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(54) **Linear-to-rotary motion converter utilizing reciprocating pistons**

(57) Four reciprocating pistons 20 arranged in pairs at right angles have connecting rods 22 jointly connected via a floating crankshaft 24 to output shafts 42, 44, reciprocation of the pistons 20 jointly effecting rotation of the output shafts 42, 44 via the floating crankshaft 24.

Fig.2.

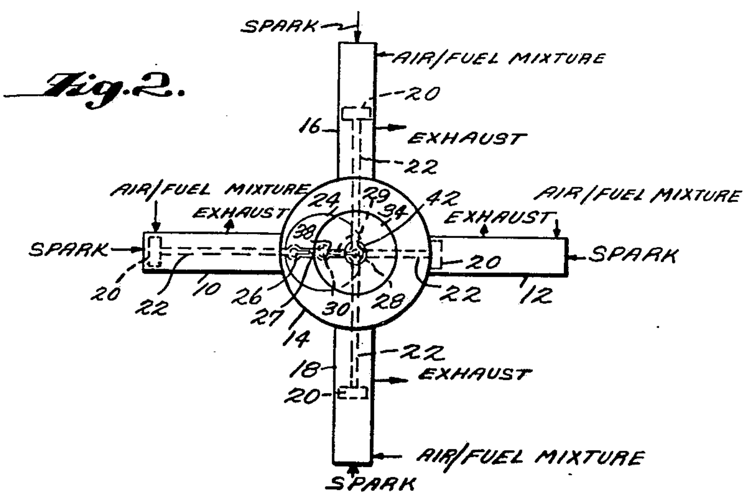

Fig.3.

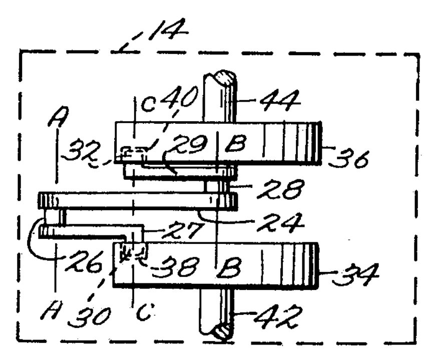

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Fig.1.

