United States Patent

[11] 3,557,761

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[54] **SELF-CHARGING AND -SCAVENGING LEVER ENGINE**
20 Claims, 13 Drawing Figs.

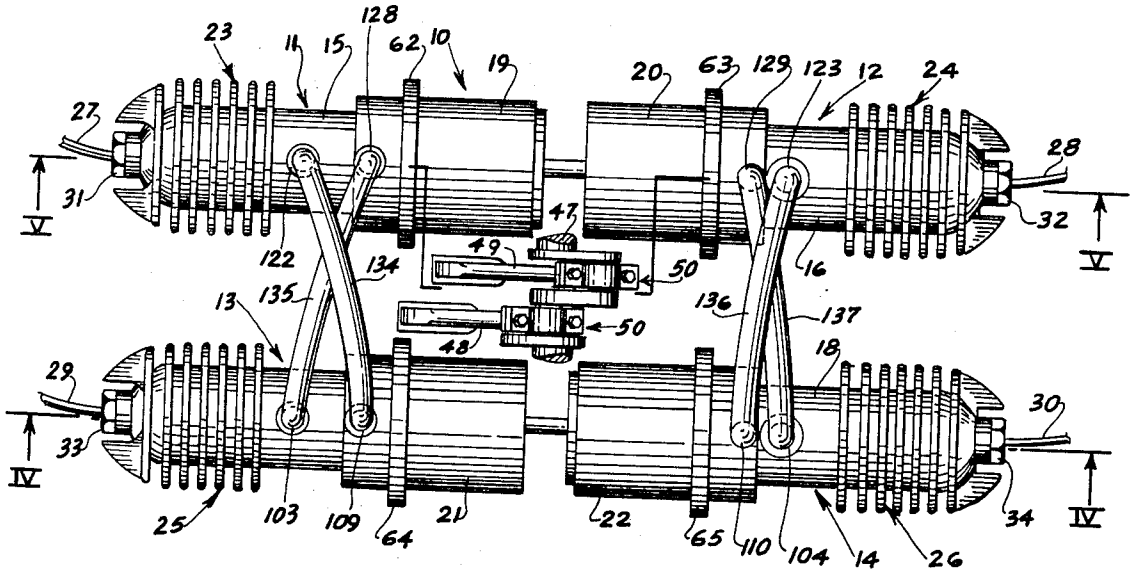
[52] **U.S. Cl.** **123/56,** 123/71
[51] **Int. Cl.** **F02b 75/24,** F02b 33/10
[50] **Field of Search** 123/56B2, 56A2, 71

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Primary Examiner—Wendell E. Burns
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ABSTRACT: The present invention includes a two-stroke cycle internal combustion engine having a crankshaft, a pair of opposed cylinder assemblies each formed with a combustion chamber and a compression chamber of a larger diameter than the combustion chamber, a piston assembly reciprocable within each of the cylinder assemblies and comprising integral compression and combustion portions slidably supported within said compression and combustion chambers respectively, and a lever assembly of the bellcrank type interconnecting said piston assemblies to the crankshaft. Air is supplied through valve means from a compression chamber of one of the cylinder assemblies to the combustion chamber of the other.



