Dec. 4, 1923. 1,476,307

C. J. TÓTH

INTERNAL COMBUSTION ENGINE

Filed April 15, 1922 2 Sheets-Sheet 1

Fig. 1.

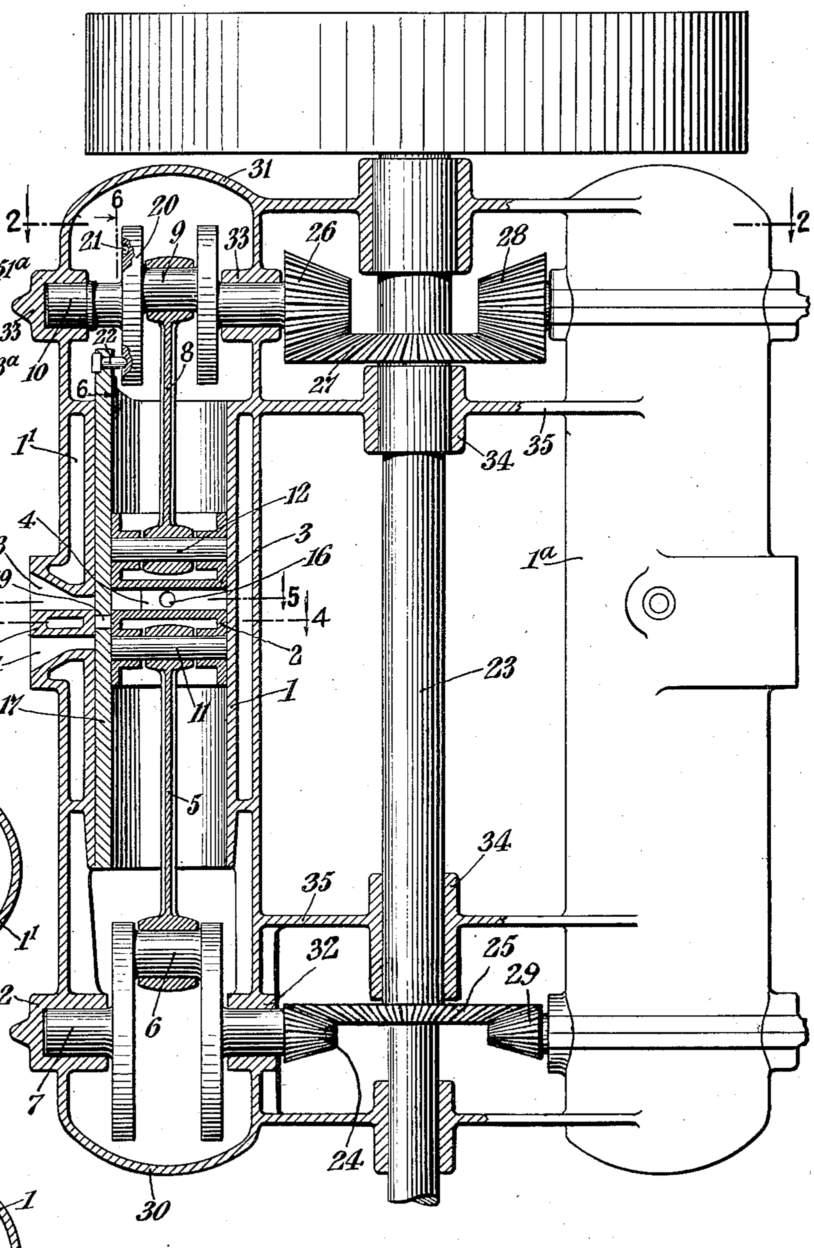


Fig. 6.

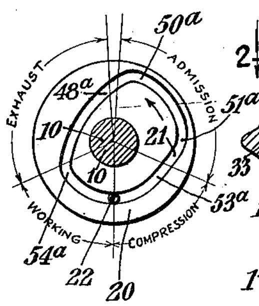


Fig. 5.

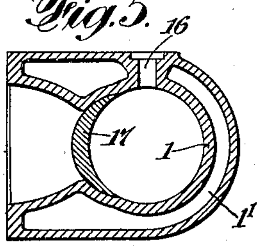
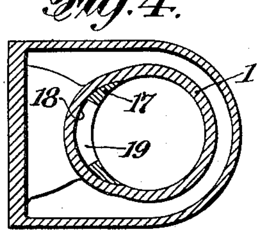


Fig. 4.



