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Abbey

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[54] **BALANCED ROTARY COMBUSTION ENGINE**

[76] Inventor: **Harold G. Abbey,** 75 Prospect St., East Orange, N.J. 07017

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[52] **U.S. Cl.** **123/8.33,** 418/248

[51] **Int. Cl.** **F02b 53/08**

[58] **Field of Search** 123/8.09, 8.33; 418/248, 418/243–251

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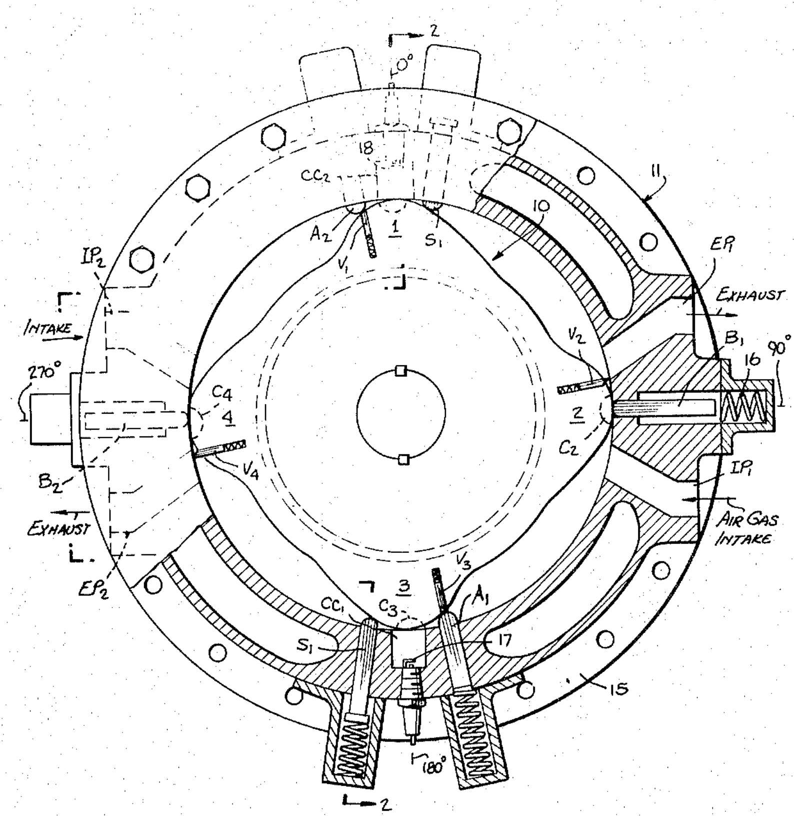
Primary Examiner—C. J. Husar

[57] **ABSTRACT**

A rotary internal combustion engine of symmetrically balanced construction. The engine includes a stator having a circular chamber provided with a pair of diametrically-opposed combustion cavities having igniters therein. Concentrically mounted within the stator is a rotor having at least one pair of lobes. The stator chamber is effectively divided into two distinct sections by means of gas-separating vanes which are disposed at diametrically-opposed positions along an axis at right angles to the common axis of the combustion cavities, the gas-separating vanes continuously engaging the surface of the rotor. Associated with each vane is an exhaust port through which spent gases are forced out by a lobe advancing toward the vane, and an air-gas intake port through which a fuel mixture is admitted for compression by a lobe moving away from the vane.

8 Claims, 9 Drawing Figures



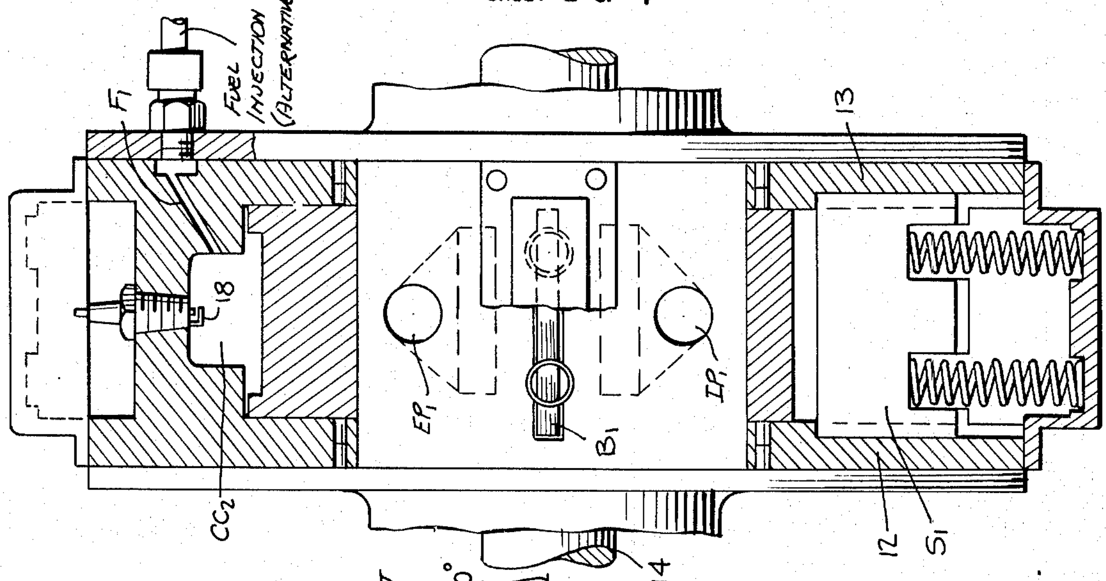

FUEL INJECTION (ALTERNATIVE)
F1
18
CC2
EP1
B1
IP1
13
12
S1
14

Fig. 2.

