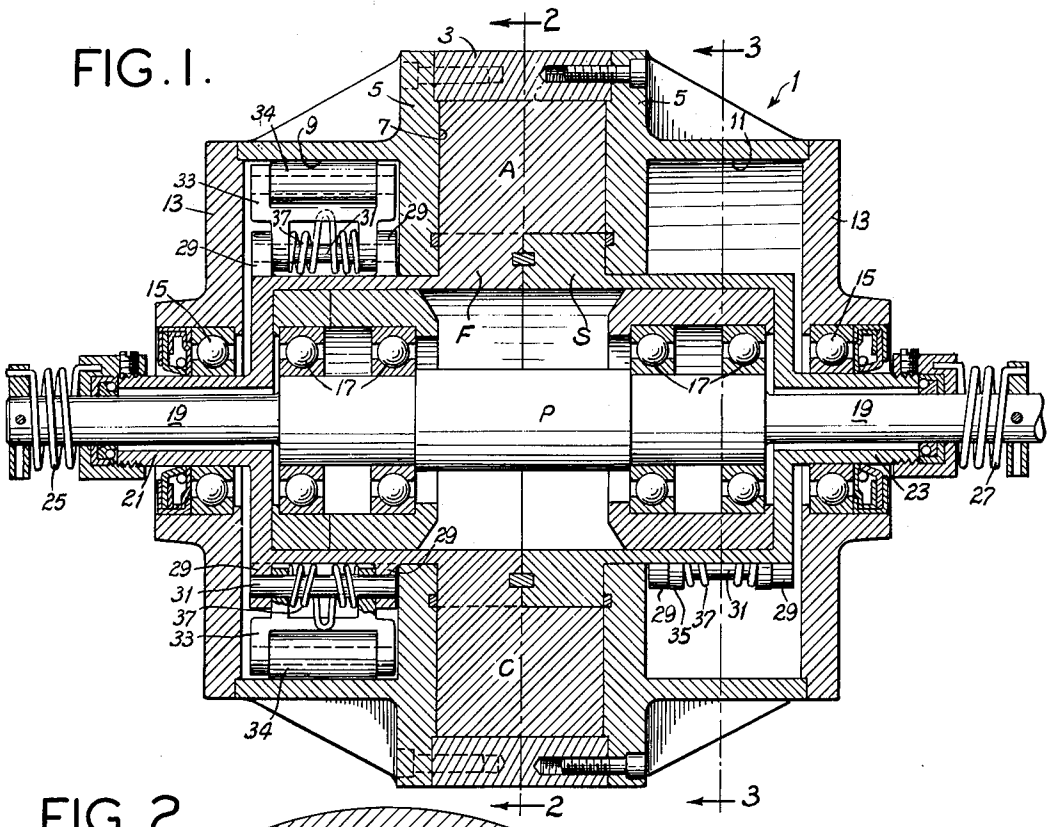
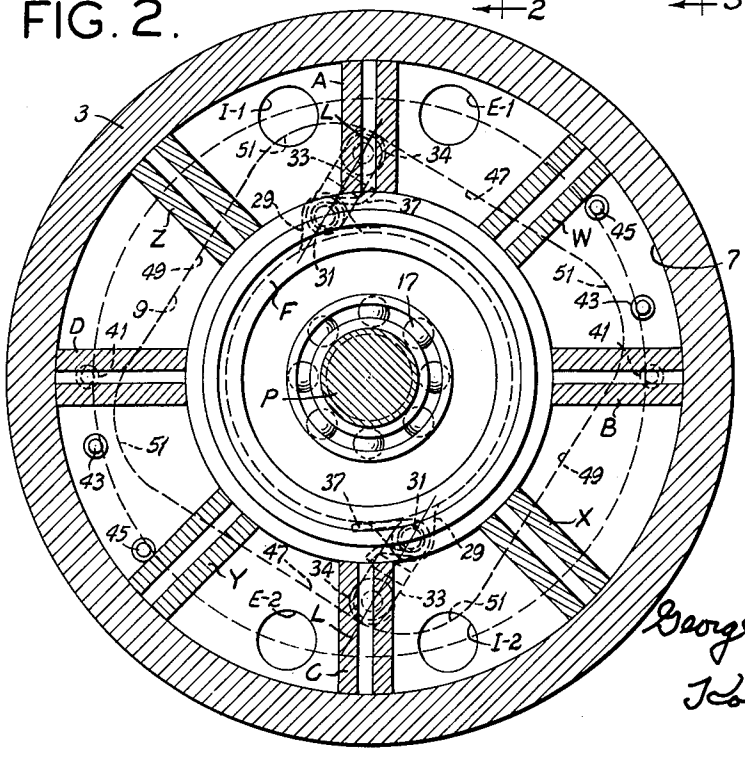


FIG. 2.



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FIG. 3.