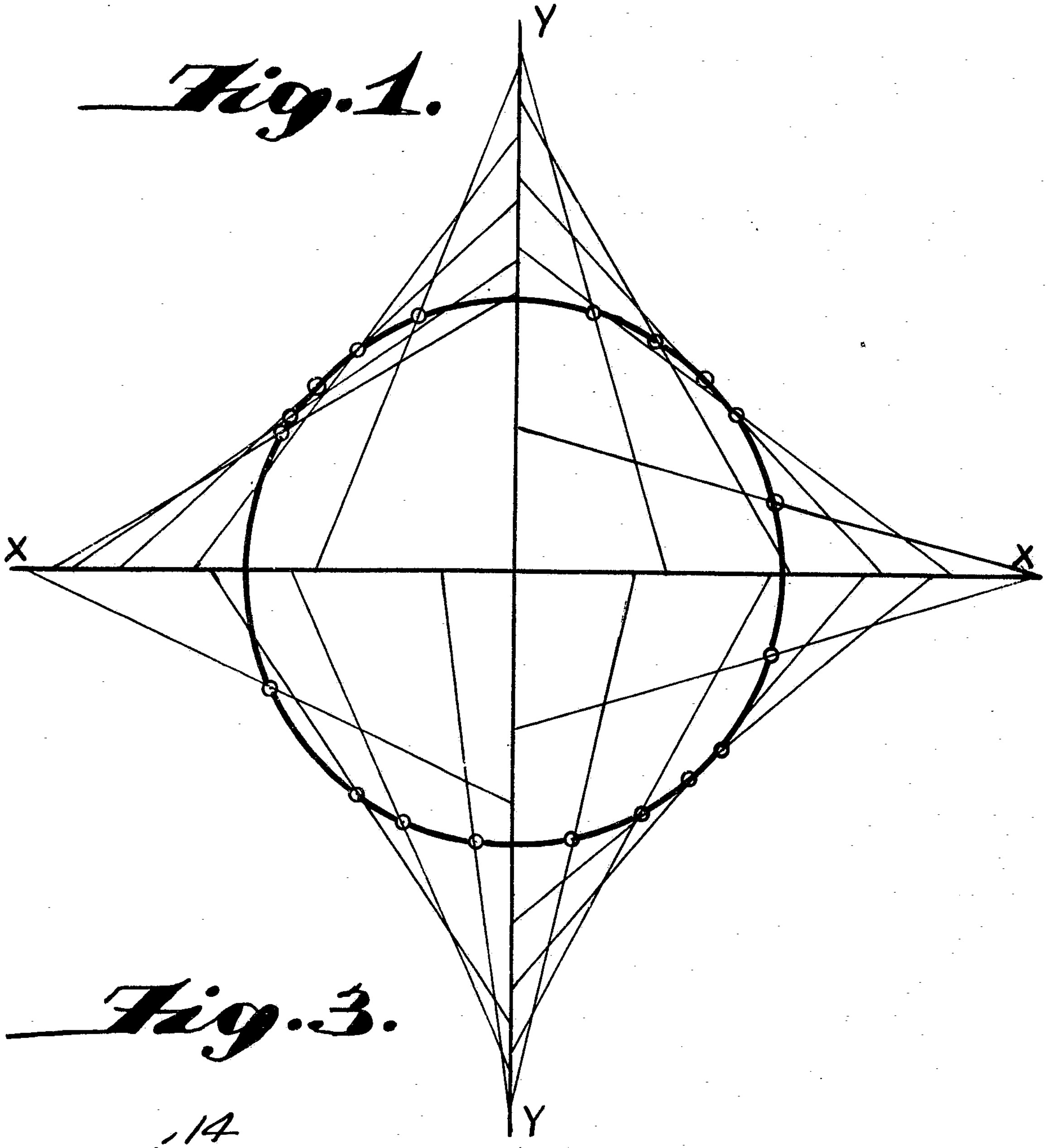
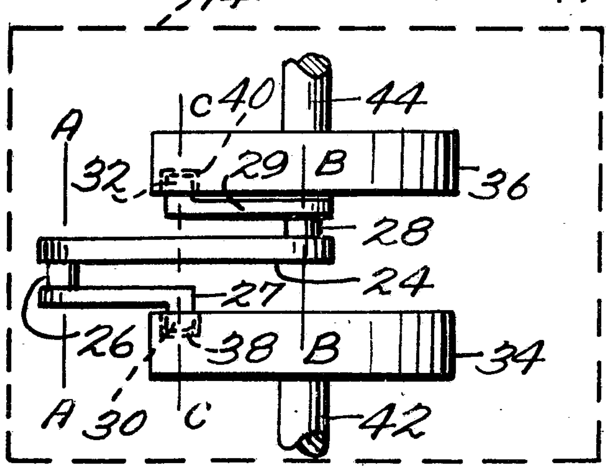


Fig.3.