Inventor

Charles J. Tóth

By his Attorneys

Ward Crosby and Smith

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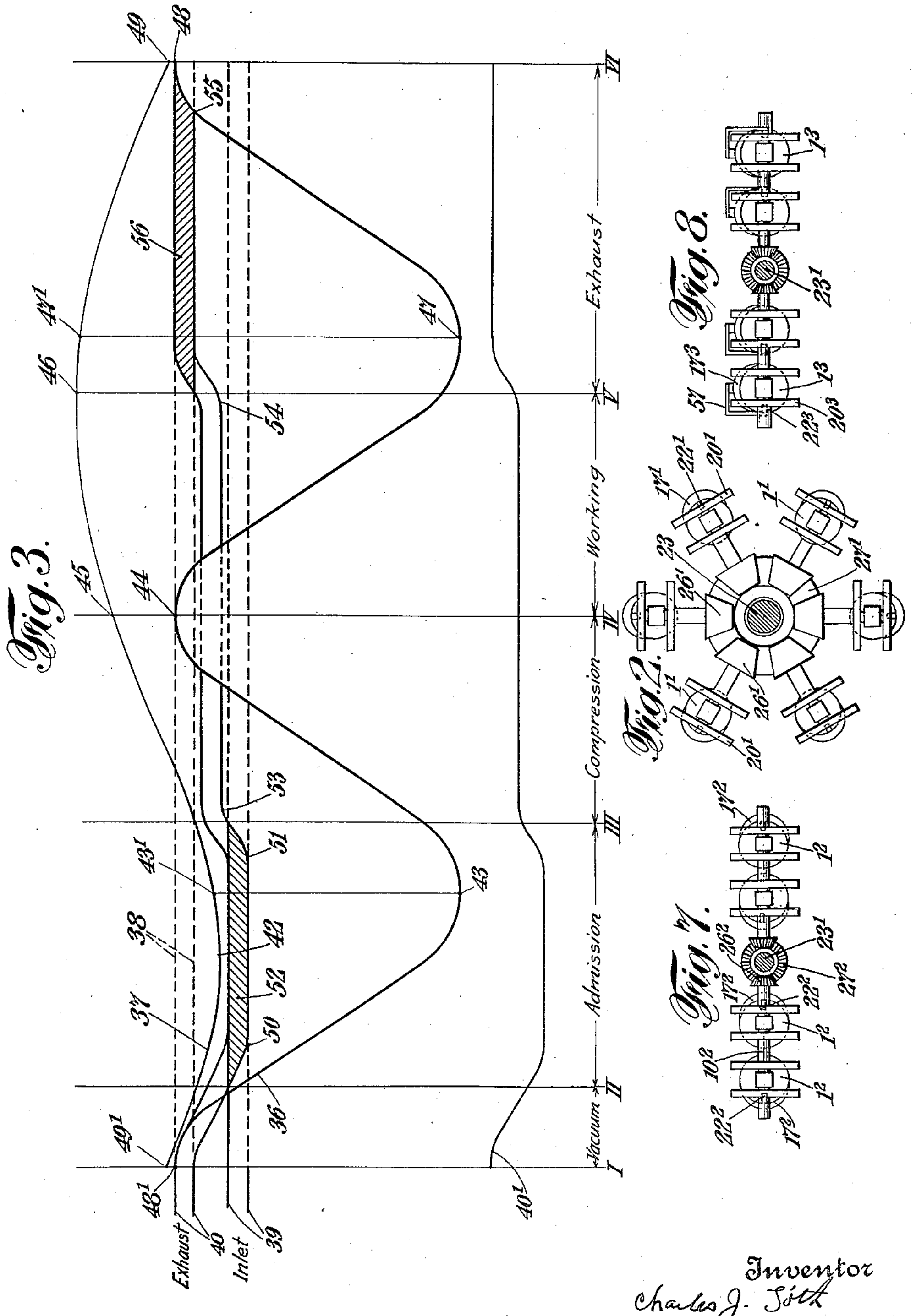

Inventor
Charles J. Tóth

By his Attorneys
Ward Crosby and Smith

Patented Dec. 4, 1923. **1,476,307**

UNITED STATES PATENT OFFICE.

CHARLES J. TÓTH, OF STAPLETON, NEW YORK, ASSIGNOR TO INTERNATIONAL PROCESS AND ENGINEERING CORPORATION, OF NEW YORK, N. Y., A CORPORATION OF NEW YORK.

INTERNAL-COMBUSTION ENGINE.

Application filed April 15, 1922. Serial No. 553,054.

To all whom it may concern:

Be it known that I, CHARLES J. TÓTH, a citizen of the Republic of Uruguay, and resident of Stapleton, New York city, county of Richmond, and State of New York, have invented certain new and useful Improvements in Internal-Combustion Engines, of which the following is a specification.

The invention relates to improvements in internal combustion engines, and includes among its objects the provision of novel structures of great simplicity and high economy and efficiency.

In accordance with one form of the invention a pair of pistons are mounted in a cylinder to move in such a manner as to leave a combustion chamber or working cylinder space, of varying volume, between them. Valve means are so constructed and operated as to open communication between an inlet opening and this space, and between an exhaust opening and this space, at suitable times.

More broadly speaking, a pair of relatively movable members are mounted in the cylinder, at least one of which serves as a movable piston, the space between these members being connected at suitable times to the inlet and the exhaust. The combustion space between the relatively movable members is varied in volume in such a manner that various desirable effects are obtained. One of these effects is that the volume of this space increases to a greater maximum during the working or expansion stroke of the engine than it does during the admission stroke. The expanding charge performs useful work throughout its expansion. Accordingly the expansion of the compressed charge after explosion or ignition of the same will proceed to a greater degree than is possible with engines in which the maximum volume of the cylinder is the same during admission as during expansion. Increased output and economy result from this arrangement.

In the preferred construction two pistons are employed, one connected to one crank shaft rotating at one speed and the other to a second crank shaft rotating at a different speed. Both crank shafts are preferably connected, as by suitable gearing, to drive a single shaft, from which power may be taken. The movements of the two pistons are so timed as, preferably, to bring the pistons very close together at the end of the exhaust stroke, to scavenge the cylinder positively and quite completely; and to separate the pistons to one extent during admission, and to separate them to a greater extent during expansion of the charge, after explosion thereof, so as to provide an increased expansion. These results are obtained by moving the pistons towards each other, and away from each other, at suitable times, at their different speeds.

The shaft driven by the two crank shafts may, if desired, be of comparatively low speed, making a suitable drive for a low speed high pitch propeller or screw.