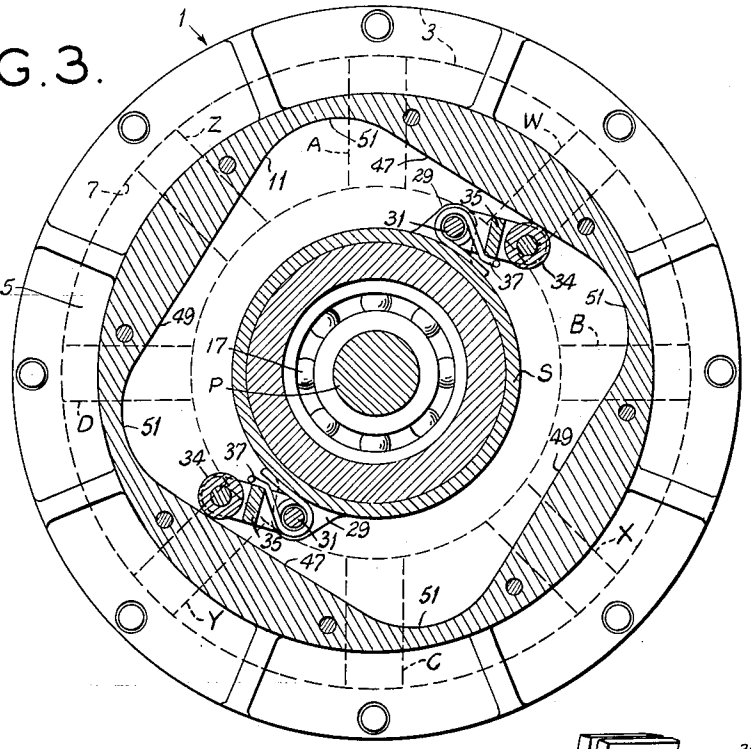


FIG. 7.

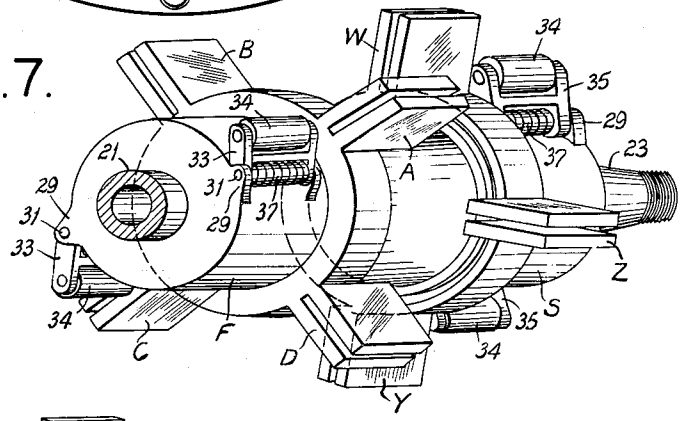
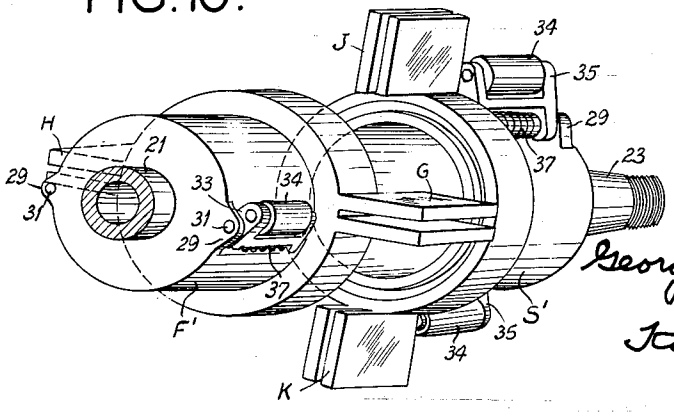


FIG. 10.



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ROTARY MACHINE

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FIG.4.

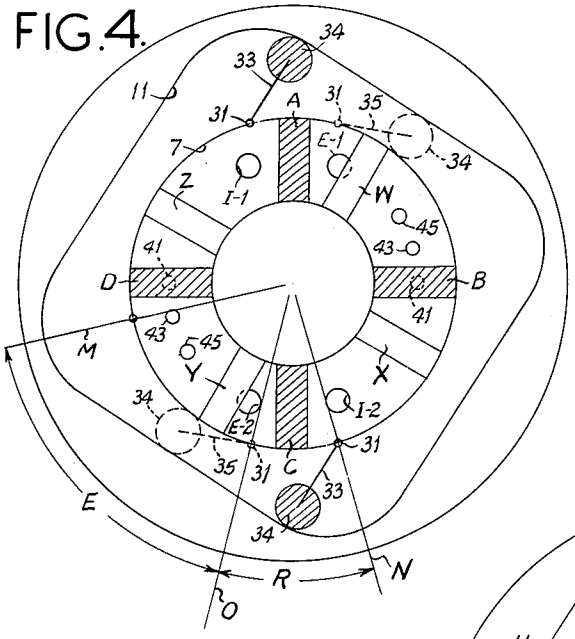


FIG.5.

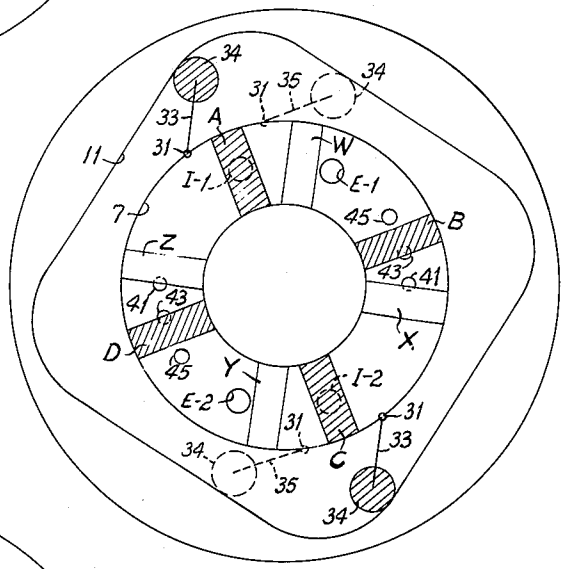
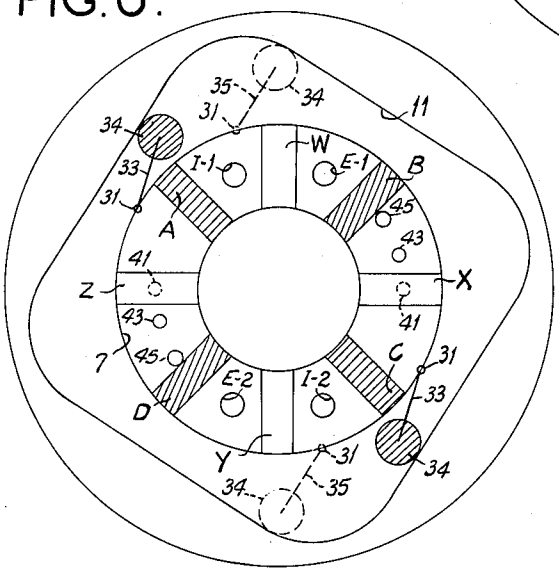


