March 30, 1965 G. E. MALLINCKRODT 3,175,467

ROTARY ENGINE

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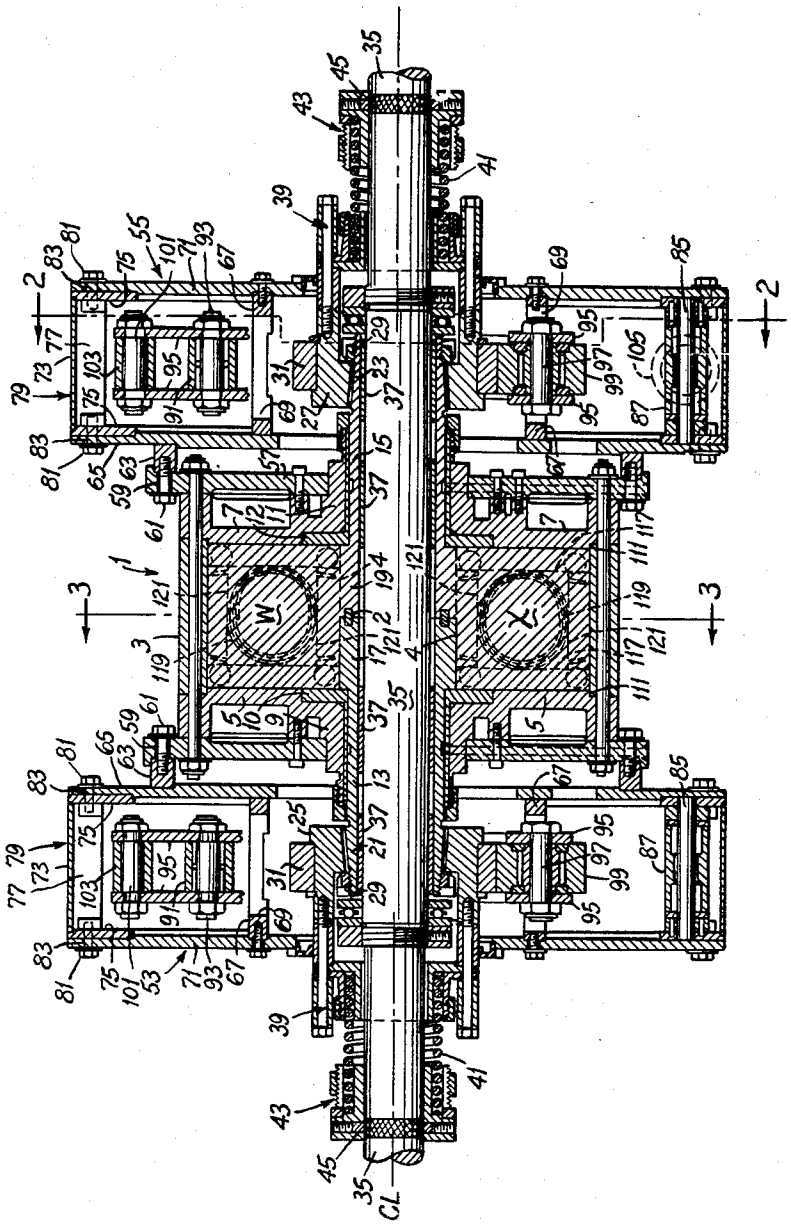


FIG. 1.

George E. Mallinckrodt,
Inventor.
Koenig, Pope, Senniger and Powers,
Attorneys.