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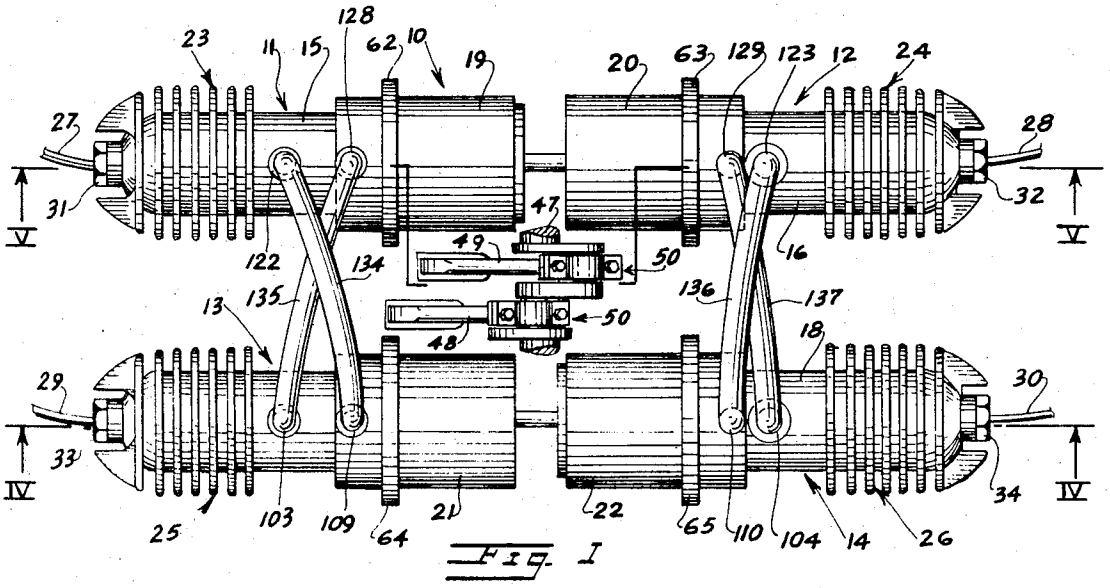


