Feb. 3, 1970 H. KREIMEYER 3,492,974

ROTARY NUTATING POWER DEVICE

Filed Jan. 30, 1968 3 Sheets-Sheet 1

Fig. 1

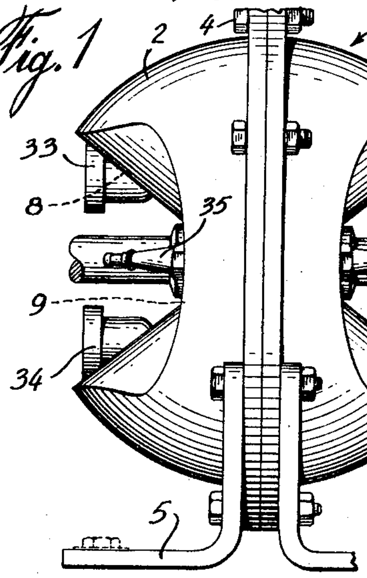
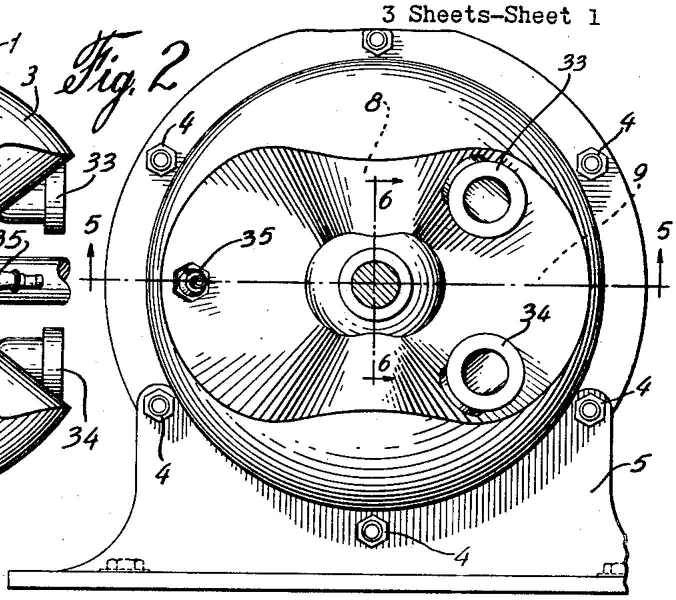