The admission and exhaust are preferably controlled by a single special form of sleeve valve; this is arranged at one time to open communication between an inlet opening of the cylinder and the space between the two pistons, at another time to open communication between an exhaust opening and this space, and at other times to shut off this space from both the inlet and exhaust ports of the cylinder.

Various arrangements or combinations of duplex cylinders of the character referred to may be made within the invention, or, of course, an engine may comprise a single such cylinder.

Other features and advantages of the invention will be more fully described hereinafter. The objects of the invention include the provision of various combinations, sub-combinations and features of construction, all as will be more fully set forth hereinafter.

A further feature of the invention is that the cylinder volume may be made considerably less at the end of the exhaust stroke than it is at the time of the explosion of the charge, at the end of the compression stroke. The two pistons may come practically together at the end of the exhaust stroke, to effect scavenging of practically 100% efficiency.

In order that the invention may be more clearly understood attention is hereby directed to the accompanying drawings forming part of this application and illustrating one embodiment of the invention. In the drawings—

Fig. 1 represents a view partly in vertical section and partly in front elevation of an engine comprising the invention;

Fig. 2 is a diagrammatic top plan view of one arrangement of a plurality of cylinders cooperating with a common driven shaft, this view being considered as taken on line 2—2 of Fig. 1;

Fig. 3 is a diagrammatic representation of the working conditions within one of the engine cylinders;

Figs. 4, 5 and 6 are sections taken respectively on lines 4—4, 5—5 and 6—6 of Fig. 1, and

Figs. 7 and 8 are respectively diagrammatic top plan views of modified forms of arrangement of a plurality of cylinders connected with a common driven shaft.

Referring to the drawings, a duplex cylinder 1 is illustrated, having two pistons 2 and 3 mounted therein in opposite ends of the cylinder, the combustion chamber of the cylinder comprising the space, 4, between the two pistons. The lower piston 2 is connected by connecting rod 5 to a crank 6 of the crank shaft 7, while the upper piston 3 is connected by a connecting rod 8 to the crank 9 of a crank shaft 10. Crank 9 of the upper crank shaft, as shown, has a less radius or throw than crank 6 of the lower crank shaft. Connecting rods 5 and 8 may be rotatably mounted at their inner ends on transverse pins 11 and 12 respectively, carried by pistons 2 and 3. Crank shaft 10 is intended to rotate at a fraction of the speed of crank shaft 7, crank shaft 10 rotating at one-half of the speed of crank shaft 7 in the construction illustrated in the drawings. The manner in which the volume of combustion chamber 4 will be varied by the movements of pistons 2 and 3 will be described hereinafter.

The engine illustrated operates on the four cycle principle.

Cylinder 1 is formed in a casting having a suitable water jacket 1^1. The cylinder casting has an opening 13 extending therethrough, this being the exhaust opening, and an opening 14 which serves as an inlet opening. As indicated, these two openings may be located adjacent to a plane midway between the two ends of the cylinder, the exhaust opening 13 being shown as being somewhat above the median plane, that is on the side of the said plane towards the half speed crank shaft 10, while the inlet opening 14 is on the other side of said plane, that is, the side thereof towards the full speed crank shaft 7. As shown these two openings may be separated by a portion 15 of the cylinder casting. The position of the spark plug or spark plugs within the combustion chamber is indicated at 16.

The admission of charge to the combustion chamber and the exhaust of burnt gases therefrom is preferably controlled by a single sleeve valve 17 which is adapted to reciprocate at suitable intervals in the axial direction of the cylinder. As is indicated in Figs. 4 and 5, valve 17 is preferably crescent shaped in cross section and is mounted within a similarly shaped recess 18 formed within one side portion of the bore of the cylinder. This recess is so positioned that the sleeve valve will extend between openings 13 and 14 and the interior of the cylinder, pistons 2 and 3 having sliding contact throughout a greater portion of the periphery of each against the bore of cylinder 1 and through a lesser portion of the periphery of each against the inner surface of the sleeve valve.

The sleeve valve has a single opening 19 therethrough, as is indicated in Figs. 1 and 4. This opening 19 is adapted to register in one position of the sleeve valve with inlet opening 14 and in another position of the sleeve valve with exhaust opening 13, opening 19 corresponding in shape and size with the inner ends of openings 13 and 14.

The sleeve valve is so controlled as to cause opening 19 to align with opening 14 during the times when the charge, such as the usual gaseous mixture, (or air, if liquid fuel is to be injected into the cylinder later) is to be taken in. Opening 19 will align with opening 13 at all times when the exhaust of burnt gases is to take place; and it will be in an intermediate position, out of alignment with both openings 13 and 14, that is in alignment with the cylinder wall portion 15 between the openings 13 and 14, at times when neither admission or exhaust is to take place as during the compression and working of piston 2.

The reciprocating movement of sleeve 17, designed to cause the opening 19 in the sleeve to align with openings 13 and 14 at the proper times, is preferably imparted to the sleeve by means of a suitably shaped cam. In the construction shown in Figures 1 and 6 of the drawings, crank shaft 10 is provided with a disc 20 concentrically mounted thereon, having a cam groove 21 formed in the face thereof. The crescent shaped sleeve 17 carries at its upper end a pin 22 which extends into this groove. The cam groove is so shaped as to give the sleeve the desired movement, as will be more fully described hereinafter.