FIG.6.



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ROTARY MACHINE

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FIG. 8.

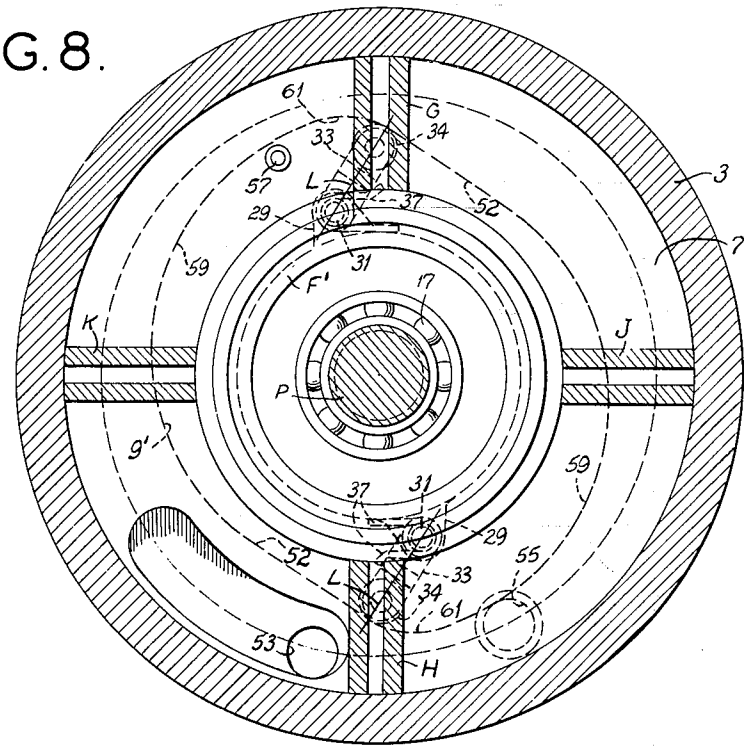
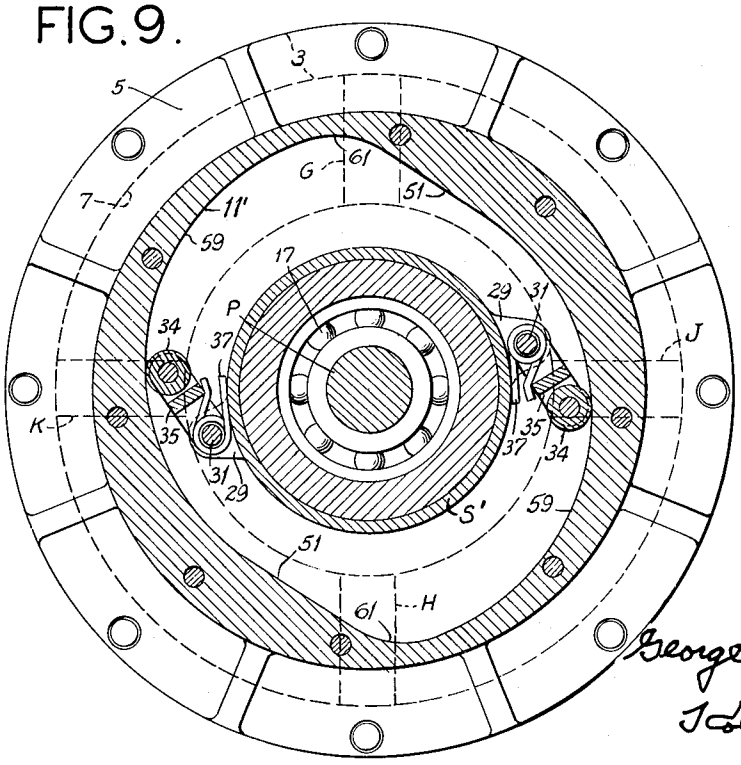


FIG. 9.



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United States Patent Office 2,736,328 Patented Feb. 28, 1956

2,736,328

ROTARY MACHINE

George E. Mallinckrodt, St. Louis, Mo.

Application February 26, 1952, Serial No. 273,392

18 Claims. (Cl. 123—11)

This invention relates to rotary machines, including expansion engines capable of operating with expansive gaseous or vapor mediums and employing several rotors having multiple pistons interdigitated and operative in an annular or toroidal cylinder. It is an improvement upon the construction disclosed in my copending United States patent application Serial No. 269,287, filed January 31, 1952, for Rotary Expansion Engine, now Patent No. 2,680,430, dated June 8, 1954.