Fig. 2



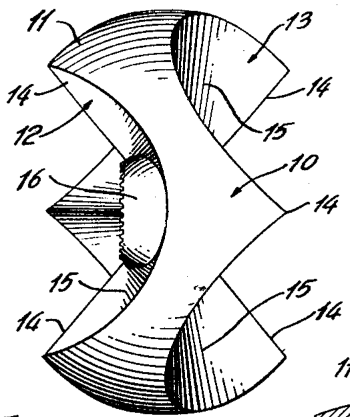


Fig. 3

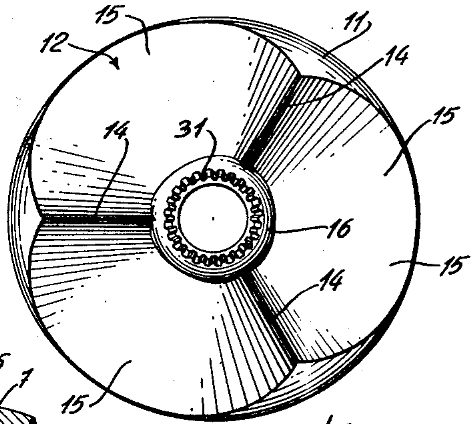


Fig. 4

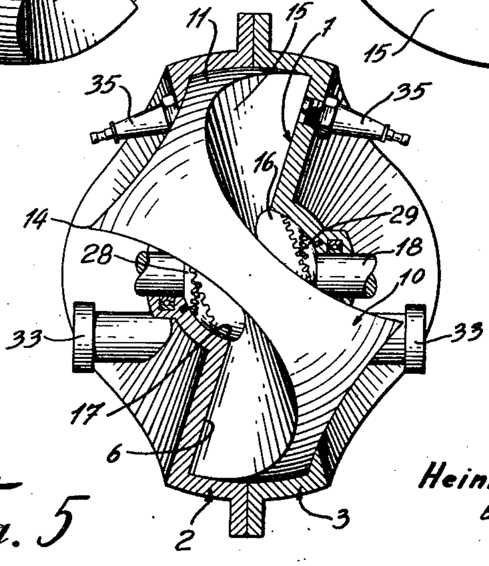


Fig. 5

INVENTOR
Heinrich KREIMEYER
BY
Raymond A. Robic
ATTORNEY

ROTARY NUTATING POWER DEVICE

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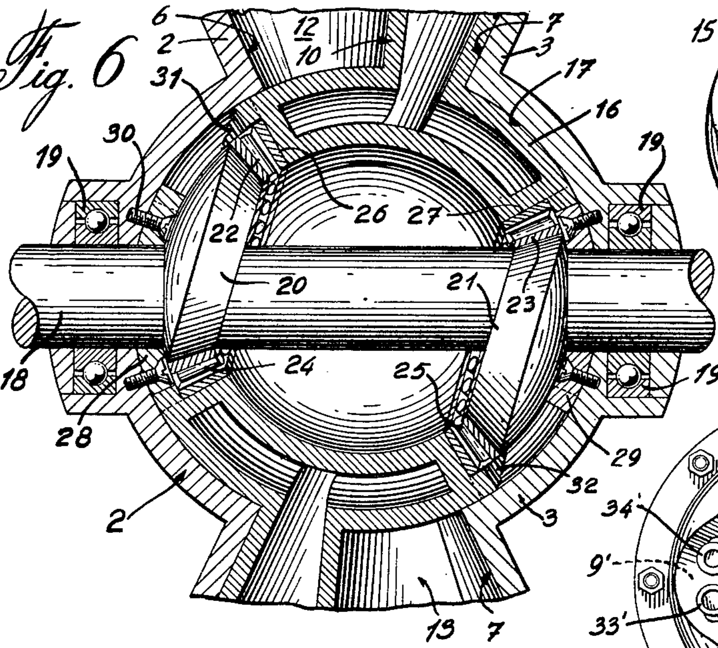

