

Jan. 3, 1967

A. JORDAN

3,295,505

ROTARY PISTON APPARATUS

Filed June 1, 1964

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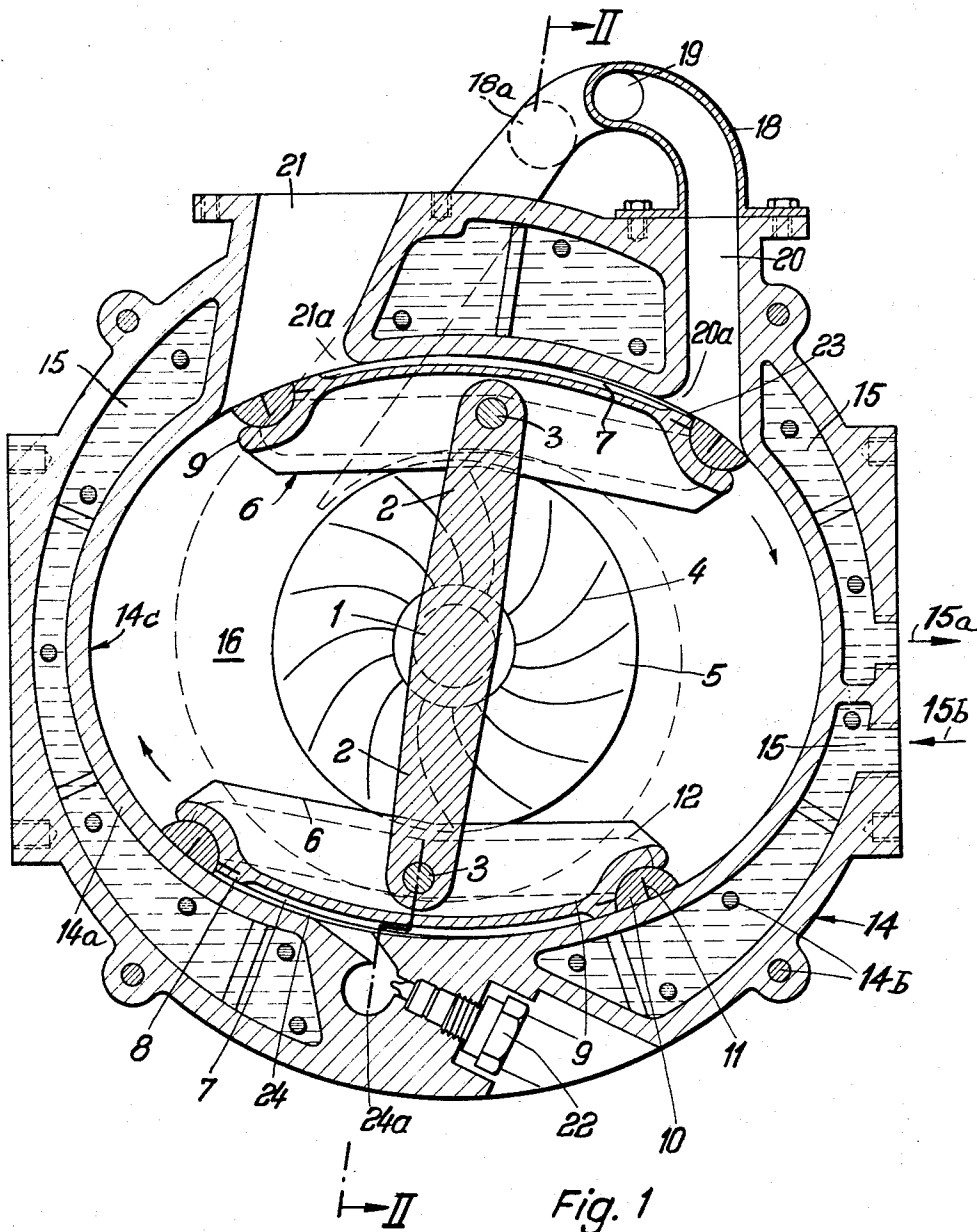


Fig. 1

Inventor:  
Alfred Jordan  
by Michael J. Striker  
N.H.

Jan. 3, 1967

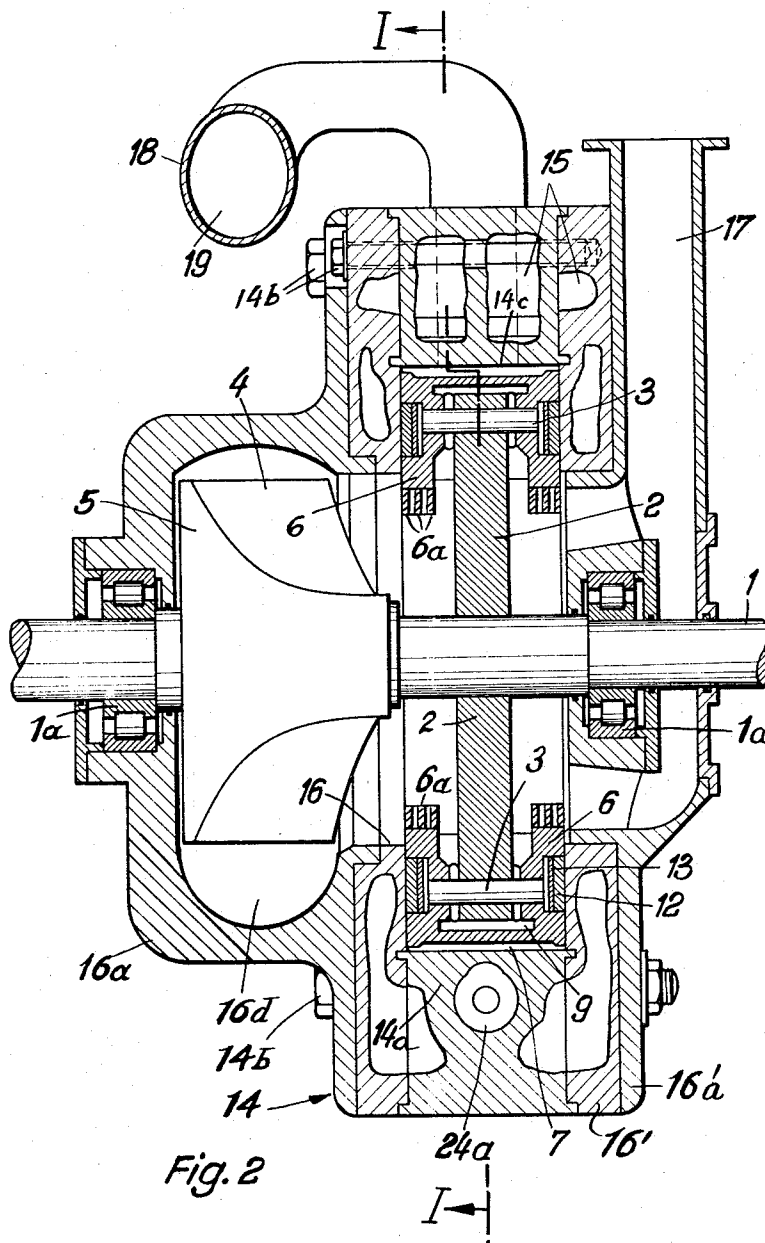
A. JORDAN

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ROTARY PISTON APPARATUS

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*Inventor:*  
Alfred Jordan  
by  
Michael J. Striker  
Attorney