Among the several objects of the invention may be noted the provision of a rotary expansion engine employing an improved form of reverse-locking arrangement for its rotors; the provision of a reverse-locking means which is capable of a silent and shockless reverse-locking action; and the provision of a reverse-locking arrangement of the class and for the purpose described which will relatively gradually store potential energy during one part of a cycle of movement and during another part of said cycle of movement will relatively rapidly convert the potential energy to kinetic energy for the purpose of facilitating interchange of energy between the engine rotors during their cyclic actions. Other objects will be in part apparent and in part pointed out hereinafter.

The invention accordingly comprises the elements and combinations of elements, features of construction, and arrangements of parts which will be exemplified in the structures hereinafter described, and the scope of which will be indicated in the following claims.

In the accompanying drawings, in which several of various possible embodiments of the invention are illustrated,

Fig. 1 is an axial section illustrative of one form of the invention;

Fig. 2 is a cross section taken on line 2—2 of Fig. 1;

Fig. 3 is a cross section taken on line 3—3 of Fig. 1;

Figs. 4, 5 and 6 are diagrammatic views based upon the cross sections shown in Figs. 2 and 3 and illustrating (with said Figs. 2 and 3) a sequence of events constituting a cycle of operations;

Fig. 7 is an isometric view illustrating certain four-piston rotors such as used in the form of the invention shown in Figs. 1–6;

Fig. 8 is a view similar to Fig. 2, but illustrating a second form of the invention;

Fig. 9 is a view similar to Fig. 3, but illustrating said second form of the invention; and

Fig. 10 is a view similar to Fig. 7, but illustrating certain two-piston rotors as used in the form of the invention shown in Figs. 8 and 9.

Similar reference characters indicate corresponding parts throughout the several views of the drawings.

Briefly, the invention has two aspects: first, the improvement constituted by said reverse-locking means forming a part of the new combination constituting a rotary engine; and second, the improvement relating to the reverse-locking means as such.

Briefly, the reverse-locking means comprises a member having what will hereinafter be referred to as an inwardly

directed cam track. A rotor which is relatively movable with respect to the cam track carries swinging follower arms having their ends biased outward toward the cam track. The ends of the arms have suitable follower rollers riding the track. The relationship between the track shape and follower arms is such that in certain positions of the rotor the followers assume positions preventing reverse movement of the rotor. The arrangement is such that impact between follower and track is avoided, thereby minimizing wear and reducing noise.

Briefly, the rotary engine elements of the invention are constituted by two rotors, a driven shaft and a surrounding annular or toroidal cylinder. Each rotor carries several pistons which are interdigitated with those of the other within the cylinder. Each rotor has a power connection to the shaft. The frame in which the cylinder is located carries cam tracks of the type above outlined, and each rotor carries follower arms having end parts engaging the cam tracks. Each rotor in response to intake, compression, expansion and exhaust events between the pistons in the cylinder is caused to rotate, the rotors alternating in application of power to the shaft. This alternating application of power is accomplished through springs, although it may be applied otherwise. The reverse-locking means permits each rotor alternately to assume the reverse-locking position with respect to the frame to function as a reaction member for effecting the driving of the other rotor.

Referring now more particularly to Figs. 1–7, there is shown at numeral 1 a casing consisting of a ring 3 to which are attached cheeks 5 forming an annular or toroidal cylinder 7. Extending from the cheeks 5 are housings containing cam tracks 9 and 11. In position the tracks are coaxial (compare Figs. 2 and 3). In shape they are essentially square, or more broadly quadrilateral with filleted or rounded corners 51. Heads 13 enclose the housings and support bearings 15 for rotors F and S. Rotor F carries pistons A, B, C, D, located in cylinder 7. Rotor S carries interdigitated pistons W, X, Y, Z, also located in the cylinder 7. The pistons are slotted for suitable sealing means, the nature of which it will be unnecessary to discuss because such are known.

A power shaft P is supported upon bearings 17 within the rotors and includes extensions 19 which pass out of the casing 1 through quills 21 and 23 of the rotors. A spring 25 connects quill 21 and shaft extension 19 to form a driving connection between the rotor F and shaft P. A spring 27 also connects quill 23 and the other shaft extension 19 to form a driving connection between the rotor S and shaft P. The springs are unstressed when the pistons assume the equiangular positions shown in Fig. 2.

Each of rotors F and S carries lugs 29 for pivot pins 31. The pivot pins 31 support clevised follower arms. The arms on rotor F are indexed 33 and those on rotor S are indexed 35. The ends of the arms 33 and 35 carry follower rollers 34 for rolling engagement with the cam tracks 9 or 11, as the case may be. In the unstressed conditions of springs 25 and 27, that is, when the pistons are as shown in Fig. 2, the pivot centers of arms 33 and 35 are phased at about 45° (compare Figs. 2 and 3). Springs 37 bias the arms 33 and 35 away from their respective rotors. Movements of the arms 33 and 35 are determined by the angular positions of the rotors F and S with respect to the cam tracks 9 and 11, respectively (compare Figs. 2 and 3). For any substantial effect the angles of follower movements relative to their respective rotors should be substantial, as shown, and not less than twenty degrees.

At I-1 and I-2 (Fig. 2) are shown fuel inlet ports, and at E-1 and E-2 exhaust ports. Numeral 41 indicates recessed ignition plugs of the glow type for high-speed op-

erations. Recessed plugs 43 are also provided for low-speed operations and recessed plugs 45 for starting the device with priming of fuel.

