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Feller

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[54] **ROTARY PISTON INTERNAL COMBUSTION ENGINE**

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[52] **U.S. Cl.** **123/8.05**
[51] **Int. Cl.** **F02b 53/00**
[58] **Field of Search** 123/8.43, 8.29, 8.05; 60/15; 418/5, 58, 59

[56] **References Cited**

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[57] **ABSTRACT**

A rotary piston engine has two pistons mounted in two communicating housings. The pistons are disposed in the order of 180° out of phase and the eccentrics for the housings are slightly offset from each other to improve the positioning of the communicating ducting between the housings.

6 Claims, 5 Drawing Figures

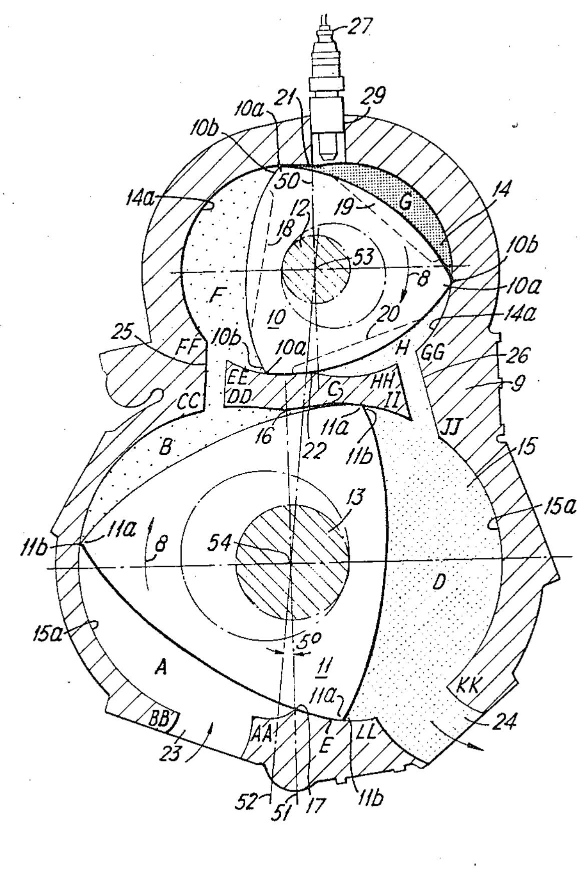

Fig. 1.