Crank shafts 7 and 10 are preferably both connected to drive the same shaft, 23, from which power may be taken. As shown in the drawings, crank chaft 7 may be connected to drive shaft 23 by means of beveled pinions 24 and 25, mounted on crank shaft 7 and the driven shaft 23 respectively. Similarly crank shaft 10 is connected to shaft 23 by means of beveled pinion 26 on crank shaft 10 which meshes with beveled gear 27 on driven shaft 23. The gear ratios between gears 24 and 25, and 26 and 27, are such that crank shaft 10 is rotated at one half the speed of crank shaft 7. As shown in the drawings gears 25 and 27 on shaft 23 are of the same size, while pinion 24 has a pitch diameter one half of that of pinion 26. Any suitable arrangement may be used which will give the desired result. It is, however, sometimes desirable, as previously stated, to have shaft 23 of comparatively low speed, and accordingly the gear 25 is shown as considerably larger than gear 24 meshing therewith so as to drive shaft 23 at a slower speed than crank shaft 7.

In Fig. 1 a second duplex cylinder 1^a is illustrated, this containing mechanism which may be exactly the same as that contained within cylinder 1. The upper crank shaft of cylinder 1^a, corresponding to crank shaft 10 of cylinder 1, is provided with a beveled pinion 28 similar to pinion 26 and also meshing with beveled gear 27. Similarly the cylinder 1^a has a lower crank shaft corresponding to crank shaft 7 and having a beveled pinion 29 similar to pinion 24 and also meshing with pinion 25 on shaft 23. Crank shafts 7 and 10 may be provided with crank cases 30 and 31 integral with or secured to the cylinder casting 1, crank shafts 7 and 10 being rotatably mounted in bosses or enlargements 32, 32, and 33, 33, formed on the crank case portions of the cylinder casting. The driven shaft 23 may be rotatably mounted in bearings 34 formed on spiders or arms 35 extending from cylinders 1 and 1^a.

The operation of the engine will be more clearly understood from the diagram illustrated in Fig. 3 in which the travel of the lower or full speed piston 2 is indicated by the line 36. The travel of the upper or half speed piston 3 is indicated by the line 37. The horizontal upper dotted lines 38, 38, indicate the upper and lower edges of exhaust opening 13, while the lower horizontal lines 39, 39 represent the upper and lower edges of the inlet opening 14 in the cylinder. The parallel lines 40, 40 indicate the upper and lower edges of the opening 19 in the sleeve during the movement of the same. For convenience the movement of the sleeve is also indicated by the single line 40^1 which is shown separately adjacent the bottom of the diagram.

Referring to the diagram it will be noted that the full speed piston 2 is at its upper dead center at the position marked I on the diagram and is about to start on its outward stroke. At the same moment the half speed piston 3 is very close to piston 2, the clearance between the two pistons at this moment representing the combustion chamber space of the cylinder, being very slight. As piston 2 moves away from position I on its outward or downward stroke, piston 3 will be moving on its inward stroke, that is piston 3 will be moving in the same direction as piston 2. Piston 3, however, moves at only half the speed of piston 2, as stated. It also has a much less travel in each direction than has piston 2 because of the fact that crank 9 of crank shaft 10 travels about a circle of much less radius than does crank 6 of crank shaft 7.

Cranks 9 and 6 are also disposed at different angular positions in relation to their stroke circles so that one of the pistons will reach its dead center positions before the other. Thus, as is shown in the diagram, piston 3 will reach its lower dead center position approximately at the point 42. Piston 2 will reach its lower dead center position somewhat later, approximately at the point 43.

Piston 2 will reach its next upper dead center position at point 44 on the diagram at which time piston 3 is still moving on its outward stroke, its position at this time being indicated by point 45 on line 37. Piston 3 reaches its outer dead center position at approximately the point 46 on line 37 at which time piston 2 has not quite completed its next outward stroke, piston 2 reaching its lower dead center slightly after piston 3 reaches its upper dead center, this lower dead center position of piston 2 being represented by point 47 on line 36. Piston 2 completes its following upward stroke when the point 48 on line 36 of the diagram is reached, at which time piston 3 is moving inwardly, its position being indicated by point 49 on line 37, this point being close to point 48, indicating that the two pistons are close together at this time. Points 48^1 and 49^1 at the left hand edge of the diagram, representing the starting points of lines 36 and 37 respectively, represent, of course, the same positions of pistons 2 and 3 as do the points 48 and 49 at the ends of lines 36 and 37.

The distance between the working faces of pistons 2 and 3 is represented by the vertical distance between lines 36 and 37, at any point in the travel of the pistons. As will be explained, the admission of fresh charge takes place during the interval marked "Admission" on the diagram, followed by the periods indicated by the words "Compression", "Working", and "Exhaust". Each of these periods corresponds approximately to a stroke of full speed piston 2. The maximum distance between the two pistons during the admission stroke is indicated by the vertical line 43—43^1, connecting points on lines 36 and 37. This, it is noted, is less than the maximum distance between the pistons during the exhaust stroke, indicated by the vertical line 47—47.

The charge is ignited at the beginning of the working stroke, at which time the distance between the two pistons is represented by the vertical line 44—45. The exhaust is completed when pistons 2 and 3 have approached very close together, as stated, their positions being indicated by points 48 and 49 (or points 48^1 and 49^1 at the left of the diagram). The distance between the pistons at this time, represented by vertical distance 48—49, is much less than the distance between them when the charge is fired, represented by line 44—45.