Fig. 6

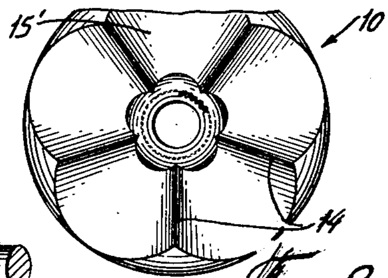

Fig. 8

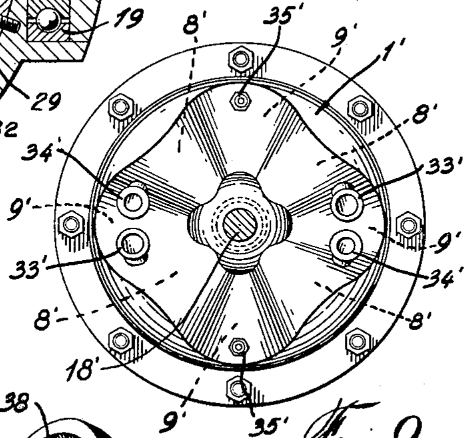

Fig. 9

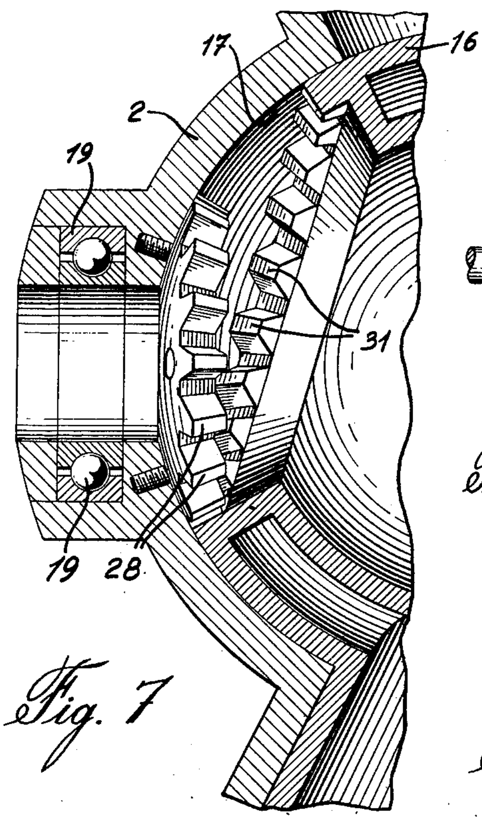

Fig. 7

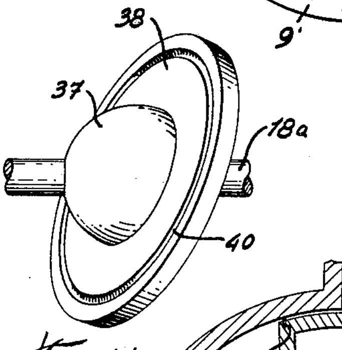

Fig. 11

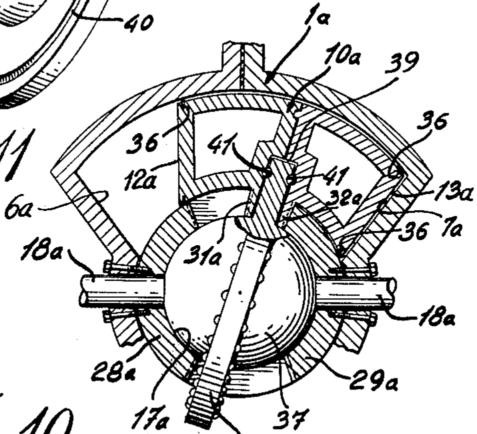

Fig. 10

INVENTOR
Heinrich KREIMEYER
BY
Raymond A. Robic
ATTORNEY

Feb. 3, 1970 H. KREIMEYER 3,492,974

ROTARY NUTATING POWER DEVICE

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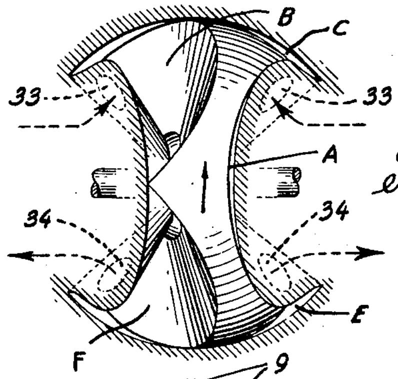