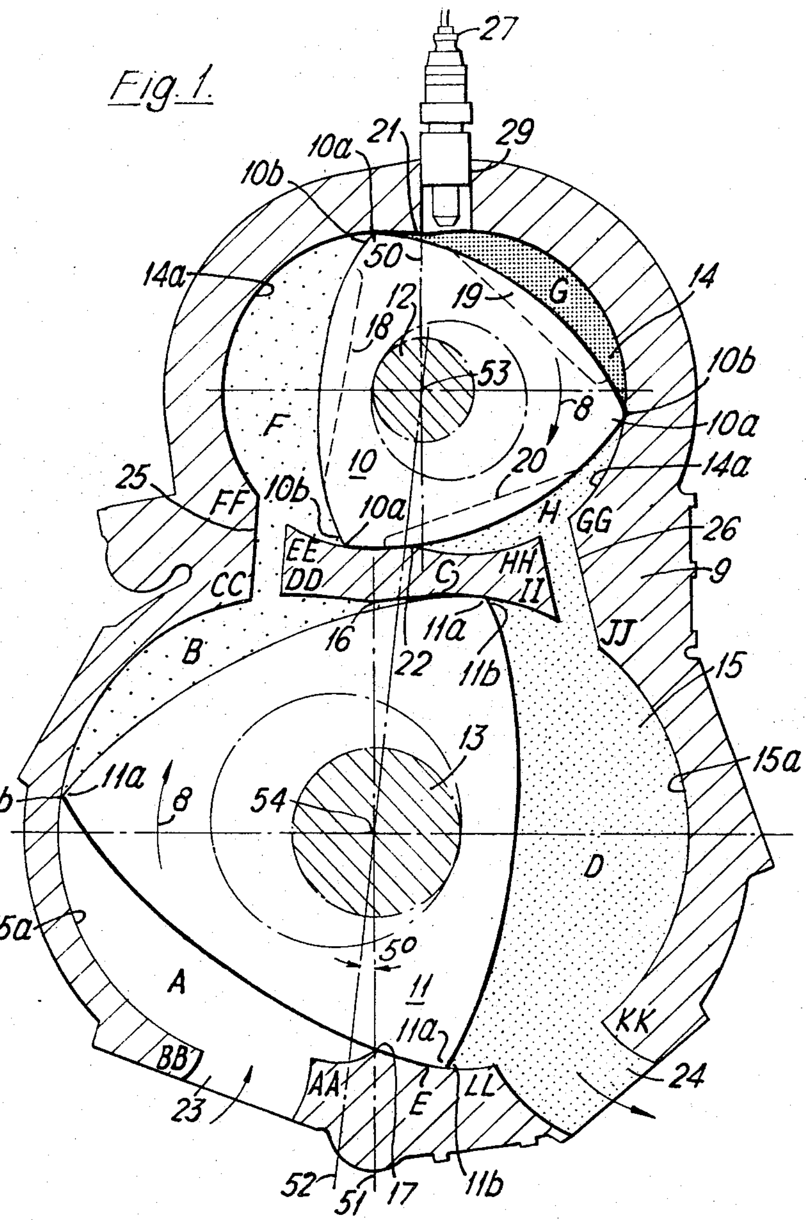

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Fig. 2.

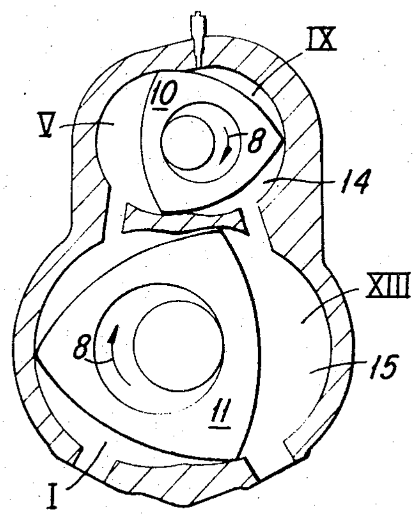


Fig. 3.

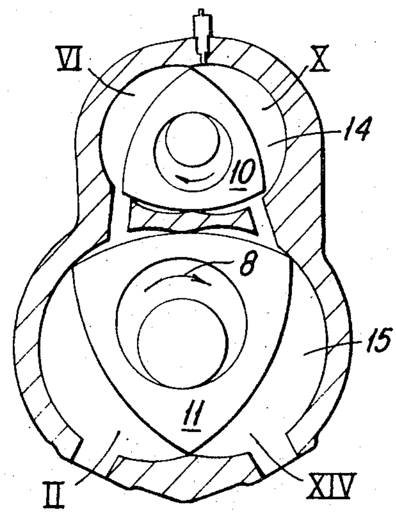


Fig. 4.

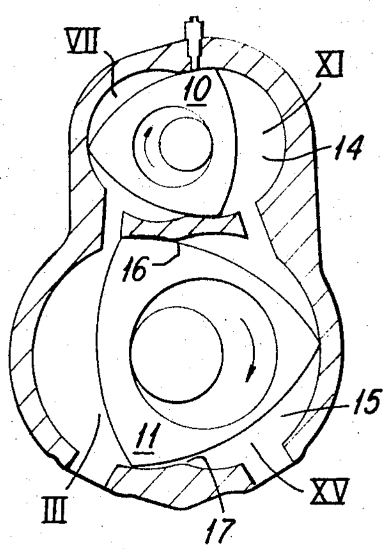
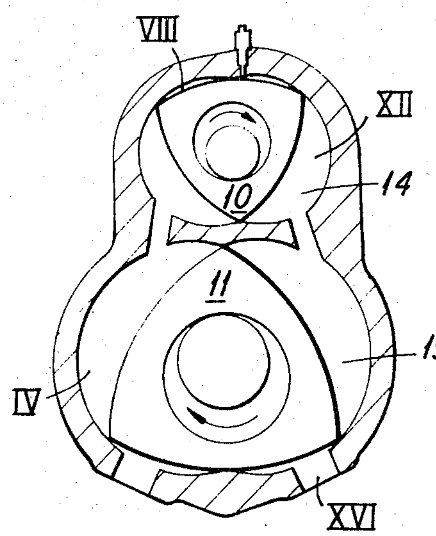


Fig. 5.