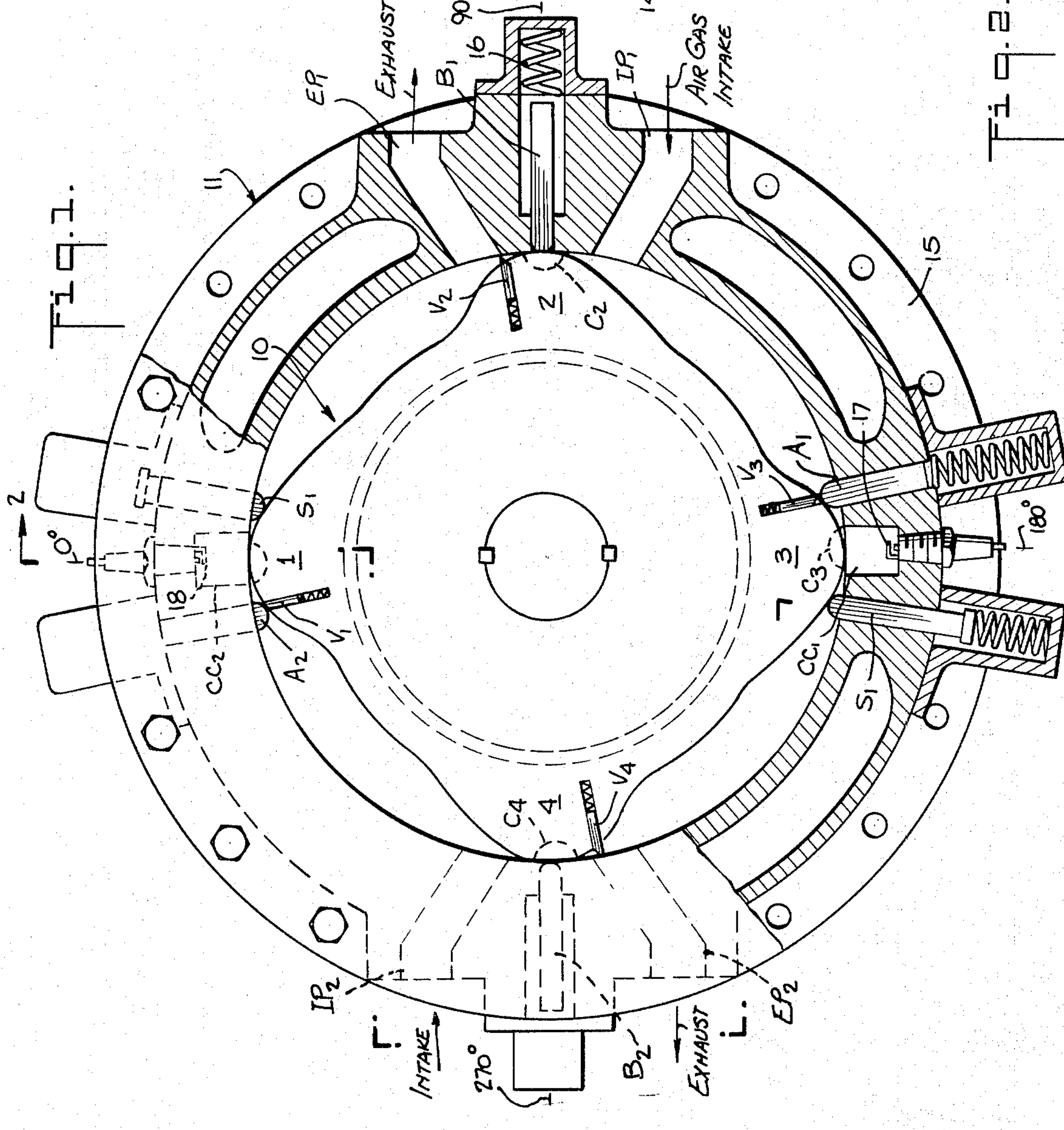
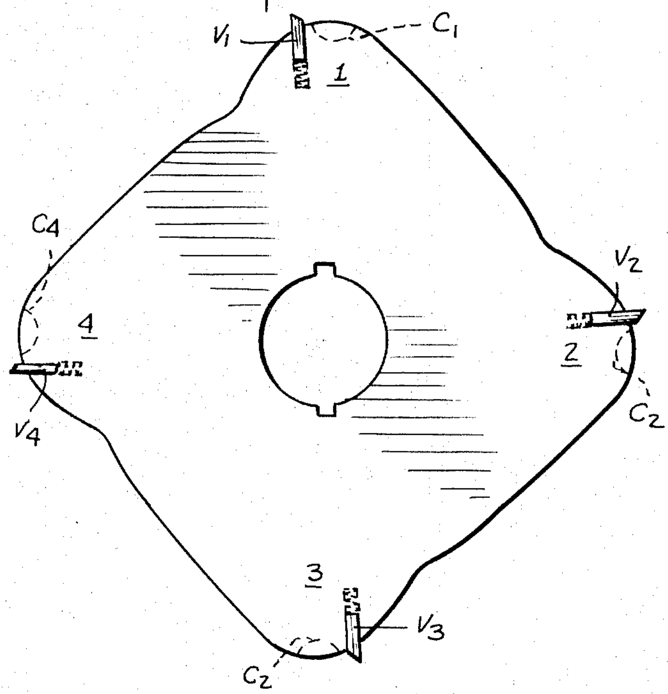

EXHAUST
EP
90°
16
B1
IP1
AIR GAS INTAKE
11
10
V2
2
C2
15
S1
1
18
CC2
A2
V1
0°
2
A1
V3
17
180°
3
C3
CC1
S1
2
C4
4
V4
IP2
INTAKE
270°
B2
EXHAUST
EP2

Fig. 1.

Fig.3.