Fig. 1

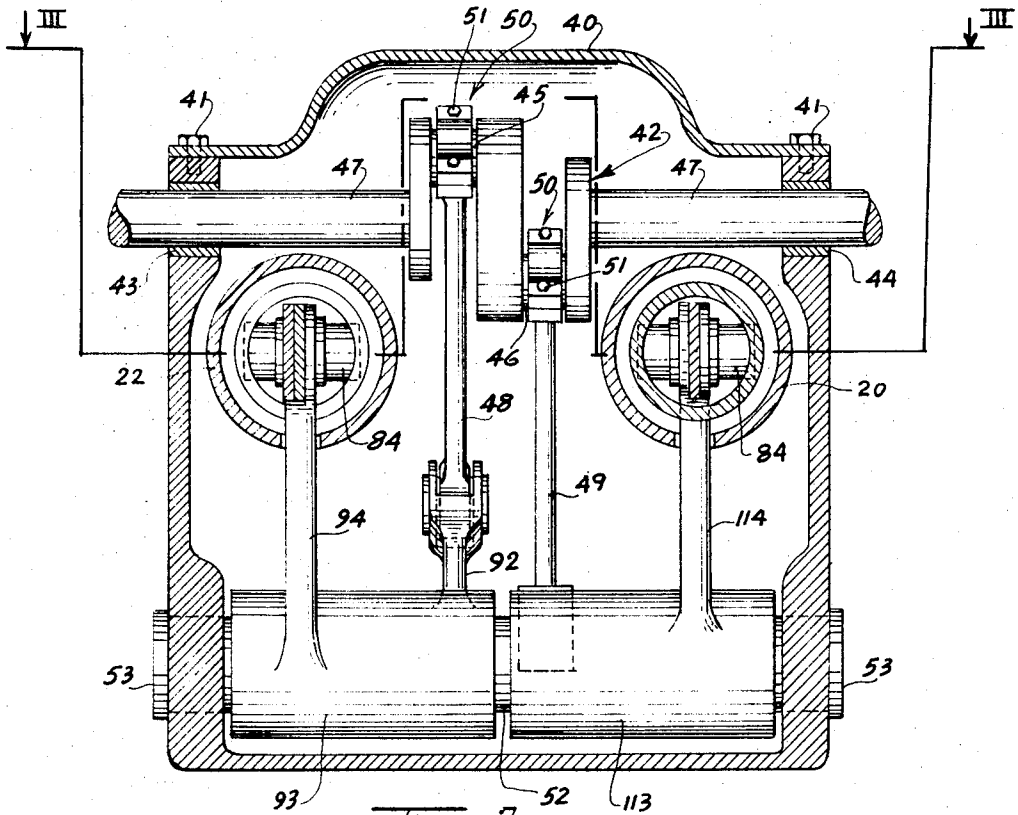


Fig. 2

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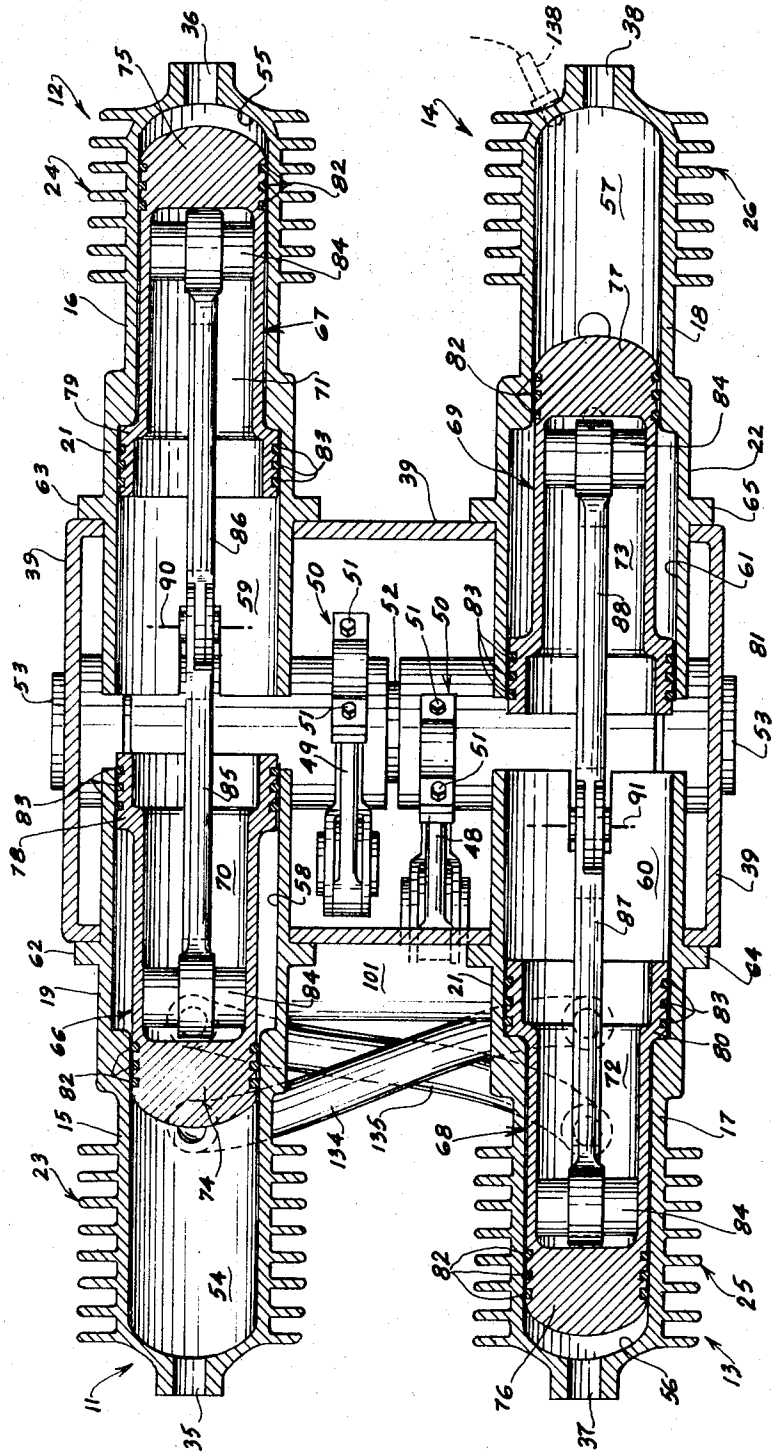


