# United States Patent [19]

**Kamiya**

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[54] **INTERNAL COMBUSTION ENGINE HAVING TWO PISTONS ROTATABLE THROUGH SEPARATE INTERSECTING CIRCULAR PATHS**


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[52] **U.S. Cl.** ..... **60/39.61,** 123/8.25

[51] **Int. Cl.** ..... **F02g 3/00**

[58] **Field of Search** ..... 60/39.61; 123/8.49, 8.47, 123/8.19, 8.25



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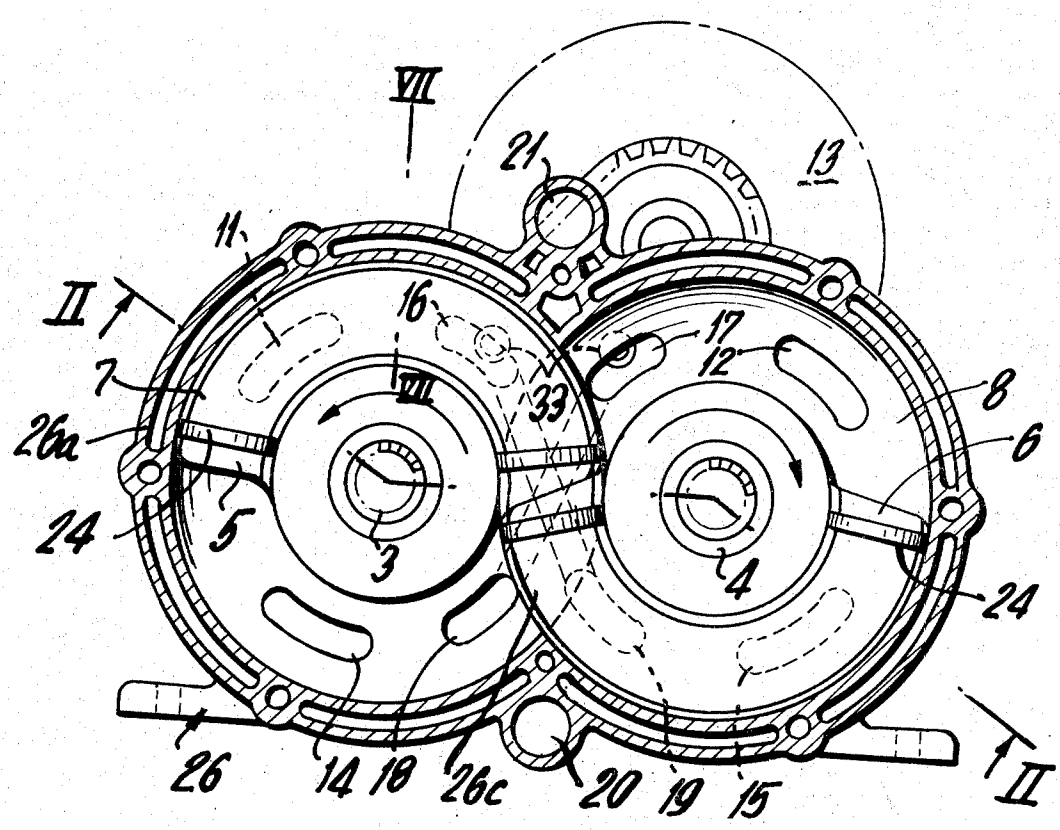
*Primary Examiner*—Clarence R. Gordon
*Attorney, Agent, or Firm*—McGlew and Tuttle



[57] **ABSTRACT**

An internal combustion engine comprises a cylinder in the general form of a 'Figure eight,' and comprises two engine cylinder portions, for example, of toroidal form arranged side by side and interconnected centrally so that the toroids intersect at an intermediate portion common to both. Pistons are centrally rotatably mounted in each associated cylinder portion and operate through a path which moves them through the associated adjacent cylinder portion. The pistons are timed for rotation at a substantially 180° phase difference so that they alternately and cyclically run through the common intermediate portion. The cylinders advantageously rotate with parallel arranged shafts interengaged by appropriate gearing to provide for the necessary phase difference operation. The construction includes a rotary valve for timing the opening and closing of inlet and outlet ports which are connected to the respective cylinder parts and which regulate the inlet air flow from a compressor and the exhaust of gases from the cylinder. Each cylinder part is provided with a port which leads to a small sized combustion chamber and the rotation of the pistons is such that the fuel and gas mixture is directed into each combustion chamber during each revolution, where it is ignited in the chamber and the compressed combustion gases are directed outwardly behind the pistons to provide the driving power.