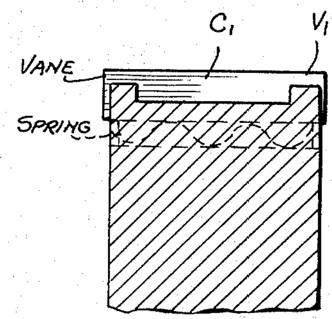
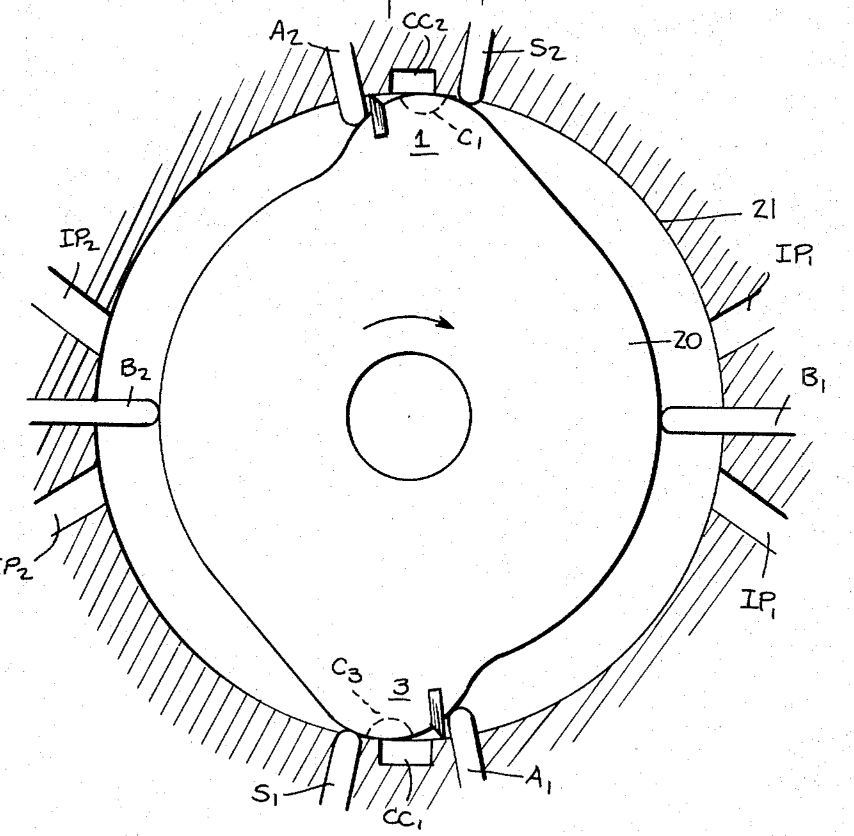


Fig.4.

Fig.5.



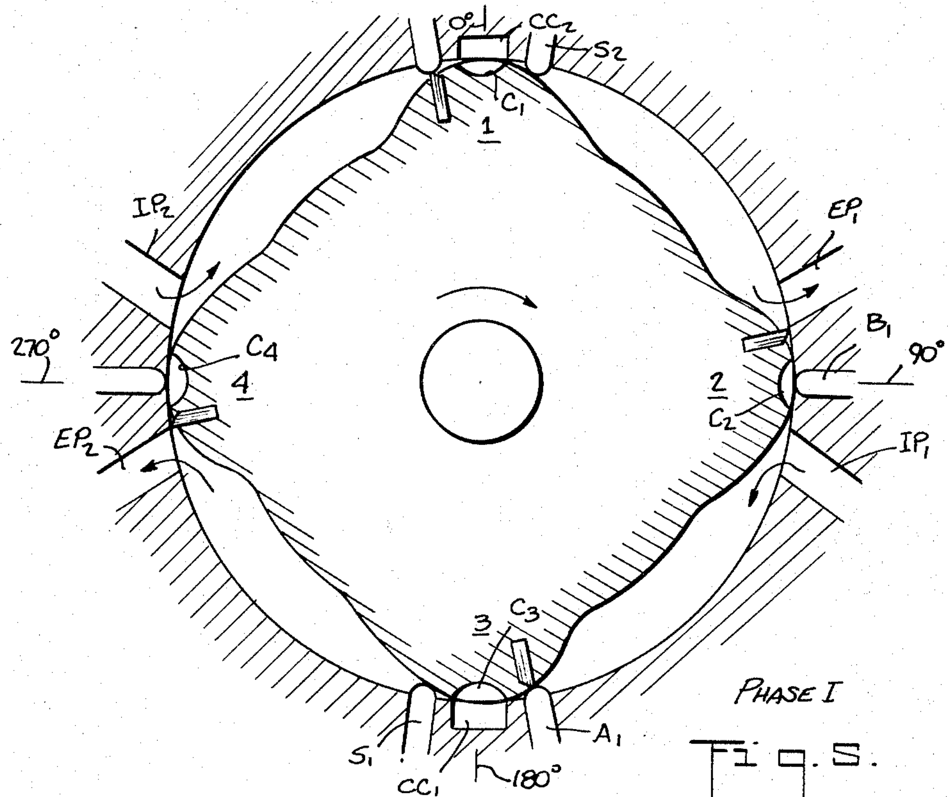
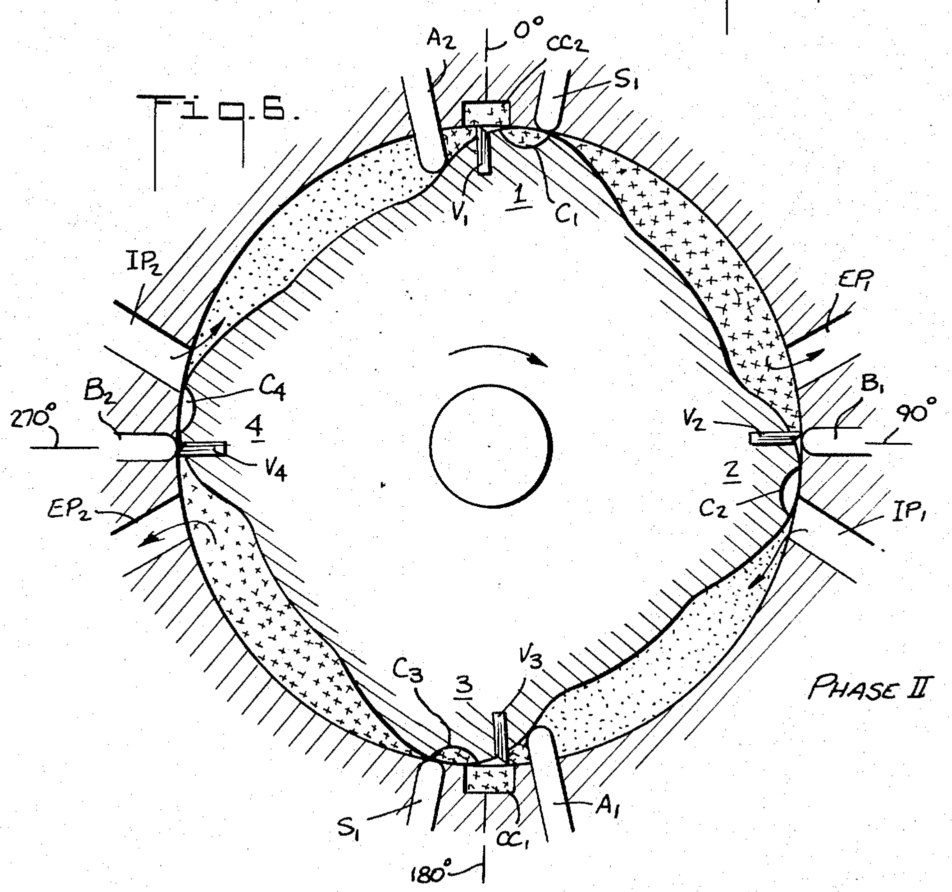