Fig. 12

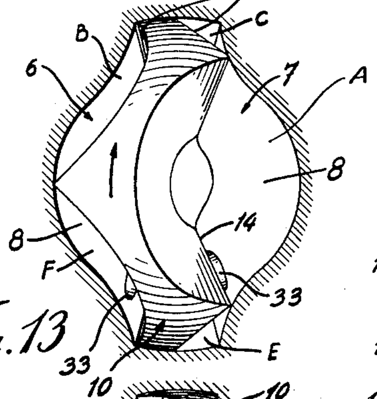

Fig. 13

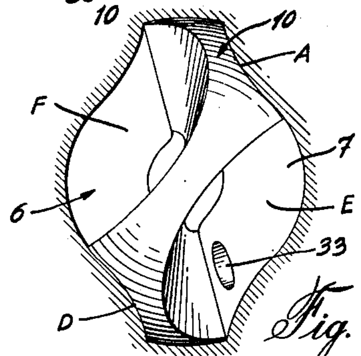

Fig. 14

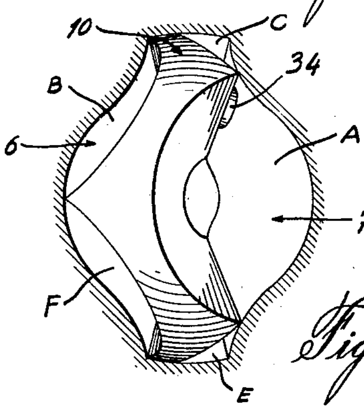

Fig. 15

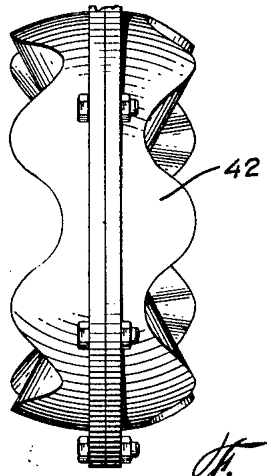

Fig. 16

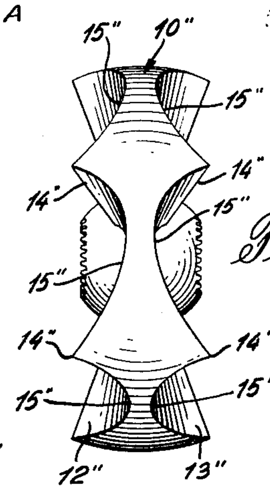

Fig. 18

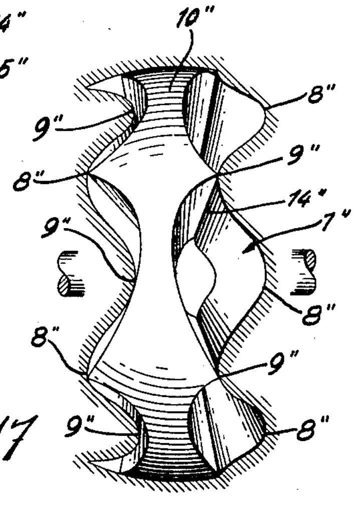

Fig. 17

INVENTOR
Heinrich KREIMEYER
BY
ATTORNEY

United States Patent Office

3,492,974
Patented Feb. 3, 1970

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3,492,974
ROTARY NUTATING POWER DEVICE

Heinrich Kreimeyer, Leadville Road, Mansonville, Quebec, Canada

Filed Jan. 30, 1968, Ser. No. 701,711
Int. Cl. F02b *53/00, 55/14;* F04c *17/00*
U.S. Cl. 123—8 10 Claims

ABSTRACT OF THE DISCLOSURE

The invention is an internal combustion engine or pump with a casing having sinuous walls and a piston with sealing ridges movable within the casing, the shape of the casing and of the piston cooperating with gearing to impart to the piston a combined rotating and nutating motion, the connection between the piston and a drive shaft being effected through an off-set bearing arrangement.

This invention relates to a power device, the basic structure of which may, as in the case of most devices of this type, be embodied as an internal combustion engine, a compressor and air motor, a hydraulic pump or a hydraulic motor.

Power devices including a piston reciprocating in a cylinder have, of course, been known for a long time. More recently, various devices have been proposed in which the piston performs a rotary motion within a chamber, the peripheral walls of which form expansion chambers in cooperation with the piston.

An even more recent development is the use of a piston which performs a nutating motion within a chamber.

The present invention seeks to achieve both the high displacement per revolution characteristics of rotary power devices and the favorable balance characteristics of nutating type power devices by a combination of the two principles, namely, by the provision of a piston which performs a combined rotating and nutating motion. This motion is similar to that of a coin spun on a flat surface, shortly before it comes to rest.