**10 Claims, 15 Drawing Figures**



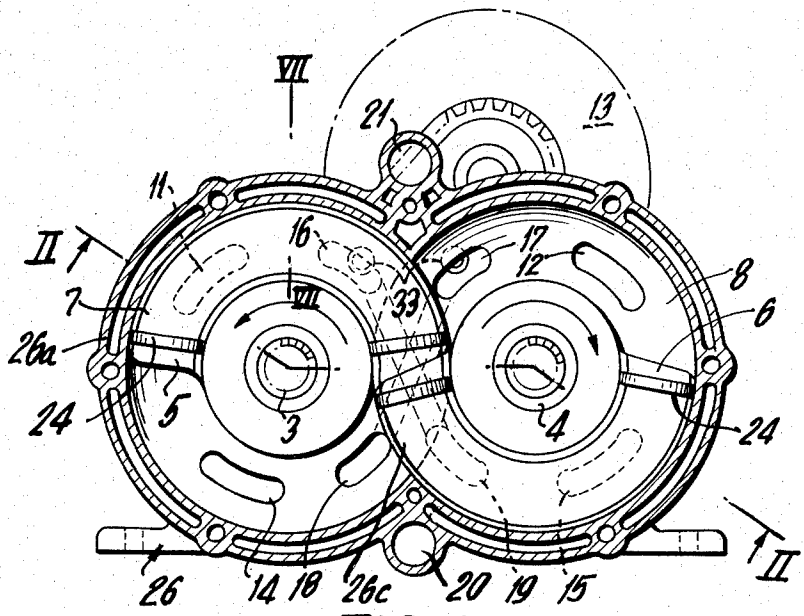



FIG. 1

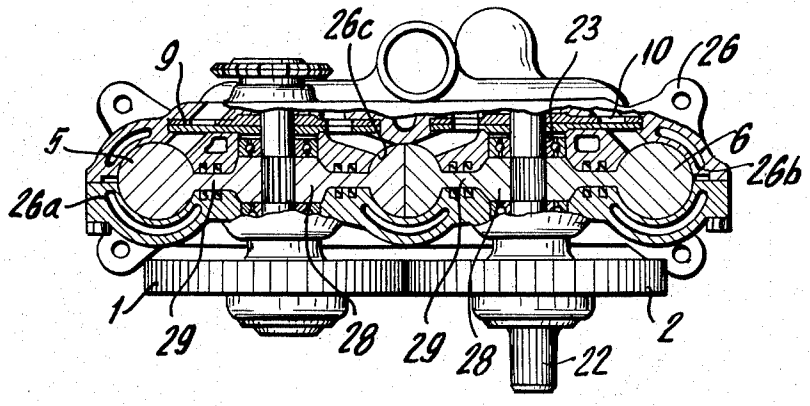



FIG. 2

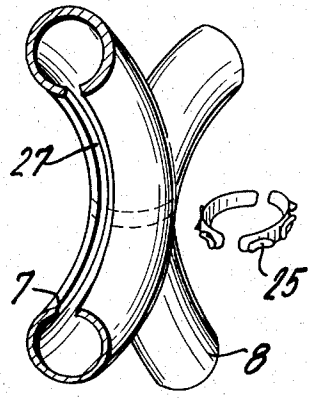



FIG. 3

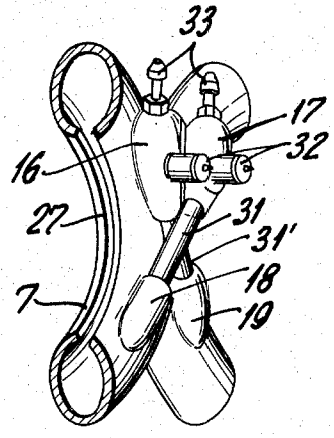



FIG. 4

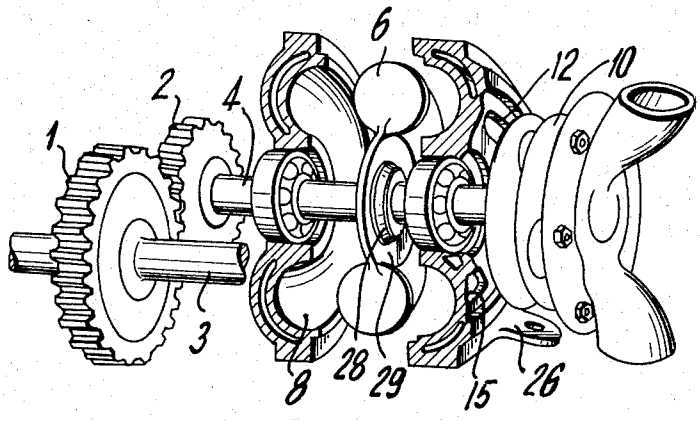



FIG. 5

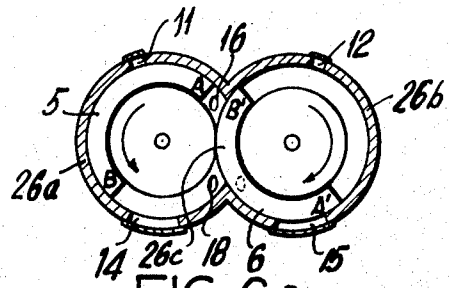



FIG. 6a

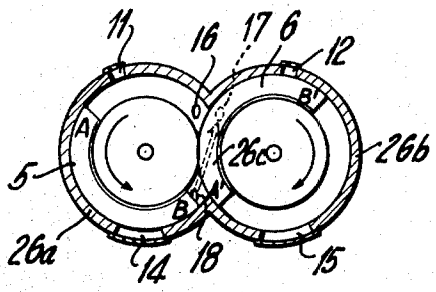



FIG. 6b

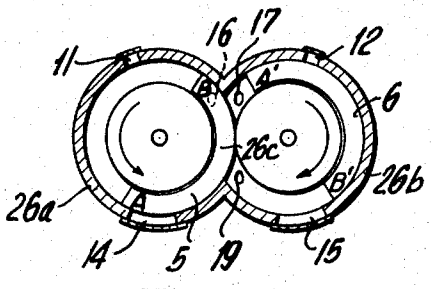



FIG. 6c

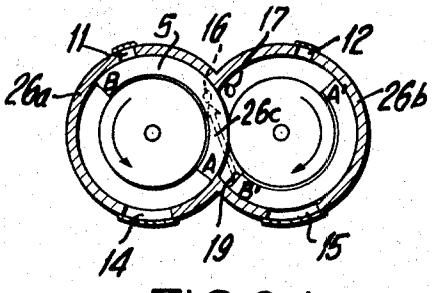



FIG. 6d

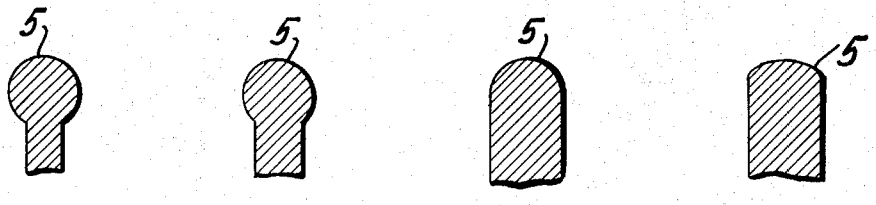



FIG. 7a FIG. 7b FIG. 7c FIG. 7d

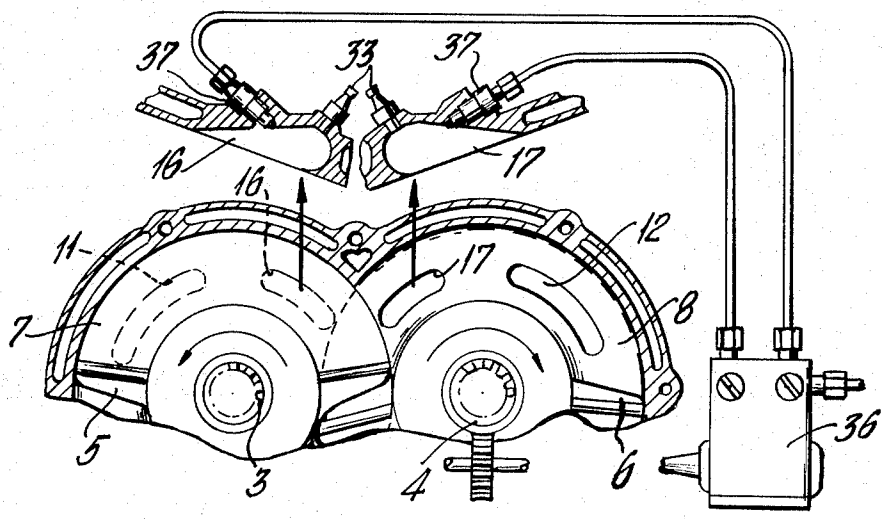

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FIG. 8

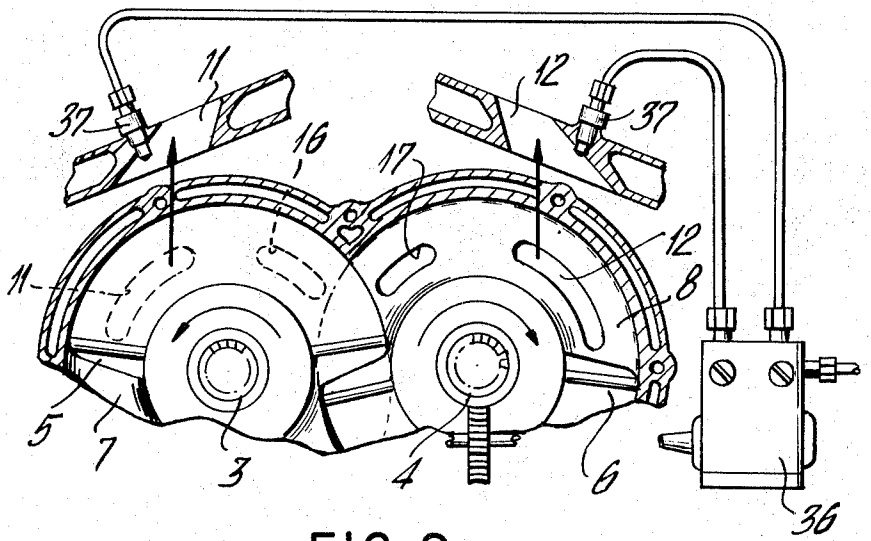
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FIG. 9

# INTERNAL COMBUSTION ENGINE HAVING TWO PISTONS ROTATABLE THROUGH SEPARATE INTERSECTING CIRCULAR PATHS

## BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates in general to the construction of internal combustion engines and in particular to a new and useful rotary engine having two rotating piston members which rotate in respective cylinder portions of a cylinder member having side by side parts with a common intersecting part, and wherein pistons are geared to run 180° out of phase.

2. Description of the Prior Art

It is well known in the internal combustion field that engines having rotary moving pistons run more quietly and have better mechanical efficiency than engines having pistons which reciprocate and which are connected through a crank drive. The practical development of such engines has lagged due to various structural difficulties. For example, in respect to gas turbines the turbine rotor which is designed for operation from about 10,000 to 50,000 rpm requires costly reduction gearing and they cannot react to a sudden change in speed. In addition, they require a great deal of time for starting and stopping. The so-called Wankel engine has a disadvantage that it is very difficult to seal it because the pressure boundary is given by the lines like an apex seal. It is also very difficult to operate at very slow speeds.