0°
CC2
S2
C1
1
IP2
EP1
B1
90°
270°
C4
4
2
C2
EP2
IP1
C3
3
S1
CC1
180°
A1
PHASE I

Fig. 5.

Fig. 6.


A2
0°
CC2
S1
V1
1
C1
IP2
EP1
B2
C4
B1
270°
4
V2
90°
V4
2
EP2
C2
IP1
C3
3
V3
S1
CC1
A1
180°
PHASE II

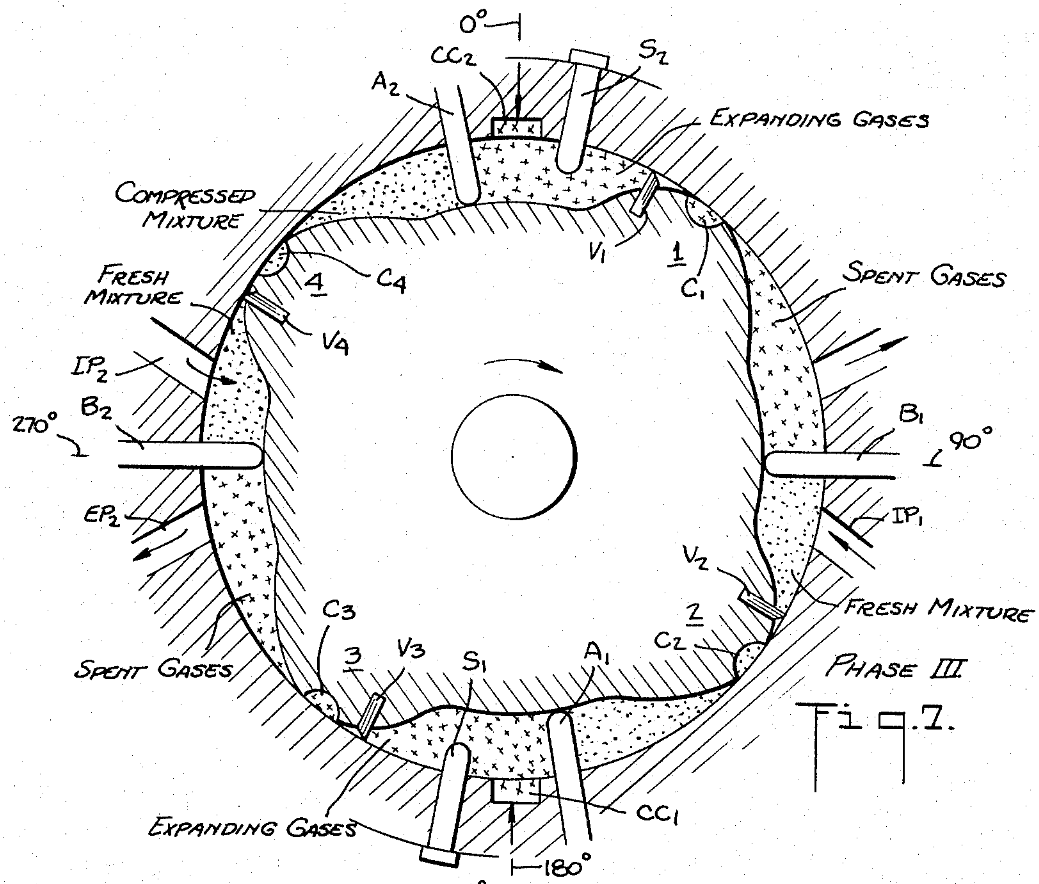
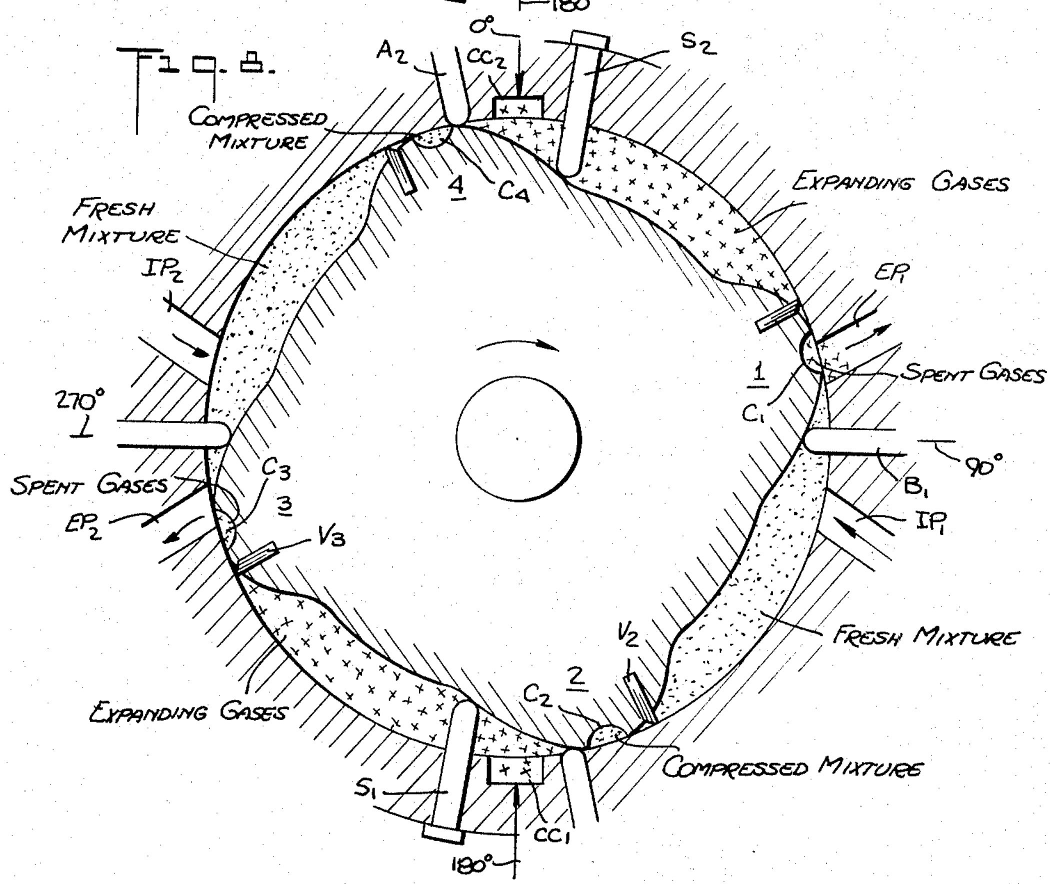