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ROTARY PISTON INTERNAL COMBUSTION ENGINE

This invention concerns a rotary piston internal combustion engine and is concerned with improvements in the rotary piston engine described in our prior U.K. Patent No. 1,008,745.

In U.K. Patent No. 1,008,745 there is described a rotary piston internal combustion engine comprising first and second rotary pistons which are respectively mounted within first and second cavities of a housing or housings so as to define first and second sets of working chambers therewith, each cavity and its respective piston having n and $n + 1$ lobes, the second piston and its cavity being substantially larger than the first piston and its cavity, means for producing planetary rotation of the first and second pistons in their cavities and substantially in phase with each other, means for supplying air to the second working chambers, means for permitting the withdrawal of exhaust gases therefrom, a first duct for transferring air which has been compressed in the second working chambers to the first working chambers for further compression therein, a second duct for transferring combustion gases which have been partially expanded in the first working chambers to the second working chambers for further expansion therein, and means for supplying fuel to the first working chambers, the first working chambers and second working chambers varying in volume and position during the rotation of the pistons, so that a working cycle is effected and the arrangement being such that communication via a said duct starts to become established between the respective first and second working chambers when one said chamber is substantially at its maximum volume and the other said chamber is simultaneously substantially at its minimum volume, and ceases to be established substantially when the said one chamber has reached its minimum volume and the said other chamber is simultaneously at its maximum volume.

According to one aspect of the present invention there is provided a rotary piston internal combustion engine comprising first and second rotary pistons which are respectively mounted within first and second cavities of a housing or housings so as to define first and second sets of working chambers therewith, each cavity and its respective piston being trochoidal and respectively having n and $n + 1$ lobes, the second piston and its cavity being substantially larger than the first piston and its cavity, means for producing planetary rotation of the first and second pistons at the same rotational speed in their cavities, means for supplying air to the second working chambers, means for permitting the withdrawal of exhaust gases therefrom, a first duct transferring air which has been compressed in the second working chambers to the first working chambers for further compression therein, a second duct for transferring combustion gases which have been partially expanded in the first working chambers to the second working chambers for further expansion therein, and means for supplying fuel to the first working chambers, the first and second working chambers varying in volume and position during the rotation of the pistons so that a working cycle is effected, and the arrangement being such that communication via a said duct starts to become established between the respective first and second working chambers when one said chamber is substantially at its maximum volume and the other said chamber is simultaneously substantially at its minimum volume, and ceases to be established substantially when the said one chamber has reached its minimum volume and the said other chamber is simultaneously at its maximum volume, the first and second pistons being out of phase with each other.

In this specification the term "the pistons are in phase with each other" means that pistons are simultaneously in the same angular positions and the term "the pistons are out of phase with each other" means that the pistons are not simultaneously in the same angular positions.

Preferably the pistons are arranged on eccentrics which are between substantially 150° and substantially 210° out of phase with each other.

The pistons may be arranged on eccentrics which are in the order of substantially 180° out of phase with each other, but preferably with the eccentrics for the second piston, leads the eccentrics for the first piston by 210°.

In some positions of the second piston, the number of second working chambers may exceed the number of first working chambers by at least one.

The profile of the inner surface of each said cavity is preferably that of a two-lobed epitrochoid, the profile of the peripheral surface of each said piston being substantially that of the three-lobed inner envelope of the two-lobed epitrochoid,

There may be three first working chambers, there being four second working chambers in certain predetermined positions of the second piston.

The peripheral surface of the first piston may have circumferentially spaced recesses therein so that preferred combustion shapes and volumes and preferred compression ratios can be achieved.

According to a further feature of the present invention a plane through the minor axis and the polar axis of the first cavity is substantially parallel to a plane through the minor axis and the polar axis of the second cavity.

A two-lobed epitrochoid has a substantially oval shape, and by minor axis, we mean the smallest diameter of the substantially oval shape.

Preferably a plane through the polar axes of both the first and second cavities cuts the plane through the minor axis and the polar axis of either the first or second cavities at an angle of up to substantially 10°.

Preferably the angle is substantially 5°.

Further features of the invention will become apparent from the folowing description of embodiments of the invention given merely by way of example in which:

FIG. 1 is a diagrammatic view of a rotary piston internal combustion engine according to one aspect of the present invention and,

FIGS. 2 – 5 illustrate the operation of the engine of FIG. 1.