This general explanation having been made, the movements of the two pistons and of sleeve valve 17 will now be described in greater detail. In the diagram, Fig. 3, the cycle of the engine is represented as commencing at the point indicated by I, at the end of the exhaust stroke. At this moment piston 2 is at its upper dead center position, represented by point 48^1 on the diagram. Piston 3 is close thereto, its position being represented by point 49^1. Sleeve valve 17 at this time is in its uppermost position, in which its opening 19 would open communication between exhaust port 13 and the interior of the cylinder, except for the fact that the upper edge of piston 2 is slightly above opening 19 so that the latter is closed.

Piston 2 moves downwardly from the position referred to its downward or outward travel being represented by the downwardly extending portion of line 36 which terminates at point 43. The half speed piston 3 at the same time is moving in the same direction, that is to say, it is moving on its inward or downward stroke, which terminates at the lower dead center position, indicated by point 42 on line 37. The volume of the space between the two pistons will constantly increase during this movement of the pistons because of the fact that while both pistons are moving in the same direction piston 2 is moving more rapidly, and also because of the fact that piston 2 has a longer stroke than piston 3.

The sleeve valve begins to move downwardly at or about the time that piston 2 leaves its upper dead center position I. As stated, the travel of the sleeve valve is indicated by the parallel lines 40, 40, and also for convenience by the single line 40^1. The upper edge of piston 2 and the upper edge opening 19 in the sleeve valve will move approximately together as they descend below exhaust opening 13, so that communication between the exhaust port 13 and the interior of the cylinder will not be opened at this time. Opening 19 in the sleeve valve descends until it opens communication with the inlet port 14. As is indicated by the diagram, the lower edge of opening 19 in the sleeve valve passes downwardly past the upper edge of inlet opening 14 when the point indicated by II is reached in the diagram. At this time the upper edge of the lower piston 2 has descended below opening 19, as is indicated by the line 36, so that communication is opened between inlet port 14 and combustion chamber 4 of the cylinder, when opening 19 aligns with the inlet port.

The sleeve valve descends until its opening 19 completely aligns with the inlet port 14 of the cylinder, as is indicated at the point marked 50 on the lower one of the two lines 40 in the diagram. The sleeve valve will be held stationary in this position until the point 51 on the lower of the two lines 40 is reached, at which time the sleeve valve begins again to move upwardly, opening 19 of the sleeve valve passing entirely out of communication with inlet port 14 when the position indicated by III is reached. A charge of gaseous mixture is accordingly admitted to the combustion chamber during the period represented by the distance between points II and III, the entire admission period being represented by the cross hatched area 52. It will be noted that piston 2 moves downwardly, more rapidly than does piston 3, between positions I and II, before the fresh charge begins to be admitted, and during this period a high vacuum will be produced within the combustion chamber, the burnt gases of the previous charge having been practically completely expelled from the cylinder when the position I was reached, as will be explained hereafter. As the piston 2 continues to move downwardly more rapidly than does piston 3 during the admission stroke this vacuum will be increased throughout the downward stroke of piston 2 represented by the portion of line 36 which terminates at point 43.

Beginning with point 43 on line 36 piston 2 commences its next inward or upward stroke which terminates when position 44 on line 36 is reached. During this time piston 3 is also moving on its upward or outward stroke, that is in the same direction as piston 2, but at a rate which is considerably less than that at which piston 2 travels. Accordingly the volume of the combustion space between the two pistons will be continually decreased during the upward movement of piston 2, terminating at point 44, and the intaken charge will be compressed between the two pistons until piston 2 reaches the position 44, which is denoted at the bottom of the diagram by the indication IV. The explosion or firing of the compressed charge takes place at or about the upper dead center position 44 of piston 2 at which time the next outward or downward stroke of piston 2 begins.

The sleeve valve, having closed inlet port 14 at position III, rises slightly to its position intermediate ports 14 and 13, indicated by point 53 on the lower of the two lines 40 in the diagram. The sleeve valve is held stationary in this intermediate position until point 54 on the diagram has been reached. The sleeve valve is thus held stationary, between points 53 and 54 during the greater part of the compression stroke of piston 2 and during the greater part of the succeeding working or expansion stroke of piston 2.

Piston 2 starts its working or expansion stroke, as stated, at the point 44 on the diagram, this outward movement of piston 2 terminating at point 47. Figure 1 of the drawings represents the position of the parts at the moment when the charge is fired, and when piston 2 is about to start on its working stroke. During the outward or downward travel of piston 2 piston 3 is also moving on its outward or upward stroke, until the upper dead center position of piston 3 is reached, at point 46. As is shown by the diagram, piston 3 moves only a slight distance on its succeeding inward or downward stroke between the points 46 and 47^1, at which time piston 2 completes its downward stroke. Accordingly the volume of the combustion chamber space between the two pistons will increase rapidly during all the time that the expansion of the exploded charge takes place. Also, as has been previously stated, the gases are expanded at the end of the working stroke of piston 2 to a volume considerably greater than the maximum volume occupied by the charge during the admission stroke of piston 2.

The sleeve valve begins to move upwardly, that is towards the exhaust port 13, at point 54 on the diagram. Communication between the combustion chamber and the exhaust port is established shortly thereafter at about the point indicated at 46 in the diagram, when opening 19 in the sleeve valve begins to register with exhaust opening 13. Opening 19 will register completely with exhaust port 13 shortly thereafter, valve 17 then being held stationary in its upper position until point VI, which is the same as point I, is reached.