0°
CC2
S2
A2
EXPANDING GASES
COMPRESSED MIXTURE
V1
1
C1
4
C4
SPENT GASES
FRESH MIXTURE
V4
IP2
B2
270°
B1
90°
EP2
IP1
V2
FRESH MIXTURE
C3
2
C2
SPENT GASES
3
V3
S1
A1
PHASE III
EXPANDING GASES
CC1
180°

Fig. 7.

Fig. 8.


0°
A2
CC2
S2
COMPRESSED MIXTURE
4
C4
EXPANDING GASES
FRESH MIXTURE
IP2
EP1
SPENT GASES
1
C1
270°
90°
SPENT GASES
C3
B1
EP2
3
IP1
V3
FRESH MIXTURE
V2
2
C2
EXPANDING GASES
COMPRESSED MIXTURE
S1
CC1
180°

BALANCED ROTARY COMBUSTION ENGINE

BACKGROUND OF THE INVENTION

This invention relates generally to rotary internal combustion engines, and more particularly to a statically and dynamically balanced engine of this type which incorporates a multi-lobed rotor concentrically mounted within the circular chamber of a stator.

The rotary internal combustion engine, often referred to as the "Wankel" engine after the name of its inventor, is far simpler in construction than the reciprocating piston engine, which currently dominates the automotive field. In the Wankel engine, the triangular rotor carries out essentially the same function as the piston in a reciprocating internal combustion engine; that is to say, the rotor acts to draw in a fresh air-gasoline mixture, to compress the mixture, and after ignition thereof, to capture the force of the expanding gases, the rotor finally serving to sweep the exhausted gases out of the engine housing.

The rotor of a Wankel engine operates within a chamber that is the functional equivalent of the cylinder in a reciprocating engine. This chamber or housing has an epitrochoid shape dictated by the motion of the rotor as it revolves about an eccentric on a rotating main shaft. The eccentric movement is constituted by a gear rotating about an off-center axis, causing the rotor to travel with a non-uniform or wobbling motion. Equivalent motion in some engines is obtained by a cam and roller or by a linkage mechanism.

In the Wankel engine, no valves exist to admit a mixture of gasoline and air, or to discharge combustion products. To carry out these functions, the engine is provided with two ports that open directly into the stator chamber, the air-gas mixture entering the chamber through one port and the exhaust gases leaving through the other. These ports are effectively closed only when the moving rotor passes over them to block the flow of the incoming mixture or the outgoing spent gases. The three apexes of the triangular rotor engage the internal wall of the stator chamber and thereby divide the interior of the chamber into three distinct zones. As the rotor revolves in an eccentric path within the stator, the respective dimensions of the three zones undergo constant change.

In the course of an operating cycle of the Wankel engine, a fresh air-gas charge is drawn in and compressed in the first zone, a previous charge is ignited in the second zone and expanded therein to provide thrust, and a still earlier charge--having previously been ignited and expanded--is purged from the third zone.

As compared to a conventional reciprocating piston engine, relatively little energy is wasted in a Wankel engine, for while the piston must come to a complete halt every time it reverses direction, the rotor of a Wankel engine is never arrested and functions continuously to convert the force of the expanding gas into a torque that is applied directly to the main shaft. The reciprocating piston, on the other hand, requires a connecting rod and a crank to transfer its motion into a rotational force.

Moreover, with a Wankel engine, one full turn of the triangular rotor results in the application of three power impulses to the main shaft, whereas in a reciprocating engine, one full operating cycle of four strokes yields but a single power stroke.

Yet despite the generally recognized fact that the Wankel engine is lighter and far more compact than a reciprocating engine of equivalent horsepower and is mechanically much less complex and less costly, it has heretofore failed to replace the reciprocating engine to any significant degree. Though Wankel engines are now used to a limited extent in some power tools, in lawn mowers and in minor industrial applications, they have by no means supplanted the reciprocating piston engine in vehicular applications, for in this major commercial field the internal combustion piston engine is still dominant throughout the world.

The main reason why the Wankel engine has not received widespread acceptance despite its low cost and other significant advantages, lies in its inherent lack of balance. Because of its eccentric mounting, the wobbling motion of the rotor gives rise to energy-dissipating forces which not only materially impair the efficiency of the engine, but also produce objectionable vibration and noise at levels that are unacceptable in a modern automobile or other vehicle.

Moreover, because the asymmetrical Wankel engine is statically and dynamically unbalanced, its life is relatively short, for the wobbling action of the rotor quickly degrades and wears out the engine parts particularly those made of standard materials.

It is for these reasons that expensive wearing surfaces using exotic metals have, in recent years, been introduced in Wankel engines, but these materials offer no solution to the deficiencies inherent in the standard design of a Wankel-type engine.

SUMMARY OF THE INVENTION

In view of the foregoing, it is the main object of this invention to provide a rotary internal combustion engine that obviates the drawbacks of existing Wankel-type engines, and which operates with an exceptionally high degree of efficiency.