Referring first to FIG. 1, a rotary piston internal combustion engine has two rotary pistons **10,11** which are respectively mounted on separately eccentric shafts **12,13**. The eccentric shafts **12,13** are constrained to run in the order of 180° out of phase and at the same speed by means which are not shown, which may be constituted by gears, by a number of connecting rods running on eccentrics by chains, or by any other suitable means. The pistons **10,11** are respectively rotatable in a planetary manner in cavities **14,15** formed in a stationary housing **9**, the pistons being adapted to be rotated 180° out of phase with each other in the direction of the arrows **8**.

The minor axes **50,51** of the cavities **14** and **15** are offset and parallel to each other. The line **52** joining the polar axes **53** and **54** cuts the minor axes **50** and **51** at substantially 5°.

The pistons **10,11** have peripheral surfaces which includes three circumferentially spaced apex portions **10*a*,11*a*** respectively, which are symmetrically arranged with respect to the axes of the pistons **10,11**. The apex portions **10*a*, 11*a*** have sealing edges **10*b*, 11*b*** respectively parallel to the shafts **12,13** and which are at all times sealing engagement with the peripheral surfaces of the cavities **14,15** respectively. The peripheral surfaces of the cavities **14,15** include two circumferentially spaced arched lobe defining portions **14*a*, 15*a*** respectively which are successively joined together and which provide, at their junctions **21,22** and **16,17** points of minimum distance from the shafts **12,13**. Thus the peripheral surface of the cavities **14,15** are substantially those of a two-lobed epitrochoid. The peripheral surfaces of the pistons **10,11** are substantially those of the three-lobed inner envelope of the two-lobed epitrochoid.

The piston **11**, which is larger than the piston **10**, and which is in sealing engagement with the cavity **15** at points **16,17** defines with its cavity **15** either four or five of the working chambers A,B,C,D,E, according to the position of the piston **11**. These working chambers may, if desired be sealed from each other in known manner by sealing strips (not shown) at each of the three apex portions **11*b*** of the piston **11**. Additionally, the sides of the piston **11** may be provided with further sealing strips (not shown) which connect with the sealing strips at the apex portions **11*b***. Sealing strips, not shown, which are similar to the sealing strips at the apex portions **11*b*** may also be slidably mounted at the said junctions **16,17**.

The piston **10**, which is smaller than the piston **11**, has recesses or depressions **18,19,20** which are provided in the peripheral surface of the piston **10** and are circumferentially spaced apart. The piston **10**, with its recesses **18,19,20** forms with its cavity **14** three working chambers F,G,H. The working chambers F,G,H, may be sealed from each other in a manner generally similar to that in which the working chambers A,B,C,D,E are sealed from each other, except that it is not necessary to provide slidably mounted sealing strips at the said junctions **21,22**. It is, of course, by reason of the lack of such sealing strips at the said junctions **21,22** that the piston **10** forms with its cavity **14** only three working chambers F,G,H whereas the piston **11** forms with its cavity **14** either four or five of the working chambers A–E.

Air may enter the engine through an inlet port **23**, exhaust gases leaving the engine from an exhaust port **24**. A transfer duct **25** permits air to flow from the cavity **15** to the cavity **14**, while a transfer duct **26** permits combustion gases to flow from the cavity **14** to the cavity **15**.

A fuel injector **27** is arranged at position **29** in the wall of the cavity **14**, opposite the side thereof where the transfer ducts **25** and **26** are situated. The fueld injector **27** thus supplies fuel to the working chamber G. A further fuel injector may be arranged in the wall of the cavity **14** near the fuel injector **27**. The fuel may be ignited by means of a spark plug arranged in the wall of the cavity **14** adjacent to the injector **27**, preferably downstream of the injector **27**. If two injectors are provided two spark plugs may be provided. The use of such external means of ignition as spark plugs however may not in all cases be necessary and reliance may be placed merely on compression ignition. This engine preferably operates solely on the compression ignition cycle.

The various working chambers A–H vary in both volume and position during the rotation of the pistons **10,11** so that a working cycle is effected in which the air entering the cavities **14,15** is compressed and the combustion gases therein are expanded.

The nature of said working cycle will be apparent from an examination of FIGS. **2–5** of the drawings. Thus, as will be seen from the reference numerals I,II,III,IV the working chamber communicating with the inlet port **23** is of successively increasing volume as the rotors **10,11** rotate in the direction of the arrows, **8**. A "suction stroke" is thus provided in which air is sucked through the inlet port **23**.