During the exhaust from the combustion chamber full speed piston 2 has completed its downward stroke and moves upwardly on its succeeding inward stroke. At the point marked 55 on line 36 the upper edge of piston 2 begins to move past opening 19 in the sleeve valve. At the end of this upward stroke of piston 2, represented by point 48 on the diagram, piston 2 has completely covered opening 19 in the sleeve valve, thus closing the exhaust from the combustion chamber. The period of exhaust is indicated by the cross hatched area 56 on the diagram, the exhaust extending from point 46 to point 48.

During the upward travel of piston 2 from position 47 to position 48, that is the upper dead center position of piston 2, piston 3 is moving on its inward or downward stroke. The exhaust port having been open all of this time the burnt gases are scavenged or driven out of the cylinder, positively, by the movement of the two pistons towards each other. As the two pistons come almost together at positions 48 and 49, the burnt gases will be scavenged or driven out of the cylinder with an efficiency which may be practically 100%, before the period of admission of fresh mixture into the cylinder is again started.

The movement of the sleeve valve, as described, may readily be accomplished by properly shaping the cam groove 21 with which pin 22 on the sleeve valve co-acts. Referring to Fig. 6, the cam disc 20 may be considered as rotating in a counter clockwise direction. When pin 22 is at point 48^a in the cam groove, piston 2 is just leaving its upper dead center position I. The cam groove is so shaped as to force pin 22 downwardly, from point 48^a of the groove to approximately point 50^a at which time inlet opening 14 is fully uncovered. The cam groove has a portion substantially concentric with the crank shaft from point 50^a to point 51^a, where the direction of the cam groove changes so as to raise pin 22 slightly.

When point 53^a has been reached by pin 22 opening 19 in the sleeve valve will have reached its intermediate position, and a concentric portion of the cam groove follows, until point 54^a has been reached when the cam groove again moves inwardly from its concentric path so as to again raise pin 22 to bring opening 19 in the sleeve valve into alignment with exhaust port 13. A concentric portion of the groove then follows, to hold the pin stationary until point 48^a is against reached.

As has been stated engines constructed in accordance with the invention may comprise one or more cylinders and the cylinders may be grouped or arranged in various ways. In Fig. 2 is indicated a construction in which six cylinders 1^1 are mounted at equal angular distances about the driven shaft 23. The driven shaft is represented as having a beveled gear 27^1 thereon with which the beveled pinions 26^1 on the upper crank shafts of the various cylinders mesh. This may be considered as the same arrangement as that shown in Fig. 1, Fig. 1 being taken on a section which may be considered as extending along the axis of the upper crank shaft of any cylinder and of the cylinder diametrically opposed thereto. The crescent shaped sleeve valve of each cylinder is represented at 17^1, a pin 22^1 on each sleeve valve being indicated as cooperating with the cam groove on the crank disc 20^1 of the upper crank shaft of that cylinder. With such an arrangement power will be applied to the driven shaft 23 at equally spaced points around the periphery of shaft 23 both at the level of the upper crank shaft and at the level of the lower crank shaft.

In Figure 7 a different multi-cylinder engine arrangement is indicated in which the various duplex cylinders 1^2 are mounted in straight line relation with the driven shaft 23^1 parallel to all of the cylinders. In this case all of the sleeve valves 17^2 are positioned in the direction of the crank shafts. The cylinder 1^2 at the extreme left of the diagram is represented as having its sleeve 17^2 at the extreme left, connected by pin 22^2 to the crank shaft 10^2, to which the next adjacent cylinder 1^2 is also connected. This second cylinder has its sleeve valve 17^2 mounted at the right of the cylinder, and connected by its pin connection 22^2 to crank shaft 10^2, this crank shaft being connected by beveled pinion 26^2 to the beveled gear 27^2 on shaft 23^1. The two cylinders indicated at the right of the driven shaft 23 are similarly connected. With this arrangement the pair or other plurality of cylinders at the left of the driven shaft all drive the same pair of crank shafts which impart power to the shaft 23^1 at one side of the same while the plurality of cylinders to the right of the driven shaft operate a pair of crank shafts which apply power to the shaft 23^1 on the opposite side of the same.

A somewhat different arrangement is shown in Figure 8 in which cylinders 1^3 are mounted in straight line relation with the driven shaft 23^1 parallel thereto and situated between the same, the same as has been described in connection with Figure 7. In the arrangement shown in Figure 8, however, the sleeve valves 17^3 of the cylinders are not positioned in alignment with the crank shafts, but are mounted on the sides of the cylinders, 90° away from the positions indicated in Figure 7. In this case the pin 22^3 cooperating with the crank disc 20^3 of the upper crank shaft of any cylinder may be connected by an angular connection 57 with the sleeve valve 17^3 of that cylinder. With such an arrangement all of the cylinders at one side of the driven shaft 23^1 cooperate with the same upper and lower crank shafts, while all of the cylinders at the opposite side of the driven shaft cooperate with the same pair of upper and lower crank shafts in the same manner as has been described in connection with Figure 7. This arrangement permits the cylinders to be more closely spaced than does the arrangement shown in Fig. 7.

In connection with the constructions which have been described, it will be noted that an extremely simple engine construction is provided. In each engine cylinder the only moving parts which do not take part in the transmission of power to the driven shaft are the single sleeve valve and the pin and cam groove by which the valve is operated. The usual cam shaft and plurality of valves commonly operated thereby, in usual prior constructions, are eliminated. The only moving parts are the two pistons and one sleeve valve in each cylinder together with the two crank shafts and connections between the same and the two pistons, both crank shafts being power transmitters.