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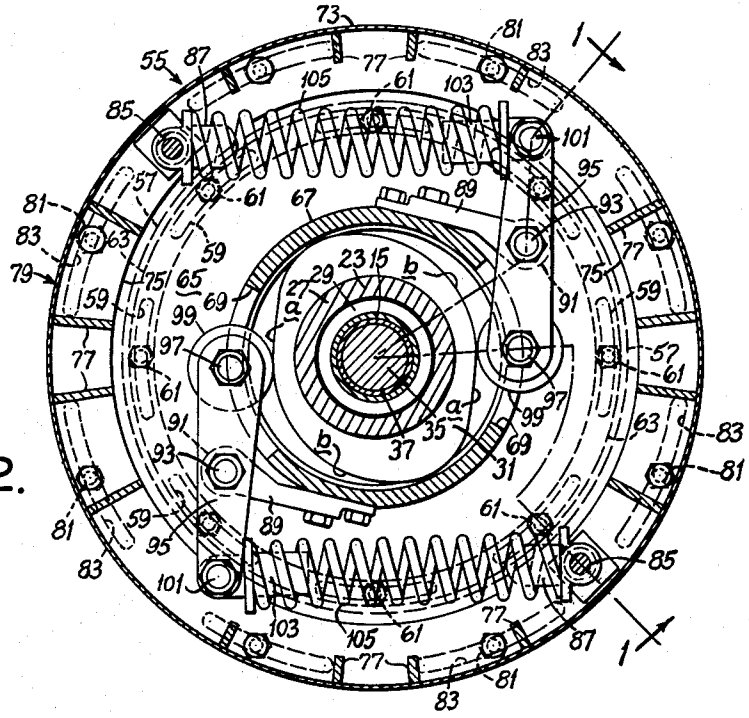


FIG. 2.

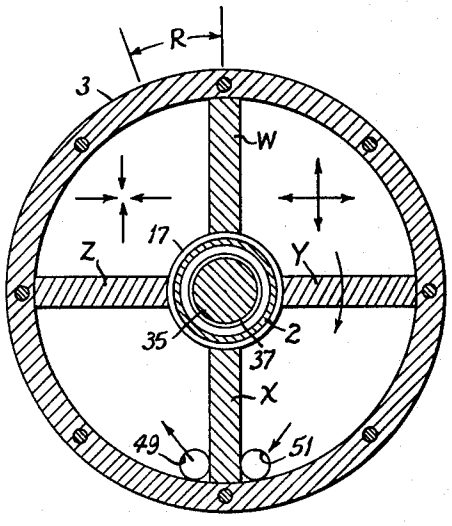


FIG. 3.

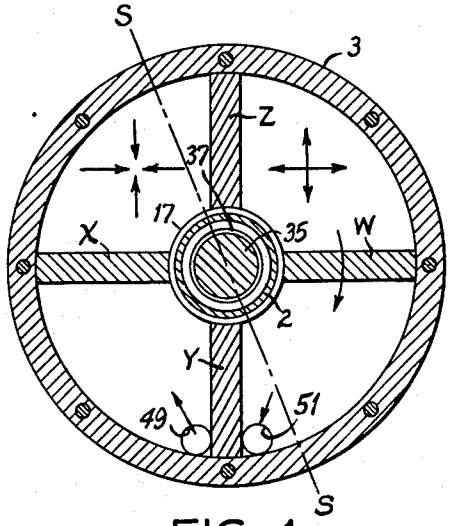


FIG. 4.

George E. Mallinckrodt,
Inventor.
Koenig, Pope, Senniger and Powers,
Attorneys.