Jan. 3, 1967

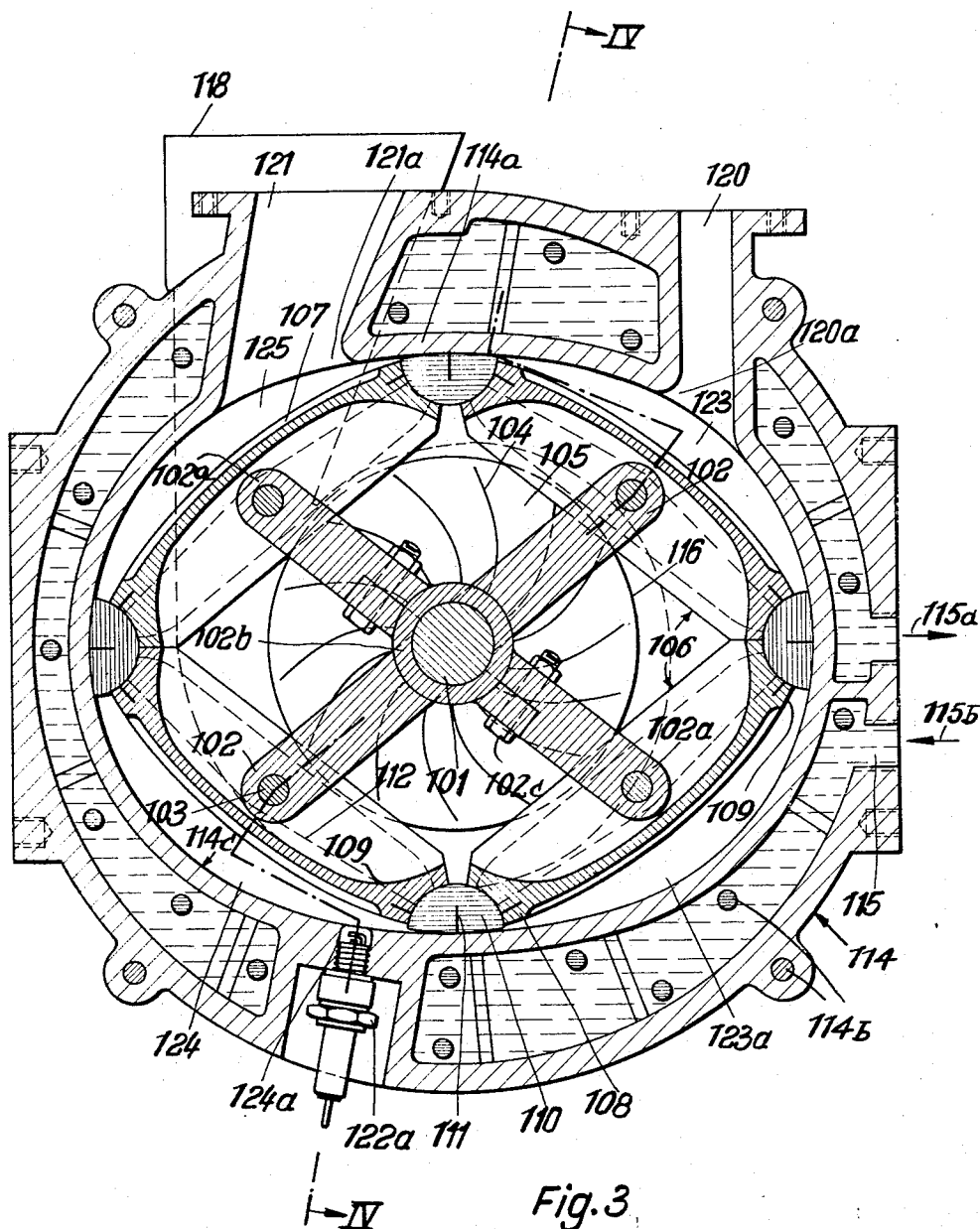
A. JORDAN

3,295,505

ROTARY PISTON APPARATUS

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8 Sheets-Sheet 3



*Inventor:*

*Alfred Jordan*

*by*  
*Michael J. Striker*  
*attorney*

Jan. 3, 1967

A. JORDAN

3,295,505

ROTARY PISTON APPARATUS

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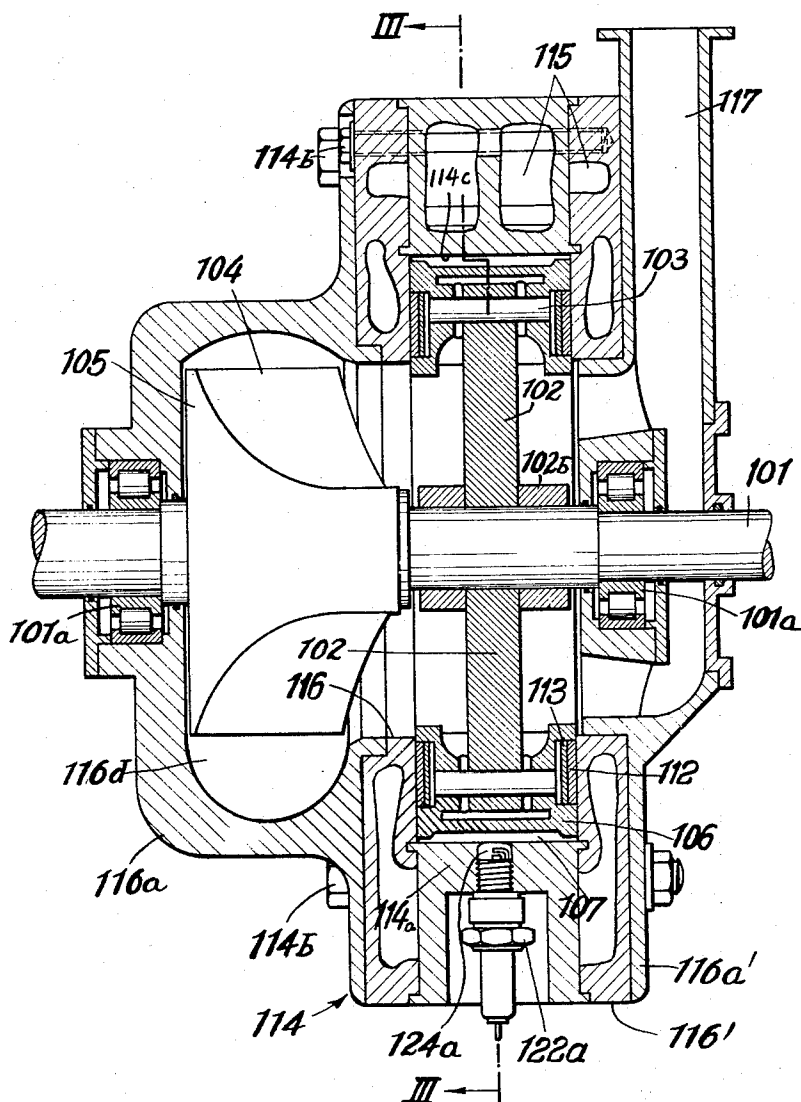


Fig. 4

Inventor:

