July 2, 1935. W. H. STONE 2,006,372

ENGINE

Filed July 9, 1932 3 Sheets-Sheet 1

Fig. 1

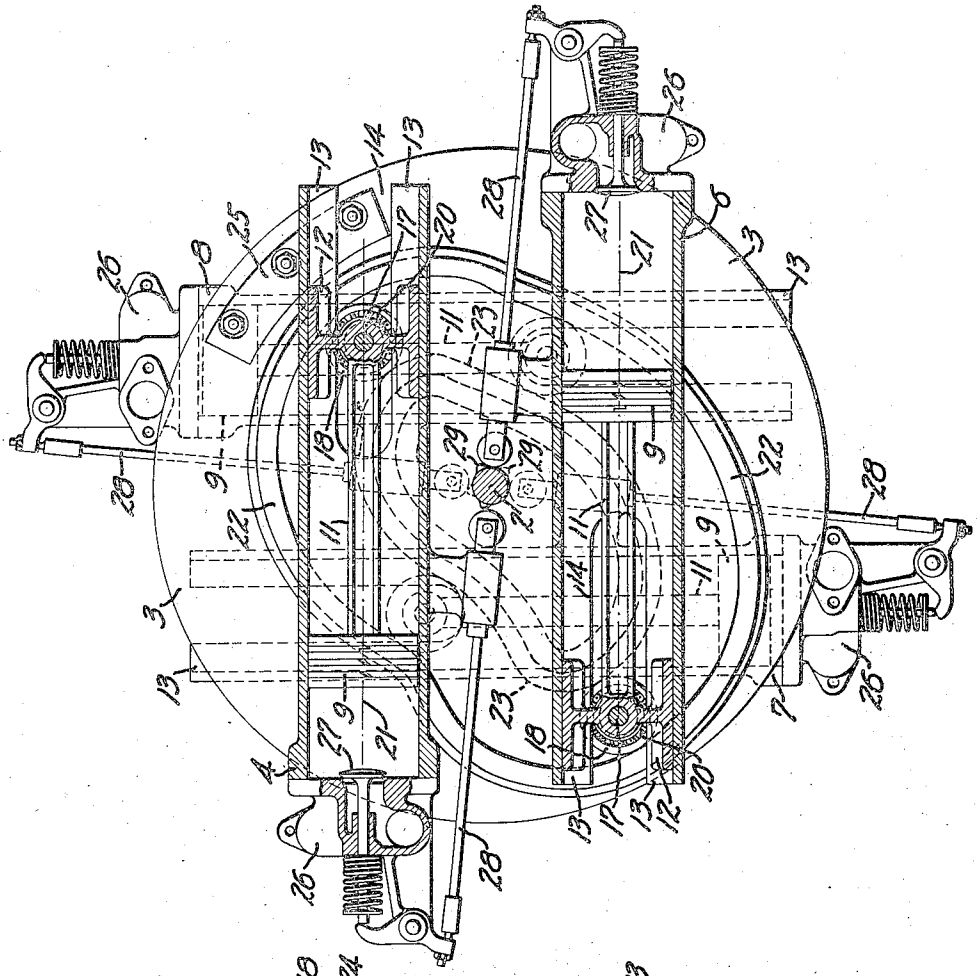
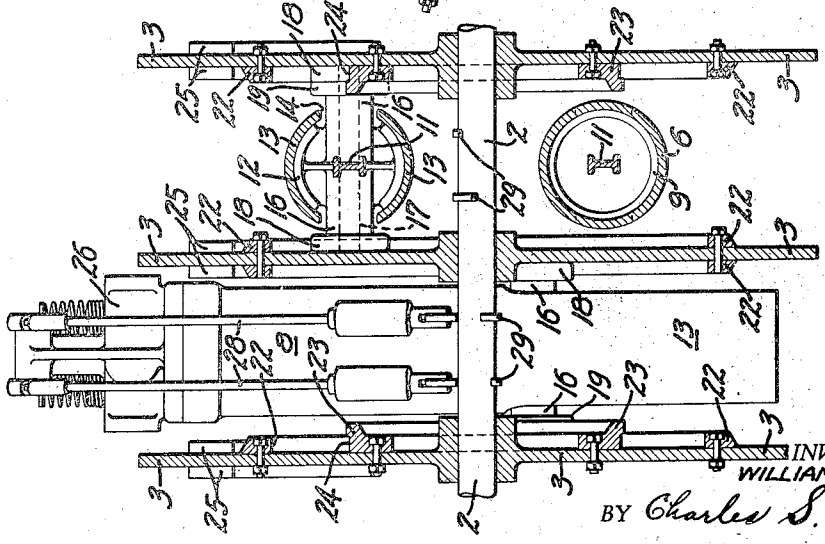