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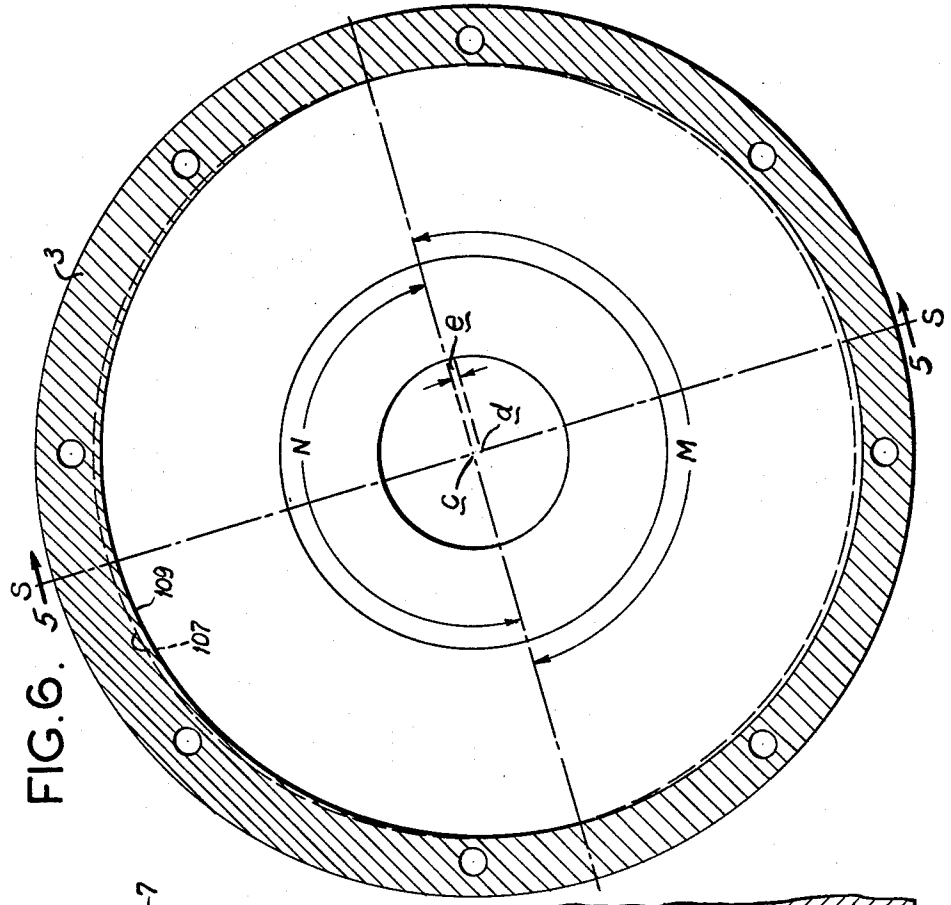


FIG. 6.

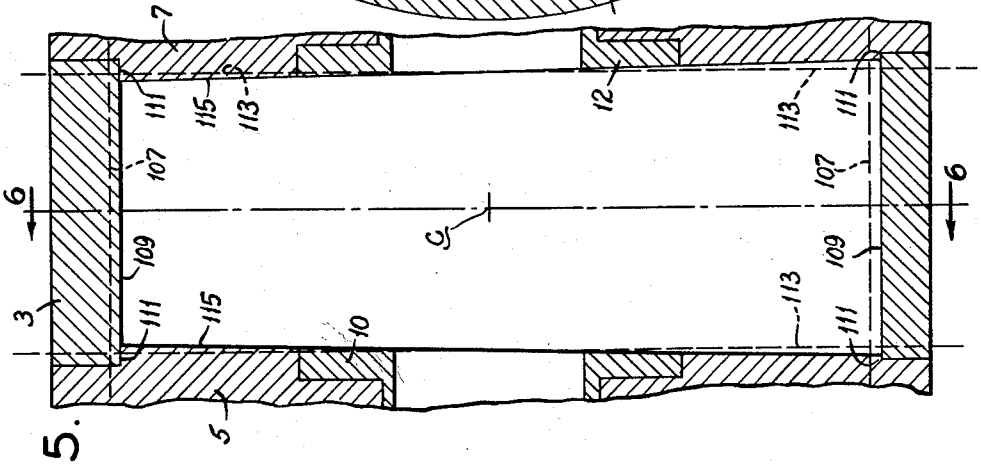


FIG. 5.

George E. Mallinckrodt,
Inventor.
Koenig, Pope, Senniger and Powers,
Attorneys.