Alfred Jordan

by Michael J. Strake  
Attorney

Jan. 3, 1967

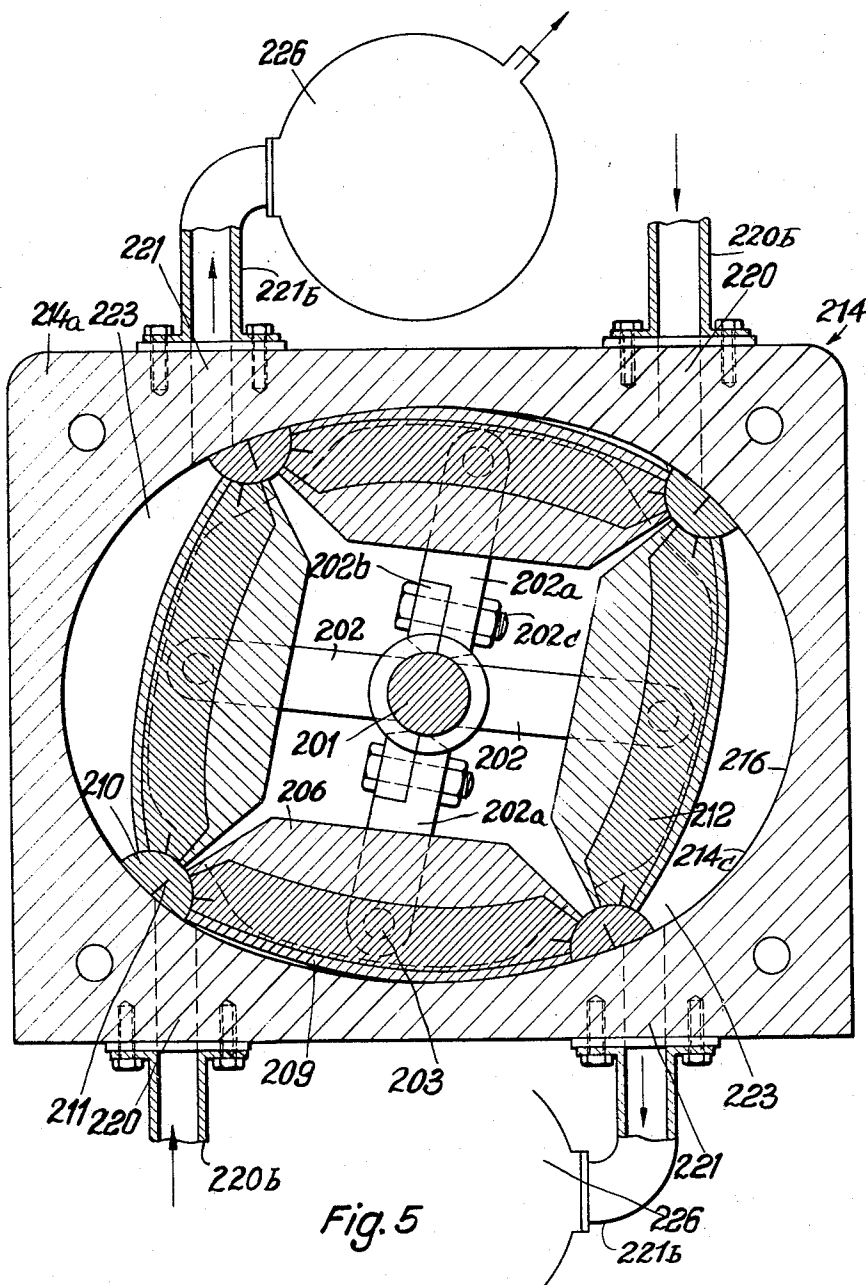
A. JORDAN

3,295,505

ROTARY PISTON APPARATUS

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8 Sheets-Sheet 5



**Inventor:**

Alfred Jordan

by Michael J. Strick  
Attorney

**Jan. 3, 1967**

A. JORDAN

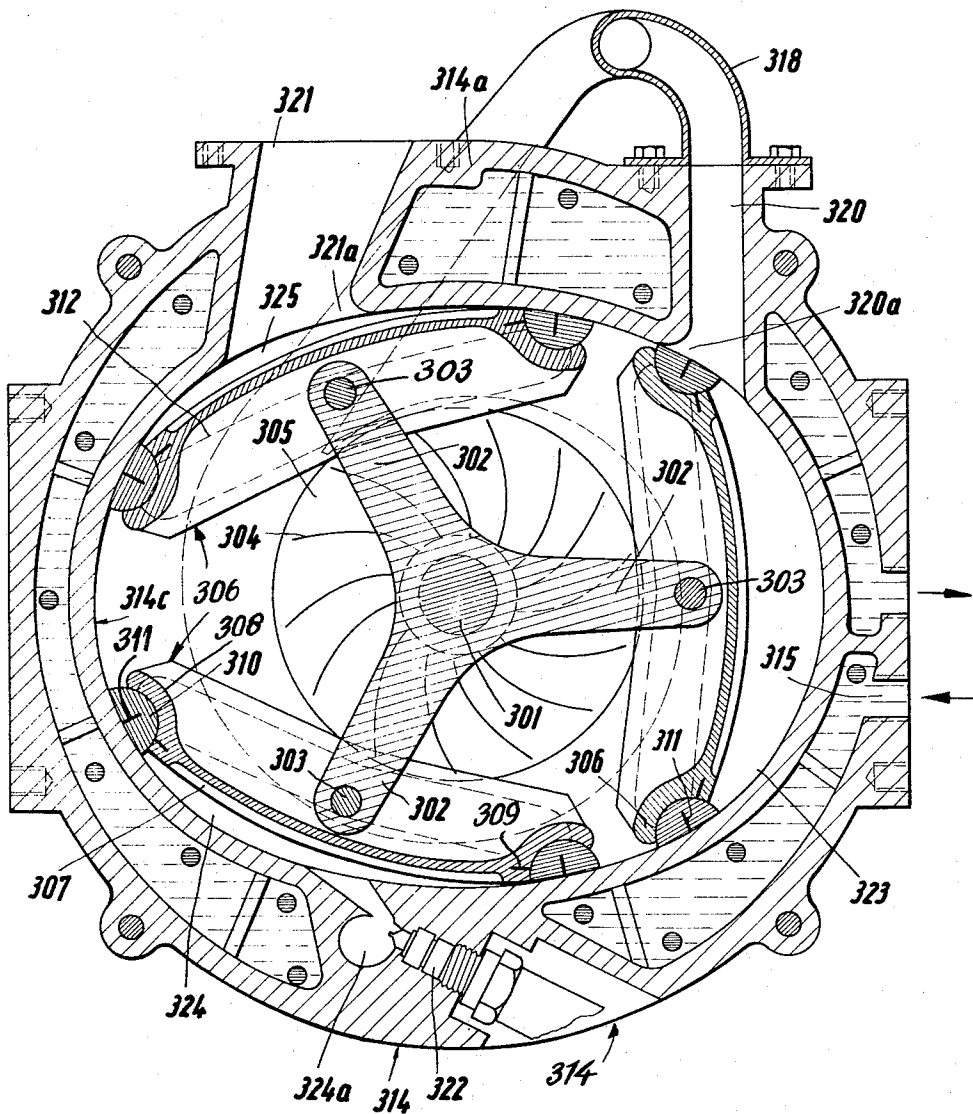
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**Fig. 6**