Preferred embodiments of the invention are illustrated by way of example in the accompanying drawings in which:

FIGURE 1 is a side elevation of an internal combustion engine according to the present invention;

FIGURE 2 is a front elevation of the engine;

FIGURE 3 is a side view of the piston;

FIGURE 4 is a front view of the piston;

FIGURE 5 is a section along line 5—5 of FIGURE 2;

FIGURE 6 is a partial section along line 6—6 of FIGURE 2 on an enlarged scale;

FIGURE 7 is a still further enlarged section on the same plane as FIGURE 6 showing a detail, with the drive shaft of the engine removed;

FIGURE 8 is a front view of the piston according to another embodiment of the invention;

FIGURE 9 is a partial front view of the engine according to the embodiment of FIGURE 8;

FIGURE 10 is a partial longitudinal section of an engine according to still another embodiment of the invention;

FIGURE 11 is a perspective view showing a detail of FIGURE 9;

FIGURES 12, 13, 14 and 15 are schematic views of the engine according to the embodiment of FIGURES 1–7 showing various stages in the engine cycle; FIGURE 12 being a side view, FIGURES 13 and 14 top views and FIGURE 15 a bottom view;

FIGURE 16 is a partial side elevation of an engine according to a further embodiment;

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FIGURE 17 is a schematic side view of the engine according to a still further embodiment; and

FIGURE 18 is a side view of a piston common to the embodiments of FIGURES 16 and 17.

Referring to FIGURES 1 to 5, the internal combustion engine according to the invention comprises a casing **1** formed by two sections **2** and **3** held together by bolts **4** and mounted on a base **5**.

The internal periphery of the casing, as defined by the two assembled sections **2** and **3**, is spherical. Each of the sections **2** and **3** provides an inside wall **6**, **7** respectively, which is of sinuous configuration and includes rounded recesses **8** alternating with rounded projections **9**. In the embodiment of FIGURES 1 to 7 and 12 to 15, each inside wall of the casing **1** has two such recesses **8** and two such projections **9**.

A piston **10** is mounted inside the casing to form, in cooperation therewith, the expansion chambers required by the engine. The piston **10** has a spherical periphery **11** matching the spherical inside periphery of the casing **1**. The piston **10** further comprises two faces **12** and **13** on opposite sides thereof, each face having a plurality of sealing ridges **14** alternating with rounded cavities **15**. The faces **12** and **13** of the piston cooperate respectively with the inside walls **6** and **7** of the casing **1**.

In the first embodiment, each face **12** and **13** of the piston **10** has three ridges **14** and three cavities **15**. The cavities **15** must be of sufficient depth to clear the projections **9** as the piston **10** moves within the casing **1**.

As best seen in FIGURE 3, the ridges **14** of one face are aligned with the cavities **15** of the opposite face while in the casing, the projections **9** of one inside casing wall **6** face the projections **9** of the opposite inside casing wall **7** and similarly the recesses **8** of one casing wall **6** face the corresponding recesses of the opposite casing wall **7**.

The piston **10** comprises a central partial hollow sphere **16** concentric with its spherical periphery **11** which is journalled in a spherical central bearing cavity **17** formed by the two sections **2** and **3** of the casing **1**. The central bearing cavity **17** is concentric with the inside spherical periphery of the casing **1**.

A drive shaft **18** is journalled in the casing on ball bearings **19** secured to each section **2** and **3**. The shaft **18** traverses the spherical bearing cavity **17** and the sphere **16** and projects outside the casing **1** on either side thereof.

The shaft **18** has mounted thereon inside the bearing cavity **17** on opposite sides a pair of off-set frusto conical members **20** and **21** supporting the inner races **22** and **23** of tapered roller bearings **24** and **25**, the outer races **26** and **27** of which are attached to the central sphere **16** of the piston **10**.

The bearings **24** and **25** are coaxial and have their apices at the center point common to the casing **1** and to the piston **10**.