Fig. 2



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Filed July 9, 1932 3 Sheets-Sheet 2

Fig. 3

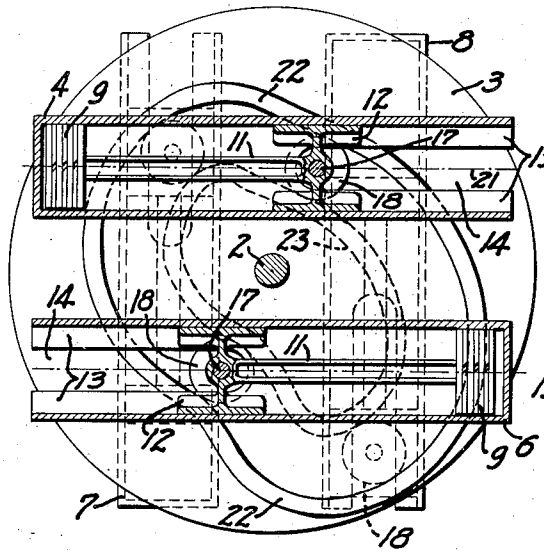


Fig. 4

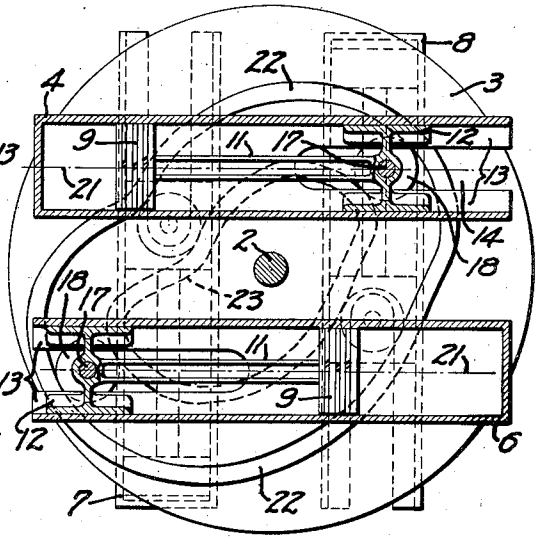


Fig. 5

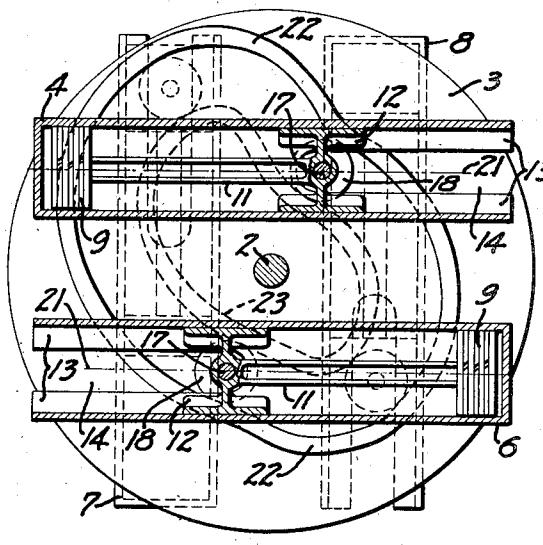
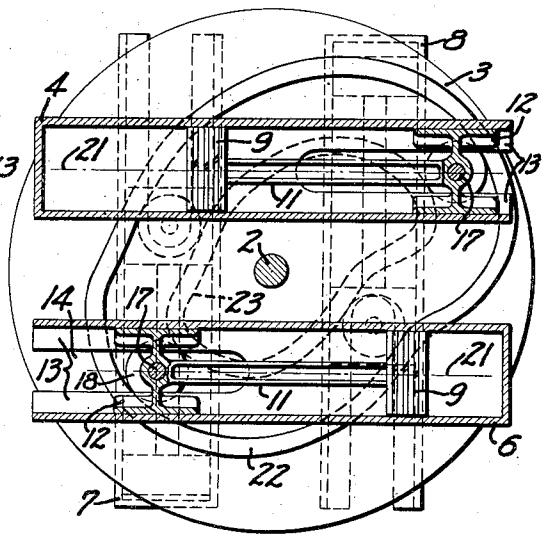