## SUMMARY OF THE INVENTION

In accordance with the present invention there is provided a rotary engine which may be made very compact and lightweight and has a high output and quiet running characteristics. The invention includes a rotary engine which combines the air tightness of a piston crank engine and the mechanical advantage of direct circular movement which is one of the principal advantages of the gas turbine, but it operates without noise or vibration, such as gas shudder which might be encountered in an engine such as a gas turbine.

The invention comprises a rotary engine which operates with two sector pistons arranged to rotate about rotation axis which define two intersecting circles, and which operate in two cylinder portions which are arranged with an intersecting common part in the form of a figure 8. Each piston is mounted to rotate within each circle and in so doing they move through a path which is common to each circular part of the cylinder. The pistons turn in circles in respective opposite directions and they are arranged to operate at 180° phase difference. They transmit their torque to two parallel shafts which are advantageously interconnected by gearing to provide for the phase operation of the pistons. The output can be taken from either shaft or, for example, from a central shaft which is connected thereto by gearing.

In a preferred form, the rotary engine includes two toroidal cylinder parts which are arranged together in the form of a figure 8 and include a common intersecting part. The inner end of each toroid is provided with a slot and the flange portion of the sector piston slide along the slot thereby causing the rotatable shaft at the flange turning center to rotate. Each cylinder part is equipped with a suction port and an exhaust port for a fuel and air mixture, and each is provided with a connecting combustion chamber into which the mixed gas is directed during the rotation of the pistons and compressed therein, and subsequently ignited. The operation of the pistons is such that one of the pistons allows the mixed gas into the combustion chamber when the other piston rotates and each piston in turn is subsequently driven when the gas explosion occurs in the associated combustion chamber portion. Because of the 180° phase difference of operation, each piston can act as a gas shutter or valve which cuts off communication between the next adjacent cylinder portion and prevents back spurting of high pressure combustion gases.



Accordingly, it is an object of the invention to provide an improved rotary piston engine, comprising two rotatable pistons which rotate through circular paths in cylinder portions which are formed together in the general outline of a figure 8 and wherein the pistons are interconnected so that they rotate at 180° out of phase from each other and pass through a common connecting portion of the two cylinder parts.

A further object of the invention is to provide a rotary piston engine having a housing or cylinder part formed of two intersecting toroid sections in the form of a figure 8 with the intersecting part forming a common passage therebetween which is alternately blocked or uncovered by the piston associated with each cylinder part, and wherein each cylinder part is connected to a separate small combustion chamber through a port so that the rotating pistons drive the gas and air mixture into the combustion chamber where it is ignited for moving the associated pistons.

A further object of the invention is to provide a combustion chamber which is simple in design, rugged in construction and economical to manufacture.

For an understanding of the principles of the invention, reference is made to the following description of typical embodiments thereof s illustrated in the accompanying drawings:

## BRIEF DESCRIPTION OF THE DRAWING

In the drawing:

FIG. **1** is an axial sectional view of a rotary engine constructed in accordance with the invention;

FIG. **2** is a section taken along the line II—II of FIG. **1**;

FIG. **3** is a partial perspective view showing the cylinder portions and a cylinder ring associated therewith;

FIG. **4** is a partial perspective view indicating the combustion chamber connections to the cylinder parts;

FIG. **5** is a partial exploded perspective view of the engine shown in FIG. **1**;

FIGS. **6***a*, **6***b*, **6***c*, and **6***d* are schematic axial sectional views showing the operation of the engine;

FIGS. **7***a*, **7***b*, **7***c* and **7***d* are transverse sectional views taken along line VII—VII of FIG. **1** of various embodiments of sector pistons usable with the engine.

FIG. **8** is a detail sectional view of a modification of the invention.

FIG. **9** is a detail sectional view of a further modification of the invention.