A pair of stationary gears **28**, **29** are affixed by means of screws **30** to the casing sections **2** and **3** respectively within the bearing cavity **17** on opposite sides thereof. The stationary gears **28** and **29** are coaxial with the drive shaft **18** which extends through them.

A pair of ring gears **31** and **32** is formed within the periphery of the central sphere **16** of the piston. The ring gears **31** and **32** are disposed on opposite sides of the sphere **16** and are coaxial with the piston **10**.

The ring gears **31** and **32** mesh respectively with the stationary gears **28** and **29** and perform thereon a combined nutating and planetary motion.

The ridges **14** of the piston **10** are provided with seal bars (not shown) as commonly used in rotary engines, which continuously engage the walls **6** and **7** of the inside of the casing.

A fuel mixture intake port **33** and an exhaust port **34** are provided for each section **2** and **3** of the casing **1** opening into the interior of the casing through the side walls thereof. Two spark plugs **35** are similarly provided, one on each side of the casing **1**. The spark plugs **35** are located at the crest of facing projections **9** of the inside walls **6** and **7** of the casing while the intake and exhaust ports **33** and **34** are on either side of the other facing projections **9**, the intake port leading the exhaust port in the direction of rotation of the piston **10**.

In operation, the ring gears **31** and **32**, due to their nutating planetary motion, impart to the piston **10** a rotating and nutating motion which is identical to the motion which the piston **10** is forced to follow due to the shape of the inside casing walls **6** and **7**. The design of the gears **28–31** and **29–32** will, of course, be correlated with the design of the casing walls **6** and **7** in such a way that the locus of the sealing ridges **14** of the piston **10** as determined by the gears, will coincide with the sinuous configuration of the corresponding inside casing walls **6** and **7**.

As can be seen in FIGURES 12 to 14, the piston **10** in its movement within the casing **1** cooperates with the casing to form chambers which alternately expand and contract. By the aforementioned positioning the intake and exhaust ports **33** and **34** and the spark plugs **35**, the expansion chambers can be filled with fuel mixture while they are expanding, can be closed off during the subsequent contraction to provide compression of the fuel mixture, the compressed mixture can then be fired by the spark plugs to provide a combustion stage during the next expansion and the spent gases can then be exhausted during the next contraction so as to provide the known four-stage cycle.

Alternatively, the inlet and outlet ports and the spark plugs may be arranged (in an obvious manner not illustrated herein) so as to provide a two-cycle operation, namely, intake and compression during one chamber contraction and the combustion and exhaust during the subsequent chamber expansion.

Some of the stages of the engine cycle are shown in FIGURES 12 to 15. The arrows in the figures indicate the direction of rotation of the piston **10**.

It will be recalled that FIGURE 12 is a side view, FIGURES 13 and 14 are top views and FIGURE 15 is a bottom view.

The chambers are designated sequentially around the piston **10** on either side thereof by references A to F which indicate the same chambers in the four figures in relation to the cavities **15** of the piston **10**.

In FIGURE 12, chamber A is past the end of the exhaust stage and at the beginning of the intake stage, chamber B is part-way through the intake stage while chamber F is part-way through the exhaust stage.

In FIGURE 13, the sealing ridge **14** of chamber A is just moving past the intake port **33** and the chamber A is therefore at the end of the intake stage and at the beginning of the compression stage. Chamber B is part-way through the compression stage while chamber F is part-way through the intake stage. Chamber E is near the end of the exhaust stage and at the beginning of the intake stage, these two stages overlapping slightly. Chamber C is part-way through the combustion stage.

In FIGURE 14, the chamber A has now reached the end of the compression stage and the beginning of the combustion stage. Chamber F is part-way through the compression stage. Chamber D is past the end of the exhaust stage and at the beginning of the intake stage. Chamber E is part-way through the intake stage.

In FIGURE 15, chamber A is at the end of the combustion stage and at the beginning of the exhaust stage. Chamber B is part-way through the exhaust stage. Chamber F is part-way through the combustion stage and chamber E is at the end of the intake stage and at the beginning of the compression stage.

