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Geung

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(54) **DOUBLE THROW ENGINE**

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(52) **U.S. Cl.** **123/54.1**; 124/55.5
(58) **Field of Search** 123/54.1, 55.2, 123/55.3, 192.1, 192.2, 197.4, 193.2, 193.3, 55.5, 55.7

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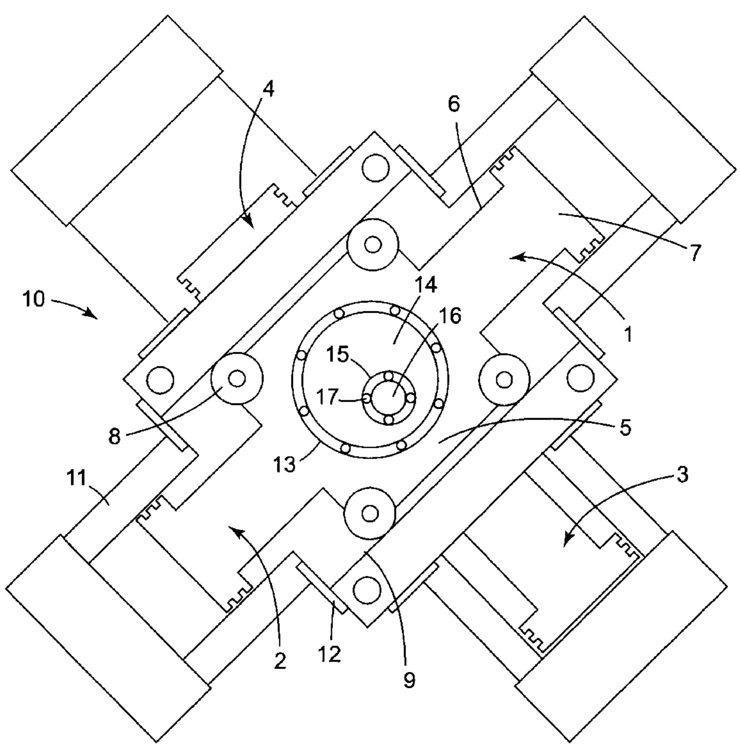
(57) **ABSTRACT**

An engine is described having pistons and cylinder arranged in mutually orthogonal pairs. Each pair is driven by a respective crank, with the pairs of cranks rotating about a primary crank which in turn rotates about an axis orthogonal to the axes of the pairs of pistons and cylinders. The throw of the respective cranks about the primary crank is the same as the throw of the primary crank about its axis. A counter-balancing weight is provided opposite to the primary crank. The resulting engine is balanced and lateral forces on the cylinder wall are reduced allowing the use of ceramic materials for the cylinders.

11 Claims, 16 Drawing Sheets



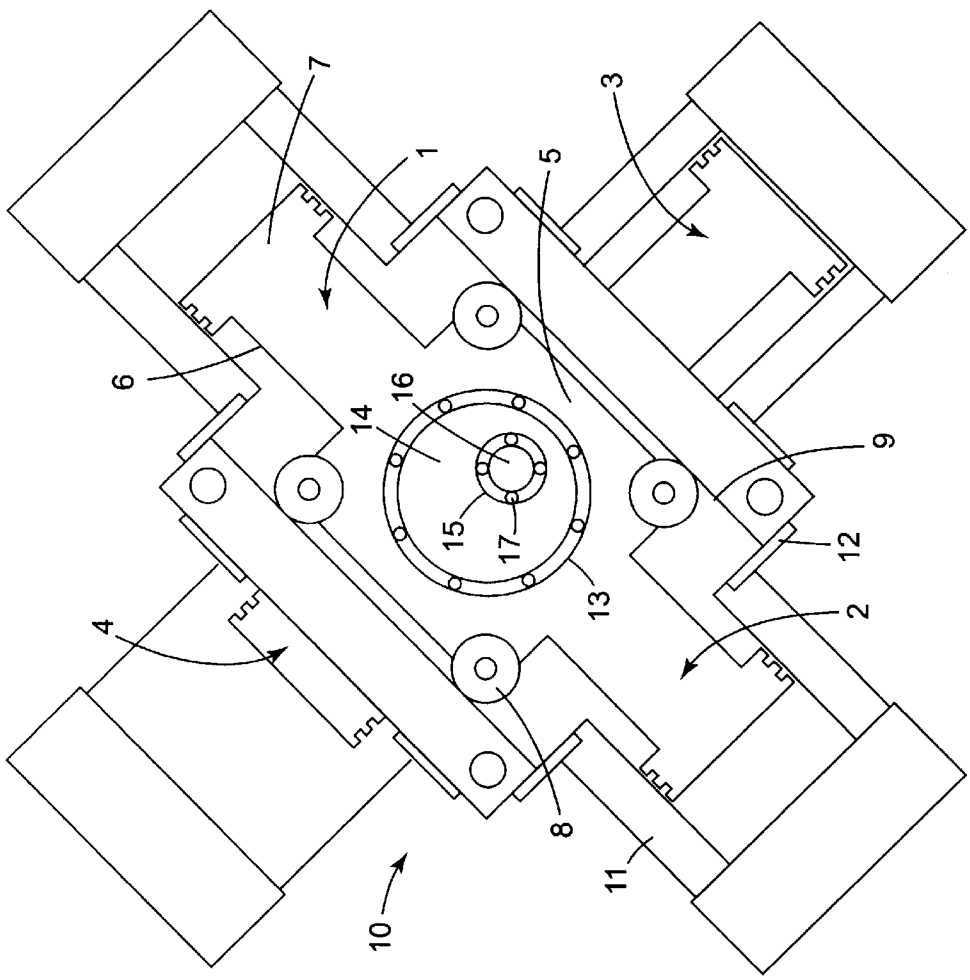
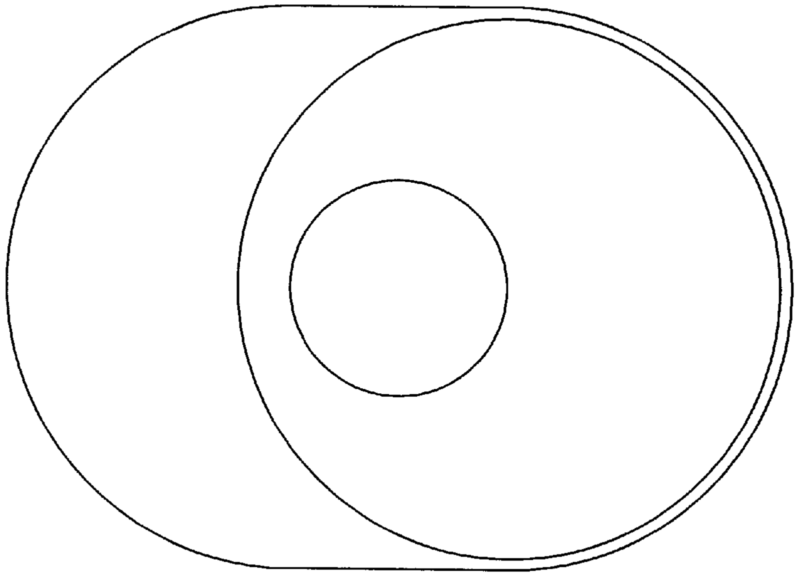