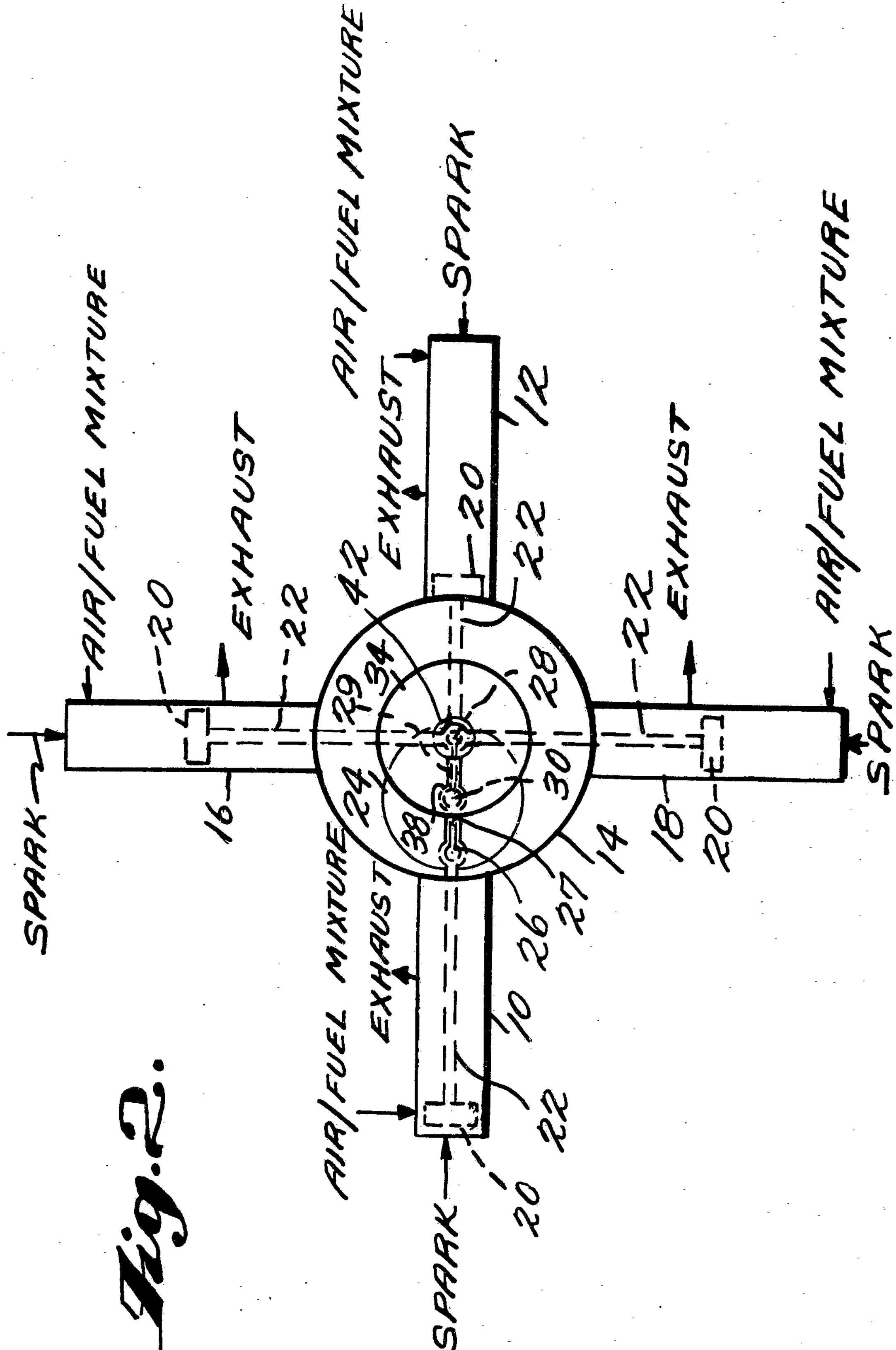

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Fig. 2.

SPECIFICATION

Linear-to-rotary motion converter utilizing reciprocating pistons

BACKGROUND OF THE INVENTION

Linear-to-rotary motion converters previously have been proposed which utilize the hypocycloid principle. An example of such a device is described in United States Patent 4,121,422 entitled "Power Plant" which was granted to the applicant on Octover 24, 1978.

Additionally, the hypocycloid principle has been employed in steam engines and in various motion converters. These are described in:

U.S. Patent 2,023,250, issued to Jacob Stalder on December 3, 1935;

U.S. Patent 2,309,047, issued to William J. Culbertson on January 19, 1943;

An article entitled "Matthew Murray's Q.E.D. With Steam" by T. E. Bristol, appearing in the February 7, 1963 issue of *Model Engineer*; and

"Ingenious Mechanisms For Designers and Inventors" published by The Industrial Press, 10th printing — 1954, pp. 288—293.

In each of the examples just cited, an internal ring gear and a cooperating pinion are employed to effect hypocycloidic movement. Such an arrangement is complex and expensive, inasmuch as precisely dimensioned gears are required to achieve the proper dimensional relationships between components which is essential to achieve correct motion in accordance with the hypocycloid principle.