Fig. 6



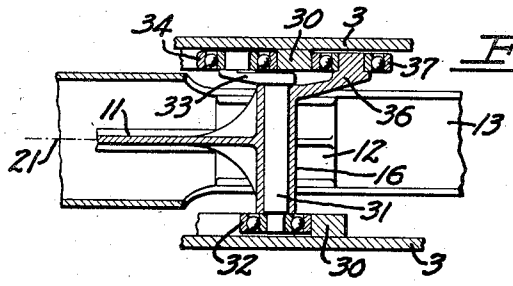


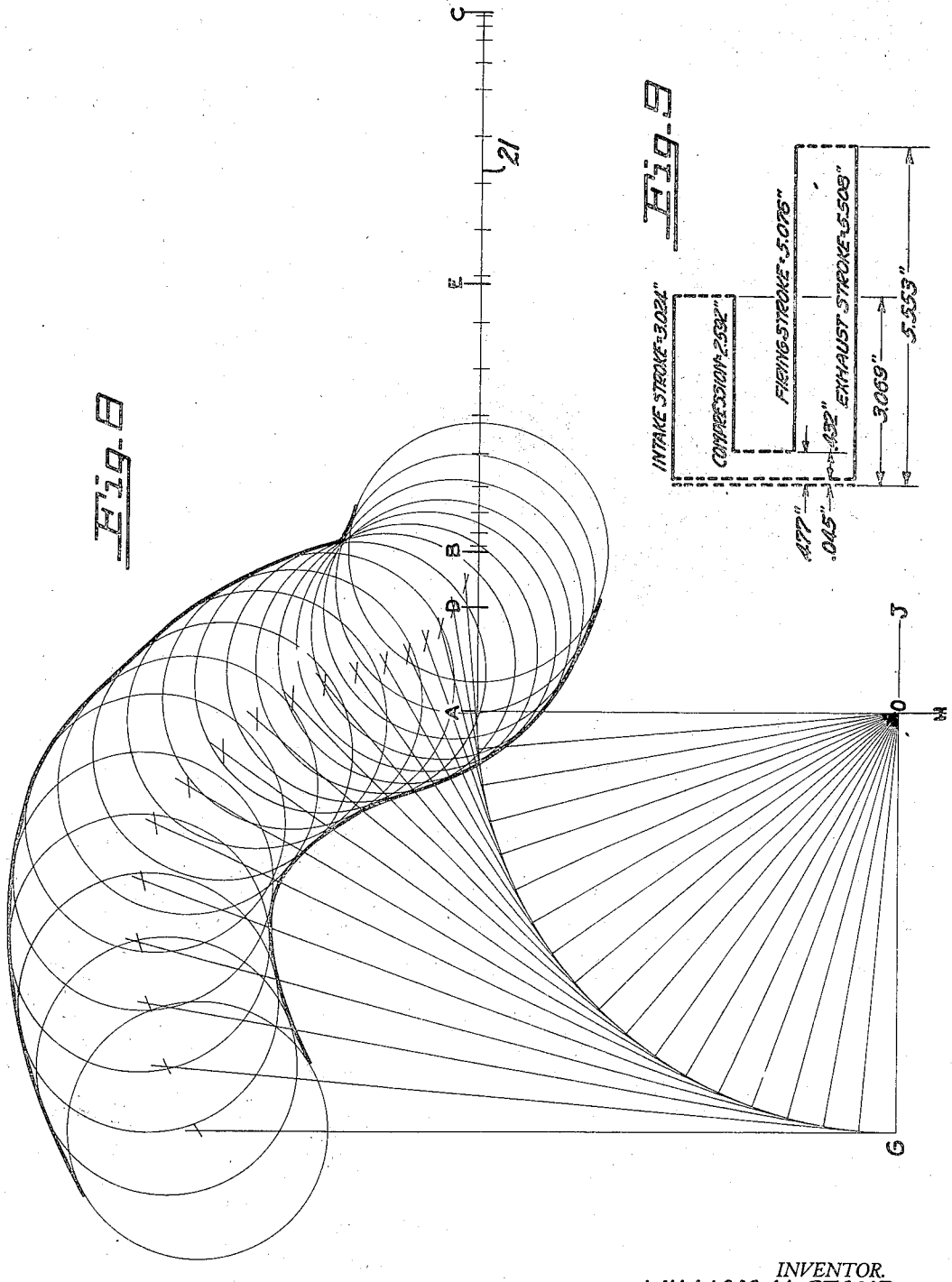
Fig. 7

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ENGINE

Filed July 9, 1932 3 Sheets-Sheet 3



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Patented July 2, 1935 2,006,372

UNITED STATES PATENT OFFICE

2,006,372

ENGINE

William H. Stone, Santa Barbara, Calif.