United States Patent Office 3,175,467 Patented Mar. 30, 1965

3,175,467

ROTARY ENGINE

George E. Mallinckrodt, St. Louis, Mo., assignor to Elliot Enterprises, Incorporated, St. Louis, Mo., a corporation of Missouri

Filed June 12, 1961, Ser. No. 116,390
3 Claims. (Cl. 91—60)

This invention relates to rotary internal combustion engines and, with regard to certain more specific features, to such engines of the free-piston type.

The invention is an improvement upon free-piston rotary engine constructions such as disclosed in my United States Patents 2,736,328, 2,756,728, 2,796,216, 2,834,322 and 2,943,785.

Among the several objects of the invention may be noted the provision of improved reverse-locking means operative between the engine rotors and the engine frame, wherein the effects are avoided of centrifugal force upon reverse-locking rocker arm parts; the provision of reverse-locking means of the class described which is adapted for convenient adjustment of reverse-locking functions; the provision of a rotary engine of the class described having means for improving sealing efficiencies during compression and explosion events; and the provision of means for accomplishing such sealing improvements without any substantial increase (if any) in the parasitical frictional load carried by the machine. Other objects and features 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 one of various possible embodiments of the invention is illustrated,

FIG. 1 is an axial section, parts being broken away, illustrating the invention;

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

FIG. 3 is a diagrammatic cross section taken on line 3—3 of FIG. 1, illustrating certain operating events;

FIG. 4 is a view similar to FIG. 3, showing succeeding operating events;

FIG. 5 is a diagrammatic view illustrating in an exaggerated manner certain cylinder improvements, the view being taken on line 5—5 of FIG. 6; and

FIG. 6 is a cross section taken on line 6—6 of FIG. 5.

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

Briefly, the present invention provides an improved rotary free-piston internal combustion engine in which the rotors, instead of the engine frame, carry certain reverse-locking cams while the engine frame, instead of the rotor, carries locking arms which cooperate with the cams. The annular engine cylinder is eccentrically constructed in a manner such that leakage clearances between its cylinder and pistons are minimized in an arc of action in which compression and explosion events occur.

Referring now more particularly to FIG. 1, there is shown in general at numeral 1 an annular cylinder formed by an outside ring 3, to which are bolted side cheek pieces 5 and 7. The latter have extensions 9 and 11 for containing bearings 10 and 12, respectively, in which are rotatable quills 13 and 15. Adjacent ends of the quills 13 and 15 are formed as abutting rotor-forming rings 17 and 19, respectively, between which a suitable running sealing means 2 is located. Thus the annular cylinder 1 has a quadrilateral cross section formed by the inside of the ring 3 and inside faces of the cheek pieces 5 and 7, and by the co-extensive outside cylindrical forms 4 of rings 17 and 19.

As diagrammatically illustrated in FIG. 3, ring 19 carries two pistons W and X at 180° intervals. These pistons are rectangular in cross-sectional form and have marginal sealing means such as shown in Patent 2,756,728 and to be further particularized below. Ring 17 carries two pistons Y and Z, also spaced at 180° intervals. These are also rectangular in cross-sectional form and carry similar suitable sealing means. The pistons W, X and Y, Z interdigitate in the annular cylinder 1. The quills 13 and 15 have tapered extensions 21 and 23, to which are splined hub pieces 25 and 27, respectively, the latter being held in proper splined positions by axially threading fastening nuts 29. The hubs 25 and 27 carry identical cams 31, one being shown in FIG. 2. At numeral 35 is shown a drive shaft carried on sets of bearings 37 within the quills 13 and 15.