## GENERAL DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to the drawings in particular the invention embodied therein in FIGS. **1** to **6** comprises a rotary internal combustion engine which includes two sector pistons **5** and **6**, of substantially the same shape which are rotatably mounted at shaft portions **3** and **4** for rotation about axis which are spaced apart and substantially parallel. The pistons **5** and **6** move through separate circular paths which intersect and they are operated 180° out-of-phase to permit such rotatable movement. To ensure the defined out of phase rotation of 180°, the shafts **3** and **4** carry gears **1** and **2**, respectively, which intermesh.

Both the shafts **3** and **4** and the associated gears **1** and **2** are rotatably supported in a housing or frame **26**, which includes separate engine cylinder parts **26***a* and **26***b*, which, in the embodiment shown, include substantially toroidal cylinder areas which intersect and which define a common communicating engine cylinder part **26***c*. The pistons **5** and **6** move around in their associated cylinder parts **26***a* and **26***b*, and alternately move through the common connecting part **26***c*.

Valve means in the form of rotary disks or valve plates **9** and **10** are connected to the associated shafts **3** and **4** for rotation therewith, and they open or close periodically respective suction ports **11** and **12**, and exhaust ports **14** and **15**. The suction and exhaust ports open to the inside of the associated cylinder parts **26***a* and **26***b*, and they are either opened or closed by the position of the associated pistons **5** or **6**. The suction ports are connected through a suction valve assembly to the carburetor of a supercharger **13**. The exhaust ports **14** and **15** are connected through an exhaust valve externally to a muffler.

The inventive engine includes relatively small sized combustion chambers **16** and **17** which are formed on the exterior of the cylinder parts **26***a* and **26***b*, and are equipped with a suitable ignition means such as a spark plug **33**. Each combustion chamber **16** and **17** is connected directly to the cylinder parts **26***a* and **26***b* and also through a connecting passage **31, 31'** to respective combined gas and air mixture inlets and compressed combustion gas discharges **18** and **19**, which communicate with the cylinder spaces in the parts **26***a* and **26***b*, respectively.

A water cooling system includes a water supply pipe **20**, which directs cooling water through a space in the cylinder jacket wall. A drain pipe **21** is provided to drain the system.

Each shaft **3** and **4** is rotatably mounted on bearings **23, 23'** which are supported in housing **26**. Each piston has a piston ring **24** near each end. It is also advisable to install a cylinder ring **25** at the central portion of the communicating part **26***c*. The cylinder ring **25** is advantageously split into two parts and it carries exteriorly located springs which permit it to be placed in position.

The valve mechanism in the embodiment shown comprises disk valves **9** and **10** which are mounted on the associated shafts **3** and **4**, and they are made to slide in close contact with the suction ports **11** and **12** and the exhaust ports **14** and **15**, in order to permit openings thereon to move periodically to a position overlying respective ports for opening them and to move beyond the ports for closing them for timing the suction and exhaust. This valve mechanism is shown by way of example but any suitable type of valve timing arrangement may be employed with the engine.

In FIG. **4** the connection between the combustion chamber cylinder parts **26***a* and **26***b* together with the compressed gas ports **18** and **19** and the combustion chambers **16** and **17** are shown in detail. The compressed gas ports **18** and **19** open into the cylinder wall and each cycle of movement of the associated pistons **5** or **6** as indicated by the dotted line **7** and **8**. The combustion chambers **16** and **17** are connected through pipes **31** and **31'** to the associated gas ports **18** and **19** respectively. Midway between the ports **18** and **19** and the chambers **16** and **17** there is installed a non-return valve **32** which permits passage only in one direction. It should be appreciated that it is possible to use a rotary disk valve such as the valves **9** and **10** in place of the non-return valve for the same purpose.

As best shown in FIG. **5**, each piston includes a boss **28** which is shown connected to piston **6** which extends to the shaft **4**. The circular piston portion **6** is shaped to ride in the toroidal cylinder chambers and the boss **28** rides in the annular slot **27** formed on the internal surface. The boss **28** includes a flange part **29** which rides in sliding engagement to provide an operating seal and the necessary clearance for slight relative shaft displacement.