Application July 9, 1932, Serial No. 621,554

1 Claim. (Cl. 74—55)

The broad object of my invention is to provide an engine in which a greater amount of the energy available at the piston is converted into useful work than is possible in the ordinary motor of present design.

It is among the more specific objects of my invention to provide an engine in which the reciprocating motion of the piston is translated into a rotary motion of the driven shaft without involving the usual crank shaft dead centers.

Another object of my invention is to provide an engine in which the energy available at the piston is applied to the driven shaft as a torque acting with a substantially constant lever arm, instead of a torque acting with a lever arm which varies from zero to the length of the crank arm as in the usual crank shaft motor.

Another object of my invention is to provide an internal combustion engine in which the piston strokes may be of different length, so that a motor design may be effected in which the expansion ratio is greater than the compression ratio.

Another object of my invention is to provide an engine of the character described which is capable of higher piston speeds with respect to driven or crank shaft speeds than is possible with the ordinary motors of present design.

Another object of my invention is to provide an engine which permits a more rapid and complete expansion of the gases under combustion, so as to effect less loss of power in exhaust and radiation.

Another object of my invention is to provide an engine which is capable of and able to maintain a better mechanical balance than the crank shaft type of motor.

Still another object of my invention is to provide an engine in which the mechanical causes of piston slaps and detonation knocks are largely eliminated.

A further object of my invention is to provide an internal combustion engine whose operation approaches that of a constant torque motor.

A still further object of my invention is to accomplish the above objects by an engine which is more compact in structure, lighter in weight, possesses fewer working parts, and which operates with less noise and vibration than the ordinary internal combustion motor.

The invention possesses other objects and features of advantage, some of which, with the foregoing, will be set forth in the following description of my invention. It is to be understood that I do not limit myself to this disclosure of species of my invention, as I may adopt variant embodiments thereof within the scope of the claim.

Referring to the drawings:

Figure 1 is a vertical sectional view showing an engine embodying my invention; the plane of section being taken transversely of the driven shaft and through the center lines of the two forward cylinders, except at the heads of the cylinders where the plane is brought forward to the axis of one of the valve shanks.

Figure 2 is a vertical sectional view of the same taken in a plane passing through the driven shaft axis and at right angles to the center lines of the two forward cylinders shown in Figure 1.

Figures 3 to 6 are vertical sectional views, largely diagrammatic, taken in a plane transversely of the driven shaft and through the center lines of the two forward cylinders; these views showing the relation between the pistons and the track at the beginning of the several strokes.

Figure 7 is a transverse vertical sectional view taken in a plane through the axis of the cylinder, and illustrates a variant form of track and engaging element construction.

Figure 8 is a diagrammatic view showing the manner in which the track is laid out for the firing stroke.

Figure 9 is a diagrammatic view showing the relation between the various strokes of a piston.

In terms of broad inclusion, the engine embodying my invention comprises a shaft having an endless track mounted for rotation therewith. A track-engaging element is provided, and guide means are provided for limiting movement of the element along an axis spaced from the shaft axis. Means are also preferably provided for moving the track-engaging element; the track being preferably designed to accord with a reciprocating motion of its engaging element. The means for moving the track-engaging element preferably comprises a cylinder having a piston working therein, together with means connecting the track-engaging element for movement with the piston.

By this mechanism the reciprocating motion of the piston is translated into a rotary motion of the shaft without involving the usual crank shaft dead centers, and the energy available at the piston is applied to the shaft as a torque acting with a substantially constant lever arm. When the mechanism is incorporated in an internal combustion engine the track is preferably designed to accord with piston strokes of varying lengths. Preferably the design is such that the firing stroke is longer than compression stroke to give an expansion ratio greater than the compression ratio. In a four cycle engine the track is preferably designed to complete the four cycles in one revolution of the shaft.

In greater detail, the engine embodying my invention is described as a four cycle internal combustion engine in which the four cycles are completed in one revolution of the shaft being driven, and in which the strokes of a cycle are of different lengths. It is to be understood however that this particular embodiment of my invention is

shown merely for purposes of illustration in order to show the various features of my improved mechanism. Referring particularly to Figures 1 and 2, the engine comprises a straight shaft 2 which replaces the ordinary crank shaft. A plurality of spaced driving disks 3 are mounted on the shaft 2; in the four cylinder motor shown there are preferably three of these disks.

The cylinders are positioned on opposite sides of the shaft 2 being driven, and two of the cylinders, 4 and 6, are arranged between one pair of the disks 3, while the other two cylinders, 7 and 8, are arranged between the other pair of disks. The cylinders in a pair are arranged substantially parallel and are positioned with their heads extending in opposite directions. Also, the cylinders in one pair are preferably positioned at substantally right angles to the cylinders in the other pair. This arrangement of the cylinders is probably best shown in Figure 1.