The present invention is an improved converter which eliminates gear arrangements previously employed in hypocycloidic devices. The result is a simple, inexpensive converter construction which lends itself to multicylinder radial construction.

SUMMARY OF THE INVENTION

In accordance with one embodiment of the invention disclosed in detail hereinafter, a first pair of axially aligned cylinders are disposed on opposite sides of a sealed casing, and a second axially aligned cylinder pair are similarly oriented with respect to the casing, but displaced 90° from the first pair. Piston rods from pistons in the first cylinder pair are journalled to a first point on one side of a first movable element located within the casing, and the rods from pistons in the second cylinder pair are journalled to a second point on the opposite side of the movable element the second point being laterally spaced from the first one. A connecting link secured to the first point is pivotally connected to a second element within the casing, the axis of the pivotal connection passing through a point at the centroid of the first element, and an output shaft is connected to the second element with its axis extending normal to the paths of movement of the piston rods and passing through the location at which the paths overlap one another as the aforesaid first and second points are reciprocated by movement of the pistons. By such an arrangement, the reciprocating pistons produce rotation of the output shaft.

Particulars of the invention are more fully described in the following detailed description and are shown in the accompanying drawings wherein:

FIGURE 1 is a diagram illustrating the principle of reciprocating-to-rotary motion conversion utilized in the present invention;

FIGURE 2 is a side elevational view schematically illustrating one embodiment of a linear-to-rotary motion converter according to the invention; and

FIGURE 3 is a top plan view of a portion of the converter illustrated in FIGURE 2.

DETAILED DESCRIPTION OF THE INVENTION

In order to obtain an appreciation of how the invention functions, Figure 1 has been presented to illustrate one application of the principle involved. The diagram illustrates an arrangement whereby opposite ends of a straight line of a given length are moved along respective orthogonal axes, designated X and Y. It will be observed that when the straight line is placed in various positions, the center points of the lines described a circular locus. Consequently, if it is assumed that the straight lines represent a structural element having spaced points which are reciprocated at right angles to one another, and further assuming that the center point is joined to an additional structural element rotatable about an axis extending normal to the paths of reciprocation of the two reciprocating points and through the point where their paths over lap, the reciprocation of the first element is converted to rotation of the second element.

In the arrangement just described, the paths of reciprocation are at right angles to one another. However, it should also be appreciated that if the corners of a polygon are constrained to reciprocate in suitably inclined straight lines, the centroid of the polygon moves in a circular path. Since each straight line movement of the polygon's corners may represent the path of movement of a piston rod associated with a separate cylinder-housed piston, if the centroid of the polygon is connected to a rotatable structural element, a converter having three or more cylinders may be constructed to produce a rotary output.

Referring now to Figures 2 and 3, the application of the principle discussed with respect to Figure 1 will be described with respect to an illustrative embodiment of a new and improved linear-to-rotary motion converter.

The converter comprises a first pair of axially aligned cylinders 10 and 12 extending from opposite sides of a generally cylindrically shaped sealed casing 14 having an axis substantially perpendicular to the common axis of cylinders 10 and 12. A second pair of axially aligned cylinders 16 and 18 are similarly disposed on opposite sides of casing 14 with their common axis disposed at an angle of 90° from that of the cylinders 10 and 12 and also at right angles to the axis of casing

14. Consequently, the axes of the cylinder pairs generally correspond in orientation to the orthogonal axes and X and Y of Figure 1. Each cylinder includes a piston 20 and a piston rod 22. Rods 22 pass through sealed apertures in casing 14 to terminate within the casing.

The end of casing 14 has been removed in Figure 2 to expose structure positioned within the casing. This structure includes a disk 24. On one side of the disk, along an axis A (Fig. 3) parallel to that of casing 4, a projection 26 extends from the disk. A similar projection 28 extends from the opposite side of the disk along an axis B (Fig. 3) parallel to axis A. Axes A and B are separated by a desired distance.