Bolted to the hub 27 is a gripping assembly 39 for one end of a right-hand drive spring 41. A second gripping assembly 43 is provided for the opposite end of this spring 41, said assembly 43 being attached to the shaft 35 by a set screw gripping arrangement shown at 45. Thus the right-hand spring 41 affords a driving connection between rotor 19 and the right-hand end of shaft 35. Identical connecting means 39, 41, 43 and 45 connect hub 25 with the opposite end of the shaft 35. Thus the left-hand spring 41 affords a driving connection between rotor 17 and the left-hand end of shaft 35. The resilient connections provide for relative angular movements between rotors 17 and 19 as they rotate and drive the shaft 35 through spring 41. The springs 41 are in neutral or unstressed positions when the parts are in the positions (hereinafter called neutral positions) illustrated in FIGS. 3 and 4. In such positions, the cams 31 are in identical angular positions, as illustrated by cam 31 in FIG. 2. The shaft 35, with the operating parts of the auxiliaries connected thereto, has sufficient moment of inertia that it will maintain a substantially constant angular velocity while receiving pulses of energy from the rotors 17 and 19 through springs 41.

Referring to FIGS. 3 and 4, there is shown at numeral 49 a fuel inlet port to which a suitable carburetor or fuel injection device is attached (not shown, being conventional). At numeral 51 is shown an exhaust port. The ports 49 and 51 are separated sufficiently to admit therebetween any one of the pistons W, X, Y, Z.

The cams 31 constitute parts of reverse-locking mechanisms which are in general numbered 53 and 55. All parts of each of these reverse-locking mechanisms are identical, including the component cams 31. The parts of each mechanism 53 and 55 are therefore given the same letters and a description will be given for those in mechanism 55, it being understood that the same description applies to the identical parts in mechanism 53.

Referring to FIGS. 1 and 2, the following parts (in addition to cams 31) constitute the reverse-locking mechanism 55. Bolted to cheek piece 7 is a supporting plate 57, in which are crescent slots 59 for reception of bolts 61 for holding ring 63. The ring 63 is attached to annular plate 65. Plate 65 supports one end of an inner sleeve 67 in which are openings 69. Attached to the other end of the sleeve 67 is an annular plate 71. Between the outer margins of the rings 65 and 71 is located a sleeve 73. To this are attached inwardly directed flanges 75 connected by ribs 77. Parts 73, 75, 77 form a rigid annular assembly between parts 75 and 73, hereinafter designated in general as an adjustment ring 79. The flanges 75 receive bolts 81, which pass through arcuate slots 83 cut into the margins of the annular plates 65 and 71. Thus by loosening the bolts 81, the ring assembly 79 is made angularly adjustable relative to members 65,

67 and 71. After an angular adjustment has been made it may be maintained by tightening the bolts 81.

Supported between the flanges 75 are two pins 85 which form pivots for spring abutment members 87. Brackets 89 are attached to the inner sleeve 67, each bracket having an end knuckle 91 in which is a pivot pin 93 for a rocker arm 95. Each rocker arm carries a pin 97 at one end, upon which is mounted a follower roller 99, engageable with cam 31. The openings 69 respectively accommodate the roller ends of rockers 95 and their rollers. Each rocker 95 at its other end carries a pivot pin 101 for pivotally supporting a second spring abutment member 103. Between each pair of spring abutment members 87 and 103 is located a compression spring 105.

Operation is as follows, the general direction of rotation of the machine being clockwise as viewed in FIGS. 2–4:

Pistons W, X are reverse-locked approximately in the position shown in FIG. 3. Reverse-locking occurs because of the inability of cam 31 (FIG. 2) readily to turn anticlockwise against the holding action of rollers 99. The locked positions of pistons W, X are approximate because the locking action on the cam against its reverse rotation by the rollers depends upon the slope of the cam in regions *a*, the compression in springs 105 and other dynamic factors. Therefore the exact reverse-locking point will vary somewhat from that shown in FIGS. 2–4 in accordance with operating conditions of speed, load and the like. For descriptive purposes, an ideal reverse-locking position has been chosen for the showing in FIGS. 2–4. Actually it may occur approximately within the range indicated by the darts R in FIG. 3.