The air which has been so sucked through the inlet port **23** is first subjected to a low pressure compression stage, indicated by the reference numerals V–VII and is thereafter subjected to a high pressure compression stage, indicated by the reference numerals VIII. During the low pressure compression stage, some of the air being compressed is within the cavity **15** whilst some of it is within the cavity **14**. At the end of the low pressure compression stage, all the air being compressed is within the cavity **14**. It will therefore be appreciated that the air received by the cavity **14** has been precompressed in passing through the cavity.

Combustion takes place when the air has been compressed to the volume indicated by the reference numeral IX (see FIG. **2**).

Thereafter expansion proceeds in two stages, a high pressure stage indicated by the reference numerals X–XI, and a low pressure stage indicated by the reference numerals XII–XIII. It will be noted that the high pressure expansion stage, indicated by the reference numerals X–XI, occurs substantially wholly within the cavity **14**, whilst the low pressure expansion stage indicated by the reference numerals XII–XIII. It will be noted that the high pressure expansion stage, indicated by the reference numerals X–XI, occurs substantially wholly within the cavity **14**, whilst the low pressure expansion stage indicated by the reference numerals XII–XIII, occurs partly within cavity **14** and partly within the cavity **14**. Thus, it **15**. be appreciated that, after the combustion gases have been partially expanded within the cavity **14**, they are expanded yet further within the cavities **14** and **15**.

The "exhaust stroke" is represented by the decreasing volume indicated by the reference numerals XIV–XVI.

It will be noted that the communication, via the transfer duct **25**, starts to become established between the working chambers B, F, when the working chamber B is substantially at its maximum volume and the working chamber F is substantially at its minimum volume, and ceases to be established when the working chamber B is substantially at its minimum volume and the working chamber F is simultaneously substantially at its maximum volume.

Similarly, communication via the transfer duct **26** starts to become established between the working chambers H,D when the chamber H is substantially at its maximum volume and the chamber D is simultaneously substantially at its minimum volume, and ceases to be established substantially when the chamber H has reached its minimum volume and the chamber D is simultaneously substantially at its maximum volume.

The engine has the following transfer port timing:

LP inlet transfer port 25 opens 306° BTDC.LP

HP inlet transfer port 25 closes 171° BTDC HP

HP exhaust transfer port 26 opens 203° ATDC HP

LP exhaust transfer port 26 closes 330° ATDC.HP

BTDC means "Before top dead centre"

ATDC means "After top dead centre"

LP means "Low Pressure"

HP means "High Pressure"

Top dead centre in a rotary piston engine is when apex of the piston is pointing vertically downwards when viewed in the drawings and when the eccentric on its particular eccentric shaft is in its uppermost position. The angles referred to are eccentric shaft angles.

The edges of the ports are marked, AA, BB, CC, DD, EE, FF, GG, HH, II, JJ, KK and LL.

Further port timing details are as follows:

AA 249° BTDC LP

Inlet port 23 starts to close at maximum summated inlet volume, i.e. when the total volume of the LP and HP chambers receiving a new charge is at a maximum. Charge momentum prevents blow-back before edge BB is reached by the rotor apex. The function is the same as that of the normal reciprocating piston engine inlet valve.

BB 189° BTDC LP

Inlet port 23 closes. This position is determined by port size and shape.

CC 306° BTDC LP

LP inlet transfer port 25 opens before maximum LP volume is reached to allow HP filling, but as late as possible to reduce dead loss volume in LP when the gas transfer is completed. It is also late to prevent exhaust gas blow down from the HP exhaust transfer port 26.

DD 274° BTDC LP

LP inlet transfer port 25 closes. This position depends on the port shape and size.

EE 213° BTDC HP

HP inlet transfer port 25 starts to close. This position is determined from FF and depends upon port size and shape.

FF 171° BTDC HP

HP inlet transfer port 25 closes before HP exhaust transfer port 26 opens to prevent contamination of the transferred charge and to allow time for exhaust scavenging. It closes late to suit the position of the LP inlet transfer port 25 and thus minimise transfer passage length. The pressure of the remaining charge in LPTDC chamber helps to prevent exhaust gas carry-over.

GG 203° ATDC HP

HP exhaust transfer port 26 opens as late as possible to reduce percentage losses in the exhaust transfer passage 26 and to delay opening until FF is closed. It should also coincide with minimum LP volume while retaining a short exhaust transfer passage.