More particularly, it is an object of this invention to provide a rotary engine of the above-noted type, the engine being characterized by a multi-lobed rotor concentrically mounted within the circular chamber of a stator whereby the rotor and stator of the motor and the forces generating internal combustion, are in balanced relation, the motor being substantially free of vibration, noise, and other objectionable factors.

Also an object of the invention is to provide a concentrically-mounted rotor for a rotary combustion engine, the rotor in one embodiment having two pairs of diametrically-opposed lobes adapted to produce four opposed pairs of power pulses per revolution, this being equivalent in power output to a sixteen-cylinder, four-stroke conventional reciprocating piston engine. In another embodiment of the invention, the rotor may include but a single pair of lobes, in which event two opposed pairs of power strokes are produced per revolution, equivalent to that obtainable with a conventional eight-cylinder reciprocating engine. In practice, more than two pairs of lobes may be included in the engine for exceptionally high power outputs.

Another significant advantage of the invention is that it is even simpler mechanically than a Wankel engine, for it dispenses with the usual eccentric gearing. Not only is an engine according to the invention less costly than a Wankel-type engine of equivalent horsepower, but it also has a longer life, for with concentric rotary motion and the attendant freedom from imbalance, considerably less wear is experienced.

Briefly stated, these objects are attained in a rotary combustion engine in which a rotor is concentrically mounted within a stator having a perfectly circular chamber, the rotor being formed with at least one pair of opposing lobes which engage the inner wall of the chamber to define concave zones in the spacing between the lobes. Formed in each lobe at the crest thereof, is a small cavity.

The stator is provided with two sets of intake and exhaust ports associated with first and second gas-separating vanes which are mounted at diametrically-opposed positions on the stator, and which are spring-biased or otherwise controlled to continuously engage the rotor surface. These vanes serve to separate the fresh air-gas mixture fed into the intake port and the spent gases discharged through the exhaust port in the port-set related thereto.

Formed on the inner wall of the stator are first and second diametrically-opposed combustion cavities whose common axis is at right angles to the axis passing through the gas separation vanes, an igniter being placed in each cavity.

Mounted adjacent the incoming side of each combustion cavity (with respect to the direction of rotor movement) is a spring-biased closure vane which continuously engages the surface of the rotor. Mounted adjacent the departing side of each combustion cavity is a spring-biased sealing vane whose maximum extension is limited so that it only engages the rotor surface when it lies in close proximity to the stator wall, the sealing vane otherwise being spaced from the rotor surface.

In the course of each revolution of the rotor, as each lobe approaches the first gas-separation vane, the air-gas mixture from the related intake port is admitted into the zone in front of the lobe. As the lobe moves toward the first combustion cavity, it acts to compress the gas in the front zone against the closure vane related to the first combustion cavity, until a point is reached at which the lobe cavity lies in registration with the first combustion cavity. At this point, ignition of the compressed gas mixture confined between the closure and sealing vanes in the lobe and combustion cavities, takes place.

As lobe movement continues, the sealing vane associated with the first combustion chamber loses contact with the rotor surface to permit expansion of the exploded mixture, and as the lobe moves toward the second gas-separation vane, the spent gases from the previous ignition are forced out of the exhaust port associated with the second vane. The lobe then occupies a position in line with the second vane, at which point the above-described sequence of actions is repeated with respect to the intake of the mixture, the compression thereof, and ignition at the second combustion cavity, followed by gas exhaust and the return of the lobe to its initial position at the first gas-separation vane.

OUTLINE OF THE DRAWING

For a better understanding of the invention as well as other objects and further features thereof, reference is made to the following detailed description to be read in conjunction with the accompanying drawings, wherein:

FIG. **1** is a longitudinal section taken through a preferred embodiment of a four-lobe rotary combustion engine in accordance with the invention;

FIG. **2** is a transverse section taken through line **2–2** in FIG. **1**;

FIG. **3** is a separate view of the four-lobe rotor included in the engine shown in FIG. **1**;

FIG. **4** is a detail of one of the lobes of the rotor shown in FIG. **3**;

FIG. **5** is a simplified showing of the engine to illustrate the manner in which it operates in the course of an operating cycle, the engine position being that occupied in Phase I;

FIG. **6** shows the same engine in Phase II;

FIG. **7** shows the same engine in Phase III;

FIG. **8** shows the same engine in Phase IV; and

FIG. **9** schematically illustrates two-lobe rotary combustion engine according to the invention.

DESCRIPTION OF THE INVENTION

Referring now to FIGS. **1** to **4**, there is shown a preferred embodiment of a balanced rotary internal combustion engine in accordance with the invention. The main components of the engine are a rotor, generally designated by numeral **10**, and a stator, designated by numeral **11**.

Rotor **10**, also shown separately in FIG. **3**, is constituted by a cylinder whose outer surface is profiled to define four symmetrically-arranged lobes **1, 2, 3** and **4**, whose principal radial axes are displaced ninety degrees from each other. At the crest of each lobe is a small cavity C_1, C_2, C_3 and C_4, respectively, as well as a spring-biased sealing vane V_1, V_2, V_3 and V_4. The springs are adapted to urge these vanes outwardly to continuously engage the circular inner wall of the stator **11**.

Inasmuch as the rotor, in the example shown is arranged to rotate in the clockwise direction, the front of each lobe shall be referred to as the "leading edge", and the rear thereof, as the "trailing edge." The zone or recess in advance of a moving lobe shall be referred to as the "front zone," and the zone behind a moving lobe, as the "rear zone." Since the sealing vanes V_1 to V_4 on the lobes are located adjacent the trailing edges thereof, in the course of movement each lobe cavity (C_1 to C_4) appears before its associated sealing vane, is seen from any station along the stator.

Rotor **10** is concentrically mounted within stator **11**, which is formed to define a perfectly circular cylindrical main chamber enclosed by end plates **12** and **13**. The stator is provided with bearings for supporting the main shaft **14** on which rotor **10** is keyed. The stator, which also constitutes the housing of the engine, includes annular side seals for the rotor, as well as a mounting flange **15**.