Flats 47 and 49 and fillets 51 of the cam tracks 9 and 11 have certain relationships to the pivoted arms 33 and 35 on the respective rotors, as may be seen from Figs. 2–6. When the rotor F is in a position as shown in Fig. 2 (wherein its pistons A, C are vertical and D, B horizontal), the arms 33 are in positions wherein lines L, which pass through their pivot and roll centers, are substantially perpendicular to the ends of flats 47. As a result, the rotor F cannot move clockwise (Fig. 2) but only anticlockwise. This reverse locks the rotor, the reason being that there is an insufficient component of the thrust at 90° to lines L to angle inward the arms 33. When lines L are exactly perpendicular to the flats 47, there is no normal component of thrust. If the angles deviate slightly from 90° there still may not be sufficient normal thrusts to overcome the actions of springs 37. The action is similar to that of a toggle wherein the springs 37 have a large mechanical advantage in preventing inward movements of the arms 33 or 35. Such advantage occurs in the reverse-locking positions such as shown in Fig. 2. It may be noted that when rotor F has advanced 90° from the Fig. 2 position, the same reverse-locking effect will occur with lines L normal to flats 49. In Fig. 3, which relates to rotor S, is shown how the arms 35 angle inward as the flats 47 of cam track 11 are traversed in making an approach to conditions such as described for rotor F in connection with Fig. 2. The action is the same in this respect for the arms 33 of rotor F as they move between reverse-locked positions.

The radius of curvature of each fillet 51 is preferably slightly less than the distance from the center of a pivot pin 31 to the outermost point on a corresponding roller 34. Each arm 33 or 35 is in the substantially perpendicular position L with respect to a flat 47 or 49 only when at the end of the flat. Thus, this arrangement prevents the springs 37 from moving the arms further outward than said perpendicular position L when in the reverse-locked position.

Operation is as follows, assuming that the engine is running:

Referring to Fig. 2, an expansion event is occuring between pistons D and Y; also between B and W, assuming ignition by plugs 43. Reaction occurs against the pistons D and B, the rotor F being reverse locked for reasons stated above. Thus, rotor S is moving anticlockwise. Exhaust events are occuring between pistons Y and C; also between A and W (see ports E-1 and E-2). Suction events draw fuel in at ports I-1 and I-2 between pistons A and Z and between pistons C and X, respectively. A compression event is occuring between pistons Z and D; also between pistons B and X. Under these conditions the unit pressure of expansion is greater than the unit pressure of compression. The arms 33 of rotor F are reverse locked as shown in Fig. 2, and the arms 35 of rotor S are as shown in Fig. 3.

As expansion progresses, the conditions illustrated in Fig. 4 occur in which the said events are about terminated. Then, as shown in Fig. 5, the expansion event dissipates by exhaust through ports E-1 and E-2. The compression events between pistons Z and D (also X and B) then have a sufficient pressure to move the pistons D and B anticlockwise, thus accelerating the rotor F. The arms 33 at this time leave their reverse-locked positions while arms 35 move toward their reverse-locked positions. The compression events may be referred to as gas-buffered collision events between pistons. Such events transfer momentum between the rotors. The compression pressure engendered in the gas during each compression event is essentially a function of, or determined essentially by the speed of operation of the engine, and not primarily by kinematic geometry, as for example is the case in reciprocating engines. Thus in the present engine the compression pressure is higher at higher piston velocities because of the larger momentum transfer between the rotors at such higher velocities. Nevertheless this velocity-controlled compression pressure, even though it may reach critical detonating values, does not appear as deleterious thrust on any bearing parts such as the cam tracks 9 or 11, or the follower mechanisms associated therewith. This is because the pressure events upon collision occur before reverse locking takes place on the cam tracks. The cycle is completed, as shown in Fig. 6, by the pistons W, X, Y, Z having assumed the formerly reverse-locked positions of pistons A, B, C, D as the latter are accelerated. At this time the arms 35 are in reverse-locked positions, thus reverse locking the rotor S. It will be noted that there are four reverse-locked positions for each rotor.

In Fig. 4, lines M and N, which subtend 90°, indicate the travel of centers of pins 31 of one of the rocking arms 33 or 35 during a cycle of operations, i. e., between reverse-locked positions. At line O arm 33 or 35 (as the case may be) is angled a maximum towards its rotor. As a center of a pin 31 of an arm 33 or 35 moves from line M to line O, potential energy will be gradually stored with respect to the rotor, storage being in the compressed springs 37. This potential energy is relatively rapidly converted to kinetic energy in the rotor as the center moves from line O to line N and the springs re-expand. The angle during which energy storage occurs is indexed E, and the angle during which energy is released is indexed R. Angle E should preferably be substantially greater than angle R, and in the present embodiment is of the order of twice as large. The result of this arrangement is that as either rotor F or S moves through a compression or collision event, it receives a rapid influx of kinetic energy (converted from potential energy) which assures that its pistons can move up into and take the reverse-locked positions of the pistons of the other rotor. At the same time, the other rotor is storing potential energy relative slowly, so that this rotor is readily moved out of its reverse-locking position in response to the action of the other rotor as it approaches such position. Moreover, due to the toggling action effected by the shape of the cam track in relation to the arms 33 and rollers 34, the latter by their increasing mechanical advantage increasingly aid forward motion of their respective rotors as the Fig. 4 position is reached.

With regard to the spark plugs, each is of the continuously ignited type such as a glow plug, ignition being timed by presentation of a charge to the plug. Thus if the plugs 41 are ignited, the charge is presented earlier for ignition. The plugs 41 are therefore excited under high-speed conditions. Plugs 45 are excited only under starting conditions.