As can be seen in Figure 2, the piston rods 22 associated with cylinders 10 and 12 are journalled to projection 26, and the rods 22 connected to the pistons within cylinders 16 and 18 are journalled to projection 28. (For convenience of illustration, the cylinders, pistons and rods have been omitted in Figure 3, and the casing 14 has been shown in broken lines.(Thus, when the piston rods reciprocate, the projections 26 and 28 move in respective paths which are at right angles, but which do not intersect.

An additional pair of disks 34 and 36 are positioned on opposite sides of disk 24. A first connecting link 27 is secured at one of its ends to the outer end of the projection 26 extending from disk 24. The opposite end of link 27 is provided with a projection 30 which extends into a mating recess 38 in disk 34. A second connecting link 29 is fixed at one of its ends to the outer end of the projection 28 from disk 24, and the opposite end of link 29 also is provided with a projection 32 which is received within a mating recess 40 in disk 36. The projections 30 and 32 are aligned along an axis C (Fig. 3) parallel to, and midway between, axes A and B. It is apparent, therefore, that disk 24 and its projections 26 and 28 operate as a two-throw crankshaft orbiting about an axis parallel to the centroid of the disk with the throw equal to eccentricity, thereby allowing projections 26 and 28 to move in straight lines instead of circles.

The disks 34 and 36 also support output shafts 42 and 44 which are positioned in axial alignment, their common axis extending normal to the paths of movement of projections 26 and 28 and passing through the location where the paths overlap. The shafts 42 and 44 are supported by suitable bearings (not shown) in the casing 14.

A converter of the type which has been described can be utilized for a variety of purposes. For example, it is envisioned that the converter may be adapted for use as a compressor, air motor, steam engine, pump, or internal combustion engine. The arrangement illustrated in Figure 2 generally indicates application of the converter as an internal combustion engine wherein an air-fuel mixture is supplied to the ends of cylinders 10, 12, 14 and 16 adjacent to spark plugs. Each cylinder is provided with an exhaust to release the combustion gases after the pistons 20 have completed a substantial portion of their power strokes. In the arrangement disclosed, a two-stroke operation is performed. The timing of fuel introduction and exhausting arrangements which may employed are well-known in the art and need not be described in detail. However, it should be pointed out that the stroke of each piston is identical, and the firing order is such that when the piston in one cylinder of a pair reaches its firing position, the piston in the other cylinder of the pair is at the end of its stroke. At this time, the two pistons of the other cylinder pair are midway in their strokes, one heading towards compression and the other towards exhaust. Such an arrangement in shown in Figure 2.

With the arrangement just described, it is apparent that the reciprocating movement of projection 26 along the axes of the piston rods associated with cylinders 10 and 12, and the movement of projection 28 along the axes of the piston rods associated with cylinders 16 and 18, correspond with the Fig. 1 description, wherein the ends of the straight lines move along respective ones of the orthogonal X and Y axes. Consequently, the projections 30 and 32 describe circular loci about an axis through the location where the paths of projections 26 and 28 overlap. Since the aligned axes of shafts 42 and 44 pass through this location and are normal to the reciprocating paths of the projections, the shafts rotate. Thus, the reciprocating action of the pistons is converted into rotation of the output shafts.

The foregoing description is of a preferred embodiment of the invention. However it is apparent that a number of variations are possible. For example, instead of using two cylinder pairs, it is possible to employ only a single pair. In such an arrangement, it then is necessary to position within a suitable slot or track that projection 26 or 28 which is not joined to pistons. Such a slot or track would be oriented orthogonally with respect to the axis along which the piston-driven projection moves.

With arrangements involving a plurality of cylinder pairs aligned along axes angularly related to one another, the replacement of one of the cylinders of a pair by a slot or track, as just described, permits the construction of linear-to-rotary motion converters with odd numbers of cylinders.

The elements 24, 34 and 36 are described as disks. However, it is unnecessary that these elements be so configured. In the case of disk 24, other configurations are possible provided that the element is able to support projections 26 and 28 at spaced points. Similarly, elements 34 and 36 need not be disks so long as they are capable of being operatively related to their associated projections 30 and 32 and can support an output shaft along an axis positioned as described previously.