HH 238° ATDC HP

HP exhaust transfer port closes.

II 303° ATDC LP

LP exhaust transfer port starts to open.

JJ 330° ATDC LP

LP exhaust port opened at minimum summated volume around the exhaust transfer passage. The increasing LP volume provides good initial HP exhaust scavenging prior to the next secondary scavenging stage.

It should also be positioned to give a short exhaust transfer passage.

KK 195° ATDC LP

LP exhaust port 24 opens 50° before maximum sumated expansion volume. This early opening matches the time required for gas acceleration to facilitate exhaust as with a reciprocating piston engine exhaust valve.

LL 255° ATDC LP

LP Exhaust port 24 fully open.

While actual angles have been quoted we are by no means restricting ourselves to such angles as obviously these can readily be varied. It is envisaged that these angles may be varied by up to ± 25°.

By arranging the eccentric shafts for the pistons out of phase and particularly substantially 180° out of phase from each other has enabled the transfer ducts 25 and 26 to have an improved positioning in respect of engine timing and has also enabled the ducts to have a shorter length and hence a smaller volume. The shapes of the ports where the transfer ducts communicate with the chambers, also improved for greater efficiency.

By arranging the minor axes of the cavities out of line has also helped in arranging the transfer ducts in positions where they provide improved timing characteristics.

The engine of the present invention could incorporate a plurality of the pistons 10 and a corresponding plurality of the pistons 11 in the same way as a reciprocating engine may be provided with a plurality of cylinders. Alternatively in such a case a single piston 11 may provide for the pre-compression of the air and final expansion of the exhaust gases of a plurality of the pistons 10.

I claim:

1. A rotary piston internal combustion engine comprising a housing, said housing having first and second cavities closely adjacent one another, a first rotary piston mounted in said first cavity to define a first set of working chambers therewith, a second rotary piston mounted in said second cavity to define a second set of working chambers therewith, each cavity and its respective piston being trochoidal in shape and respectively having n and $n+1$ lobes, each cavity having a major, a minor, and a polar axis, said two cavities being arranged adjacent to each other with their major axes substantially parallel to each other, means for producing planetary rotation of said first and second pistons at the same rotational speed in said cavities, a first duct for transferring compressed air from said second set of working chambers to said first set of working chambers for further compression therein, a second duct for transferring combustion gases which have been partially expanded in said first set of working chambers to said second set of working chambers for further expansion therein, means for rendering the length of said first and second ducts approximately the same and for aligning said first and second ducts to communicate with said cavities with a small oblique angle therebetween, said means including a plane through said minor axis and said polar axis of said first cavity being arranged substantially parallel to and offset from a plane through

said minor axis and said polar axis of said second cavity wherein said first duct and said second duct communicate with the peripheries of said cavities and are at a less oblique angle and are shorter than if said minor axis of said first and second cavities were in line, means for supplying air to said second set of working chambers for compression therein, means for permitting the withdrawal of exhaust gases from said second set of working chambers, means for supplying fuel to said first set of working chambers, said first and second sets of working chambers varying in volume and position during the rotation of said pistons so that a working cycle is effected, the arrangement being such that communication via said duct starts to become established between the respective first and second sets of working chambers when one of said chambers if substantially at its maximum volume and the other of said chambers is simultaneously at its minimum volume, and ceases to be established substantially when the said one chamber has reached its minimum volume and the other chamber is simultaneously at its maximum volume, said means for producing planetary rotation of said first and second pistons being out of phase with each other.

2. A rotary piston internal combustion engine as claimed in claim **1** wherein a plane through said polar axes of both said first and second cavities cuts said planes through said minor axes and said polar axes of said cavities at an angle of up to substantially 10°.

3. A rotary piston internal combustion engine is claimed in claim **2** wherein said angle is substantially 5°.

4. A rotary piston internal combustion engine as claimed in claim **1** in which said means for producing planetary rotation of said first and second pistons are eccentric shafts arranged between substantially 150° and substantially 210° out of phase with each other.

5. A rotary piston internal combustion engine as claimed in claim **4** in which said eccentric shafts are arranged substantially in the order of 180° out of phase with each other.

6. A rotary piston internal combustion engine as claimed in claim **4** in which said eccentric shaft for said second piston leads said eccentric shaft for said first piston in the order of 210°.

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