Stator **10** is effectively split into two like operating sections by first and second gas-separating vanes B_1 and B_2. By means of springs **16**, or other means, which may be hydraulic or pneumatic in nature, gas-separating vanes B_1 and B_2 are urged into continuous engagement with the surface of rotor **10**.

Gas-separating vanes B_1 and B_2 are installed at diametrically-opposed positions 90° and 270° on the stator), the vanes shifting in and out in the radial direction in guide and support slots formed in the end housings of the stator to accommodate the varying contours of the rotor surface. Thus at no time do the gas-separating vanes permit fluids in one sections of the main chamber of the stator to enter the other section thereof.

Each gas-separating vane is associated with a set of ports. The first set is constituted by a fresh air-gas mixture intake port IP_1 disposed below vane B_1, and an exhaust port, EP_1 disposed above the vane. The second set is reversely related to the first set, and is provided with fresh air-gas mixture intake port IP_2, disposed above vane B_2, and an exhaust port EP_2 placed below the vane. Thus any lobe of the rotor traveling clockwise first encounters exhaust port EP_1, then vane B_1, followed by intake port IP_1, after which it meets exhaust port EP_2, then vane B_2, followed by intake port IP_2.

Formed in stator **10** are first and second combustion cavities CC_1 and CC_2 disposed at diametrically-opposed positions on a common axis lying at right angles to the axis common to gas-separating vanes B_1 and B_2. Thus combustion cavity CC_1 is situated at 180° and cavity CC_2 at 0° or 360°. Placed within these cavities are spark plugs **17** and **18**, which, when energized, serve to explode the charge therein.

Near the incoming side of combustion cavity CC_1 (assuming clockwise movement), is a closure vane A_1, and similarly placed with respect to combustion chamber CC_2 is a closure vane A_2. Both closure vanes A_1 and A_2 are spring-biased or otherwise operated to act in the same manner as gas-separating vanes B_1 and B_2, so that the closure vanes always remain in contact with the face of rotor **10** to continuously seal the recesses or zones defined on either side thereof.

Near the departing sides of combustion cavities CC_1 and CC_2 (again assuming clockwise movement), are special sealing vanes S_1 and S_2 which, though also spring-biased, are provided with end stops serving to limit the maximum extension of the vanes. The stop positions are such as to cause special sealing vanes S_1 and S_2 to close the recesses associated therewith only during a short portion of the operating cycle, rather than continuously, as in the case of vanes A_1 and A_2.

In other words, special sealing vanes S_1 and S_2 are only able to engage the rotor surface when the depth of the recesses between successive lobes on the rotor is relatively shallow, these vanes otherwise being unable to reach the rotor surface. This part-time sealing action of vanes S_1 and S_2 is an important aspect of the invention, and will be analyzed later in greater detail.

We shall now consider the operation of the engine in the course of a single rotor turn. Intake ports IP_1 and IP_2 are both coupled to a suitable carburetor supplying a proper mixture of gasoline and fresh air. (Alternatively, air alone may be supplied to the intakes, in which event timed fuel injection takes place at combustion cavities CC_1 and CC_2 through fuel injection duct FI, as shown in FIG. **2**.

PHASE I.

As shown in FIG. **5**, in this phase, lobes **1** and **3** are aligned at 0° and 180° with combustion cavities CC_2 and CC_1, the lobe cavities C_1 and C_3 lying in registration with the combustion cavities. Lobes **2** and **4** are in line at 90° and 270° respectively with gas-separating vanes B_1 and B_2.

In phase I, the charge confined within the combustion cavities by vanes A_1 - S_1 and A_2 - S_2, has just been ignited, and lobes **1** and **3** are moving clockwise to begin exhausting through exhaust ports EP_1 and EP_2, respectively.

Lobes **2** and **4** in phase I, as shown in FIG. **5**, are at the end of induction, in line with vanes B_1 and B_2, and now, as the lobes move clockwise, proceed to compress the fresh fuel mixture introduced through intake ports IP_1 and IP_2, in preparation for ignition.

Let us consider what happens in the clockwise direction, just before lobes **2** and **4** reach vanes B_1 and B_2. For this purpose, let us position lobes **2** and **4** so that they block exhaust ports EP_1 and EP_2, in which position EP_1 and EP_2 are both open to supply the gas-air mixture into the space between the leading edge of lobe **2** and the trailing edge of lobe **3**, and into the space between the leading edge of lobe **4** and the trailing edge of lobe **1**. The volume of these spaces increases as lobes **2** and **4** advance toward intake ports IP_1 and IP_2, respectively. This increasing volume creates induction of the mixture, the end of the induction period being shown in FIG. **5**.

PHASE II.

As shown in FIG. **6**, lobes **1** and **3**, which are positioned at about 10° and **190°**, are at the beginning of power expansion at their trailing edges, and at the start of their exhaust at their leading edges. Lobes **2** and **4**, which have just passed vanes B_1 and Bhd 2, are proceeding to block intake ports IP_1 and IP_2, just prior to compression.

It will be seen in this Figure that gas-separating vane B_1 provides a barrier between the spent gases beginning to exhaust from the zone behind lobe **2** engaged by vane B_1, and the zone in front thereof, which is being supplied by a fresh charge through IP_1. Similarly, vane B_2 is carrying out the same function with regard to the zone behind lobe **4**, which is discharging into port EP_2, and the zone in front of lobe **4**, which is being supplied by a fresh charge through IP_2.

PHASE III.

As shown in FIG. **7**, in phase III, lobes **1** and **3** continue their power expansion at their trailing edges. In this phase, lobes **1** and **3** are about 30° beyond 0° and 180° (dead center of the ignition points), hence sealing vanes S_2 and S_1 fall short of the receding surface of the rotor, so that expansion of the power stroke can continue with increasing volume of the space between closure vanes A_2 and A_1, and the trailing edges of lobes **1** and **2**. As lobes **1** and **3** move toward exhaust ports EP_1 and EP_2, their leading edges force the spent combustion products toward these ports.