FIG. 3

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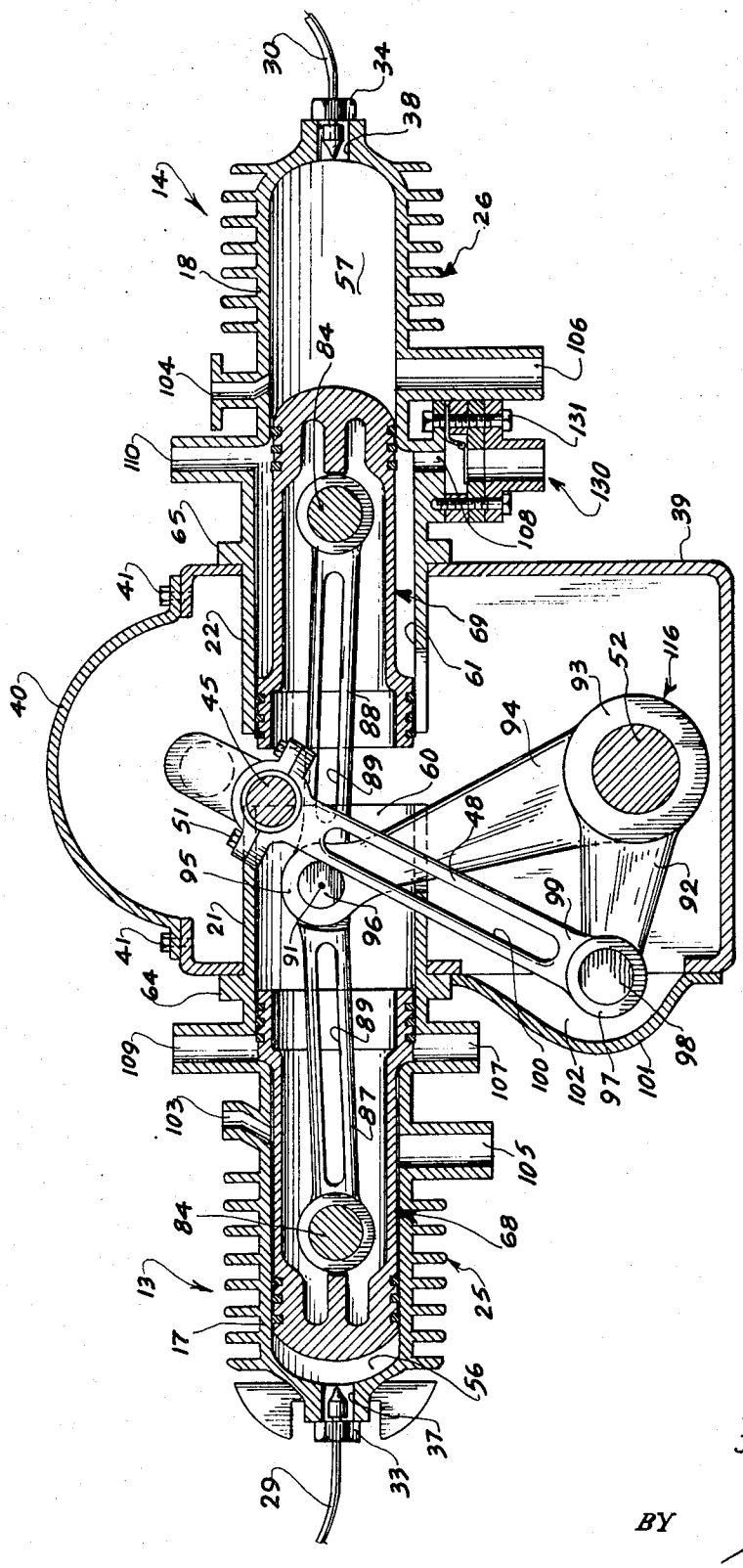