Fig. 1



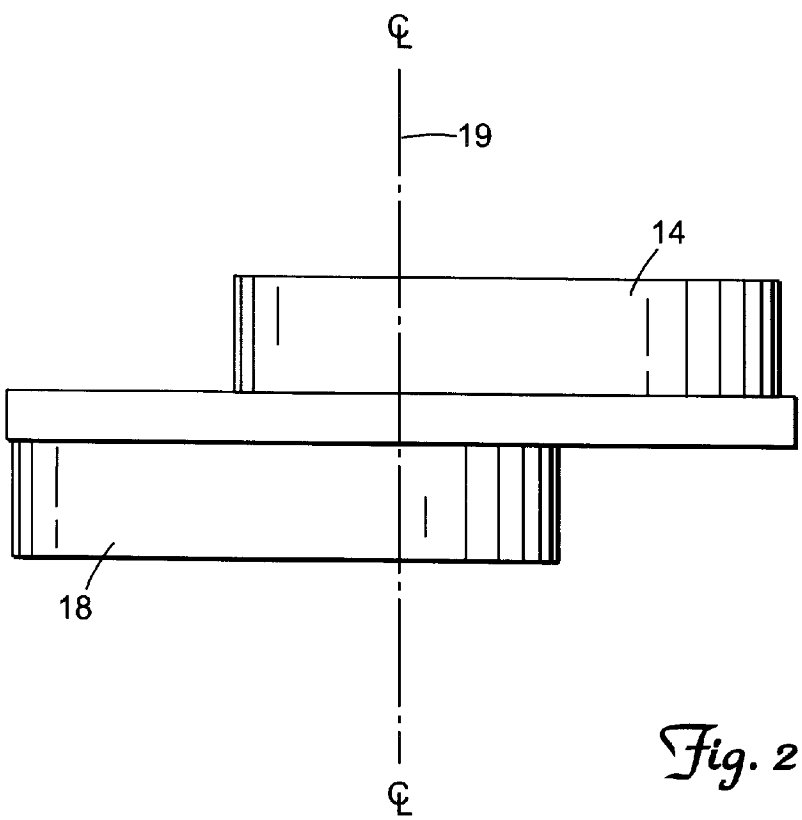


Fig. 2

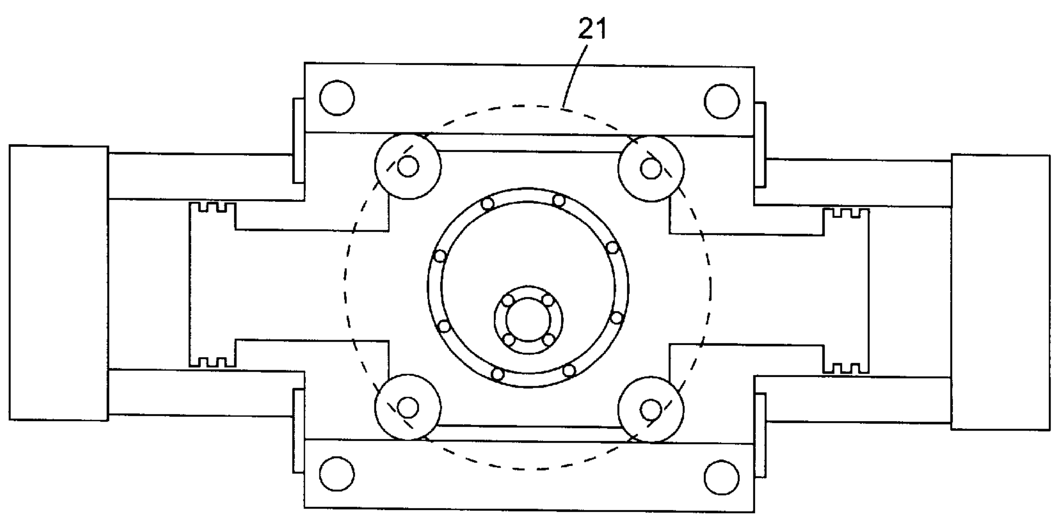


Fig. 3

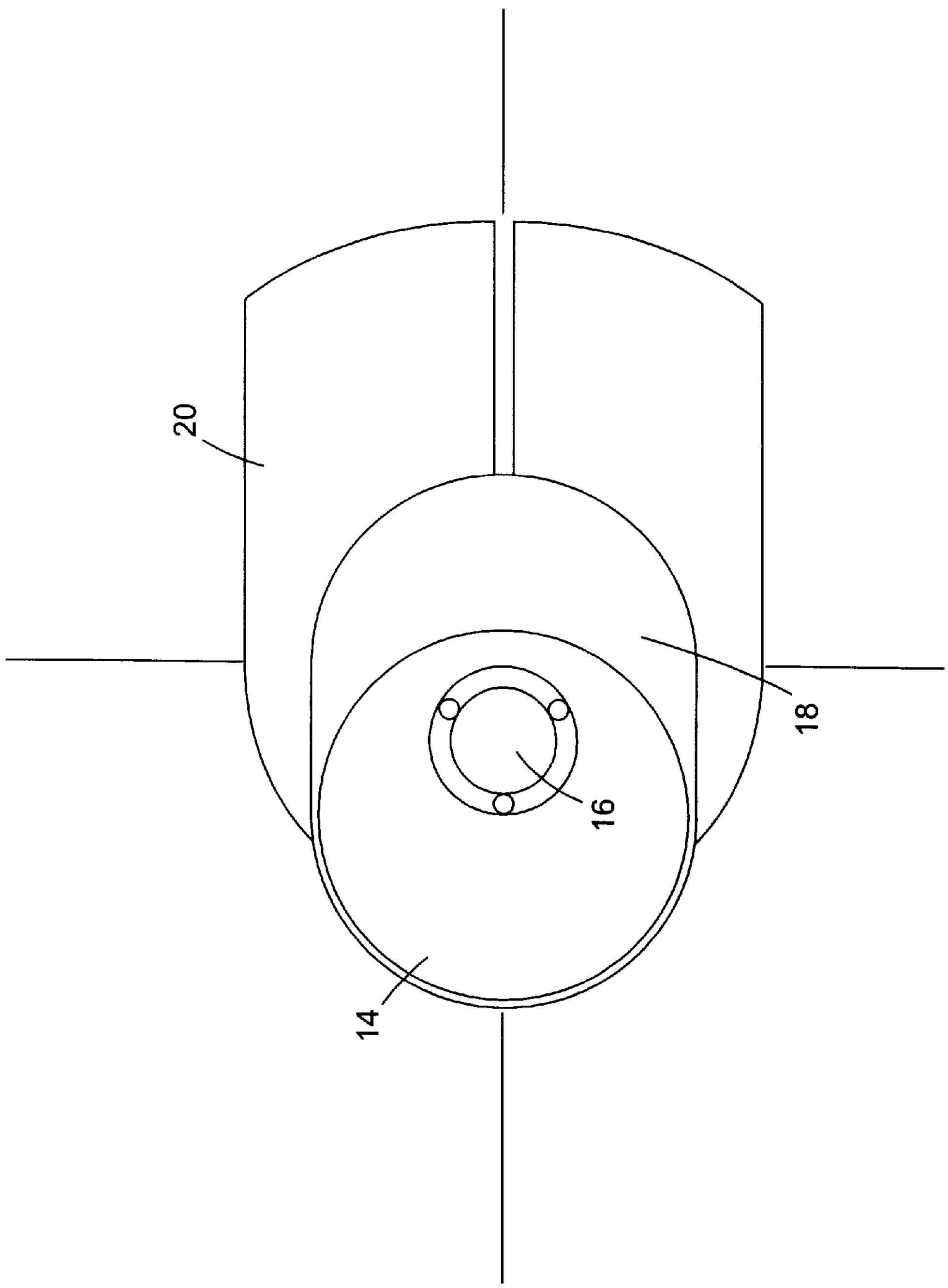


Fig. 4

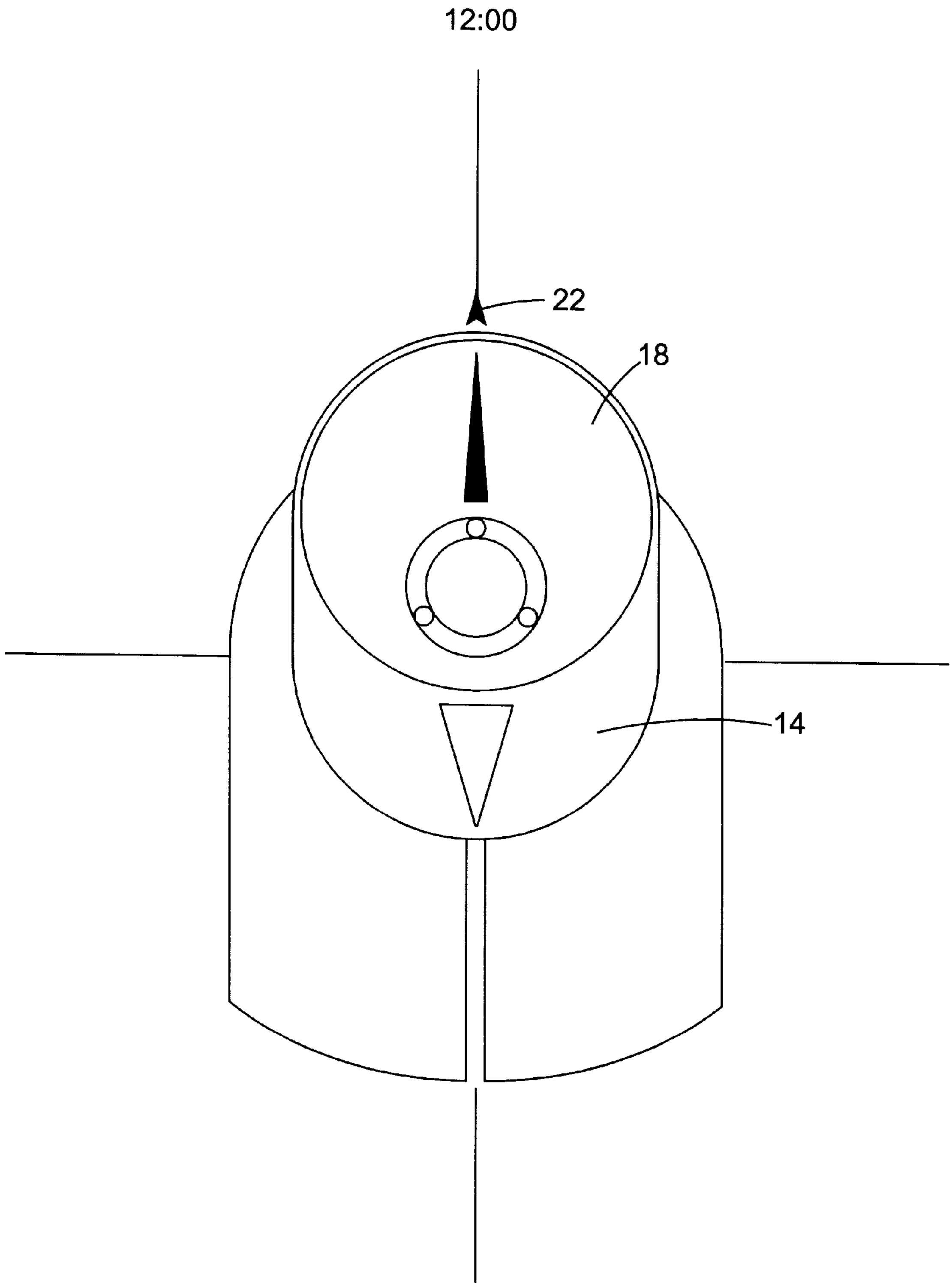


Fig. 5

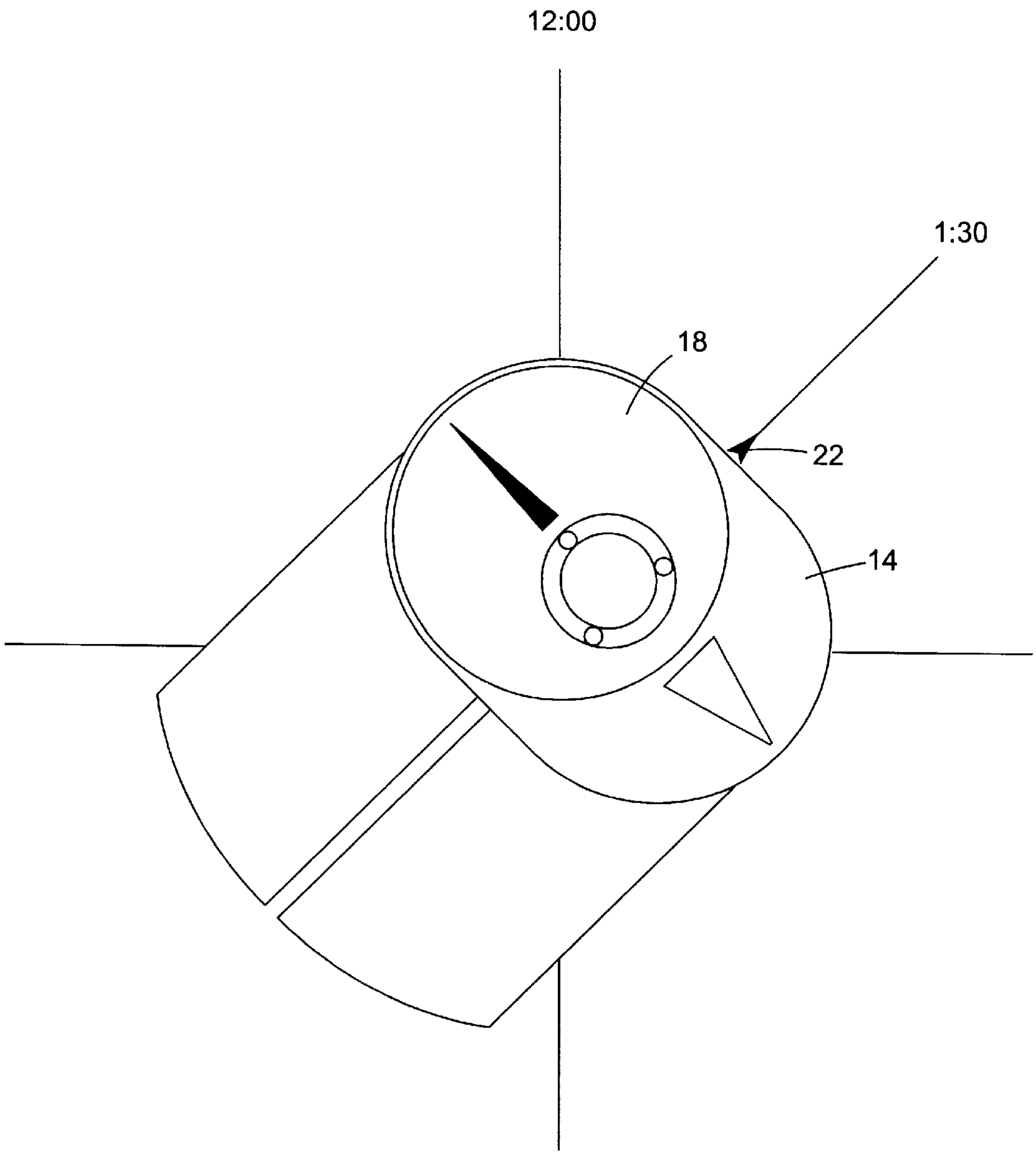


Fig. 6

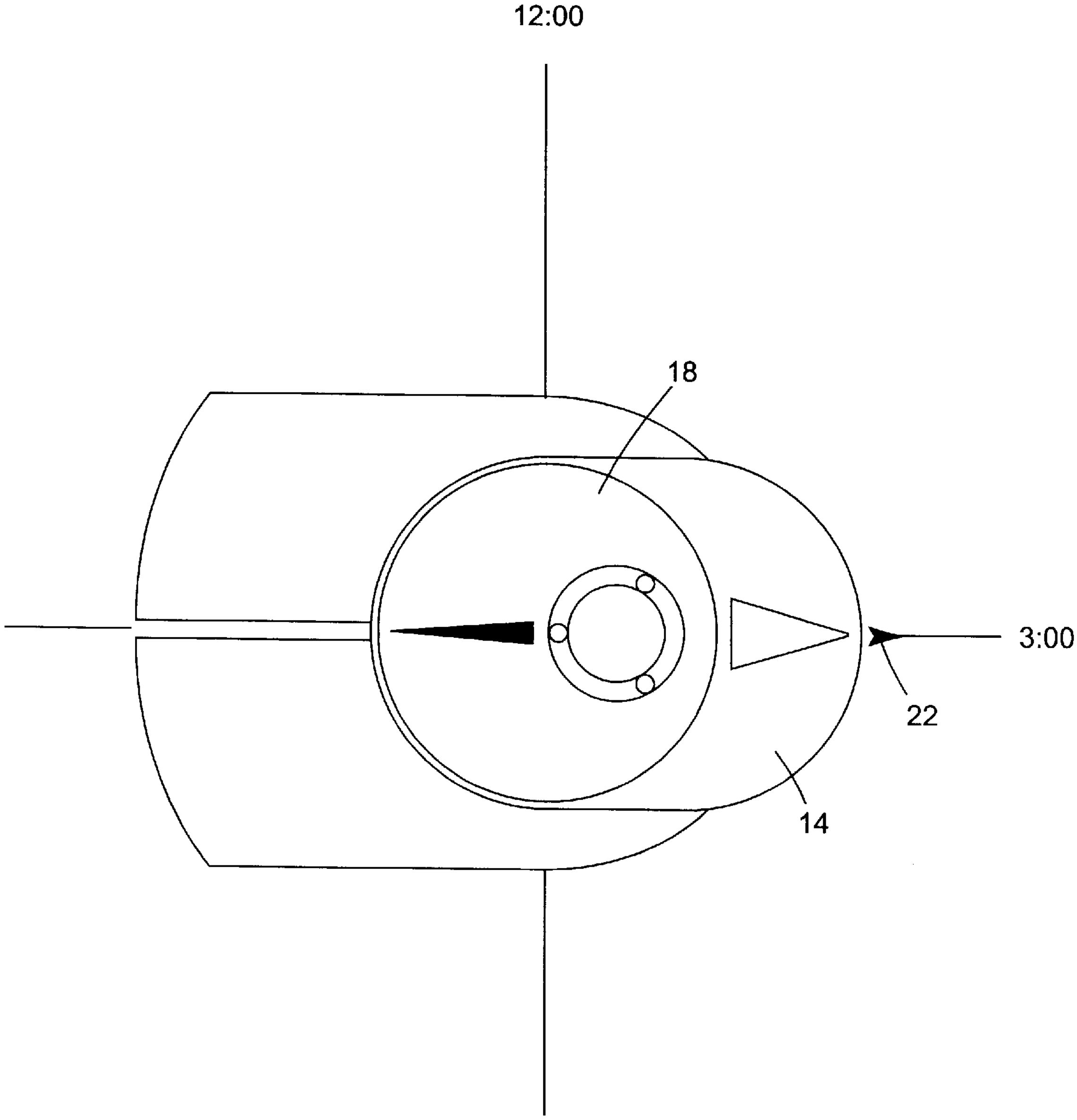


Fig. 7

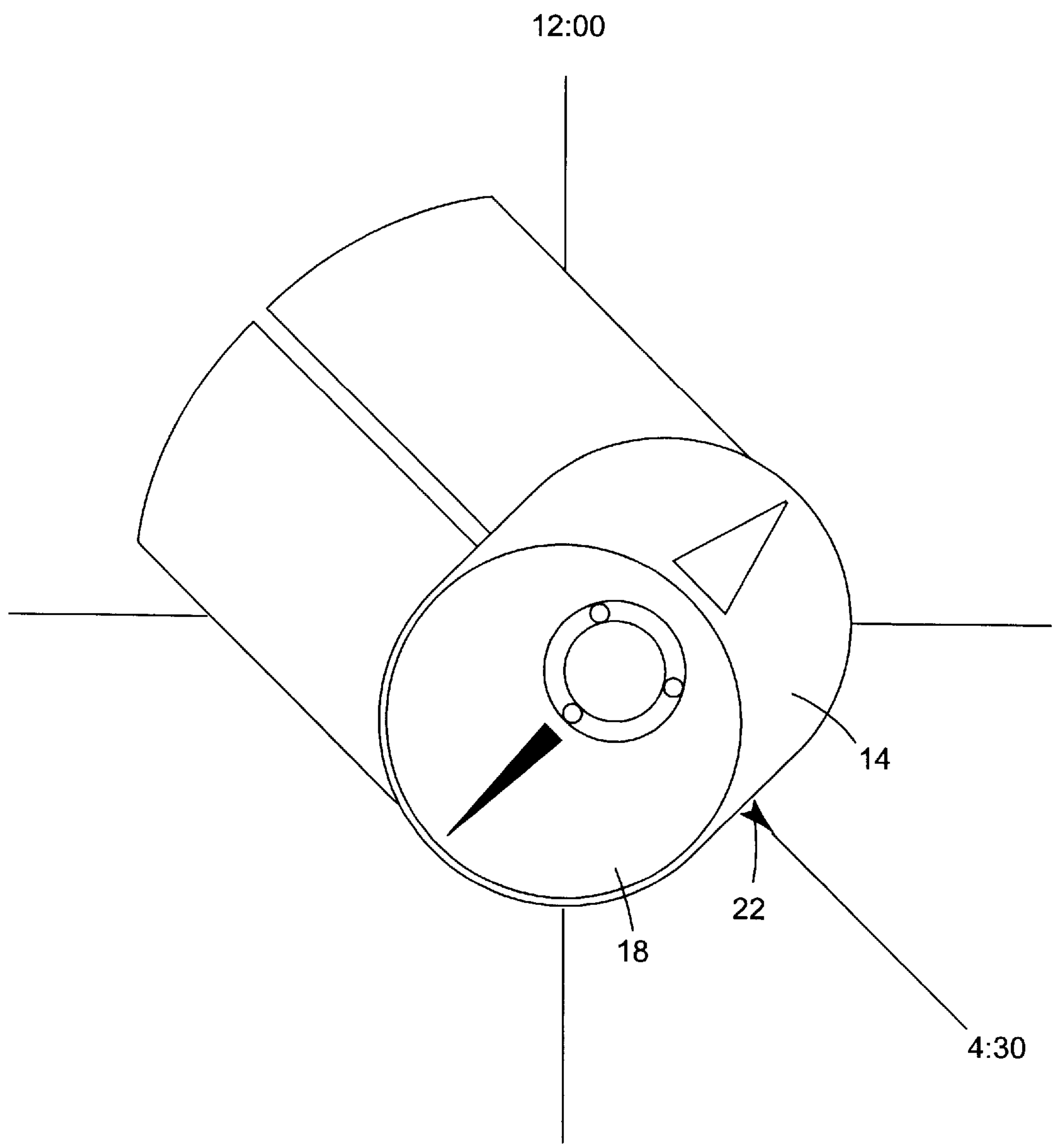


Fig. 8

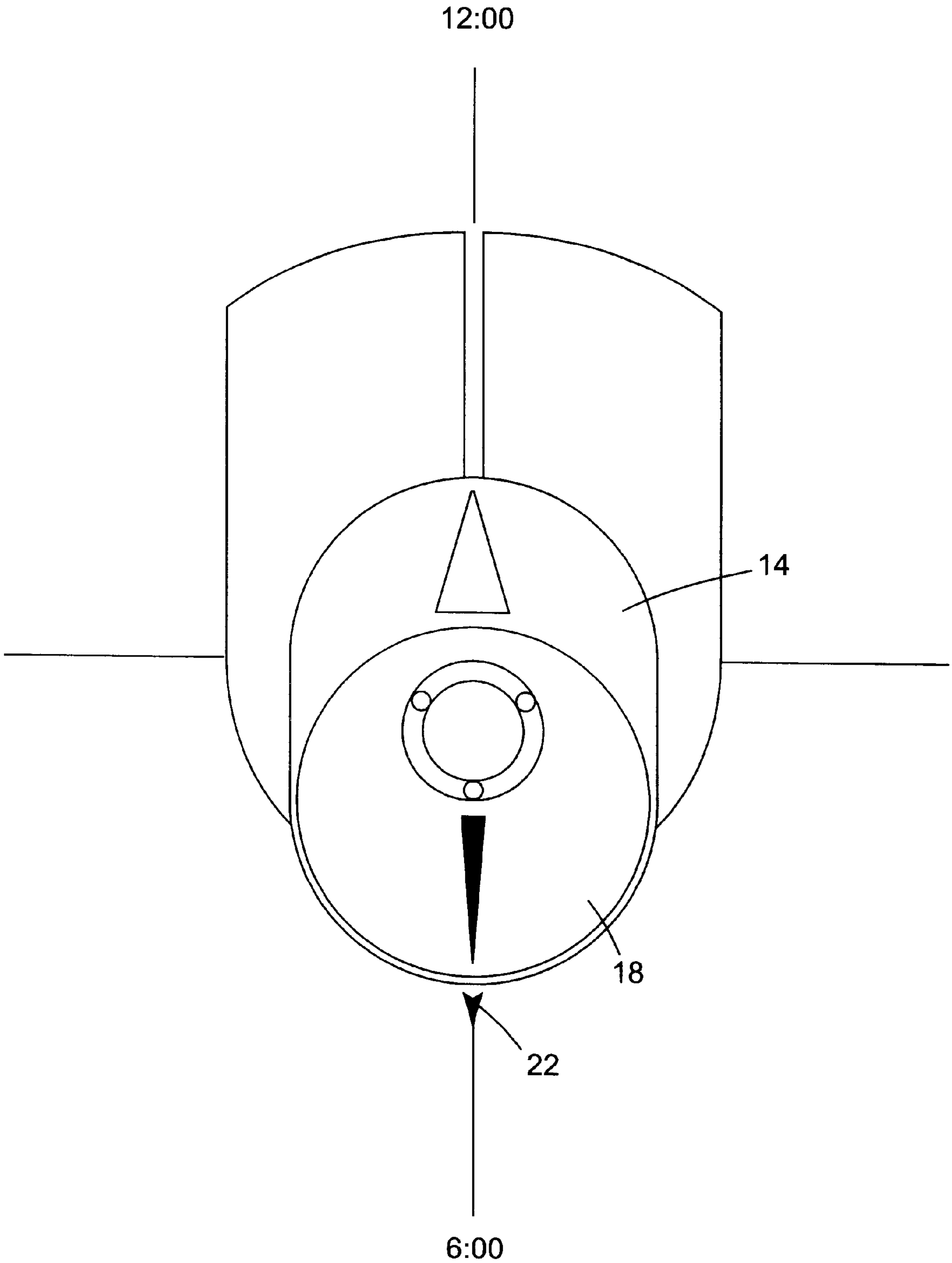


Fig. 9

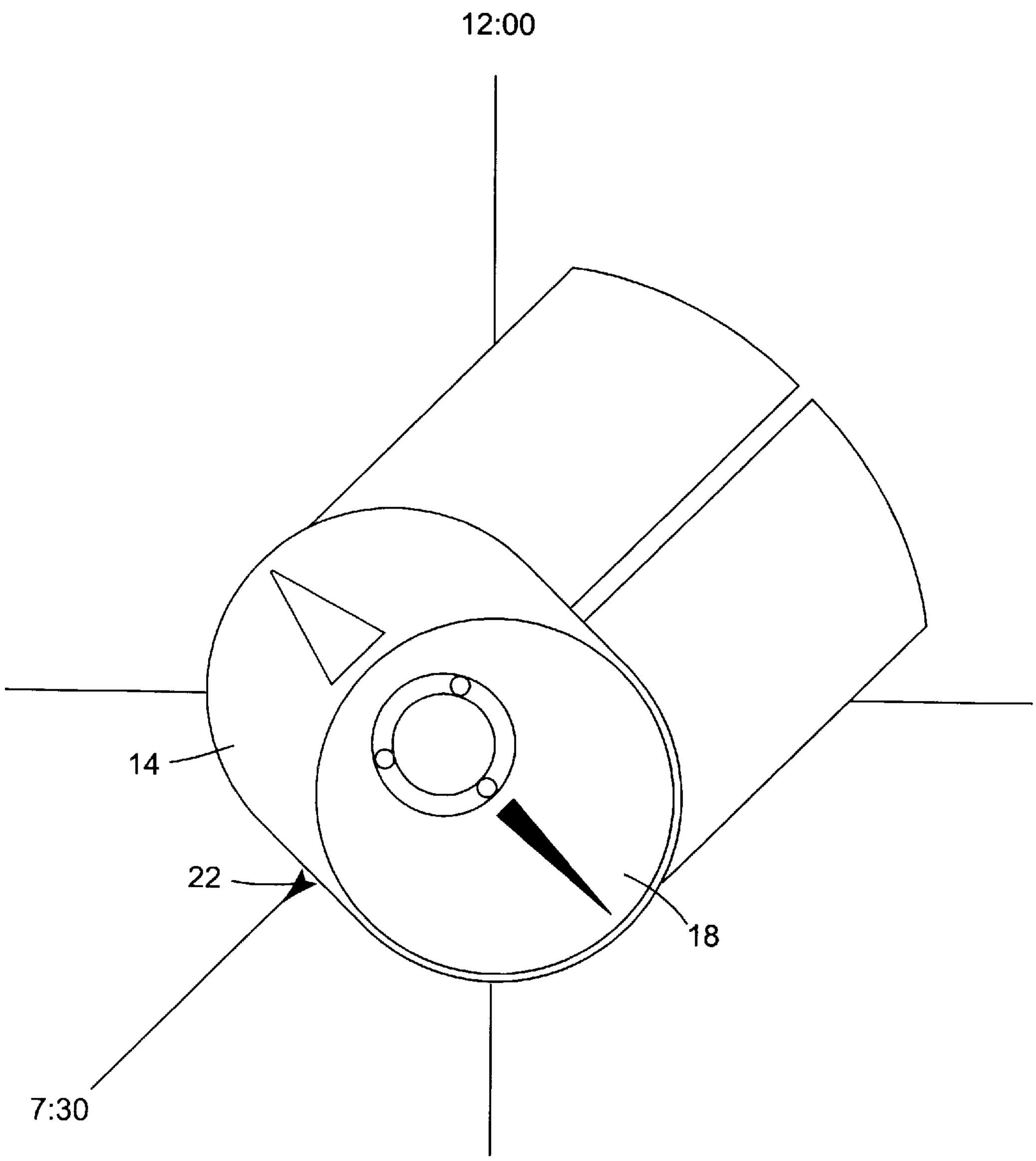


Fig. 10