Each cylinder is provided with a piston 9 fixed on the end of a connecting rod 11. The outer end of each rod is connected with a crosshead 12 slidably arranged in the guideways 13. The crosshead 12 is preferably circular in shape and the guideways 13 are preferably formed as extensions of the cylinder walls, the slot-like openings 14 being provided between the guideways to allow passage of projecting portions 16 of the crosshead. A shaft 17 is mounted in the tubular portions 16 of the crosshead 12 and carries adjacent the ends thereof a pair of rollers 18 positioned adjacent the opposing surfaces of the driving disks 3.

A third roller 19 is also mounted on the shaft 17 and is positioned alongside the outer roller 18. These rollers are freely journaled on suitable bearings, such as the ball bearings 20. By this arrangement it is apparent that the crosshead 12 and consequently the rollers 18 and 19 are connected for reciprocation with the piston 19, and are limited in their movement to a path along an axis 21 which is spaced from the shaft axis at all points.

A track is mounted on and disposed circumferentially of the driven shaft 2. This track is mounted on the driving disks 3, and is in the nature of matched track sections 22 suitably secured to opposing faces of the driving disks and along the inside of which the rollers 18 are adapted to ride. Another track section 23 is also provided on the inner face of each outer driving disk, on the outer side of which the inner rollers 19 are adapted to ride. The track sections 23 are provided with a recessed peripheral portion 24 in order to clear the rollers 18.

The general shape of the preferred track is shown in Figure 1, and it is to be noted that there are four operating portions; one for the intake stroke, another for the compression stroke, another for the firing stroke and still another for the exhaust stroke. The design of the track and the arrangement of the cylinders and pistons is such that each of the four pistons is operating in a different stroke and on a different operating portion of the track at a given time. In the set-up shown in Figure 1 it happens that the piston of cylinder 8 is about to begin its intake stroke, the piston of cylinder 4 is about to begin its compression stroke, the piston of cylinder 7 is about to begin the firing stroke, and the piston of cylinder 6 is about to begin its exhaust stroke; the shaft 2 being rotated in a clockwise direction. Suitable counterweights 25 are mounted on the driving disks 3 in order to balance the system.

It is to be noted that during the compression, firing and exhaust strokes the track engaging elements or rollers 18 are driving against the outer track sections 22, and that during the intake stroke the piston is moved by the action of the track engaging element or roller 19 bearing against the inner track sections 23. This accounts for the double construction as indicated by the pairs of rollers 18 and the lighter construction as indicated by the single roller 19.

An important feature of the mechanism resides in the fact that the track engaging elements move in a path along the axis 21 which is spaced from the shaft axis at all points. By this arrangement the reciprocating motion of the piston is translated into a rotary motion of the shaft 2 without involving the usual crank shaft dead centers, and the energy available at the piston is applied to the shaft as a torque acting with a substantially constant lever arm; viz., the force of the piston acts along the line 21 which is fixed with respect to the shaft axis so that the perpendicular distance between the line 21 and the shaft axis is constant.

The cylinder heads 26 have the usual spring pressed intake and exhaust valves 27, and in my machine are actuated by suitable push rods 28 operated by cams 29 mounted directly on the shaft 2 being driven. This is possible because the four cycles are completed in one revolution of the shaft 2, and there is consequently no need of a cam shaft operating at half speed as required in the ordinary four cycle engine.

By the mechanism shown in Figure 1 it will be observed that power is being applied to the driven shaft 2 throughout its entire revolution. The firing strokes of the respective cylinders follow in succession, each operating during 90 degrees of rotation of the shaft 2. In other words, the operation of the engine approaches that of a constant torque motor. It is thus seen that the four cylinders in this design will give the the same number of power impulses as any ordinary eight cylinder four cycle motor of the present design. One of the advantages of my engine however is that the design leads to a compact arrangement and light weight; these features being particularly desirable in airplane work.

Another important feature of this particular design of my engine is the increased piston speed with respect to the crank shaft speed. In the present type of crank shaft motors, where the four cycles are completed in two revolutions of the crank shaft, the piston speeds are definitely limited to a point less than the speed limits of the expanding gases. This limitation comes in because of the fact that present crank shafts will not function properly above certain speeds. If these speeds are exceeded serious balancing and mechanical troubles arise. In the engine of my invention the piston speeds are materially increased without increasing the speed of the shaft being driven. Furthermore, the straight shaft eliminates many of the balancing troubles inherent in the present type of crank shaft construction. This furthers the possibilities of still higher piston speeds.