The nutating component of the motion of the piston **10** is applied through bearings **24** and **25** to the shaft **18** which, therefore, in the present embodiment, will turn through 360° while the piston **10** turns through 120°.

The number of cavities on one face of the piston **10** will preferably exceed by 1 the number of recesses of one casing inside wall. The engine, however, is not limited to having three cavities on one piston face and two recesses on the adjacent wall. Thus, for example, in the embodiment of FIGURES 8 and 9, each face of the piston **10′** has five cavities **15′** alternating with five sealing ridges **14′** while each wall on the inside of the casing **11′** has four recesses **8′** and four projections **9′**. In this embodiment, the piston will rotate through 72° for each full revolution of the shaft **18′**.

The number of intake and exhaust ports **33′** and **34′** and of spark plugs **35′** is doubled. A spark plug **35′** is located at the crest of each alternate projection **9′** and the intake and exhaust ports **33′** and **34′** are located partway down the sides of the alternate projections **9′** on either side thereof, the intake port **33′** leading the exhaust port **34′** in the direction of rotation of the piston **10′**.

This arrangement of intake and exhaust ports and spark plugs which is the same as in FIGURE 1, will apply to internal combustion engines having any chosen number of cavities on one piston face greater by one than the number of projections on one casing wall.

FIGURES 17 and 18 show an inverted arrangement with respect to the first embodiment. In this case, the ridges **14″** of the two faces **12″** and **13″** of the piston **10″** are aligned with each other while in the casing, each projection **9″** of one casing wall **6** or **7** faces a recess **8″** on the opposite casing wall **7** or **6**. The phasing of the cycles of the various chambers will therefore be different in this embodiment, but the operation is otherwise essentially the same and need not be detailed herein. In the embodiment of FIGURES 17 and 18, the piston **10″** has on each face thereof seven sealing ridges **14″** and seven cavities **15″** while the corresponding casing wall has six projections **9″** and six recesses **8″**.

It will have been noted that in each of the three embodiments so far described, the number of recesses and the number of projections of each casing wall is an even number. This is necessary for the four-stage cycle to provide the required alternation of spark plugs and intake and exhaust ports on the consecutive projections **9**, **9′** or **9″**. In two-cycle engines, however, or for other applications such as pumps, an odd number of recesses and corresponding projections may come under consideration.

In the embodiments so far described, all the surfaces of the piston faces such as **12** and **13** and of the casing walls such as **6** and **7** lie on radii of the spheres defining the peripheries of the piston and of the inside of the casing. This geometrical relationship, however, is not essential. A deviation therefrom is illustrated in the embodiment of FIGURES 10 and 11 wherein the surfaces of the casing **1*a*** and piston **10*a*** as indicated by references **6*a***, **7*a***, **12*a*** and **13*a***, are not disposed along the radii of the spherical peripheries thereof. The only essential limitation is that the casing walls **6*a*** and **7*a*** must, as above described, be shaped to coincide with the loci of the piston ridges as determined by the gears **31*a*** and **32*a*** meshing respectively with the stationary gears **28*a*** and **29*a***.

The embodiment of FIGURES 10 and 11 illustrates an alternative arrangement of the connection between the piston **10*a*** and the shaft **18*a***. In this embodiment, the piston **10*a*** is journalled between the internal spherical periphery of the casing **1*a*** and the external spherical periphery of the stationary gears **28*a*** and **29*a***. Suitable sealing strips **36** are provided on the journal faces of the piston **10***a*.

The shaft **18***a* has at the center a ball **37** concentric with the casing **1***a*. The ball **37** carries an off-set circular plate **38** intersecting the center thereof and extending into an annular channel **39** of the piston **10***a* which, for this purpose, is made in two sections as shown. The channel **39** and the plate **38** have, on the contiguous side portions thereof on both sides of the plate **38**, grooves **40** in which bearing balls **41** are mounted.