FIG. 4

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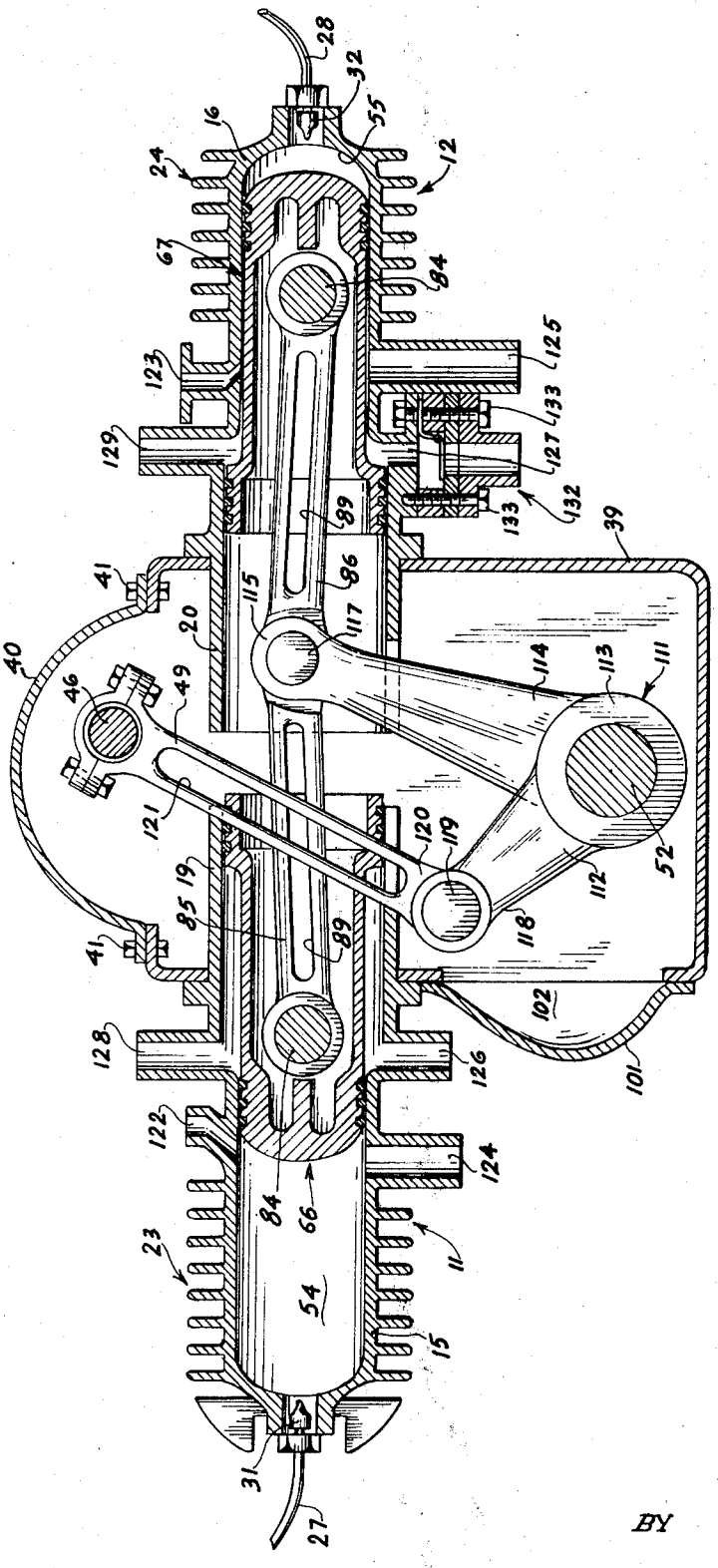