*Inventor*

**ALFRED JORDAN**

**BY** *Michael J. Stricker*  
**his ATTORNEY**

Jan. 3, 1967

A. JORDAN

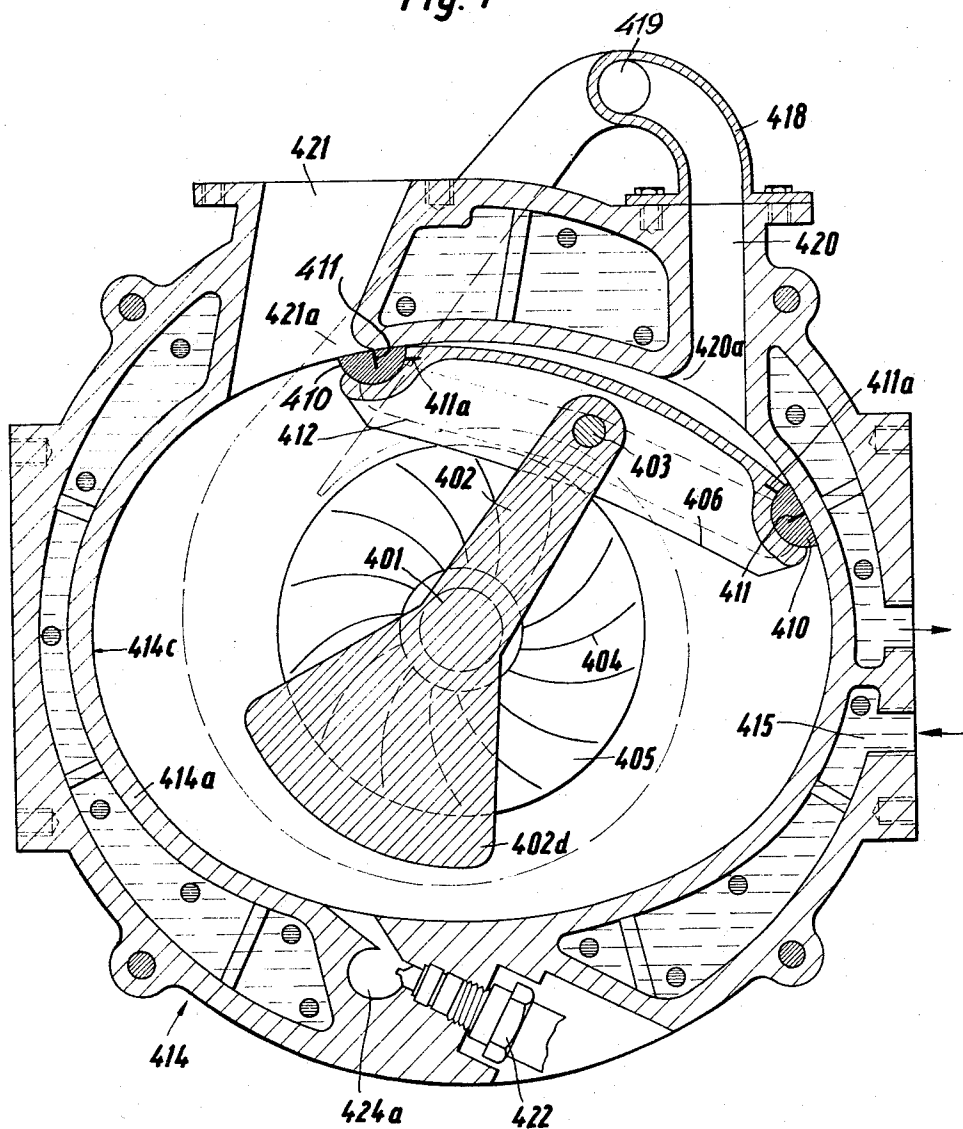
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Fig. 7



*Inventor:*

ALFRED JORDAN

BY *Michael J. Straker*  
his ATTORNEY

Jan. 3, 1967

A. JORDAN

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ROTARY PISTON APPARATUS

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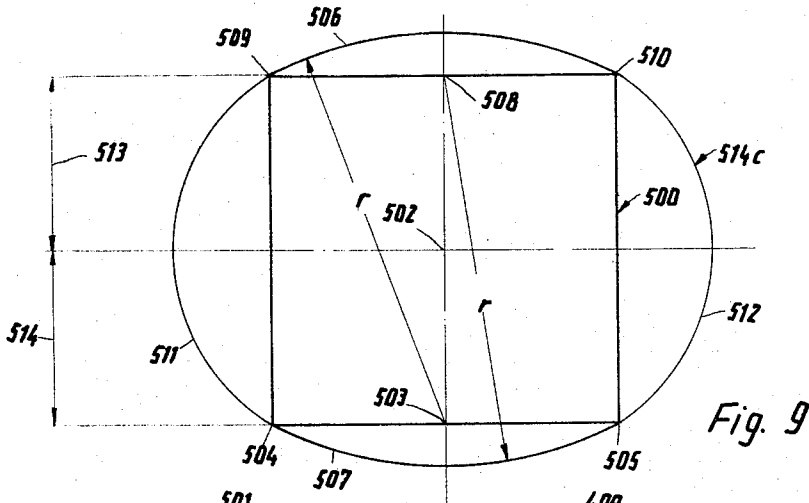


Fig. 9

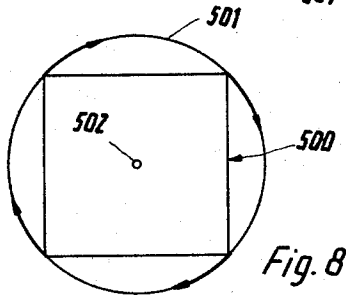


Fig. 8

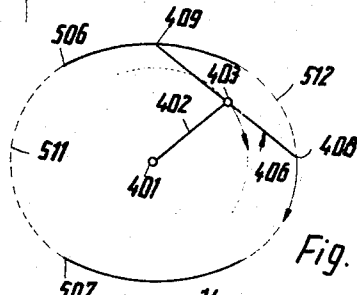


Fig. 10

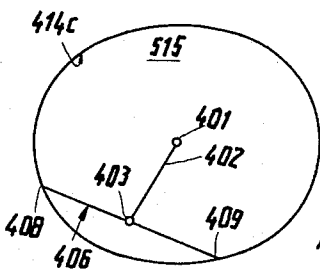


Fig. 11

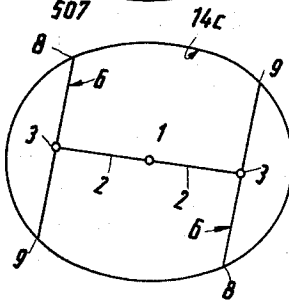


Fig. 12

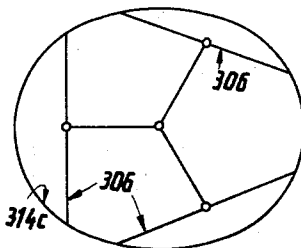


Fig. 13

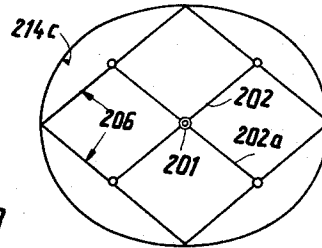


Fig. 14

Inventor:  
Alfred Jordan  
by Michael S. Striker  
RMH



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## ROTARY PISTON APPARATUS

Alfred Jordan, Drususstrasse 25, Bonn, Germany

Filed June 1, 1964, Ser. No. 371,271

Claims priority, application Germany, May 31, 1963,

J 23,801

19 Claims. (Cl. 123—17)

The present invention relates to rotary piston apparatus in general, and more particularly to rotary piston apparatus of the type wherein one or more pistons orbit in an oval path defined by the internal surface of a stationary housing. Such apparatus may be used as internal combustion engines, as pumps and/or as hydraulic or pneumatic motors.

It is an important object of my invention to provide an improved cooling system for rotary piston apparatus of this general character and to provide in such apparatus a novel sealing system which insures that the working chamber or chambers between the piston or pistons on the one hand and the stationary housing on the other hand are completely sealed from each other and from the atmosphere.

Another object of the invention is to provide a rotary piston apparatus which may be used as an internal combustion engine with one or more pistons to operate on the diesel principle or on the Otto principle, and which is equally useful as a pump or hydraulic or pneumatic motor.

A further object of the invention is to provide a very simple and comparatively inexpensive rotary piston apparatus which comprises a small number of parts, which operates without gears, which is of rugged construction, and which may be manufactured in any desired size or shape to suit the requirements in a vehicle or in a fluid operated machine.

An additional object of the invention is to provide an improved cooling system for a rotary internal combustion engine and to construct the cooling system with a view that all such parts of the engine which exchange heat with the products of combustion are cooled in a fully automatic way and to a degree which suffices to prevent deformation and other undesirable results of overheating.

A concomitant object of the invention is to provide a cooling system of the just outlined characteristics which occupies little space, which is particularly effective to cool the piston or pistons and the housing of the engine, and which is not prone to malfunction so that there is no need for frequent maintenance or replacement of parts.

Still another object of the invention is to provide a rotary internal combustion engine which embodies a cooling system of the above outlined type and which, in addition to protecting the parts against overheating, may also perform an additional important function, particularly as regards preheating of air which is to be admixed to and which forms a combustible mixture with gasoline, diesel oil or another suitable fuel.