Referring to FIG. 3, pistons Z and Y are turning clockwise. This draws in a charge of fuel through the inlet 49 between pistons Z and X. A compresison event is occurring between the pistons Z and W upon a previously drawn-in charge. Piston W does not move forward because of an explosion event occurring between pistons W and Y. Pistons W and X can move backward only a small amount in view of the reverse-locking action of cam 31, connected with their rotor. Piston Y is being driven clockwise and exhaust is occurring between it and locked piston X. Piston Y of course drives its connected piston Z.

As the compression pressure rises between pistons W and Z and the explosion pressure falls upon expansion between pistons W and Y, a condition is reached in which the compression pressure moves piston W clockwise, allowing piston Z to replace it in reverse-locked condition. During the movements of pistons W and Z from and to the reverse-locked position respectively, ignition occurs due to the temperature increase induced by adiabatic compression. However, by the time the resulting explosion has developed, piston Z has arrived at a position to become reverse-locked, as shown in FIG. 4. The process, which occurs according to the diesel thermodynamic cycle, is then repeated. In FIG. 4, a suction event is occurring between pistons X and Y, a compression event between pistons X and Z, an explosion event between pistons Z and W, and an exhaust event between pistons W and Y.

From the above it will be seen that the reversely operative rise portions *a* on the cams 31 are steep, resulting in the reverse-locking functions thereon by the spring-pressed rollers 99. The forwardly operating rise portions *b* are not as steep, permitting clockwise rotation without locking effect by said rollers.

In order to obtain the desired angular phase relationships between the rollers 99 and cams 31, and proper compression forces in springs 105, the adjustment features above described are employed. To adjust for the proper phase angles of the rollers 99 with respect to the cams 31, bolts 61 may be loosened, thus allowing the entire assemblies carried on rings 63 to be adjusted angularly. This

adjustment controls the locations at which the pistons will reverse-lock. In order to make the adjustments for compression in springs 105, bolts 81 are loosened and the ring assemblies 79 are rotated relative to then fixed annular plates 65 and 71. This causes angling movements of the centers of pins 85 relative to the centers of the pins 93 and 97. Thus the compression in springs 105 may be changed at any adjusted positions of the rollers 99 relative to the cams 31. The exact reverse-locking point for pistons W, X, Y, Z is in part controlled by the first-mentioned phase adjustment and in part by the second-mentioned compression adjustments for springs 105.

Referring to FIGS. 5 and 6, there are illustrated the improvements concerning the sealing between pistons W, X, Y, Z and the annular cylinder 1. These features are incorporated in the structure shown in FIG. 1, but this figure is on such a small scale as not to show them. Thus in FIGS. 5 and 6, important small dimensional variations are exaggerated and dealt with diagrammatically.

In these figures, the ring 3 is illustrated with an outside surface which is concentric with a point *c* on the axial center line CL of the machine. Ordinarily the insides of such cylinders are concentric with the same point such as *c*. To illustrate such a former inside surface, a dotted circle 107 is shown which is concentric around point *c*. This is the usual concentric type of inner cylinder surface such as shown in the above-mentioned patents. According to the present invention, the inner surface of ring 3 is defined by a circle 109, centered on an eccentric point *d*. The eccentricity is indicated at *e*, which may be on the order of .007" or so, assuming a 10" inside diameter or so of the ring 3. The eccentricity is in the direction of a sloping line S—S which, as shown on FIG. 4, is in a position passing through the range of movements of the pistons W, X, Y, Z in which maximum pressures may be expected, due to compression and explosion events.

As shown in FIG. 5, the ring 3 is carried upon shoulders 111, machined into the cheek pieces 5 and 7. These shoulders are also machined circularly around center *d* but eccentrically around point *c*. The eccentricity is *e*, the same as above mentioned.