FIG. 5

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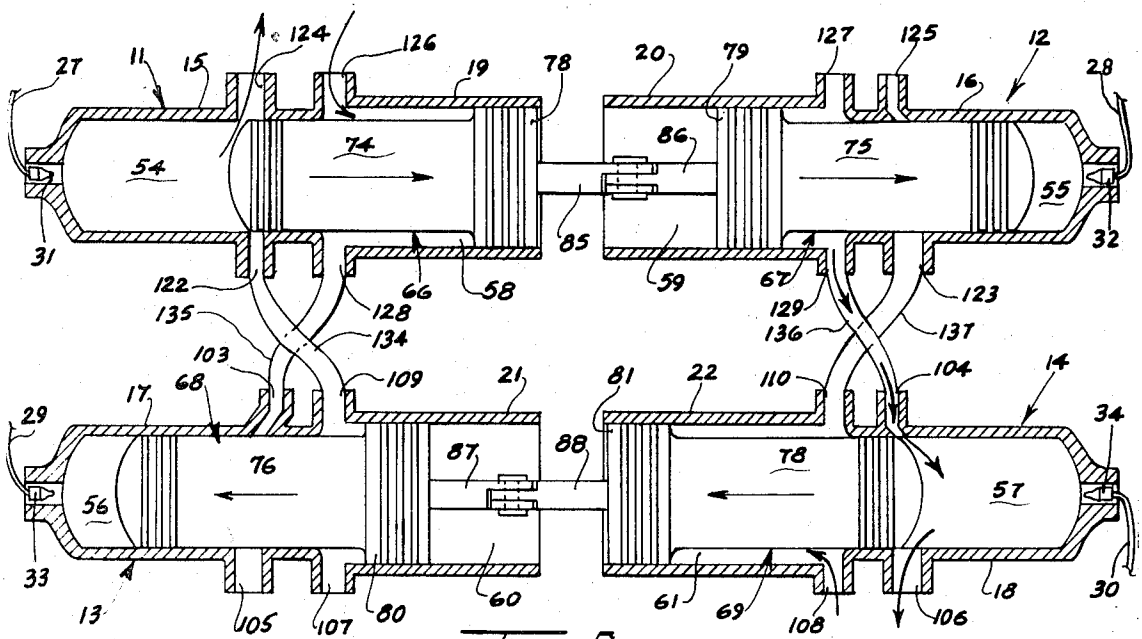