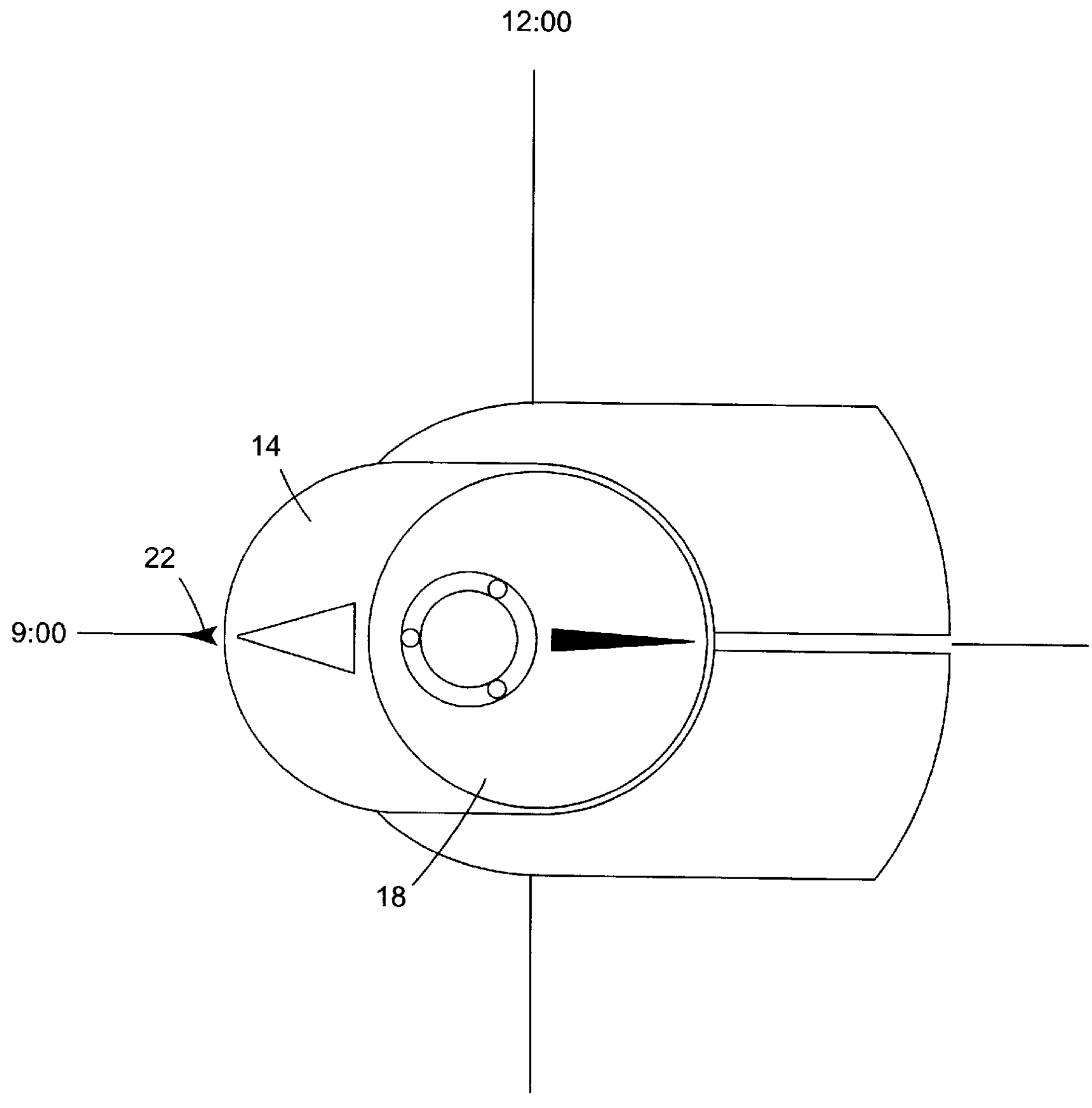


Fig. 11

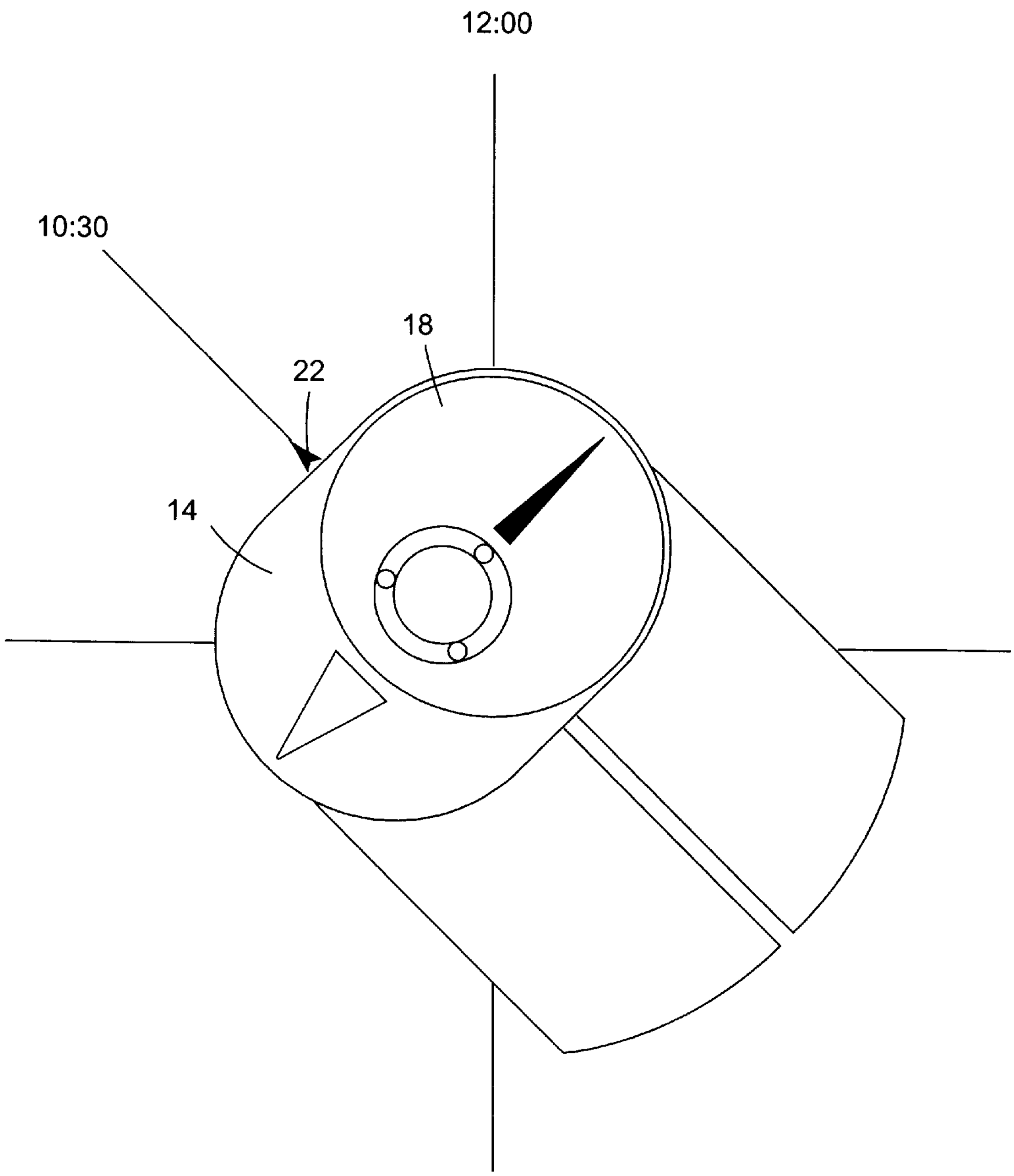


Fig. 12

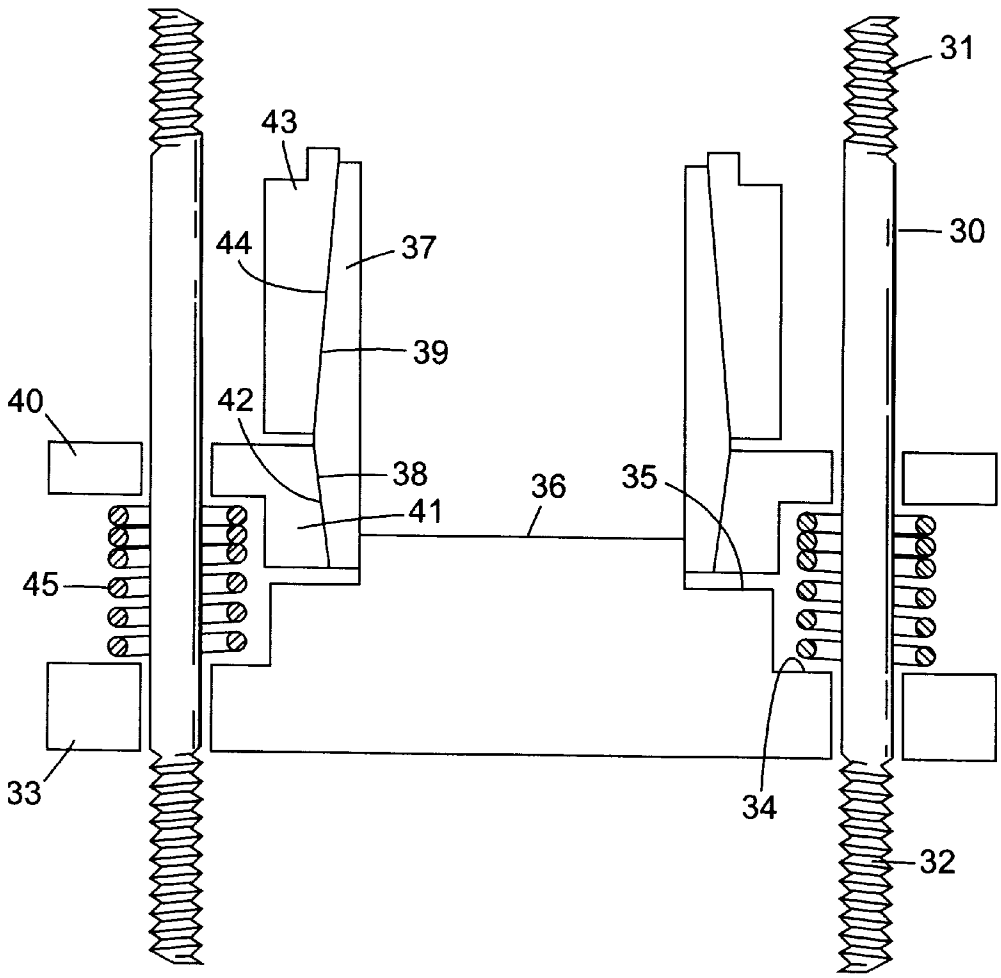


Fig. 13

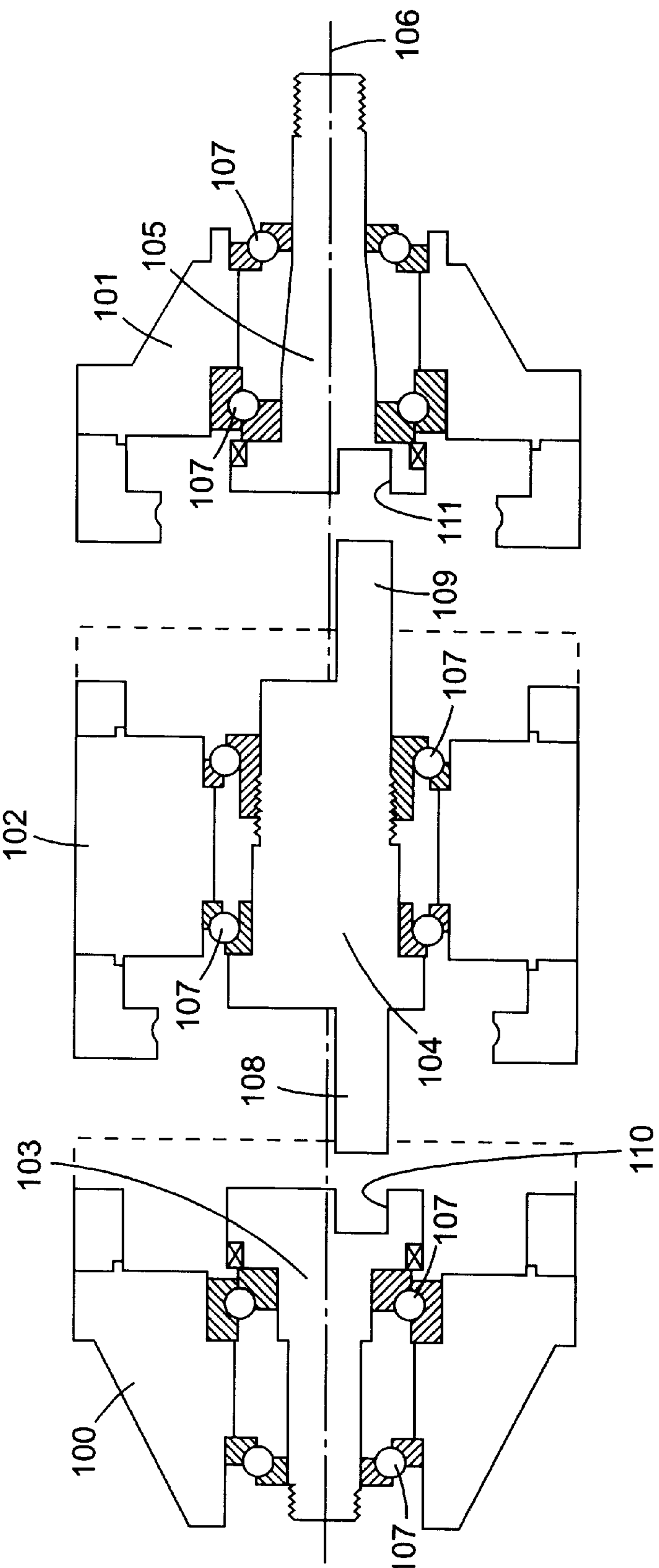

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Fig. 14

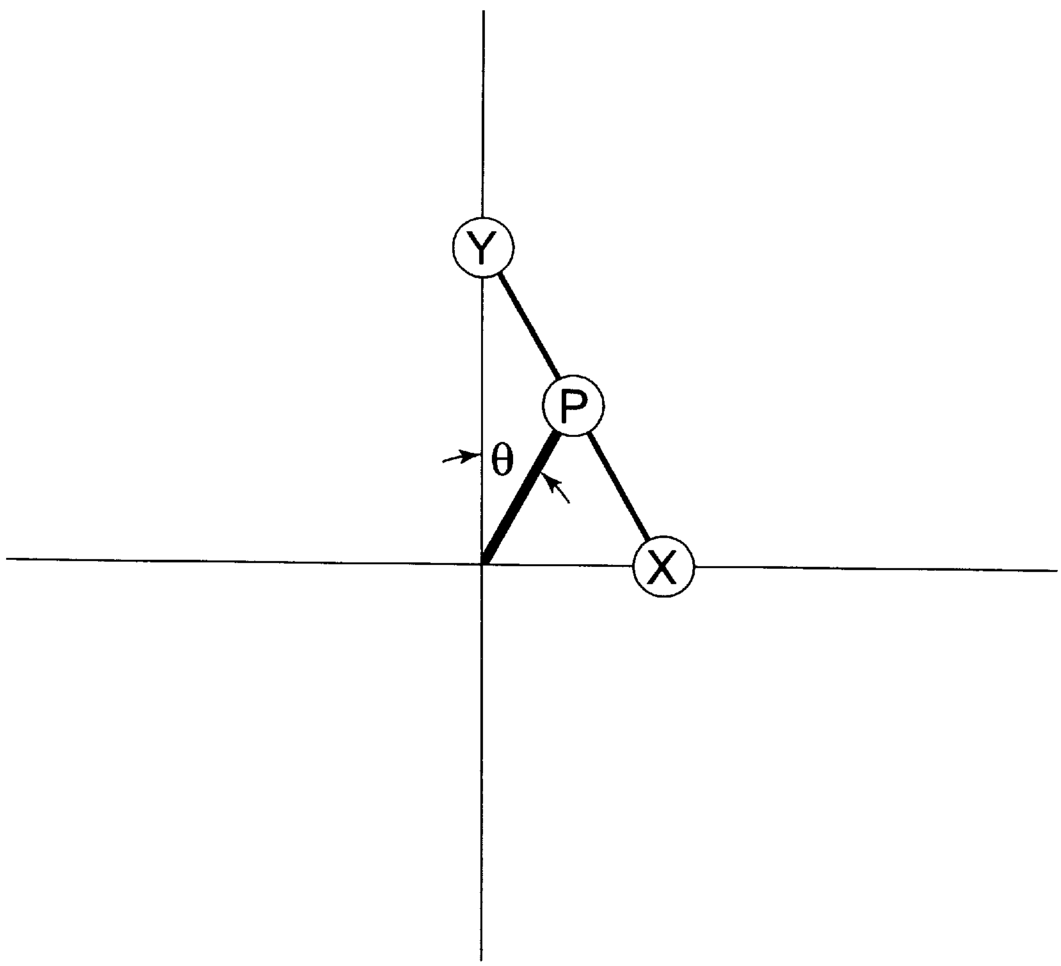

Fig. 15

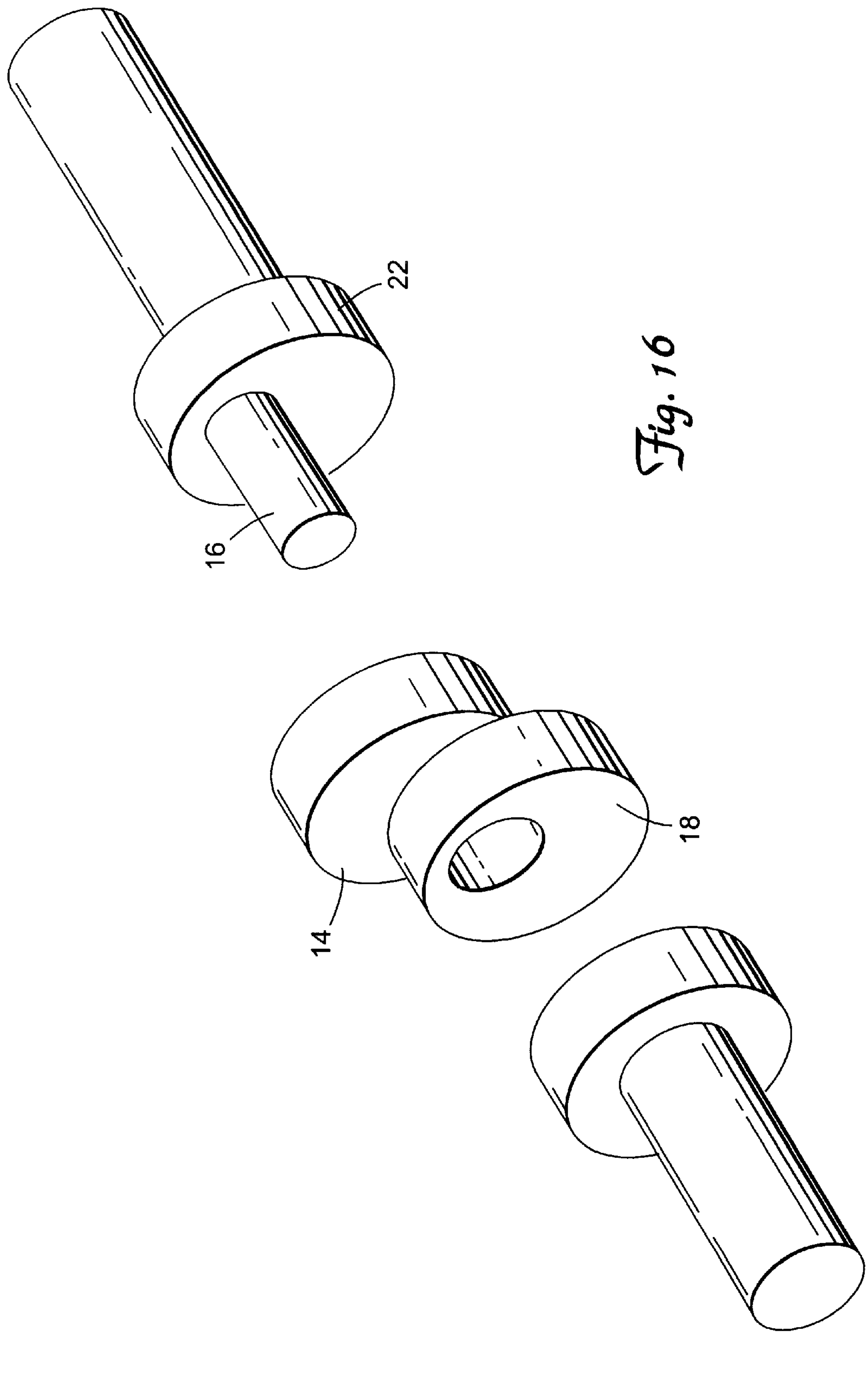

Fig. 16

DOUBLE THROW ENGINE

FIELD OF THE INVENTION

This invention relates to an engine, and in particular to an improved form of engine that is better balanced than the prior art. The invention may be applied to an internal combustion engine, hydraulic or pneumatic pumps and/or motors, a compressor and the like.

BACKGROUND OF THE INVENTION AND PRIOR ART

A problem with known engines, be they IC engines, hydraulic pumps, compressors and the like, that have pistons moving in cylinders, is that a consequence of the piston being driven from a rotating crank is that there are lateral forces that act cyclically on the walls of the cylinder as the piston goes through one cycle of operation. The presence of these lateral forces places a number of restrictions on the design of the cylinders since they must be designed in such a way as to overcome these problems.

SUMMARY OF THE INVENTION

According to the present invention there is provided an engine comprising at least two pairs of pistons and cylinders, said pairs being disposed along mutually orthogonal first and second axes, said pairs being driven by respective first and second cranks, said first and second cranks rotating about a primary crank, said primary crank in turn rotating about a third axis orthogonal to said first and second axes, said first and second cranks having a radius of throw from said primary crank equal to the radius of throw of said primary crank from said third axis.

Preferably a counter-balancing weight is provided opposite said primary crank.