Lobes **2** and **4** in phase III, having moved beyond intake ports IP_1 and IP_2, proceed to compress the fresh air-gas mixture in the zone in advance of their leading edges against closure vanes A_1 and A_2, while a new charge is being drawn from the intake ports in the zone behind the trailing edges.

PHASE IV.

As shown in FIG. **8**, lobes **1** and **3** are coming to the end of power expansion at their trailing edges before exhaust takes place through exhaust ports EP_1 and EP_2. The leading edges of lobes **1** and **3** are finishing their exhaust of the previously exploded charge through exhaust ports EP_1 and EP_2.

At the same time, the trailing edges of lobes **2** and **4** are completing their fresh charge intake through intake ports IP_1 and IP_2, while their leading edges are carrying the compressed mixture contained in lobe cavities C_2 and C_4 into combustion cavities CC_1 and CC_2, where it is held for ignition between sealing and closure vanes S_1 - A_1, and S_2 - A_2, at which point we are back at phase I to repeat the operating cycle.

Thus, in the course of each revolution of the rotor lobe **1**, it encounters two ignition stations to produce two power impulses. Lobe **3**, which is diametrically opposed to lobe **1**, concurrently goes through the same operating sequence, for when lobe **1** is in line with combustion cavity CC_1, lobe **3** is in line with combustion cavity CC_2, whereby the forces produced by simultaneous ignition in these cavities are equal and opposite. A similar relationship exists as between lobes **2** and **4**, and the combustion cavities.

Power is therefore applied simultaneously to the rotor at two exactly opposed points, effectively providing inherent dynamic balance. Similarly, induction pressures as well as exhaust and compression pressures are always equal and opposite in the course of rotor movement, resulting in a balanced performance.

Since the simultaneous action of lobe twins **1** and **3** is followed by the simultaneous action of lobe twins **2** and **4**, a pair of drive impulses is generated every 90° per revolution, or four double impulses per revolution. This rotary-engine arrangement is equivalent in power output to a sixteen-cylinder, four-stroke conventional reciprocating-piston internal combustion engine. In practice, the rotary engines of the type disclosed herein may be arranged in tandem relationship to produce exceptionally high horsepower ratings in a relatively confined space. The cooling systems may be of the type presently used with Wankel engines.

The cooperative actions of closure valves A_1 and A_2 with gas-separating vanes B_1 and B_2, give rise to induction, compression and exhaust. The action of sealing vanes S_1 and S_2 in first sealing the combustion zone and then allowing expansion of power against the trailing edges of the lobes, in effect transfers the compressed charge from the leading edge to the trailing edge of the lobe during the combustion period.

Referring now to FIG. **9**, there is shown a rotary engine in accordance with the invention, which employs a rotor **20** having only one pair of opposed lobes **1** and **3**, the rotor profile otherwise being circular. Rotor **20** cooperates with a stator **21** which is essentially the same as stator **11**, and includes opposed gas-separating vanes B_1 and B_2, associated with two sets of reversely related intake and exhaust ports IP_1 - EP_1, and IP_2 - EP_2, as well as closure and sealing vanes A_1 - S_1, A_2 - S_2.

For very small engines having a two-lobed rotor, all that is necessary is one set of ports, one separating vane and one set of compression and combustion vanes which provide maximum power at slow speeds.

The operation of the two-lobe engine is such as to produce simultaneous power pulses in combustion cavities CC_1 and CC_2, which are diametrically opposed. Two double power pulses are produced per revolution, this being equivalent to a four-stroke, eight-cylinder reciprocating-piston engine.

One may also provide a rotor with three lobes, which are displaced 120° from each other, in combination with only one pair of compression-ignition and intake-exhaust closure vanes. This may be arranged to fire alternately, top and bottom, every 60°, or six alternate power pulses per revolution, this being equivalent to a twelve-cylinder, four-stroke engine.

While there have been shown and described preferred embodiments of balanced rotary combustion engine in accordance with the invention, it will be appreciated that many changes and modifications may be made therein without, however, departing from the essential spirit of the invention.

I claim:

1. A rotary internal combustion engine comprising a rotor concentrically-disposed within a stator having a circular chamber, said rotor being formed with at least one pair of lobes whose crests engage the inner wall of the chamber, concave zones being formed in the space between the lobes, each lobe having a cavity formed in the crest thereof, said stator including:

A. first and second gas-separating vanes mounted at diametrically-opposed positions and adapted continuously to engage the surface of the rotor;

B. an intake port adjacent each separating vane at a position subsequent to the vane in the direction of rotor movement, an air-gas mixture being supplied to said intake port,

C. an exhaust port adjacent each separating vane at a position in advance of said vane in the direction of rotor movement;

D. first and second combustion cavities disposed at diametrically-opposed positions along a common axis at right angles to the axis passing through said gas-separating vanes, said combustion cavities including igniters to ignite the mixture brought therein when the cavity of each lobe lies in registration therewith;

E. a closure vane adjacent each combustion cavity at a position in advance thereof in the direction of rotor movement, said closure vane being adapted to continuously engage the surface of the rotor in the course of rotor movement and

F. a sealing vane adjacent each combustion cavity at a position subsequent thereto in the direction of rotor movement, said sealing vanes being adapted to engage the surface of said rotor only when the depth of the concave zones between lobes is relatively shallow.

2. An engine as set forth in claim **1**, wherein each lobe is provided with a sealing vane at its crest which engages the wall of the chamber, said sealing vane being subsequent to the lobe cavity in the direction of movement.

3. An engine as set forth in claim **1**, wherein said rotor is provided with two pairs of lobes, the lobes being radially displaced ninety degrees from each other.

4. An engine as set forth in claim **1**, wherein said igniters are spark plugs.

5. An engine as set forth in claim **1**, wherein said vanes are spring-biased.

6. An engine as set forth in claim **1**, wherein said gas-separating vanes are displaced ninety degrees and two-hundred seventy degrees with respect to said circular chamber, and said combustion cavities are disposed at zero degrees and one-hundred eighty degrees, respectively.

7. An engine as set forth in claim **1**, wherein said rotor is centrally mounted on a shaft supported by bearings in the ends of said stator.

8. An engine as set forth in claim **1**, wherein said rotor has two lobes diametrically-opposed to each other.

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