In the embodiment which has been disclosed herein, a pair of output shafts are employed.

These may be used in driving the same or different components or they may be connected by a jack shaft to balance the load on the two sides of the converter. It will be appreciated that, if desired, only a single projection 32, disk 34, and output shaft 42 can be utilized.

With the arrangement which has been described, the casing 14 is completely sealed from the cylinders. All bearings within it are continuously lubricated by a pressure pump, scavenge pump and/or oil sump in a known manner without contamination of the lubricant. Similarly, the lubricant cannot escape to contaminate the environment beyond the casing.

The use of the converter in an engine as mentioned during the description of the preferred embodiment of the invention contemplates two-stroke operation. However, the engine may also be operated in a four-stroke manner. This may be accomplished by arranging for the engine to drive a valve gear in a manner well known to persons skilled in the art of engine design.

With respect to the internal combustion engine embodiment discussed above, it has been pointed out that the working space under each piston is completely sealed from the common casing 14. Consequently, compression within the working space may be utilized to recharge its own or another cylinder with fresh explosive mixture without the contamination problems experienced with common two-stroke engines employing crankcase compression as a means of recharging the working cylinder.

Recharging another cylinder also can improve the phase relation between the working piston and the charging piston, which, in a conventional crankcase charged two-stroke engine, is limited to 180°.

In four-stroke working, the underside of each piston, sealed in the manner described and making two pumping strokes for each induction stroke, may be used to supercharge the engine either by combining the output of several cylinders into a common receiver or by arranging for each cylinder to charge itself separately.

Additionally, when the linear-to-rotary motion converter is used in a stream, compressed air or four stroke engine, or in a pump or compressor, the underside of the piston may also be used as a working space and the device operated in a double-acting mode in a manner well known to persons versed in the art. Also, such applications of the converter may incorporate pistons of different sizes in the same cylinder or of different sizes in different cylinders to obtain compound or multi-stage expansion and compression.

Further in regard to the illustrative embodiments described with respect to Figures 2 and 3, the connecting links 27 and 29 are described as being pivotally connected to disks 34 and 36, respectively. However, it should be appreciated that to perform an identically equivalent function, the disks may instead be gears engaged by teeth machined in the projections 30 and 32 of links 27 and 29, respectively, so as to effect rotation of disks 34 and 36 in response to the movement of the connecting links. In this case, the axes of the connections which pass through a point located at the centroid of the movable element 24 would be the central axes of the projections 30 and 32.

CLAIMS

1. A linear-to-rotary motion converter comprising:

a sealed casing;

a cylinder positioned in juxtaposition with said casing;

a piston located within said cylinder;

a piston rod joined to said piston, said rod passing through one end of the cylinder and through a sealed aperture in said casing;

a first movable element position within said casing;

means pivotally connecting an end of the piston rod within said casing to a first point on said movable element;

means for reciprocating the piston, the piston rod and said first point on the movable element in a first path;

means operably joined to a second point on said movable element for causing said second point to reciprocate in a second path angularly related to the first path during reciprocal movement of the first point whereby said first and second paths intersect a common axis to which the paths are normal, the intersection of the paths respectively occurring at points spaced along the axis;

connecting means secured to said first point and pivotally connected to a second movable element about an axis which is parallel to said common axis and which passes through a point located at the centroid of said first element; and

an output shaft fixed to the second movable element, said shaft having an axis of rotation lying along said common axis.

2. A linear-to-rotary motion converter as set forth in claim 1, further comprising:

a second cylinder positioned in juxtaposition with said casing on the opposite said thereof from the first-mentioned cylinder, whereby said cylinders are in axial alignment;

a second piston located within the second cylinder;

a second piston rod joined to the second piston, said rod passing through one end of the second cylinder and through a second sealed aperture in the casing; and

means pivotally connecting an end of the second piston rod within the casing to said first point on the movable element.

3. A linear-to-rotary motion converter as set forth in claim 2, further comprising additional reciprocating means for reciprocating the second piston and piston rod in cooperative relationship with the reciprocation of the first-mentioned piston and piston rod.