The engine may be a four-cylinder engine having two pairs of orthogonally disposed cylinders, or may be an eight-cylinder engine, having four pairs of cylinders and wherein the cylinders are divided into two groups of four disposed in parallel planes, each plane comprising two mutually orthogonal pairs.

A major advantage of the present invention is that by selecting the correct counter-balancing weight all lateral forces on the cylinders may be eliminated or at least substantially reduced and this permits the use of alternative materials for the cylinder construction. Preferably therefore the cylinders are formed of a ceramic material.

In a particularly preferred embodiment the ceramic cylinders are pre-stressed. This may be achieved by forming the external surface of each cylinder with an at least partially tapering portion, and providing an annular surrounding member having an inner surface tapering in the opposite sense to the external surface of the cylinder, and means being provided for urging said surrounding member such that said tapering surfaces are brought together to generate a radially inwardly directed force. Preferably the urging means comprises spring means.

Viewed from another aspect the present invention provides an engine having four pairs of pistons and cylinders, said four pairs being grouped into two groups of two pairs in each group, the piston and cylinder pairs in each group being disposed on mutually orthogonal first and second axes and being driven by first and second cranks respectively, said first and second cranks rotating about a primary crank, said primary crank rotating about a third axis orthogonal to the first and second axes and comprising three interconnecting sections, junctions between said three sections defining spaces for receiving the respective first and second cranks of said two groups of pistons and cylinders, each said first and second crank having a radius of throw from said primary crank equal to the radius of throw of said primary crank from said third axis, and a counterbalancing weight being provided at each junction opposite said primary crank.

Viewed from still another aspect the present invention provides a cylinder for an engine wherein said cylinder is formed of ceramic material, and wherein said cylinder has an external surface having two portions tapering in opposite senses, and wherein an annular surrounding member having an internal surface tapering in an opposite sense to a first of said two portion-surrounds said first of said two portions, and wherein urging means acts upon said surrounding member whereby the tapering internal surface of said surrounding member and said first tapering portion of said external surface of said cylinder are brought together to generate a radially inwardly directed force, and wherein an annular locking member surrounds said second tapering portion of the external surface of said cylinder and having an internal tapering surface of opposite sense to the said second tapering portion.

BRIEF DESCRIPTION OF THE DRAWINGS

Some embodiments of the invention will now be described by way of example and with reference to the accompanying drawings, in which:

FIG. **1** is a plan view through part of an engine according to an embodiment of the invention showing the plane in which the pistons reciprocate,

FIG. **2** is a view of first and second cranks,

FIG. **3** shows the location of the counter-balancing weight receiving chamber,

FIG. **4** shows the crank assembly,

FIGS. **5** to **12** show the relative positions of the cranks during one firing cycle,

FIG. **13** is cross-section through a cylinder,

FIG. **14** is a section through an embodiment of the invention in the form of an eight-cylinder engine, and

FIG. **15** schematically illustrates the cranks for the purposes of explanation.

FIG. **16** is an isometric perspective view showing the relationship of the cranks

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Referring firstly to FIG. **1** there is shown a first embodiment of the present invention showing a double throw engine having two mutually perpendicular piston pairs. Since the invention can be applied to a large number of different applications, such as an IC engine, or a hydraulic motor, pump, compressor or the like, for clarity the description here will be limited to the piston, cylinder, crank construction. The remaining parts of the engine, e.g. the exhaust and inlet design, are conventional.

The two pairs of pistons do not however lie in the same plane but in two parallel planes, a first plane comprising pistons **1**,**2** being above a second plane in which are located pistons **3**,**4**. In the following description for convenience reference shall be made to just one piston pair, but unless otherwise stated it should be understood that the description applies to both pairs equally.

Pistons **1**,**2** (and equivalently pistons **3**,**4**) are formed integrally with and extend in opposite directions from a central piston body **5** and each piston comprises a piston shaft **6** with a piston head **7** at a distal end thereof. The piston body **5** is provided with four guide means **8**, for example guide wheels, at each comer of the body **5**—two on each side of the piston body **5**. The guide wheels **8** are adapted to engage guide rails **9** formed on the interior of an engine block **10** so as to allow the piston body **5** and pistons **1**,**2** to reciprocate. It will be understood that pistons **1**,**2** are therefore always exactly 180° out of phase.

Pistons **1**,**2**,**3**,**4** reciprocate within respective cylinders **11** which will be described in greater detail below. In the meantime it is sufficient to note that the cylinders **11** are secured to the engine block **10** and guard plates **12** are provided at the ends of the guide rails to prevent lubricating fluid from leaking out of the guide rails **9** and engine block **10**.

Formed in the centre of the piston body **5** is a circular crank receiving aperture **13** within which is located a first crank **14** to be described further below. Pin roller bearings are disposed between aperture **13** and crank **14** to permit rotation of the crank **14** within the aperture **13**. Crank **14** is in turn provided with an aperture **15** in which is received a crank pin **16**. Again bearings **17** or the like are provided to permit relative rotation of the crank **14** about the pin **16**.

First crank **14** is one part of an integrally formed double-crank as shown in FIG. **2** the other part of the double crank is a second crank **18** which is identical to the first crank **14**. The first and second cranks **14**,**18** are, however, offset by equal but opposite amounts with respect to a common crank axis **19** as shown in FIG. **2**—that is to say they have the same radius of throw, but out of phase with each other. It will be understood that the second crank **18** is received within a crank aperture formed in the piston body of the second pair of pistons **3**,**4** in a manner corresponding identically to the crank **14** and the first piston pair **1**,**2**.

As is also shown in FIG. **4** also fitted to the crank pin bearing first and second cranks **14**,**18** is a counter-balancing weight **20** which is adapted to rotate relative to the first and second cranks **14**,**18**. The counter-balancing weight is received within a chamber **21** formed above the two super-imposed piston bodies **5** (FIG. **3**), the chamber being sized sufficiently to allow rotation of the counter-balancing weight **20**.

The crank pin **16** is formed with an integral primary crank **22** and FIG. **4** shows the assembly of the first and second cranks **14**,**18** located on the crank pin **16** bearing the primary crank **22**. FIG. **16** shows the relationship between the first and second crank **14**, **18** and the primary crank **22**. The following figures illustrate the relative positions of the first and second cranks **14**,**18** and the primary crank **22**. In these figures the axis x-x corresponds to the axis of reciprocation of pistons **1**,**2**, while the axis y-y corresponds to the axis of reciprocation of pistons **3**,**4**, it is orthogonal to axis x-x.

If the engine is a two stroke four cylinder engine, the firing sequence of pistons **1**–**4** will be **4**,**1**,**3**,**2**. With this firing sequence the primary crank **22** will rotate in a clockwise direction as viewed in FIG. **1**, while the first and second cranks **14**,**18** will rotate in an antic-clockwise direction. FIG. **5** shows the position with the primary crank **22** and the second crank **18** at twelve o'clock, and the first crank **14** at six o'clock (the positions of first and second cranks **14**,**18** being described with reference to primary crank **22**). The subsequent Figures show the positions of the cranks during one complete cycle. Upon rotation into the position of FIG. **6** the primary crank **22** is at a position corresponding to half-past one, crank **14** is at half-past four, crank **18** is at half-past ten. In FIG. **7** primary crank **22** has advanced to three o'clock, crank **14** is also at three o'clock, while crank **18** is at nine o'clock. In FIG. **8** primary crank **22** is at half-past four, first crank **14** is at half-past one, second crank **18** is at half-past seven. In FIG. **9** primary crank **22** is at six o'clock, crank **14** is at twelve o'clock, and crank **18** is at six o'clock. In FIG. **10** the primary crank **22** is at half-past seven, first crank **14** is at half-past ten, second crank **18** is at half-past four. In FIG. **11** primary crank **22** is now at nine o'clock, first crank **14** is also at nine o'clock while second crank **18** is at three o'clock. Lastly in FIG. **12** primary crank **22** has advanced to half-past ten, first crank **14** is at half-past seven and second crank **18** is at half-past one. This completes one cycle.

It will be seen from FIGS. **5** to **12** that the first and second cranks **14**,**18** rotate in an opposite sense from the primary crank **22**. The first and second cranks **14**,**18** each have the same radius of throw as the primary crank **22** and rotate at the same angular velocity. This means that the pistons **1**,**2** and **3**,**4** reciprocate along their axes harmonically. Furthermore because the first **14** and second **18** cranks are at 180° with respect to each other, their rotations balance each other out.

In the engine of the present invention one advantage is that while the linear velocities of the cranks **14**,**18** along the x-x and y-y axes are variables depending on the angular position of the primary crank **22**, provided that the angular velocity of crank **22** is constant the sum of the kinetic energies of the pistons **1**,**2** and **3**,**4** is constant. Similarly although the linear accelerations and decelerations of the cranks **14**,**18** along the x-x and y-y axes are dependent on the angular position of primary crank **22**, again provided that the angular velocity of the primary crank **22** is constant the sum of the acceleration vectors of the pistons **1**,**2** and **3**,**4** corresponds to a constant centrifugal force acting through the centre O towards the primary crank **22** and which can be finely balanced by a counterweight.

This can be seen by the following analysis, which is best understood with reference to FIG. **15** which schematically shows the positions of cranks **14** (<X>), **18** (<Y>) and **22** (<P>) and in which the radii of throw of the cranks r=ØP=PX=PY, mass of <X> Mx=mass of <Y> My=K_2, and angular velocity=dθ/dt=K_1. <P> is rotating about Ø (the z-axis) in a clockwise direction at an angular velocity of K_1 while <X> and <Y> rotate about <P> in a anti-clockwise direction with the same angular velocity. With this situation the following conclusions can be drawn about the position, velocity, kinetic energy and acceleration of the pistons as they move along the X and Y axes.

Position	<Y> = 2rcosθ	<X> = 2rsinθ
Velocity	dy/dθ = −2rsinθ	dx/dθ = 2rcosθ
	dy/dt = dy/dθ.dθ/dt	dx/dt = dx/dθ.dθ/dt
	dy/dt = −2rsinθ.K_1	dx/dt = 2rcosθ.K_1

Thus the sum of the kinetic energy

$$\tfrac{1}{2}My(dy/dt)^2+\tfrac{1}{2}Mx(dx/dt)^2=\tfrac{1}{2}K_2(2r)^2(K_1)^2$$

which is a constant
The acceleration can be calculated as follows

$$d^2y/dt^2=-2rK_1\cos\theta \quad d^2x/dt^2=-2rK_1\sin\theta$$

and the vector sum of the acceleration along the X and Y axes is $2rK_1$ in the direction of ØP. This corresponds to a constant centrifugal force in the direction of the Z-axis which can easily be balanced by a counter-balancing weight.