A concomitant object of the invention is to provide a rotary internal combustion engine wherein the products of combustion are evacuated in a fully automatic way and wherein not only the major part but also all remnants of combustion products may be expelled in response to orbiting of one or more pistons along the oval internal surface of a stationary cylinder.

Still another object of the invention is to provide an air-cooled rotary internal combustion engine which operates without crank shafts, wherein one or more articulately mounted pistons may transmit substantial torque to one or more output shafts, which consumes little fuel, wherein the wear on the parts is reduced to a

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minimum, and wherein high efficiency and long useful life are insured by a combination of exceptionally simple parts which may be assembled in a compact capsule-like housing.

5 An additional object of the invention is to provide a novel method of determining the outline of the oval pathway for one or more pistons in a rotary piston apparatus of the above outlined characteristics.

10 A concomitant object of the invention is to provide a cylinder for a rotary piston apparatus whose internal surface forms an oval pathway which is determined in accordance with the just outlined method.

A further object of the invention is to provide a rotary piston apparatus wherein the ends and the side faces of each piston are in permanent and very accurate sealing engagement with the cylinder of the apparatus.

20 Another object of the invention is to provide a rotary piston engine with an improved cooling system which generates little noise, which is capable of continuously directing fresh coolant against such parts of the engine which are subjected to direct heating action of combustion products, and which may convey two or more streams of coolant through the interior of the housing.

25 Still another object of the invention is to provide a rotary piston apparatus wherein the number of pistons may be varied and to construct the apparatus in such a way that two or more such apparatus may be assembled to form a compact unit.

30 With the above objects in view, one feature of my invention resides in the provision of a rotary piston apparatus which comprises a fixed housing or cylinder having an internal surface of oval outline, a shaft member coaxially journaled in and extending into the housing, an arm member secured to the shaft member in the interior of the housing so that one of these members may transmit motion to the other member or vice versa, and a piston which is articulately connected with the arm member. The piston has a leading end and a trailing end, and each of these ends is in full and permanent sealing and sliding engagement with the oval surface. The connection between the piston and the arm member preferably comprises a pivot pin which is parallel with the shaft member and whose axis passes through the center of gravity of the piston.

35 When the invention is embodied in an internal combustion engine, the shaft member drives a fan which circulates a stream of air in the axial direction of the housing to cool the arm member, the piston or pistons and at least some parts of the housing. The volume of one or more working chambers defined by the piston or pistons with the internal surface of the housing varies continuously when the shaft member rotates.

40 The method of my invention is restored to for determining the outline of an oval pathway for one or more pistons of a rotary piston apparatus which is constructed and assembled as per above. The method comprises the steps of arbitrarily selecting two arcuate portions of the pathway by drawing arcs of equal length from a pair of points which are located diametrically opposite each other and are equally spaced from the axis of the shaft whose arm or arms are articulately connected with an equal number of pistons in such a way that the point of connection between a piston and the corresponding arm is located midway between the leading and trailing ends of the piston, and orbiting a piston about the axis of the shaft while simultaneously maintaining one end of the piston in sliding contact with the concave sides of the pre-selected arcuate portions whereby the other end of the piston describes the remainder of the oval pathway.

45 50 55 60 65 70 The distance between the ends of each piston equals the length of one side of a regular four-sided polygon (a square or a rhombus) whose center is located on the axis

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of the shaft of the rotary piston apparatus and whose four equidistant corners track the oval pathway.

The novel features which are considered as characteristic of the invention are set forth in particular in the appended claims. The improved rotary piston apparatus itself, however, both as to its construction and its mode of operation, together with additional features and advantages thereof, will be best understood upon perusal of the following detailed description of certain specific embodiments with reference to the accompanying drawings, in which:

FIG. 1 is a transverse section through a rotary internal combustion engine which operates on the diesel principle and which comprises two symmetrically mounted pistons, the section of FIG. 1 being taken in the direction of arrows as seen from the line I—I of FIG. 2;

FIG. 2 is an axial section through the engine as seen in the direction of arrows from the line II—II of FIG. 1;

FIG. 3 is a transverse section through a modified rotary internal combustion engine which operates on the Otto principle and which comprises four pistons, the section of FIG. 3 being taken in the direction of arrows as seen from the line III—III of FIG. 4;

FIG. 4 is a substantially axial section as seen in the direction of arrows from the line IV—IV of FIG. 3;

FIG. 5 is a transverse section through a rotary suction pump whose construction is somewhat similar to that of the engine shown in FIGS. 3 and 4;

FIG. 6 is a transverse section through a rotary diesel engine with three pistons;

FIG. 7 is a transverse section through a rotary diesel engine with a single piston; and

FIGS. 8 to 14 illustrate the manner of determining the outline of an oval pathway for the pistons of the apparatus shown in FIGS. 1 to 7.

Referring to FIGS. 1 and 2, there is shown a rotary piston apparatus in the form of an internal combustion engine which operates on the diesel principle and which comprises a fixed multi-section housing or cylinder 14 including an annular central section 14a, two annular side walls 16, 16', a hood 16a which is adjacent to the outer side of the side wall 16, a cover or cap 16a' which is adjacent to the outer side of the side wall 16', and bolts 14b which extend in the axial direction of the casing and serve to fasten its sections to each other. Bearings 1a in the hood 16a and cap 16a' serve to support a rotary output shaft 1 which is coaxial with the housing 14 and which carries a flywheel 5 accommodated in the internal chamber 16d of the hood 16a. The flywheel 5 preferably resembles a cone whose diameter decreases in a direction toward the side wall 16, and its conical surface is provided with a series of vanes or blades 4 so that the parts 4 and 5 together form a cooling fan which serves to draw cooling fluid, preferably air, through a suction duct 17 which is connected to or integral with the cap 16a'.

The internal surface 14c of the central section 14a is of oval outline and serves as a trackway for the leading and trailing ends 8, 9 of two specially configured pistons 6 which orbit about the axis of the shaft 1 and which are connected thereto by a pair of radial arms 2. Each arm 2 carries at its outer end a pivot pin 3 which is parallel with the shaft 1 and whose axis passes through the center of gravity of the respective piston. The arms 2 are rigidly connected with and serve to drive the shaft 1.

In the engine of FIGS. 1 and 2, the shaft 1 rotates in a clockwise direction so that each piston 6 travels along the enlarged discharge end 20a of a suction port 20 provided in the central section 14a, thereupon along a combustion chamber 24a which is machined in the central section 14a at a point past the suction port 20, and along the intake end 21a of an exhaust port 21 which is machined in the central section 14a at a point close to and upstream of the suction port 20. The chamber 24a receives jets of fuel through the orifice or orifices of a fuel

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injection nozzle 22 which is removably inserted in the central section 14a.

Instead of receiving air at atmospheric pressure, the suction port 20 is connected with a conduit 18 which communicates with the chamber 16d at the pressure side of the fan 4, 5 so that jets of fuel admitted at 22 will be mixed with air which was used to cool the pistons 6 and which was thereupon compressed by the vanes 4. Air admitted at 17 not only cools the pistons 6 but also the shaft 1, the arms 2 and such portions of the internal surface 14c which are momentarily located between the pistons, i.e., which are not overlapped by the outer faces of the pistons. It will be noted that the outer face of each piston 6 comprises an elongated recess 7 which extends between the leading end 8 and trailing end 9 and which communicates consecutively with the chamber 24a, with the intake end 21a and with the discharge end 20a when the shaft 1 rotates. The reference numeral 24 indicates in FIG. 1 the zone of communication between the recess 7 of the lower piston 6 and the combustion chamber 24a.