A further advantage of my design results from separating the crosshead and its guide from the hot portion of the cylinder, as compared with ordinary designs in which the piston per se functions as the crosshead. This leads to an increased oil efficiency and reduced friction. Thus, the limitations imposed on piston speeds by cylinder resistance in present designs is not as

great in the engine of my invention. Furthermore the separation of the crosshead from the piston makes it possible to flood the crosshead and guide with oil, and at the same time avoid oil pumping by the piston rings into the combustion chamber.

When the energy available at the piston is applied to the shaft as a torque acting with a constant lever arm, the power is not only increased, but the detonation knocks inherent in present designs are largely eliminated. This latter is true because in my mechanism the maximum lever arm is presented at the time of the explosion, and the piston does not have to drive against a dead center at this time as in the ordinary motor. My mechanism also eliminates piston slap, because the piston is rigid on the end of a piston rod which is parallel to the axis of the cylinder at all times.

The relation between the track, the several track engaging elements and the pistons at the beginning of the various cycles is best illustrated in Figures 3 to 6. In Figure 3 the piston of cylinder 4 is ready for its intake stroke, the piston of cylinder 7 is ready for its compression stroke, and the piston of cylinder 6 is ready for its firing stroke, while the piston of cylinder 8 is ready for its exhaust stroke; rotation of the shaft 2 being clockwise. Figure 4 shows the shaft and track turned through 90 degrees; with the piston of cylinder 4 now ready for its compression stroke, the piston of cylinder 7 ready for its firing stroke, the piston of cylinder 6 ready for its exhaust stroke and the piston of cylinder 8 ready for its intake stroke.

Figure 5 shows the shaft and track turned through another 90 degrees; with the piston of cylinder 4 ready for its firing stroke, the piston of cylinder 7 ready for its exhaust stroke, the piston of cylinder 6 ready for its intake stroke and the piston of cylinder 8 ready for its compression stroke. Figure 6 shows the shaft and track turned through another 90 degrees; with the piston of cylinder 4 ready for its exhaust stroke, the piston of cylinder 7 ready for its intake stroke, the piston of cylinder 6 ready for its compression stroke and the piston of cylinder 8 ready for its firing stroke.

After the shaft and track has turned through the last 90 degrees of the revolution the track and pistons will be in the position shown in Figure 3, and ready to repeat the series of cycles. It will be noted that the several strokes in the four cycles of a given piston are of different lengths, and that the firing stroke is materially longer than the compression stroke. This gives an expansion ratio greater than the compression ratio. In the design shown, taken merely for the purposes of illustration, the track was laid out to accord with strokes of the following lengths:

	Inches
Intake stroke	3.024
Compression stroke	2.592
Firing stroke	5.076
Exhaust stroke	5.508

The clearance between the piston and the cylinder head at the innermost limit of the piston movement was 0.45 inches. Figure 9 shows diagrammatically the above relation. Here it will be observed that the inner limit of the piston at the end of the compression stroke is spaced .432 inches from the inner limit of the piston at the beginning of the intake stroke. Thus, the chamber at the beginning of compression is 3.069 inches long and at the end of compression is .477 inches long, which gives a compression ratio of 3.069 divided by .477 or 6.433 to 1. The chamber at the beginning of the firing stroke is thus .477 inches long while at the end of expansion is 5.553 inches long, which gives an expansion ratio of 5.553 divided by .477 or 11.751 to 1.

The increased expansion ratio results in a more complete expansion of the gases during the power stroke, and permits the conversion of the lower pressures toward the end of the expansion into useful work, instead of being exhausted into the muffler as in present practice. This not only leads to more power and increased efficiency and economy, but also the exhaust gases will be at lower pressure and temperature. The lower pressures reduce the noise of exhaust, and the reduced temperature will largely eliminate the troubles now encountered with exhaust valves.

It is to be noted that the exhaust stroke of 5.508 inches brings the piston back to the clearance limit of .045 inches. This latter stroke thus operates to substantially completely scavenge the cylinder of the exhaust gases, which leads to better combustion of the succeeding intake gases. Furthermore, since the piston in the exhaust stroke passes through the center of the combustion chamber, carbon deposit is reduced.