Power may be transmitted very effectively to the driven shaft and applied to the latter at points so distributed as to produce a smooth and even application of power thereto. The driven shaft may be operated at a reduced speed in comparison to the speeds of the crank shafts, as is desirable for example where a screw or propeller having high pitch and low speed is to be operated.

The mechanism described enables the two pistons to come practically together at the end of the exhaust stroke, so that the exhaust of the burnt gases will be very positive and in some cases may be made practically 100% efficient. The arrangement is such that the volume of the combustion chamber is much less at the end of the exhaust stroke than it is at the time of the firing of the compressed charge. The very efficient scavenging, permits a correspondingly efficient dimensions, that is to say, the burnt gases having been entirely expelled, the cylinder will be filled practically entirely with fresh gases during the period of admission. Because of this construction an engine built in accordance with the invention will develop greater power than an engine having the same stroke, bore of cylinder and other admissions, in whch the scavenging and admission of fresh charge are not so efficient.

Because of the fact, as described, that both pistons move in the same direction during the admission stroke but move in opposite directions during the explosion stroke, the result is obtained of expanding the exploded charge to a greater volume than the maximum volume of the cylinder during the admission stroke. In prior engines so far as I am aware, the expansion of the exploded charge is not carried to a greater volume than the maximum volume of the cylinder during the admission stroke. The increased expansion permitted by the construction described utilizes the power of the charge to a greater extent and increases the efficiency of the engine correspondingly. Accordingly, it may be said that the present construction permits a greater output of power in comparison with an engine operating upon the same volume of charge in which such increased expansion is not obtained. Accordingly, the economy of the construction described is considerably enhanced. The construction described and illustrated enables a production of power which may be, for example, from 15% to 25% greater than the power obtainable from a similar unit consuming the same amount of fuel. Likewise, of course, if the same power be developed as a corresponding engine which does not expand the compressed charge in the manner described, the fuel consumption will be correspondingly decreased, so that there may be in such a case a saving of fuel of, for example. from 15% to 25%.

It will also be noted that the exceedingly efficient exhaust which has been described enables the maintenance of an average working temperature considerably less than that employed in prior engines, in which no such efficient exhaust is obtainable.

It will also be noted that the cylinder may be fully charged with pure fresh mixture at every desirable rate of engine speed, because of the extremely efficient scavenging and the extremely efficient production of vacuum in the cylinder during the period of admission.

It should be understood that while I have described certain forms and features of the invention with particularity, the invention is not limited to the exact details which have been described, but that various modifications may be employed, as will be clear to those skilled in the art, after reading this specification, the scope of the invention being indicated by the accompanying claims.

What I claim is:

1. In an internal combustion engine, the combination of a cylinder, a pair of pistons therein, movable away from and towards each other to establish a combustion chamber between them, one of said pistons having successive strokes during which admission to, compression in, expansion in, and exhaust from, said chamber take place, means comprising a single slide valve for admitting a gaseous charge to the combustion chamber and exhausting burnt gases therefrom at appropriate times, and means for so moving said pistons that the maximum volume of the combustion chamber will be greater during the working or expansion stroke than it is during the admission stroke of the pistons.

2. In an internal combustion engine, the combination of a cylinder, means comprising a single slide valve for admitting charge thereto and exhausting burnt gases therefrom periodically, two movable members therein, one of the same being a piston having successive admission, compression, expansion and exhaust strokes, and means for permitting said movable members to so move that the ignited charge will expand to greater volume in the cylinder during the expansion stroke than the volume the charge attains in the cylinder during the admission stroke.

3. In an internal combustion engine, the combination of a cylinder, a pair of pistons therein, movable away from and towards each other to establish a combustion chamber between them, means comprising a single slide valve for admitting charge to and exhausting burnt gases from said chamber periodically, and means for so moving said pistons that they will move towards each other during practically the entire period of exhaust, to drive out the burnt gases, and will come almost into contact with each other at the end of the exhaust.

4. In an internal combustion engine, the combination of a cylinder, a piston and an abutment therein, relatively movable towards and away from each other to establish a combustion chamber between them, means comprising a single slide valve for admitting charge to and exhausting burnt gases from said chamber periodically, and means for causing relative movement between said piston and abutment to take place in such manner as to vary the distance between them while said piston has successive admission, compression, working and exhaust strokes, the relative movement being so arranged that the distance between the piston and abutment will be greater at the end of the compression and the beginning of the working stroke than at the end of the exhaust stroke.

5. In an internal combustion engine, the combination of a cylinder, a pair of pistons therein, movable away from and towards each other to establish a combustion chamber between them, means for admitting charge to and exhausting burnt gases from said chamber periodically, said cylinder having successive admission, compression, working, or expansion, and exhaust periods, and means for so moving said pistons that the distance between them will be greater at the end of the compression and the beginning of the working or expansion period than at the end of the exhaust period, and that the maximum distance between them will be greater during the working or expansion period than during the admission period.

6. In an internal combustion engine, the combination of a cylinder, a pair of pistons therein, movable away from and towards each other to establish a combustion chamber between them, means for admitting charge to and exhausting burnt gases from said chamber periodically, said cylinder having successive admission, compression, working or expansion, and exhaust periods, each occupying substantially one stroke of one of said pistons, and means for so moving said pistons that they will move in the same direction

throughout the greater part of the admission period, and in opposite directions away from each other, during the working or expansion period.