The operation of the device is as follows:

Rotation of the pistons **5** and **6** is accompanied by a pressure air drop in the cylinder on the suction side of each. The suction valve may be designed to open under the effect of pressurized suction air and permit the injection of mixed gas and air alternately through the suction ports **11** and **12**. This gas and air is advantageously admitted under pressure from a supercharger but may of course be supplied from a carburetor. The gas and air mixture is compressed by movement ahead of the associated pistons and moved cyclically through gas ports **18** or **19** and communicating pipes **31** or **31'** to the associated combustion chambers **16** or **17**. The gas in the combustion chambers **16** and **17** is exploded in timed relationship to the rotation of the pistons by a spark plug **33**. This gas moves backwardly into the combustion chamber **16** and **17** and communicates to the interior of their associated spaces **26***a* and **26***b* to fully expose these spaces to a high pressure burning gas to cause the rotation of the associated piston. As the gas fully expands it continues to turn the piston and it forces open the exhaust valve at the exhaust port **14** or **15** which releases the exhaust gases through a muffler into the atmosphere. The pistons are operated at 180° phase difference so that one piston always acts as a gas shutter by cutting off the cylinder path of the other piston and causing the high pressure burning gas to work on only the rotating end face of the associated piston without being ejected in an opposite direction.

The exhaust scavenging condition of operation of this rotary engine is similar to that of a two-cycle engine where the inlet gas and air mixture is pressurized.

The pressure energy created by the burning of mixed gas is transformed into a dynamic mechanical energy through piston rotation and this energy which drives the rotatable shafts **3** and **4** in mutual opposite directions is taken as a large output from the connection **22**. The engine can be operated in any desired operation of engine output, revolution, etc., through modifications of the opening and closing of the timing valves for both

suction and exhaust, and for adjusting the mixing ratio in the carburetor.

The detailed operation shown in FIGS. 6*a* to 6*d* includes with reference to 6*a*, a condition in which the mixed gas is forced into the chamber **16** by the action of the piston **6**, and it explodes to cause a rapid pressure build up at the location A behind the piston **5** to cause movement of the piston in the direction of the arrow indicated. At the same time the piston **6** blocks off the communication between the common connecting passage **26** and the adjacent cylinder portion **26***b*. The suction port **11** and the exhaust port **14** are both closed in the condition indicated in FIG. 6*a*.

In the state shown in FIG. 6*b*, the end B of the piston **5** is moved to a point in which it has completed the forcing of the gas mixture through the compressed gas port **18** into the chamber **17** on the opposite side **26***b*. The suction port **11** and the exhaust port **14** are also closed. The piston **6** has already allowed the mixed gas in through the suction port **12** and, with the exhaust complete, it turns in the direction of the arrow indicated.

In FIG. 6*c* the left piston **5** is in a position in which it is ready to drive out the burning gas through the exhaust port **14.** Approximately the same time, the fuel mixture is introduced through the suction port **11** in order to help expel a portion of the burning gas and is also to fill the cylinder with the mixed gas. This action is identical to a scavenging step of a two-cycle engine. In the meantime the right piston **6** is in a position in which the explosive combustion takes place in the combustion chamber **17** and the fuel mixture is compressed by the piston **6** at the end of B′.

IN FIG. 6*d* while the end B of the left piston **5** is carrying the fuel gas mixture in the direction of the arrow, the end B′ of the piston **6** has just forced the mixture into the opposite combustion chamber **16** of the cylinder part **26***a*.

It can thus be seen that with the rotary engine of the invention one of the pistons is made to turn by the explosion which takes place in the combustion chamber into which the mixed gas has been forced by the other piston. Thus one end of the piston forces the fuel gas mixture into the opposite combustion chamber while the fuel gas mixture which is introduced through the suction port helps the expulsion of the burning gas, and it fills the cylinder in the same way as in a scavenging process of a two-cycle engine. In the meantime, cyclically, the mixed gas, is forced into each combustion chamber by the opposite piston. Both pistons are connected for rotation together in a definite spaced relationship. By rotating the pistons out of phase and by sizing them properly the communication between one cylinder part **26**a and the other cylinder part **26***b* is periodically cut off.