The parallel dotted lines 113 illustrate the former method of parallel machining of the faces of the cheek pieces such as 5 and 7. According to the present invention, the insides of these cheek pieces are machined (along with the bearing inserts 10 and 12), with opposed angular faces 115. Thus as each piston revolves through a cylinder 1, it passes through a portion thereof which has relatively small quadrilateral shapes throughout segment N (FIG. 6) and also through a portion thereof which has relatively large quadrilateral shapes throughout segment M. The pistons W, X, Y, Z are, as usual, of rectangular form and of size to pass through the smallest dimensions in segment N, with small clearance which is taken up by the usual piston sealing means employed. Such sealing means are diagrammatically illustrated by the dotted-line parts in FIG. 1. Briefly, the sealing means in each piston are constituted by two springy L-shaped members 117 in appropriate slots in the pistons, said L-shaped members being pressed outward from the slots toward the walls of cylinder 1 by means of an annular spring arrangement 119. The springy legs 121 of each L-shaped member 117 are capable of a slight scissors motion relative to one another as they pass through the segments M and N. Further details concerning these sealing pieces may be obtained by consulting said Patents 2,756,728, 2,976,216 and 2,834,322, any of which will be suitable.

In view of the above, it will be seen that as the pistons with their sealing members pass through the narrow-gage range N, the sealing means are pressed inward into their grooves, resulting in a relatively higher spring pressure on them so as to provide a better seal in range

N. As the pistons and their sealing means pass through the broad-gage range M, this pressure is reduced as the sealing means move outward. This results in low friction in the range M, albeit the sealing efficiency is reduced in this range. However, the sealing efficiency in the low-pressure range (corresponding to the suction and exhaust events) does not need to be as good as it does in the range N corresponding to the compression and explosion events.

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

As various 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. A rotary engine comprising a frame, a power shaft, an annular cylinder attached to the frame and surrounding the shaft, a pair of relatively movable rotors, each rotor having at least one piston in the cylinder, individual driving means between the respective rotors and the shaft adapted to accommodate said relative movements between the rotors, a cam connected with each rotor, cam follower means for each cam rotatably supported on a frame part, resilient means biasing each cam follower means into engagement with its respective cam, the cams being shaped for substantially unimpeding actions of the cam follower means on the cams in response to cam movements in one direction, but substantially impeding actions of the cam follower means on the cams in response to reverse cam movements, whereby the cams are intermittently reverse-locked, each cam follower means comprising a rocker arm, a pivot therefor on said frame part, a cam-engaging roller at one end of each rocker arm, resilient means reacting between a support on said frame part and the other end of the arm, means for adjusting the position of said frame part on the frame to rotate, relative to the frame, the follower arm pivot and said support, and second adjusting means for moving said support relative to said frame part to vary the reaction of said resilient means.

2. A reverse-locking mechanism for a rotor of a free-piston rotary engine having a frame; comprising a cam attached to the rotor, at least one roller engaged with the cam, a rocker, pivot means supporting the rocker with respect to a frame part, said rocker supporting the roller at one end portion of the rocker, and resilient means reacting between a fixed reaction point on said frame part and the opposite end portion of the rocker to bias the rocker to force it into engagement with said cam, said cam having an outline for substantially unimpeded motion in one direction but such that said roller will reverse-lock the cam against motion in a reverse direction, and means for angularly adjusting around the cam said frame part including said pivot means for the rocker.

3. A reverse-locking mechanism according to claim 2, including means for adjusting said reaction point on said adjustable frame part.

References Cited in the file of this patent

UNITED STATES PATENTS

932,321	Plates	Aug. 24, 1909
1,904,892	Trube	Apr. 18, 1933
2,413,590	Snyder	Dec. 31, 1946
2,636,478	Smyser	Apr. 28, 1953
2,649,080	Mallinckrodt	Aug. 18, 1953
2,681,046	Barrett	June 15, 1954
2,736,328	Mallinckrodt	Feb. 28, 1956

FOREIGN PATENTS

933,782	France	Jan. 5, 1948