7. In an internal combustion engine, the combination of a cylinder, a pair of pistons therein, movable away from and towards each other to establish a combustion chamber between them, means for admitting charge to and exhausting burnt gases from said chamber periodically, said cylinder having successive admission, compression, working or expansion, and exhaust periods, each occupying substantially one stroke of one of said pistons, and means for so moving said pistons that they will move in the same direction, one traveling further and faster than the other, throughout substantially all of the admission period and in opposite directions during the working or expansion period.

8. In an internal combustion engine, the combination of a cylinder, a pair of pistons therein, movable away from and towards each other at different speeds to establish a combustion chamber between them, said cylinder having inlet and exhaust ports, a single slide valve adapted to control communication between said ports and combustion chamber, at suitable times, crank shafts to which said pistons are connected, and means operatively connecting one of said crank shafts and said valve.

9. In an internal combustion engine, the combination of a cylinder having separated inlet and exhaust ports, piston means in said cylinder, a single sleeve valve controlling said ports and having a single opening therein and means for operating said sleeve valve, to cause it to move into a position to open said inlet port by aligning said opening therewith, then into position to close both ports and to remain stationary in such position for an interval, and then into position to open said exhaust port by aligning said opening therewith, said operation being repeated cyclically.

10. In an internal combustion engine, the combination of a cylinder having separated inlet and exhaust ports, piston means in said cylinder, a single valve having a sigle opening therethrough controlling said ports, and means for operating said valve, to cause it to move into a position to open said inlet port by aligning said opening therewith, then into position to close both ports and to remain stationary in such position for an interval, and then into position to open said exhaust port by aligning said opening therewith, said operation being repeated cyclically.

11. In an internal combustion engine, the combination of a cylinder having separated inlet and exhaust ports, piston means in said cylinder, a single valve having a single opening therein controlling said ports, and means for operating said valve, to cause it to move in one direction from a position in which both ports are closed to a position in which one of said ports is opened by aligning said opening therewith, then in another direction to a position in which the other port is opened by aligning said opening therewith, and then back to the position in which both ports are closed, said operations being repeated cyclically.

12. In an internal combustion engine, the combination of a cylinder having separated inlet and exhaust ports, piston means in said cylinder, a single valve having a single opening therein controlling said ports, and means for operating said valve, to cause it to move in one direction from a position in which both ports are closed to a position in which one of said ports is opened by aligning said opening therewith, then in the opposite direction, across said first position, to a position in which the other port is opened by aligning said opening therewith, and then back to the first position, said operations being repeated cyclically.

13. In an internal combustion engine, the combination of a cylinder having axially separated inlet and exhaust ports, a piston in said cylinder, a crank shaft connected to said piston and having a cam thereon, a crescent shaped sleeve valve having a single opening therein controlling said ports and means for operating said valve from said cam to cause said single opening to align with said inlet and exhaust ports respectively, with periods of movement and periods of pause.

14. In an internal combustion engine, the combination of a plurality of cylinders, having parallel axes arranged in a circle, a pair of pistons in each of the same, movable away from and towards each other, a separate crank shaft for each piston, connected therewith, extending radially of said circle, a driven shaft at the center of said circle, and gear connections between each crank shaft and said driven shaft, the gear connections between said driven shaft and the crank shafts adjacent one end of each cylinder all having the same gear ratio, and the gear connections between said driven shaft and the crank shafts adjacent the opposite end of each cylinder all having the same gear ratio, different from the first named gear ratio.

15. In an internal combustion engine, the combination of a cylinder, a pair of pistons therein, movable towards and away from each other, crank shafts at opposite ends of the cylinder to which said pistons are respectively connected, one of said crank shafts being rotatable at a fraction of the speed of the other, said cylinder having inlet and exhaust ports, a single sleeve valve having a single opening therein and means for operating said valve to cause it to control admis-

sion of charge through said inlet port into the space between the pistons, and exhaust of burnt gases from said space through said exhaust port, at appropriate times.

16. In an internal combustion engine, the combination of a cylinder having axially separated inlet and exhaust ports, a pair of pistons therein, movable towards and away from each other, a crescent shaped sleeve valve having a single opening therein, slidably mounted between said cylinder and pistons, said valve controlling both said ports, and means for operating said valve at appropriate times.

17. In an internal combustion engine, the combination of a cylinder, having axially separated inlet and exhaust ports, a pair of pistons therein movable away from and towards each other to establish a combustion chamber between them, a single sleeve valve situated between the cylinder wall and said pistons, having a single opening therein, controlling said ports, means for operating said valve to cause it to open and close said ports at suitable times, said cylinder having successive admission, compression, working, or expansion, and exhaust periods, and means for so moving said pistons that the distance between them will be greater at the end of the compression and the beginning of the working or expansion period than at the end of the exhaust period, and that the maximum distance between them will be greater during the working or expansion period than during the admission period.

18. In an internal combustion engine, the combination of a cylinder having axially separated inlet and exhaust ports both located adjacent the central portion of the length of the cylinder, a pair of pistons therein, movable away from and towards each other to establish a combustion chamber between them, a single slide valve for admitting charge to and exhausting burnt gases from said chamber periodically, and means for so moving said pistons that they will move towards each other during practically the entire period of exhaust, to drive out the burnt gases through said exhaust port, and will come almost into contact with each other at the end of the exhaust.

In testimony whereof I have signed my name to this specification, at New York city, N. Y., this 11 day of April, 1922.

CHARLES J. TOTH.