In Figs. 8–10 is shown a form of the invention employing rotors each having two pistons interdigitating in the cylinder 7. Like numerals designate like parts. Where the parts are modified, different reference numerals are used. In this case, rotor F′ carries pistons G and H, while the rotor S′ carries pistons J and K. Fig. 8 shows rotor F′ in its reverse-locking position, with the lines L of its arms 33 perpendicular to flat 52 of a cam track 9′. The pistons J and K of rotor S′ are advancing in response to an expansion event. Fig. 9 shows the arms 35 of rotor S′ moving anticlockwise toward a reverse-locking position. In this form of the invention a single exhaust port is shown at 53, a single inlet port at 55, and a single ignition plug at 57. The tracks 9′ and 11′ (functionally analogous to tracks 9 and 11 in Fig. 1), besides having the flat portions 52, have gradually outwardly spiraling portions 59. Fillets 61 are of radii preventing further outward movements of arms 33 from their reverse-locking positions substantially perpendicular to flats 51. When the arms 33 and 35 traverse the spiral portions 59 after leaving reverse-locking positions, they are gradually angled toward the rotor (springs 37 being tensioned) so as grad-

ually to build up potential energy which is rapidly released when the respective arm 33 or 35 traverses the end of the next succeeding flat portion 52 in attaining its reverse-locking position.

Again, in this form of the invention the cam tracks are coaxial (compare Figs. 8 and 9). The pivot centers of arms 35 when the pistons are in mid positions (Fig. 8) are phased at about 90° (compare Figs. 8 and 9). The cam tracks are of bilateral form with filleted or rounded corners 61.

Whereas in Figs. 1–7 a cycle of events consumes 90° of rotor movement, in Figs. 8–10 a cycle of events consumes 180° of rotor movement. Operation of the Figs. 8–10 form of the invention is then as follows, assuming the engine to be operating:

The rotor F', carrying arms 33, is in reverse-locking position of these arms (Fig. 8). This reverse locks the pistons G and H. An expansion event is occurring between pistons G and K. An exhaust event is occurring through port 53 between pistons K and H. An intake event is occurring through port 55 between pistons J and H. A compression or collision event is occurring between pistons J and G. The arms 35 of the rotor S' are as shown in Fig. 9, wherein their rollers 34 are traversing the spirals 59 so as gradually to build up potential energy.

It will be clear that ultimately piston K will cross exhaust port 53, thus relieving expansion pressure; whereupon the compression by the pistons J and G will result in movement of G from its reverse-locking position, piston J taking its place. Rotor S' will by this time have moved 90° with respect to the position shown in Fig. 9, whereupon its arms 35 will be in reverse-locking positions at the top and bottom of this view. The expansion event will then occur on piston G and the cycle be repeated, except that reaction will then occur against the then reverse-locked pistons J and K of the rotor S'.

Referring to both forms of the invention, the torque of the rotor F or F' as it is driven by an expansion event is delivered to the shaft P through spring 25; whereas the torque of rotor S or S' as it is driven by means of an expansion event is delivered through spring 27. Starting may be accomplished by cranking the shaft P at a speed near the natural frequency of oscillation of the system constituted by the rotors and their attached pistons and associated parts. Incipient relative movements between the rotors, required to build up the oscillations to a point that the operating events occur spontaneously, are brought about by reason of the varying resistances of the rotors as their rollers 34 traverse the cam tracks 9 and 11 or 9' and 11', as the case may be. The intermittent resistances or drags occur as the followers 34 leave the corners 51 (Figs. 1–7) or corners 61 (Figs. 8 and 9.) Assuming a constant angular velocity of cranking of shaft *p*, the magnitude of the drag is a function of the magnitude of this constant velocity. This is because with increase of magnitude of constant cranking velocity a greater reaction occurs between each follower 34 and the cam track, due to the more rapid angling in of arms 35 against the effects of their greater centrifugal forces.

On the other hand, under conditions of engine operation (as distinguished from cranking) this drag decreases with increase of angular velocity of the shaft, because then each rotor accelerates from a reverse-locked position, resulting in the inertia of each follower arm system around the center of its pivot pin 31 tending to rotate its center of gravity inward. Since the acceleration involved increases with increased engine operating speed, this inertia effect increases and reduces the reaction of each follower 34 on the cam track as it leaves a corner.

It will be noted in the form of the invention shown in Figs. 8–10 that there are two pistons per rotor, two reverse-locking arms per rotor, and two reverse-locking portions for each of the cam tracks 9' and 11'. In the case of the form of the invention shown in Figs. 1–7, there are four pistons per rotor, two reverse-locking arms 33 or 35 per rotor, and for reverse-locking portions for each of the cam tracks 9 and 11. It will be apparent that in this form of the invention there could be used four arms such as 33 or 35 on each rotor, with two reverse-locking portions for each cam track (as in Figs 8 and 9).

It will be clear, for example, that six pistons could be used per rotor with a 60° operating cycle, with an appropriate porting and ignition system, in which case the following design choices would be open for each rotor, i. e., six arms with two reverse-locking portions; three arms with four reverse-locking portions; four arms with three reverse-locking portions; or two arms with six reverse-locking portions.

It will be understood that by a reverse-locking portion on a cam track is meant a portion so formed with respect to an arm 33 and a roller 34 (or the like) that any tendency for a rotor to go backward under the forces involved will not result in springing the arm in toward the rotor. For example, in the absence of any springs a right-angular relationship such as shown would need to be maintained between line L and a tangent portion of the cam upon reverse locking, but with springs such as 37 this exact perpendicular relationship needs not to be exactly obtained for reverse locking.