FIGS. 7*a*, 7*b*, 7*c* and 7*d* show various embodiments of pistons **5**, **5′**, **5″** and **5‴** respectively. It is obvious that different shapes may also be employed but these are given by way of example only.

As indicated in FIG. **8**, when the present invention is applied to a diesel type internal combustion engine, the fuel jet valve the expression or nozzle **37** to be connected to the fuel jet pump **36**, and which is not shown in the present case, is connected to the combustion chambers **16** and **17.** In the suction phase of the operation of the pistons **5** and **6**, only air is drawn to the suction ports **11** and **12**, and just before or after the completion of the compression step, the fuel is ejected from the jet valve into the combustion chamber **16** or **17.** FIG. **9** shows a fuel jet valve or nozzle **37** mounted upon each of the suction ports **11** and **12.**

In the case of a very large output engine the piston may be designed in the form of a 90° sector and it is essential that both pistons be of substantially the same configuration.

While specific embodiments of the invention have been shown and described in detail to illustrate the application of the principles of the invention, it will be understood that the invention may be embodied otherwise without departing from such principles.

What is claimed is:

**1.** A rotary engine comprising an engine housing forming first and second annular cylinder portions which are arranged side by side and include a single intersecting common portion, first and second segment pistons rotatably mounted about respective parallel axes for rotation through first and second cylinder portions and alternatively through said common intersecting portions thereof, suction and exhaust port means connected to each of said annular cylinder portions operable in timed relationship to rotation of said pistons for supplying a burnable fuel mixture to, and for discharging exhaust gases from said cylinder portion, means comprising a first and second combustion chamber housing having respective communications with said first and second cylinder portions, a cross-connection from said first combustion chamber housing to said second cylinder portion, and from said second combustion chamber housing to said first cylinder for the inlet of a fuel mixture to the respective combustion chambers whereby to define an inlet which is ahead of the rotative movement of one piston of one of said cylinder portions to cause the fuel mixture to be directed thereby through said cross connection to the combustion chamber of the other of said cylinder portions; and means for igniting the fuel mixture which is directed to said combustion chambers by the rotation of said pistons and for directing combustion gases which are generated against said pistons for rotating said pistons.

**2.** A rotary engine according to claim **1**, wherein said engine housing includes an inner slot extending around the interior of each of said annular cylinder portions, said first and second pistons having a connecting boss extending through said slot and a widened piston portion located within the associated cylinder portion.

**3.** A rotary engine according to claim **1**, wherein said pistons are of a size such that they close the intersecting common portion when they are rotated to a closing position.

**4.** A rotary engine according to claim **1**, including gear means connected between said first and second pistons for operating said pistons in fixed spaced relationship 180° out-of-phase.

**5.** A rotary engine according to claim **1**, including a shaft connected to each of said pistons and centrally arranged in respect to said cylinder portions, a gear fixed to each of said shafts of said first and second pistons arranged in meshing engagement and maintaining said pistons 180° out-of-phase.

**6.** A rotary engine according to claim **1**, wherein said first and second pistons each include a shaft, a web portion extending outwardly from said shaft to said annu-

lar cylinder portions and a piston portion riding in said combustion chamber cylinder portions.

7. A rotary engine according to claim 1, wherein each of said pistons are segments of substantially 90°.

8. A rotary engine according to claim 1, wherein each of said pistons are segments of 180°.

9. A rotary engine, according to claim 1, including a non-return valve in the passage connecting said combustion chambers with the associated first and second opposite combustion chamber cylinder portions.

10. A rotary engine according to claim 1, wherein said suction and exhaust port means includes a suction opening for drawing in only air, means defining a separate combustion chamber having a connection to each of said first and second cylinder portions and also having a cross connection to the opposite one of said first and second cylinder portions, said fuel being injectable into said combustion chamber, said pistons alternately pressurizing the respective associated cylinder portions and directing the air therein to the other of said cylinder portions through said connecting passage.

* * * * *