Fig. 6

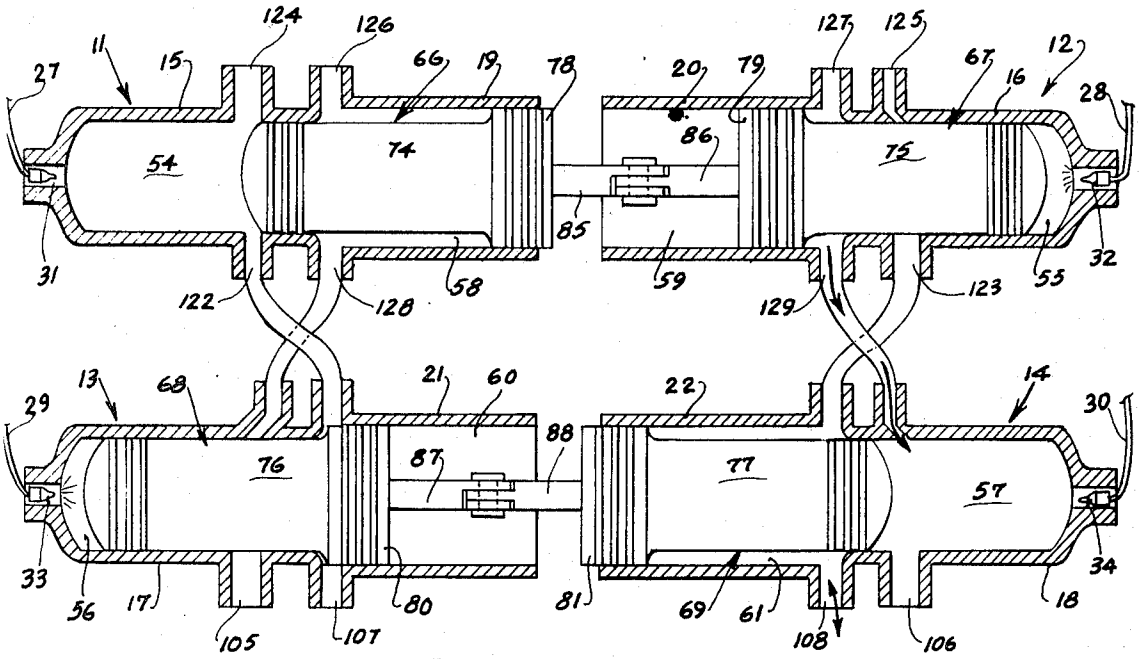


Fig. 7

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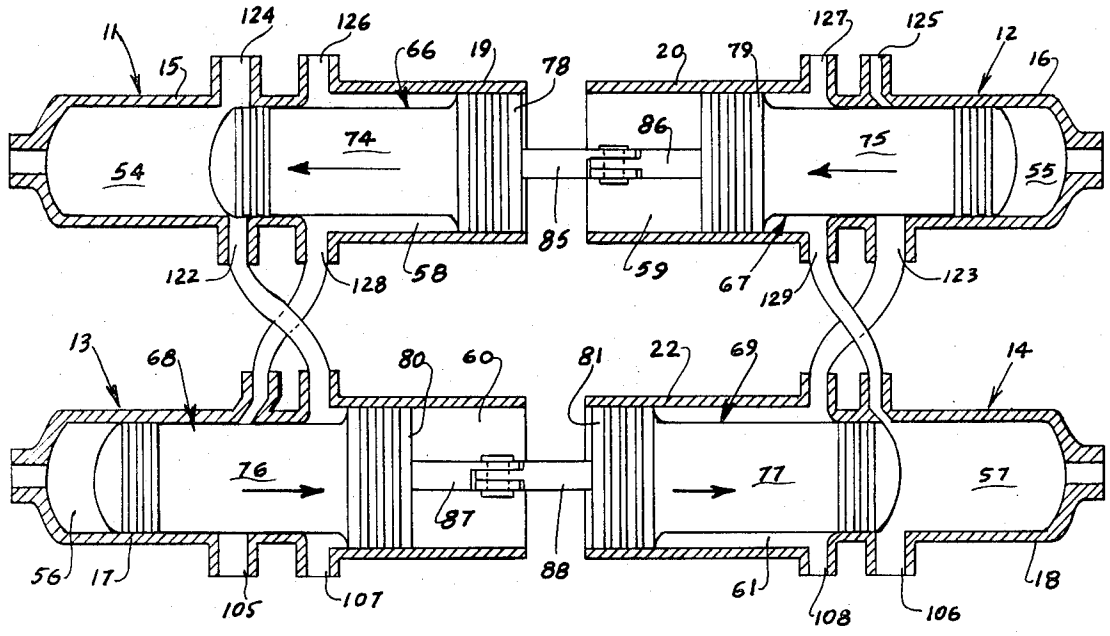