The housing 14 is provided with a series of communicating coolant-receiving compartments 15 which are connected to a source of water or another coolant so that such coolant circulates in directions indicated by arrows 15a, 15b, i.e., entering at the hot side (near to the nozzle 22) and leaving at the cool side (near to the port 20). If desired, the compartments 15 may serve to convey a gaseous coolant. In such engines, the housing 14 is connected with a fan which causes a stream of cooling gas to circulate in the central section 14a.

The means for sealing the recesses 7 from the internal space defined by the housing 14 comprises four substantially semicylindrical sealing members 10 and four arcuate strip-shaped flat sealing members 12. The sealing members 10 are rotatable in recesses provided in the ends 8, 9 of the pistons 6 in such a way that their substantially flat outer surfaces travel along the oval surface 14c whereby the members 10 seal the longitudinal ends of the respective recesses. Each sealing member 10 has a radial slot which accommodates a strip-shaped sealing bar 11. The bars 11 are reciprocable in their slots and each thereof has an edge portion in sealing engagement with the surface 14c. The axes of the sealing members 10 are parallel with the axis of the shaft 1. The strip-shaped sealing members 12 are recessed in the side faces of the pistons 6 so that they engage the side walls 16, 16' and overlap the ends of the pivot pins 3. In order to make sure that the members 12 remain in sealing engagement with the respective side walls, the pistons 6 are provided with corrugated leaf springs 13 or analogous biasing means which serve to maintain the sealing members 12 in face-to-face abutment with the side walls, 16, 16', see particularly FIG. 2. FIG. 1 shows that the ends of the strip-shaped sealing members 12 overlap the end faces of the sealing members 10 so that each recess 7 is completely sealed from the space which is ventilated by cooling air entering at 17. The sealing members 12 also serve as a means for conducting heat from the pistons 6 to the side walls 16, 16'. It will be noted that the side walls 16, 16' extend inwardly beyond the internal surface 14c.

The engine of FIGS. 1 and 2 operates as follows:

The nozzle 22 injects measured quantities of fuel at regular intervals which are selected in such a way that injection takes place only when a recess 7 communicates with the combustion chamber 24a, i.e., when one of the pistons 6 is located at the station occupied in FIG. 1 by the lower piston which overlies the zone 24. Fuel is admixed to compressed and preheated air which is drawn at 20a, and the resulting mixture is ignited spontaneously to generate products of combustion and to drive the pistons in a clockwise direction so that the recess 7 advances toward and in communication with the intake end 21a of the exhaust port 21. The pistons continue to rotate and the recess 7 which has just discharged into the port 21 thereupon communicates with

the discharge end 20a of the suction port 20 whereby it receives a new charge of preheated air and thereupon advances toward the injection nozzle 22. FIG. 1 shows that the ports 20, 21 are sufficiently close to each other so that a recess 7 whose front portion 23 has reached the discharge end 20a is still in communication with the intake end 21a whereby the stream of air entering at 20a expels the remainder of combustion products before the trailing end 9 of the respective piston moves beyond the exhaust port 21.

As the shaft 1 rotates, it drives the fan 4, 5 or that the vanes 4 draw air through the duct 17 and such air cools the inner sides of the pistons 6, the arms 2, the median portion of the shaft 1, portions of the oval surface 14c, portions of the semicylindrical sealing members 10, portions of the side walls 16, 16', the cap 16a' and the hood 16a. In addition, the fan 4, 5 drives the thus preheated stream of air in a spiral path, through the conduit 18 and into the suction port 20 so that the recesses 7 receive air at elevated pressure and at a temperature which is well above room temperature. The stream of air entering through the duct 17 cooperates with coolant which circulates in the compartments 15 so that the housing 14 is protected against excessive heating. Of course, the action of gaseous or liquid coolant circulating in the compartments 15 is also felt by the pistons 6 and by their sealing members so that all parts of the engine are protected from overheating and deformation. The walls 16, 16' are provided with large circular or oval openings which allow cooling air to flow from the duct 17 to the suction side of the fan 4, 5.

In order to further improve the cooling effect of air which is drawn in at 17, the bottom walls in which the recesses 7 are formed and/or certain other portions of the pistons 6 may be provided with one or more longitudinally extending heat-radiating ribs 6a (shown in FIG. 2) so that the area of contact between each piston and the stream of cooling air is increased accordingly. If necessary, similar cooling ribs may be provided on certain other parts of the engine. Of course, such cooling ribs also stiffen and thereby contribute to greater stability of the pistons. The arms 2 which actually impede axial flow of cooling air will produce at least some turbulence and will thereby contribute to better cooling action. The leading ends 8 of the pistons 6 are dimensioned in such a way that they can withstand high pressures which develop on ignition of fuel-air mixtures in the chamber 24a and recesses 7. The two cooling systems cooperate to maintain the engine at normal operating temperature. It is my experience that proper cooling is one of the basic requisites for satisfactory operation of a rotary internal combustion engine.

The cooling action of the fan 4, 5 is practically noiseless, particularly when the conduit 18 discharges into the suction port 20. If necessary, the exterior of the housing 14 may be provided with cooling fins and a second fan may be provided to circulate air along such external fins.

The conduit 18 defines a smooth passage 19 which does not impede the flow of compressed air to the suction port 20.

The operation of the engine may be improved still further if the conduit 18 is arranged to deliver even larger quantities of air into the suction duct 20 and into consecutive recesses 7. This can be achieved by utilizing a further compressor, for example, a suitable turbo charger. However, even without a turbo charger, the engine will operate with very high compression ratio. At the moment of ignition, the piston nearest to the nozzle 22 will be situated in such a way that its outer side extending between the sealing members 10 is in close proximity to the surface 14c. The leading ends 8 of the pistons 6 will expel some cooling air from the

interior of the housing, and such air will escape through the port 21.

If necessary, two or more engines may be assembled into a multi-engine unit wherein the same stream of cooling air may be conveyed serially through each individual engine. For example, one or both outermost engines will be provided with a fan to draw air axially of the engines (i.e., in parallelism with the common shaft of such engines). Also, the engine of FIGS. 1 and 2 may comprise two fans, one at each axial end of the housing 14, to convey two streams of cooling air which flow axially of the housing but in opposite directions to further enhance the cooling effect. The cooling air is then admitted midway between the axial ends of the housing.

FIGS. 3 and 4 illustrate a rotary four-stroke-cycle Otto engine whose construction is quite similar to that of the engine shown in FIGS. 1 and 2 with the following exceptions: The output shaft 101 is rigidly connected with two radial arms 102 which, in turn, are articulately connected with two additional radial arms 102a. Each of these arms carries at its outer end a pivot pin 103 whose axis coincides with the center of gravity of the respective piston 106. The arms 102a have semicylindrical hub portions 102b which are clamped to each other by bolts 102c and have recesses for the inner end portions of the arms 102.

Each sealing member 110 is common to the trailing end 109 of a first piston 106 and to the leading end 108 of a next-following piston 106. The four pistons 106 together form a circumferentially complete deformable annulus which surrounds the central portion of the shaft 101 and the arms 102, 102a. The injection nozzle 22 is replaced by a spark plug 122a, and the suction port 120 discharges atmospheric or preheated air or a mixture of fuel with air (produced in a suitable carburetor) into a suction or input chamber 123 which is in momentary communication with the discharge end 120a of the suction port 120. If the port 120 admits only air, such air is mixed with fuel which is injected in the compression chamber 123a, and the resulting mixture is then conveyed toward the spark plug 122a so that the mixture is exploded in the relief chamber 124 which is adjacent to the spark plug 122a. The resulting combustion products are discharged from that exhaust gas chamber 125 which is in momentary communication with the intake end 121a of the exhaust port 121, and this exhaust port communicates with the atmosphere. The spark plug 122a may be replaced by another suitable igniter device as long as its working end which extends into a small chamber 124a of the central housing section 114a is capable of igniting the mixture in the chamber 124.