Because of the variation that can be effected between the lengths of strokes, the compression ratio can be increased above ordinary practice, and this will result in an increased output of energy from the same amount of fuel, and will also permit a decrease in the difference in length between the power and exhaust strokes in my engine and at the same time scavenge the cylinder thoroughly. In ordinary internal combustion motors the ratio of piston travel during the firing stroke to the entire piston travel during the cycle is 1 to 4. In my design, above illustrated, this ratio is approximately 1 to 3. In present motors the ratio of piston travel during the firing stroke to the idle strokes during the cycle is 1 to 3. In my design this ratio is approximately 1 to 2. Considering the more complete scavengering and the increase possible in compression in the engine of my invention it is easily possble to get as much power out of my short intake stroke of 3.024 inches as in a present type motor with an intake stroke in the order of 5.508 inches, both engines having the same length of power stroke.

The design of the track is such that the several operating portions thereof will accord with slow starting and stopping movements of the piston at the beginning and end of each stroke. The operating portions of the track through the idle strokes are preferably uniformly accelerating for half their length and uniformly decelerating for the other half; while the operating portion in the power stroke is preferably a nearly constant speed curve, being uniformly accelerating and decelerating adjacent the ends only. This results in a silent operating track.

The design of the track portion which operates during the firing stroke is such to permit as rapid a start to the piston as is possible and still in keeping with silent operation. The rapid movement of the piston into its nearly constant speed during this stroke operates to absorb as useful work a larger portion of the energy derived from combustion than is possible in the ordinary motor. This feature conserves a portion of the energy which is ordinarily converted into radiating heat. As a result, the engine embody-

ing my invention is more efficient in this respect and radiates less heat to the cooling system.

The method of laying out the track is illustrated in Figure 8, which shows the operating portion of the track associated with the firing stroke. This track portion is laid out to accord with a firing stroke 5.076 inches long, and with the center line or axis of motion 21 of the track engaging element spaced 4 inches from the axis of the shaft 2; this 4 inches being measured on the perpendicular from the line 21 to the shaft axis.

Referring to Figure 8, the point O represents the axis of the shaft 2. Using O as a center a quadrant AOG of a circle is described on a 4 inch radius starting from a point A vertically above the point O. This quadrant is then divided into 18 equal sectors; viz., 18 radii are drawn 5 degrees apart. Tangents are then drawn to the circle at the intersection of the radii; these tangents extending upwardly and to the right, as shown. A tangent is also drawn to the circle at the point A; this tangent extending to the right toward point C. A point B is then located on the line AC preferably 1½ inches to the right of point A.

From B toward C a distance is then laid off 5.076 inches long; this being the length of the firing stroke. Let the point C indicate the end of this distance, so that the line BC represents the length of the firing stroke. The line BC is then divided into 18 parts, corresponding to the 18 divisions of the circle quadrant. The divisions of the line BC will vary depending upon the motion characterizing the piston. For the firing stroke, as has already been mentioned, this is preferably uniformly accelerated at the beginning, then substantially constant for the greater portion of the stroke, and finally uniformly decelerating near the end. For example, the divisions chosen in the design shown herein are as follows; the divisions or portions of length being given in inches:

.062 .437	.125 .437	.187 .437	.250 .437	.312 .253	.375 .196	.437 .140	.437 .084	.437 .028

After these divisions have been laid out along the line BC, laying off from B toward C and in the above order, as shown in Figure 8, an arc with a radius from O to the first division at the right of B is scribed to intersect the first tangent line to the left of A. This locates the second point along the curve which is to define the center line of the track; the first point located of course being the point B. Next an arc from the point O to the second division to the right of B is scribed to intersect the second tangent line to the left of A. This locates the third point on the curve.

Other points are similarly located on the tangents until finally the arc OC has been scribed to intersect the tangent line from the last radius of the quadrant. This completes the center line curve of the track for the firing stroke. In order to locate the edge portions of the track, circles are described about the located points as centers; these circles having radii equal to the radius of the track engaging rollers. Lines drawn tangent to the outer edges of these circles define the inner edges of the track.

The other operating portions of the track are developed in a manner similar to that for the firing stroke, above described. In the case of the other or idle strokes however the motion of the piston is preferably uniformly accelerating for half of its movement and then uniformly decelerating for the other half. For example, take the next operating portion of the track, which happens to be that portion operating through the exhaust stroke. Beginning at the point C a distance is laid off toward A 5.508 inches long, or the length of the exhaust stroke. This will end up at some point, say at D. The line CD is then divided into portions, of which the first portion is

$$\frac{1}{162}$$

of the total length of the stroke, the second is

$$\frac{3}{162}$$

of the total length, the third is

$$\frac{5}{162}$$

of the total length, etc. In other words lengths of the portions are:

$$\frac{1}{162}\times 5.508,$$

$$\frac{3}{162}\times 5.508 \cdots \frac{15}{162}\times 5.508,$$

$$\frac{17}{162}\times 5.508.$$

$$\frac{17}{162}\times 5.508,$$

$$\frac{15}{162}\times 5.508 \cdots \frac{3}{162}\times 5.508,$$

$$\frac{1}{162}\times 5.508.$$

The following gives the 18 divisions in inches:

.034 .578	.102 .510	.170 .442	.238 .374	.306 .306	.374 .238	.442 .170	.510 .102	.578 .034

These portions are laid out on the tangents to the 18 radii in the next quadrant GOH of the circle, as was done in developing the previous track portion.