In summary it will be seen that the pistons are driven by the first and second cranks **14,18** which rotate about the primary crank **22**. At the same time the primary crank **22** rotates about the z-z axis in the opposite sense to the rotation of the first and second cranks about the primary crank. The throw of the first and second cranks from the primary crank is equal to the throw of the primary crank from the z-z axis. The counter-balancing weight is fixed opposite the primary crank and rotates therewith.

In a conventional internal combustion engine any lateral forces acting on the pistons are taken up by the guide rails guiding movement of the piston in the engine block and by the cylinder walls. In conventional engines these lateral forces can be substantial and therefore this imposes design constraints upon the construction of the engine block and the cylinders. In particular the cylinder walls have to be constructed from a material strong enough to bear these lateral forces. This is disadvantageous because it does not allow the use of ceramic materials in the construction of the cylinders. Ceramic materials have excellent wear characteristics and also have very good heat resistant properties, but they also tend to be brittle which means they are liable to crack or break under lateral forces. In the internal combustion engine of the present invention, however, the forces acting on the pistons can be finely balanced to remove or at least substantially reduce any such lateral forces and ceramic materials may be used in the cylinder construction.

Preferably, however, if a cylinder is to be constructed from ceramic materials it must be pre-stressed. One way of achieving this is to wind a steel wire around the ceramic cylinder. This has drawbacks, however, in that the tension in the wire reduces when it expands under the action of heat, and also in that the steel wire hinders the dissipation of heat by convection.

The present invention provides an alternative method for pre-stressing the ceramic cylinders. FIG. **13** shows an exemplary cylinder in cross-section. The cylinder is located between four rectangularly disposed shafts **30**. The shafts are provided with threaded end portions **31,32**; threaded portions **31** fix the cylinder to the engine bock, while threaded portions **32** allow a cylinder end plate **33** to be located—the end plate **33** having threaded screw holes at its four corners to receive threaded end portions **32** of shafts **30**.

Cylinder end plate **33** has a stepped surface that defines by way of two stepped portions **34,35** the cylinder end surface **36**. The cylinder wall is defined by an annular cylinder wall portion **37** one end of which is received abutting against stepped portion **35** of the cylinder end plate **33**. The cylinder wall portion **37** has a smoothly cylindrical interior surface to define a space for sliding movement of the piston head. The exterior surface of the cylinder wall portion **37**, however, is formed with tapered surfaces **38,39** such that the thickness of the wall portion **37** increases away from the cylinder end plate **33** until it reaches a maximum and then decreases again.

Surrounding the portion of the cylinder wall portion **37** closest to the cylinder end plate **33** is an annular pressure means comprising plate **40** similarly sized to cylinder end plate **33** and having four apertures corresponding to the positions of shafts **30** so as to allow plate **40** to slide to and fro along the shafts **30**. Plate **40** has an inner annular portion **41** having a tapered surface **42** complementary to surface **38** of cylinder wall portion **37** and being in close engagement therewith. Spring means **45** are provided between cylinder end plate **33** and plate **40** so as to urge plate **40** away from cylinder end plate **33**. Surrounding tapered portion **39** of cylinder wall portion **37** is a locking ring **43** having a tapered inner surface **44** complementary to tapered surface **39**.

It will thus be understood that the effect of the spring means is to urge the plate **40** in a direction such that the tapered inner surface **42** acts on tapered portion **38** of cylinder wall portion **37** so as to urge portion **38** inwardly. Thus an external pressure is provided around the periphery of the cylinder so as to prevent the ceramic cylinder from cracking under the internal pressure of combustion. Plate **40** and locking ring **43** are preferably both made of aluminium for better heat dissipation. It will also be understood that the springs are not in contact with the cylinder and so do not present any obstacle to heat dissipation.

The embodiment described above is a four-cylinder engine. However the invention is equally applicable to an engine having a greater number of cylinders and FIG. **14** shows a sectional view through an engine block for an eight-cylinder embodiment. In this embodiment the engine block may be regarded as comprising three sections: two end sections **100,101** and a middle section **102**. Extending through the engine block is a crankshaft that may also be regarded as being made up of three sections **103,104,105**. In FIG. **14** the three sections are shown as being slightly separated, but this is for clarity of illustration only and in reality the three sections **103,104,105** are connected together so that they rotate as one shaft.

Each crankshaft section **103,104,105** is adapted to rotate about a common axis **106**, and each crankshaft section is rotatably mounted within respective engine block sections **100,101,102** by two annular bearing sets **107** per engine block section. Each engine block section **100,101,012** is provided with annular bearing sets at each end of the crankshaft section **103,104,105** which in addition to rotatably supporting the crankshaft sections **103,104,105** define spaces therebetween which may be used for other components. For example a lubricating pump may be located in the space defined in engine block section **100**.

As can be seen from FIG. **14** crankshaft section **104** is formed with two projecting axles **108,109** extending from opposite ends of the section **104** and parallel to but displaced from the central axis of rotation **106** of the crank shaft sections **103,104,105**. Crank shaft sections **103,105** are provided with corresponding recesses **110,111** for locating the ends of the axles **108,109** such that the three crank shaft sections come together to form a single commonly rotating crank shaft. It will be seen, however, that the recesses are shallower than the length of the axles **108,109** such that when the axles **108,109** are received in the recesses **110,111** there exists a space surrounding the axles between the ends of the crank shaft sections. Two such spaces are defined: one between crank shaft sections **103** and **104**, and the other between sections **104** and **105**. Into each such space—and fitted over the respective axles **108,109**—are located first and second cranks corresponding to first and second cranks **14,18** in the first embodiment described above. Thus four pistons may be driven in their respective cylinders by cranks located between engine block sections **100,102** and another four may be driven by cranks located between engine block sections **102,101**. This engine therefore has two sets of four cylinders disposed in mutually parallel planes.

In this embodiment, in respect of the pistons located between engine block portions **100,102** and between portions **102,101**, the crank shaft portion **104** functions as the equivalent of the primary crank **22** of the first embodiment. At the same time since the first crank shaft portion **103** and third crank shaft portion each have a weight offset caused by the presence of recesses **110,111** and so these portions can function as the respective counter-balancing weights.

What is claimed is:

1. An engine comprising of at least two pairs of pistons and cylinders, said pairs being disposed along mutually orthogonal first and second axes, said pairs being driven by respective first and second cranks, said first and second cranks rotating about a common crank pin and said crank pin being integrally formed with a primary crank, said primary crank rotating about a third axis orthogonal to said first and second axes, said first and second cranks having a radius of throw from said primary crank equal to the radius of throw of said primary crank from said third axis, wherein each said piston pair are formed integrally with and extend in opposite directions from a central piston body, said central piston body being formed with guide wheels for engaging guide rails formed within an engine block whereby said central piston body and said pistons may reciprocate within associated cylinders, and wherein each said central piston body is formed with an aperture for receiving the respective crank of the other said piston pair.

2. An engine as claimed in claim **1** wherein a counter-balancing weight is provided opposite from said primary crank for rotation about said third axis.

3. An engine as claimed in claim **1** wherein said engine is a four-cylinder engine having two pairs of cylinders disposed on two orthogonally disposed axes.

4. An engine as claimed in claim **1** wherein said engine is an eight-cylinder engine having four pairs of cylinders, said cylinders being disposed in two groups of four, said two groups being disposed in parallel planes and mutually orthogonal pairs within each said plane.

5. An engine as claimed in claim **1** wherein said cylinders are formed of ceramic material.

6. An engine as claimed in claim **5** wherein said cylinders are pre-stressed.

7. An engine as claimed in claim **6** wherein each said cylinder is formed with an at least partially tapered external surface, and wherein an annular surrounding member is provided with an internal surface tapered in an opposite sense to said tapered external surface of said cylinder, and wherein urging means are provided for urging said surrounding member such that said tapered surfaces are brought into engagement to generate a radially inwardly directed force.

8. An engine as claimed in claim **7** wherein said urging means comprises spring means.

9. An engine as claimed in claim **7** wherein an annular locking member is provided surrounding a second tapered external surface of said cylinder, said locking member having an internal tapered surface of an opposite sense to the second tapered external surface of said cylinder.

10. An engine having four pairs of pistons and cylinders, said four pairs being grouped into two groups of two pairs in each group, the piston and cylinder pairs in each group being disposed on mutually orthogonal first and second axes and being driven by first and second cranks respectively, said first and second cranks rotating about a common crank pin and said crank pin and said crank pin being integrally formed with a primary crank, said primary crank rotating about a third axis orthogonal to the first and second axes and comprising three interconnecting sections, junctions between said three sections defining spaces for receiving the respective first and second cranks of said two groups of pistons and cylinders, each said first and second crank having a radius of throw from said primary crank equal to the radius of throw of said primary crank from said third axis, and a counterbalancing weight being provided at each junction opposite said primary crank, wherein each said piston pair are formed integrally with and extend in opposite directions from a central piston body, said central piston body being formed with guide wheels for engaging guide rails formed within an engine block whereby said central piston body and said pistons may reciprocate within associated cylinders, and wherein each said central piston body is formed with an aperture for receiving the respective crank of the other said piston pair of said group.

11. A cylinder for an engine wherein said cylinder is formed of ceramic material, and wherein said cylinder has an external surface having two portions tapering in opposite senses, and wherein an annular surrounding member having an internal surface tapering in an opposite sense to a first of said two portions surrounds said first of said two portions, and wherein urging means acts upon said surrounding member whereby the tapering internal surface of said surrounding member and said first tapering portion of said external surface of said cylinder are brought together to generate a radially inwardly directed force, and wherein an annular locking member surrounds said second tapering portion of the external surface of said cylinder and having an internal tapering surface of opposite sense to the said second tapering portion.

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