All other reference numerals not specifically mentioned but shown in FIGS. 3 and 4 correspond to those which are used in FIGS. 1 and 2, but each such numeral is preceded by the digit "1." Thus, the numerals 112 denote strip-shaped sealing members, the numerals 115 denote cooling compartments, and so on.

Of course, and since the pistons 106 form a circumferentially complete but deformable annulus which seals the suction duct 117 from the internal surface 114c of the central housing section 114a, the stream of cooling air which is drawn through the suction duct and which thereupon flows into the conduit 118 cannot come in direct contact with the surface 114c. Therefore, the central section 114a is cooled mainly by fluid which circulates in the compartments 115. At least some cooling action will be produced by air which is admitted at 120a and which travels toward the igniter device 122a.

I wish to mention here that the engine of FIGS. 3 and 4 may be used as a diesel engine if the igniter device 122a is replaced by a fuel injection nozzle 22, and it is equally possible to modify the engine of FIGS. 1 and 2 so that it will operate on the Otto principle. The discharge end 20a or 120a of the suction port is normally located substantially diametrically opposite the point of ignition

(nozzle 22 or igniter device 122a) so that air admitted at 20a or 120a will take up some heat from the central section 14a or 114a prior to reaching the ignition station.

Referring now to FIG. 5, there is shown a rotary piston apparatus which is used as a suction pump and which also comprises four pistons 206 whose ends are in permanent sealing engagement with substantially semicylindrical sealing members 210 having substantially flat outer surfaces sliding along the internal surface 214c of a fixed housing 214. The manner in which the arms 202a are secured to each other by semicylindrical hub portions 202b and bolts 202c is the same as in the engine of FIGS. 3 and 4. The housing 214 has two suction ports 220 and two discharge ports 221 which are located substantially diametrically opposite each other. The suction ports 220 draw fluid from a suitable source, not shown, and the ports 221 discharge streams of compressed fluid into suitable pressure tanks 226 or to hydraulic motors, not shown. All other parts of the pump correspond to those shown in FIGS. 3 and 4, and are identified by similar reference numerals each preceded by the digit "2."

In this embodiment of my invention, the side walls 216 of the housing 214 need not be provided with openings because there is no need for an axial fan. Thus, the cap 16a' and the hood 16a may be dispensed with, and each side wall 216 resembles a rectangular plate which is adjacent to one side of the central section 214a. The shaft 201 of the pump is driven by an electric motor or in another suitable way so that the conduits 220b admit streams of fluid which is compressed in the working chambers on its way to the discharge ports 221 and conduits 221b which connect the discharge ports with the pressure tanks 226. The ports 220, 221 are distributed in such a way that the volume of working chambers 223 decreases while the pistons 206 travel from a suction port toward a discharge port whereby the pistons automatically expel the fluid into the respective conduits and pressure tanks. In the embodiment of FIG. 5, the tanks 226 deliver pressure fluid to two or more independent hydraulic motors, not shown.

FIG. 6 illustrates a rotary diesel engine with three pistons 306 each connected to one of three equidistant radial arms 302 which are rigid with the driven shaft 301. The pivot pins 303 which connect the outer ends of the arms 302 with the respective pistons 306 are equidistant from each other, and the construction of the sealing means 310, 311, 312, of compartments 315, of the fixed housing 314 including the central section 314a, of the fan 304, 305, of the ports 320, 321 and of the fuel injection nozzle 322 is the same as in the engine of FIGS. 1 and 2. The discharge end 320a of the suction port 320 communicates with the intake end 321a of the exhaust port 321 when the foremost portion of a recess 307 begins to communicate with the suction port. The recesses 307 communicate consecutively with the combustion chamber 324a so that air which is compressed in the working chamber 323 and forms a mixture with fuel admitted at 322 will develop with such fuel products of combustion which expand in the chamber 324 and are expelled from the working chamber 325. The fan 304, 305 delivers a stream of preheated air into a conduit 318 which in turn directs such air into consecutive recesses 307 in the same way as described in connection with FIGS. 1 and 2.

In the engine of FIG. 6, air drawn by the fan 304, 305 will cool portions of the internal surface 314c because the pistons 306 do not form a circumferentially complete annulus.

Referring to FIG. 7, there is shown a further rotary diesel engine which is practically identical with the one shown in FIG. 6 excepting that it comprises a single piston 406 which is balanced by a counterweight 402d secured to the shaft 401 substantially diametrically opposite the piston. The mass of the counterweight 402d balances the mass of the piston 406 when the shaft 401 rotates. All

reference numerals used in FIG. 7 correspond to those used in FIG. 6 with the exception that they are preceded by a digit "4." The body of the piston 406 accommodates a second pair of strip-shaped sealing members 411a whose edges abut against the semicylindrical surfaces of the respective sealing members 410.

The engines of FIGS. 6 and 7 may be readily modified to operate on the Otto principle.

In all embodiments of my invention, the engine or the pump may be provided with lightweight pistons which are fully balanced, either by pistons disposed at the opposite side of the shaft or by a counterweight, so that the apparatus will not vibrate when in actual use. The axes of the pivots which connect the pistons with the respective arms are preferably located in or close to the common planes of the leading and trailing ends of the respective pistons. Thus, and referring to FIG. 7, the axis of the pivot pin 403 is coplanar with the lines of contact between the oval surface 414c and the outer edge portions of the sealing members 411. As stated before, the axis of each pivot pin preferably passes through the center of gravity of the respective piston; therefore, the pistons function as a single oscillating mass even though they are free to move with reference to each other. This is due to the fact that the centers of gravity of all pistons travel on the periphery of a circle which is common to the axes of the pivot pins. In FIG. 7, the center of gravity of the counterweight 402d is located diametrically opposite the pin 403 and is located at the same distance from the shaft 401 as the axis of the pivot pin. In determining the center of gravity of a piston, the sealing members 10 etc. are not considered as forming part of the pistons. Such sealing members are subjected to the action of centrifugal force to remain in sealing contact with the oval internal surface of the housing.

The sealing members 10, 110, 210, 310 and 410 resemble half rollers which is of advantage because they allow the respective pistons to rock about the corresponding pivot pins. In other words, and referring for example to the half rollers 410 of FIG. 7, these half rollers have substantially flat outer faces of comparatively large area which are in mere sliding contact with the internal surface 414c so that the fixed housing 414 undergoes little wear but the flat outer faces insure highly satisfactory sealing action. The semicylindrical inner surfaces of the half rollers 410 are in rubbing contact with the concave surfaces bounding the semicylindrical recesses in the corresponding ends of the piston 406, but the half rollers prevent direct contact between the piston and the central housing section 414a. The wear on the housing 414 would be much greater if the piston 406 were in direct contact with the internal surface 414c.

The sealing bars 11 etc. insure highly satisfactory sealing action along the axial ends of the oval internal surface, i.e., along the lines where the internal surface 14c meets the inner sides of the walls 16, 16' in FIG. 2.

Another important feature of the present invention resides in the provision of a novel method of determining the exact outline of the oval internal surface 14c, 114c, 214c, 314c or 414c. The outline of this internal surface is derived from a circle. Thus, and as shown in FIG. 8, the four corners of a square 500 will travel in a circular pathway 501 if the square 500 is rotated about the center 502. If one is to draw an arc 506 with a radius  $r$  from a point 503 which is located midway between the corners 504, 505 of the square 500 shown in FIG. 9, and a similar arc 507 whose center of curvature is located in a point 508 midway between the corners 509, 510 of the same square, the arcs 506, 507 constitute two arcuate portions of the outline of an oval surface 514c such as may be selected in a rotary apparatus of the present invention. The remaining two arcs 511, 512 may be determined empirically or in a manner to be described later. The numerals 513, 514 indicate the equal distances between the points 503, 508 and the center 502 of the

square 500. The points 503, 508 are located diametrically opposite each other.