The next succeeding operating portion of the track, which is for the intake stroke, is laid out in a similar manner. In this case the length of the intake stroke (3.024 inches) is laid off toward C from the point D, and will terminate at some point, say at E. The line DE is then divided for uniformly accelerating and uniformly decelerating motion, as was the exhaust stroke. The divisions in inches work out as follows:

.018 .317	.056 .280	.093 .243	.130 .206	.169 .169	.206 .130	.243 .093	.280 .056	.317 .018

These divisions are laid off on tangents drawn to the 18 radii in the third quadrant HOJ on the circle, as in the previous cases.

The portion of the track for the compression stroke is similarly developed. In this case a distance is laid off from the point E toward A equal to 2.592 inches or the length of the compression stroke. This will be found to terminate at the point B. The line EB is then divided into portions to give uniformly accelerating and uniformly decelerating motion as in the other idling strokes. The divisions in inches work out as follows:

.016 .272	.048 .240	.080 .208	.112 .176	.144 .144	.176 .112	.208 .080	.240 .048	.272 .016

These divisions are laid off on the tangents to

the 18 radii in the fourth quadrant JOA of the circle about O, and the final point located on the center line of the track will be found to coincide with the point B.

Figure 7 shows a variant form of track and engaging element construction, in which there is a single track section 30 on each opposing face of the disks 3. The crosshead shaft 31 in this case is journaled in the tubular portions 16 of the crosshead, and carries at one end thereof a roller 32 engaging a track section 30. The other end of the crosshead shaft preferably carries a crank 33 on which is journaled a roller 34 engaging one side of the other track section. Disposed oppositely of the crank 33 is another crank arm 36 fixed on the crosshead. This latter crank arm carries a roller 37 engaging the side of the track section 30 opposite the roller 34. In this case the piston in the compression, power and exhaust strokes drives against both track sections through the rollers 32 and 34, and on the intake stroke is moved by the action of the roller 37.

While I have chosen to show, as the preferred form of my invention, a motor in which the four cycles are completed in one revolution of the shaft being driven, it is understood that the track may be designed to complete the four cycles in two revolutions of the crank shaft. In this case the strokes would be of substantially equal length, as in ordinary practice. The advantage over the present type of crank shaft motor however would be the elimination of crank shaft dead centers. It is also obvious that a modification of the preferred form, in which the four cycles are completed in one revolution of the shaft being driven, would be to use segments of different size instead of equal quadrants in the development of the track. Thus by using a 122 degree segment for the exhaust, a 113 degree segment for the firing stroke, a 67 degree segment for the intake stroke and a 58 degree segment for the compression stroke, the developed track will accord with strokes of equal length.

In conclusion, it is pointed out that the engine embodying my invention as compared with the ordinary internal combustion motor is of simpler and more compact design with fewer working parts; is freer of mechanical troubles and is capable of and able to maintain a better mechanical balance; and operates with less power loss in exhaust and heat radiation. At the same time, greater power can be secured in my engine with less weight, less vibration and less noise of operation. Even with the higher pressures that are possible, the long expansion stroke will operate to expand the gases to close to atmospheric pressure, and even at open throttle the engine will require very little muffling.

Since the power from the pistons in the preferred engine embodying my invention is applied to the driven shaft throughout its entire revolution, the motor approaches that of a constant torque engine; in other words, the power is applied more as a constant stream than as a series of jerks. This feature combined with the nature of the disk drive, which itself acts as a fly wheel without an increase in weight over present crank shafts per se, makes the engine particularly desirable in airplane work.

I claim:

An engine comprising a shaft, a pair of spaced disks mounted on the shaft, a matched pair of endless track sections mounted on the disks, an elongated casting disposed between the disks and alongside the shaft and having a longitudinal bore, one end of said bore providing a combustion cylinder, a piston slidable in the cylinder end of the bore, a circular crosshead connected with the piston and slidable in the other end of the bore, said casting having longitudinally extending and oppositely disposed slots adjacent the latter end, a pin in the crosshead projecting through the slots, and rollers on the pin engaging said track sections.

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