As in the first embodiment, the nutating component of the motion of piston **10***a* is applied to the off-set bearing constituted, in this case, by the disc **38** so as to rotate the shaft **18***a*.

Two or more pistons may be coupled in series on the same shaft. The intermediate sections **42** of the casing are illustrated in FIGURE 16. Suitably coordinated end sections (not shown) will of course be provided.

When the power device is used as a pump or the like the spark plugs will be omitted and the ports (such as **33** and **34**) will be used as fluid inlets and outlets. These and other required modifications are considered to be matters of skill.

It will be understood that various modifications of the aforedescribed embodiments may be made within the scope of the invention. For instance, the spark plugs **35** (FIG. 1) could be provided on the spherical portion of the periphery adjacent their presently shown location. Also, the sealing ridges **14** could be curved or other than straight, as shown. For ease in assembly, piston **10** could be made of two parts. Finally, the central sphere could be made with a cylindrical bore inclined relative to shaft **18** and the latter provided with a cylindrical member likewise inclined relative to the shaft axis to rotate in said bore.

I claim:

1. A power device comprising:

(a) a casing having a spherical inside periphery and opposite inside walls of sinuous configuration forming a series of alternating recesses and projections evenly distributed thereon;

(b) a piston in said casing having a spherical periphery matching that of the casing and opposite faces having a series of sealing ridges alternating with cavities so as to form with the inside walls of said casing a plurality of expansion chambers;

(c) gearing means within said casing for imparting to said piston a rotating and nutating motion causing the sealing ridges of said piston to follow the sinuous configuration of the inside walls of said casing;

(d) a drive shaft journalled in said casing and coaxial therewith; and

(c) means operatively connecting said piston to said drive shaft.

2. A power device as defined in claim **1** wherein said means for operatively connecting said piston to said drive shaft comprises an off-set bearing mounted on said drive shaft on an axis intersection the center point of said casing, said piston being journalled on said bearing.

3. A power device as defined in claim **1**, wherein said means for operatively connecting said piston to said drive shaft comprises off-set conical bearings mounted on said

shaft on opposite sides of the center point of said casing, said bearings being coaxial and having their apices at the center point of said casing, said piston being journalled on said bearings.

4. A power device as defined in claim **1**, wherein said means for operatively connecting said piston to said drive shaft comprises an off-set circular bearing plate mounted on said drive shaft and intersecting the center point of said casing, said piston being journalled on said bearing plate.

5. A power device as defined in claim **1**, wherein said casing further comprises a spherical central bearing cavity and wherein said gearing means comprise:

(a) a pair of stationary gears affixed to said casing within said bearing cavity on opposite sides thereof and coaxial with said casing;

(b) a pair of ring gears on said piston coaxial with said piston, meshing with said stationary gears and performing thereon nutating planetary motion, thereby imparting to said piston a rotating and nutating motion and causing the locus of said piston ridges to coincide with the sinuous configuration of the corresponding inside casing walls.

6. A power device as defied in claim **1**, further comprising:

(a) an intake port and an exhaust port disposed along the sides of each alternate projection of said casing walls, said intake port leading said exhaust port in the direction of rotation of said piston; and

(b) spark plugs at the crest of each other alternate projection of said casing wall.

7. A power device according to claim **1**, wherein the recesses of one casing wall face the recesses of the opposite casing wall and the ridges of one piston face are aligned with the cavities of the opposite piston face.

8. A power device according to claim **1**, wherein the projections of one casing wall face the recesses of the opposite casing wall and the ridges of one piston face are aligned with the ridges of the opposite piston face.

9. A power device according to claim **1**, wherein said piston has on each face thereof a number of ridges greater by one than the number of projections on each casing wall.

10. A power device according to claim **2**, wherein said bearing is conical and has its apex at the center point of said casing.

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U.S. Cl. X.R.

91—77; 103—133; 230—148