Additional understanding of the invention may be gained from the following remarks:

During intervals of constant angular velocity, or deceleration, centrifugal force, as well as springs 37, tends to move the arms such as 33 outward. As the arms approach their reverse-locking positions they have a wedging action against the flats such as 47 under this centrifugal force. The resulting reaction is applied at the pins 31 to rotating the rotor upon which said arms 33 are pinned. In addition, considering the arms and rollers to have considerable mass attached to the respective rotors, the moment of inertia of a rotor which is decelerating under compression will be increased. These two effects facilitate the advance of the rotor which is approaching reverse-locking position, so that it may fully displace the rotor which is being accelerated from such position. Therefore, the advancing rotor is sure to assume its proper reverse-locking position. It will be seen that in general the cam tracks have coaxial alignments of their corresponding contours and that the phase angle between the follower arm pivots on adjacent rotors equals the angle between pistons on adjacent rotors when such pistons are successively equally spaced.

As is often true, constructions suitable for engines are suitable as pumps, and this is also true of the present invention, insofar as are concerned the structural relationships between the cylinder, piston-carrying rotor systems, cam tracks and followers.

In view of the above, it will be seen that the several objects of the invention are achieved and other advantageous results attained.

As many changes could be made in the above constructions without departing from the scope of the invention, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

I claim:

1. In a rotary machine having a frame carrying a toroidal cylinder, a rotary power shaft and relatively movable rotors located around said shaft, each rotor having at least one piston in the cylinder, an inwardly directed cam track on the frame for each rotor, at least one reverse-locking portion in each cam track, at least one outwardly biased and pivoted swinging arm on each rotor having endwise means engaging its respective cam track and adapted to reverse lock its respective rotor upon reaching a reverse-locking portion on the cam track, first means in each cam track located in approach to its reverse-locking portion and adapted to control outward swinging movement of an arm and second means in each cam track located in recess from each reverse-locking

portion and adapted to control reverse inward movement of the arm, and a driving connection between each rotor and the shaft, each driving connection being adapted to permit overrunning of one rotor and the shaft with respect to the other rotor.

2. In a rotary machine having a frame carrying a toroidal cylinder, a rotary power shaft and relatively movable rotors located around said shaft, the rotors having equal numbers of pistons in the cylinder, an inwardly directed cam track on the frame for each rotor, each cam track having at least two substantially flat portions, at least two outwardly swingable pivoted arms on each rotor having endwise means engageable with the respective cam tracks, each flat portion being adapted to effect rapid outward swinging movements of said arms to substantially perpendicular reverse-locking thrust positions, relative to said substantially flat portions, the remainders of the tracks being adapted to enforce more gradual inward swinging movements of the arms than said outward swinging movements.

3. In a rotary machine having a frame carrying a toroidal cylinder, a rotary power shaft and relatively movable rotors located around said shaft, each rotor having four pistons in the cylinder, an inwardly directed cam track on the frame for each rotor, each cam track being shaped essentially in the form of a square with filleted corners, at least two outwardly swinging arms on each rotor having endwise roller followers engaging the cam track, the length of each arm being such as to allow it to swing outward and reverse lock the rotor when its roller follower is in a position adjacent a filleted corner.

4. In a rotary machine having a frame carrying a toroidal cylinder, a rotary power shaft and relatively movable rotors located around said shaft, each rotor having two pistons in the cylinder, an inwardly directed cam track on the frame for each rotor, each cam track being shaped essentially in the form of two parallel faces connected by inwardly directed spiral portions, two outwardly swinging arms on each rotor each having an endwise roller engaging the cam track, the lengths of said arms being such as to allow them to swing outward and reverse lock the rotor when its roller is in a position adjacent the end of a parallel face.

5. In a rotary machine, a toroidal cylinder, rotor systems having pistons in the cylinder, said systems interacting upon one another through the pistons to pass through a cycle of events occurring throughout a given angle of movement of each one of said systems, a cam track carried on the frame in connection with each rotor system, at least one follower angularly movable on and relative to each rotor system adapted to follow on its respective cam track, means in the cam track adapted to move its respective follower through an angle not less than twenty degrees from an outer reverse-resisting position occurring at one point on the track to an innermost position occurring at another point on the cam track and then again to an outer reverse-resisting position.

6. In a rotary engine, a frame, a power shaft, a toroidal cylinder connected to the frame, rotor systems having pistons in the cylinder, resilient driving connections between the respective rotors and the shaft, said rotor systems interacting upon one another through the pistons to pass through cycles of starting and operating events occurring throughout a certain angle of movement of each one of said systems, a cam track for each rotor system, each track being connected with the frame, at least one follower pivoted on each rotor system and extending rearwardly with respect to rotor rotation, means biasing the follower from its rotor system and against the cam track, first means in each cam track adapted relatively rapidly to angle its follower from an innermost position to an outer reverse-locking position relative to the track with forward thrust action on the rotor, second means in each cam track adapted to angle the follower relatively slowly from the outer reverse-locking position to an inner position, the follower drag on a rotor increasing with the magnitude of any cranking speed of said shaft, but under rotor acceleration and deceleration under running conditions decreasing with increase in the angular velocity of the shaft.

7. A rotary engine made according to claim 6, wherein said first and second means in the cam track at a given rotor speed will cause the time for inward movement of a follower to be substantially greater than the time for its outward movement.