4. A linear-to-rotary motion converter as set forth in claim 3, wherein said means for

reciprocating the first and second pistons and piston rods comprise fuel combustion means located at ends of the respective cylinders opposite said one ends thereof.

5. A linear-to-rotary motion converter as set forth in claim 4, further comprising means for selectively connecting the space within a cylinder adjacent its one end to the opposite end of a cylinder for charging the latter cylinder prior to combustion.

6. A linear-to-rotary motion converter as set forth in any one of the preceding claims, wherein the second path, in which said second point moves, is normal to the first path, in which said first point moves.

7. A linear-to-rotary motion converter as set forth in any one of the preceding claims, wherein said means for causing the second point to reciprocate comprises:

an additional cylinder positioned in juxtaposition with said casing, said cylinder having a major axis disposed with respect to the major axis of the first-mentioned cylinder at an angle corresponding to the angular relationship of said first and second paths;

a piston located within said additional cylinder;

a piston rod joined to the piston in the additional cylinder, said rod passing through one end of its associated cylinder and through an additional sealed aperture in said casing; and

means pivotally connecting an end of the piston rod associated with the additional cylinder to said second point on the movable element.

8. A linear-to-rotary motion converter as set forth in claim 7, wherein said means for reciprocating the first and second points on the movable element comprises fuel combustion means located at ends of the respective cylinders opposite said one ends thereof.

9. A linear-to-rotary motion converter as set forth in claim 8, further comprising means for selectively connecting the space within a cylinder adjacent its one end to the opposite end of a cylinder for charging the latter cylinder prior to combustion.

10. A linear-to-rotary motion converter as set forth in any one of the preceding claims, further comprising:

additional connecting means secured to said second point and pivotally connected to a third movable element about an axis which is aligned with that of the pivotal connection of the first-mentioned connecting means to the second movable element; and

an additional output shaft fixed to the third movable element, said additional shaft having an axis of rotation lying along said common axis.

11. A linear-to-rotary motion converter comprising:

a sealed casing;

a plurality of pairs of axially aligned cylinders, each cylinder of a pair being positioned in juxtaposition with said casing on opposite sides thereof, the cylinder pairs being displaced angularly with respect to one another about a common axis to which the cylinder axes are all normal, and the cylinder pairs being displaced with respect to one another along the common axis whereby the axis of each pair intersects the common axis at a different point;

a piston located within each of the cylinders;

a piston rod joined to each piston, each rod passing through one end of its associated cylinder and through a sealed aperture in said casing;

means for reciprocating pistons and piston rods along the axes of their respective cylinders;

a first movable element within said casing comprising a crankshaft with as many throws as there are pairs of cylinders;

means for pivotally connecting the ends of the piston rods associated with the respective pairs of cylinders to a corresponding number of separate points on said movable element to effect said throws when the piston rods are reciprocated;

a second movable element;

an output shaft fixed to the second movable element, said shaft having an axis of rotation lying along said common axis; and

connecting means secured to one of said separate points and pivotally connected to the second movable element about an axis which is eccentric to the axis of rotation by an amount equal to the crank throw.

12. A linear-to-rotary motion converter as set forth in claim 11, further comprising:

a third movable element;

an additional output shaft fixed to the third movable element, said additional shaft having an axis of rotation lying along said common axis; and

additional connecting means secured to another of said separate points on the first movable element and pivotally connected to the third movable element about an axis which is aligned with that of the pivotal connection of the first-mentioned connecting means to the second movable element.

13. A linear-to-rotary motion converter as set forth in claim 11 or 12, wherein said means for reciprocating the pistons and piston rods comprises fuel combustion means located at ends of the respective cylinders opposite said one ends thereof.

14. A linear-to-rotary motion converter as set forth in claim 13, further comprising means for selectively connecting the space within a cylinder adjacent its one end to the opposite end of a cylinder for charging the latter cylinder prior to combustion.

15. A linear-to-rotary motion converter substantially as herein described with reference to the accompanying drawings.

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