The area enclosed by the four sides of the square 500 changes twice from a rhomboidal to a square shape during each revolution about the center 502 whereby the four corners 504, 505, 509, 510 travel along the oval surface 514c. By moving the points 503, 508 nearer to or further away from the center 502, the curvature of the arcs 506, 507 may be increased or reduced; in fact, the arcs 506, 507 may be straight or nearly straight lines if the points 503, 508 are selected at an infinite distance from the center 502.

The manner of determining the curvature of the arcs 511, 512 is as follows: FIG. 10 shows schematically the shaft 401 and the arm 402 with the pivot pin 403. The arcs 506, 507 were determined arbitrarily by selecting the points 503, 508 (see FIG. 9) at a given distance from the axis of the shaft 401. The trailing end 409 of the piston 406 will be led along the concave side of the arc 506 and the leading end 408 then automatically describes the arc 512. When the trailing end 409 travels along the arbitrarily selected arc 507, the leading end 408 will describe the arc 511. During a full revolution, the arm 402 and piston 406 will cover an area 515 which is surrounded by the thus determined oval surface 414c (see FIG. 11).

FIG. 12 illustrates the manner in which the ends of the pistons 6 will describe an oval pathway whose outline corresponds to the outline of the surface 14c. FIG. 13 shows the pistons 306 and the oval surface 314c, and FIG. 14 shows the pistons 206 and the oval surface 214c. In all instances, the arcs corresponding to the arcs 506, 507 of FIGS. 9 or 10 are selected in advance and the arcs corresponding to the arcs 511, 512 are then determined in a manner as described in connection with FIG. 10.

Without further analysis, the foregoing will so fully reveal the gist of the present invention that others can, by applying current knowledge, readily adapt it for various applications without omitting features which fairly constitute essential characteristics of the generic and specific aspects of this invention and, therefore, such adaptations should and are intended to be comprehended within the meaning and range of equivalence of the following claims.

What is claimed as new and desired to be secured by Letters Patent is:

1. A rotary internal combustion engine comprising a fixed housing having an annular central section having an internal surface of oval outline and a pair of side walls respectively connected to opposite ends of said central section and extending radially inwardly beyond said internal surface, each of said side walls being formed with an opening therethrough; a shaft coaxially journaled in and extending into the interior of said housing; an arm secured to said shaft into the interior of said housing so that said arm may transmit rotary motion to said shaft; a piston articulately connected with said arm, said piston having a leading and a trailing end in permanent sealing and sliding engagement with said internal surface, said piston being constructed and arranged to leave said openings substantially uncovered during circumferential movement of said piston so that air passing through said openings will pass axially through said housing so as to directly cool said arm, said piston and said internal surface of said housing.

2. A rotary internal combustion engine as set forth in claim 1, wherein said piston is articulately connected to said arm by pivot means and wherein the axis of said pivot means extends through the center of gravity of said piston.

3. A rotary internal combustion engine as set forth in claim 1, comprising two arms disposed diametrically opposite each other.

4. A rotary internal combustion engine as set forth in claim 1, comprising four arms including a first pair of arms disposed diametrically opposite each other and a second pair of arms alternating with the arms of said first

pair, said second pair of arms having limited freedom of angular movement with reference to said shaft.

5. A rotary internal combustion engine as set forth in claim 1, wherein each end of each piston is provided with a substantially semicylindrical recess and wherein each of said recesses accommodates a substantially semicylindrical sealing member having a semicylindrical surface rotatably received in the respective recess and a substantially flat surface in sealing and sliding engagement with said internal surface.

6. A rotary internal combustion engine as set forth in claim 5, wherein each of said sealing members is provided with a slot extending substantially radially inwardly from said flat surface thereof, and wherein each end of said piston further comprises a second sealing member received in the respective slot and having an edge portion in sealing engagement with said internal surface.

7. A rotary internal combustion engine as set forth in claim 5, wherein said piston has a pair of side faces each adjacent to one of said side walls, a recess provided in each of said side faces, and a spring-biased strip-shaped sealing member received in each of said recesses and in sealing engagement with the respective side wall.

8. A rotary internal combustion engine as set forth in claim 7, wherein said strip-shaped sealing members overlap the ends of said semicylindrical sealing members.

9. A rotary internal combustion engine as set forth in claim 1, and including an internal chamber adjacent to one axial end of said internal surface, and fans means in said chamber and connected to said shaft for blowing a stream of cooling air in axial direction through said opening.

10. A rotary internal combustion engine as set forth in claim 9, wherein said fan means comprises a flywheel having a conical portion whose diameter diminishes in a direction toward said internal surface, and vanes secured to said conical portion.

11. A rotary internal combustion engine as set forth in claim 9, wherein said housing is provided with a suction port having a discharge end in said internal surface thereof and further comprising a conduit connecting said chamber with said suction port so that air which is drawn through said duct is compressed by said fan means and such compressed air is thereupon forced through said conduit and into said port.

12. A rotary internal combustion engine as set forth in claim 11, further comprising a compressor arranged to deliver compressed air into said suction duct.

13. A rotary internal combustion engine as set forth in claim 11, wherein said piston defines with said internal surface a working chamber whose volume varies in response to rotation of said shaft and wherein said housing is provided with an exhaust port terminating in said internal surface in such close proximity to said suction duct that, in a given angular position of said piston, said working chamber communicates with each of said ports.

14. A rotary internal combustion engine as set forth in claim 1, wherein a plurality of radially extending arms are secured to said shaft each carrying a piston articulately connected thereto and each having a leading and a trailing end, and wherein each trailing end of one piston is immediately adjacent to the leading end of the next following piston so that said pistons together form a circumferentially complete annulus about said arms and about said shaft.

15. A rotary internal combustion engine as set forth in claim 14, wherein each pair of adjacent ends is provided with a common substantially semicylindrical recess and further comprising a substantially semicylindrical sealing member for each pair of said piston ends, each sealing member having a substantially semicylindrical surface rotatably received in one of said recesses and a substantially flat surface in sealing engagement with said internal surface.

16. A rotary internal combustion engine as set forth

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in claim 15, comprising four arms and four pistons, each of said pistons being articulately connected with the respective arm in such a way that it is free to pivot about an axis which passes through the center of gravity of the respective piston.

17. A rotary internal combustion engine as set forth in claim 15, wherein each of said sealing members is provided with a substantially radial slot extending inwardly from said substantially flat surface thereof, and further comprising second sealing members each reciprocally received in one of said slots and each having an edge portion in sealing engagement with said internal surface.

18. A rotary internal combustion engine as set forth in claim 1, and including cooling ribs on the surface of said piston facing away from said internal surface of said housing.

19. A rotary internal combustion engine comprising a fixed housing having an annular central section having an internal surface of oval outline, and a pair of side walls respectively connected to opposite ends of said central section and extending radially inwardly beyond said internal surface, each of said side walls being formed with an opening therethrough; a shaft coaxially journaled in and extending into the interior of said housing; an arm secured to said shaft in the interior of said housing so that said arm may transmit rotary motion to said shaft; a piston articulately connected with said arm, said piston having a leading and a trailing end in permanent sealing and sliding engagement with said internal surface and between said ends a curved wall portion facing said internal surface, and a pair of side walls each adjacent to one of said side

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walls of said housing and integral with said curved wall portion, said piston being open at the side thereof facing away from said curved wall portion, said side walls of said piston being arranged with respect to said openings so that said side walls of said piston leave said openings substantially uncovered during movement of said piston along said internal surface of said internal housing; and means for blowing a stream of cooling air in axial direction through said openings to cool thereby said piston and any internal surface portions of said housing not momentarily covered by said piston.

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MARK NEWMAN, *Primary Examiner.*

SAMUEL LEVINE, *Examiner.*

A. S. ROSEN, *Assistant Examiner.*