8. In a rotary machine having a frame carrying a toroidal cylinder, a rotary power shaft and relatively movable rotors, each rotor having at least two rigidly connected and equally spaced pistons in the cylinder, a drive spring connecting each rotor with the shaft, an inwardly directed cam track on the frame for each rotor, first means in each cam track adapted to effect at least two reverse-locking portions which as to the two tracks are in coaxial alignment, at least one outwardly biased and swinging arm on each rotor having endwise means engaging a respective cam track, the centers of swing of the arms on the two rotors being phased at an angle equal to the angles between the pistons in the cylinder of the respective rotors when all of the pistons are successively equally spaced in the cylinder, second means in each cam track located in approach to its reverse-locking portion and adapted for outward swinging movements of an arm and third means in each cam track located in recess from each reverse-locking portion and adapted to effect reverse inward movements of the arm.

9. In a rotary machine having a frame carrying a toroidal cylinder, a rotary power shaft and relatively movable rotors, each rotor having four equally spaced pistons in the cylinder, a drive spring connecting each rotor with the shaft, an inwardly directed cam track on the frame for each rotor, each cam track being of essentially quadrilateral form having four rounded corners and providing reverse-locking portions, two outwardly biased and swinging arms on each rotor having endwise means engaging a respective cam track, the centers of swing of the arms on the respective rotors being phased at substantially a 45° angle when all of the pistons are successively equally spaced in the cylinder, first means in each cam track located in approach to its reverse-locking portions and adapted to control outward swinging movements of the arms and second means in each cam track located in recess from each reverse-locking portion and adapted to control reverse inward movements of the arms.

10. In a rotary machine having a frame carrying a toroidal cylinder, a rotary power shaft and relatively movable rotors, each rotor having two pistons in the cylinder, a drive spring connecting each rotor with the shaft, an inwardly directed cam track on the frame for each rotor, each cam track being of essentially bilateral form having two rounded corners and providing reverse-locking portions, two outwardly biased and swinging arms on each rotor having endwise means engaging the respective cam track, the centers of swing of the arms on the respective rotors being phased at substantially a 90° angle when all of the pistons are equidistant from one another in the cylinder, first means in each cam track located in approach to its reverse-locking portions and adapted to control outward swinging movements of the arms and second means in each cam track located in recess from each reverse-locking portion and adapted to control reverse inward movements of the arms.

11. In rotary apparatus having an assembly consisting of a frame, a shaft, an annular cylinder fixed with respect to the frame, two cooperative rotors carrying pistons within the cylinder, said rotors moving relatively to effect cycles of compression and expansion operations between them, and drive connections between said rotors and the shaft; comprising reverse-locking operative means

connected between each respective rotor and the frame including therein a resilient mechanical device adapted during an initial part of a cycle of operations to be compressed to accumulate mechanical potential energy with respect to the respective rotor and during a later part of the same cycle of operations to expand and by reaction between the frame and respective rotor to convert said mechanical potential energy to kinetic energy in said respective rotor.

12. Apparatus made according to claim 11, wherein each of said operative means comprises a cam track on the frame, at least one rocking arm pivoted to a rotor and guided by the cam track to be rocked with respect to the rotor, and a mechanical spring biasing the arm into engagement with the cam track to have its rocking movement controlled thereby.

13. In a rotary machine having a frame carrying an annular cylinder, a rotary power shaft, and relatively movable rotors, each rotor having at least one piston in the cylinder and having a drive connection with the shaft; a cam track on the frame for each rotor, a member movably attached to each rotor and adapted to be guided by the cam track to effect its movements relative to the rotor as the rotor moves, first means in each cam track adapted to provide at least one portion with which said movable member cooperates to reverse lock the rotor, spring means biasing each movable member into engagement with a cam track, and second means in each cam track adapted to force the movable member to compress the spring so as to store potential energy therein relative to the rotor and subsequently to allow expansion of the spring and to guide said movable member in its approach to its reverse-locking position for reaction between the cam track and the rotor to convert potential energy of the spring into kinetic energy in the rotor.

14. A rotary machine comprising a toroidal cylinder, rotor systems having coacting pistons in the cylinder, a cam track carried on the frame in connection with each rotor system, at least one follower forming part of each rotor system and adapted to follow its respective cam track to be controlled thereby for substantial inward and outward movements, the cam tracks and respective followers being arranged in response to an expansion event between pistons for reverse-reacting relationships at spaced intervals on the respective cam tracks, said rotor systems being adapted through gas-buffered collision events between their pistons in the cylinder to effect compression pressures preceding said expansion events, said compression pressures being engendered at intervals in the cycle of events preceding the intervals of reverse reaction, whereby the pressure engendered during each collision event is substantially a function of engine speed.

15. A rotary machine made according to claim 14, including means in the cam tracks located between reverse-reacting points thereon and adapted first to effect inward follower movement throughout a substantially larger angle of rotor movement and second to effect outward follower movement throughout a substantially smaller angle of rotor movement, whereby a substantial amount of potential energy is gradually accumulated in each rotor system at the expense of its kinetic energy and subsequently more rapidly returned as kinetic energy.

16. A rotary machine made according to claim 15, wherein the ratio of rotor system movements for inward and outward follower movements is of the order of 2:1.

17. A rotary machine made according to claim 14, including speed differentiating means adapted to transfer rotation from the respective rotors to a single power shaft under different rotor speeds.

18. A rotary machine made according to claim 1, including means adapted to effect angular movement of each rotor during outward movement of an arm connected therewith which is substantially smaller than the angular movement of the rotor during inward movement of said arm and adapted to control the relative movement between the respective arm and the cam track during outward movement of the arm to force the respective rotor forward with substantially increasing mechanical advantage during said outward arm movement.

No references cited.