Fig. 8

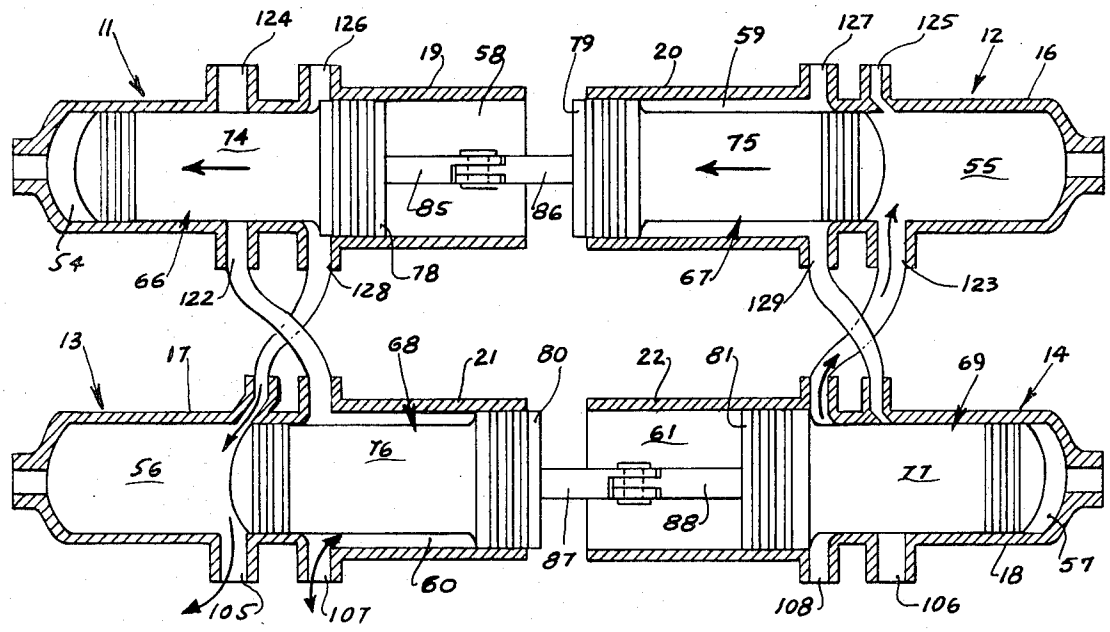


Fig. 9

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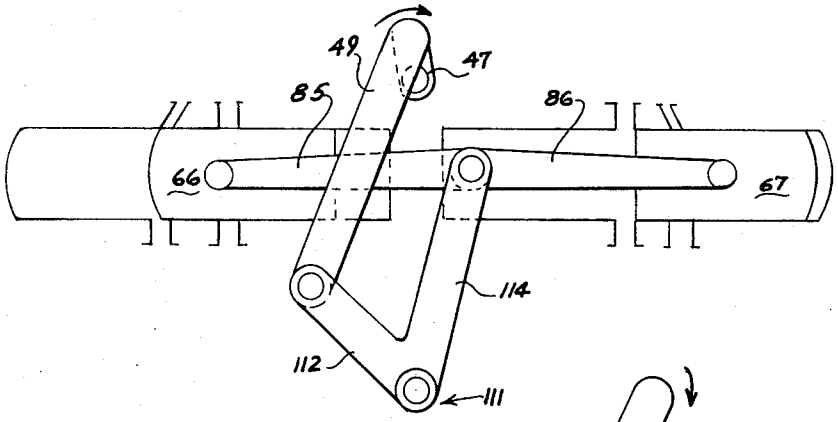


Fig. 10

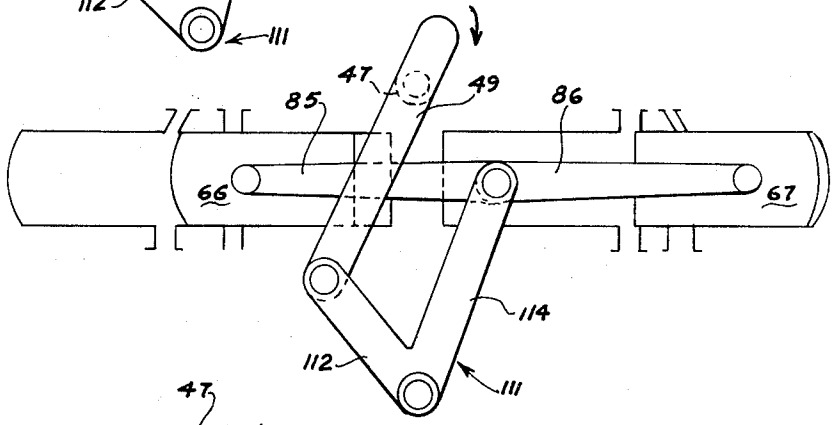


Fig. 11

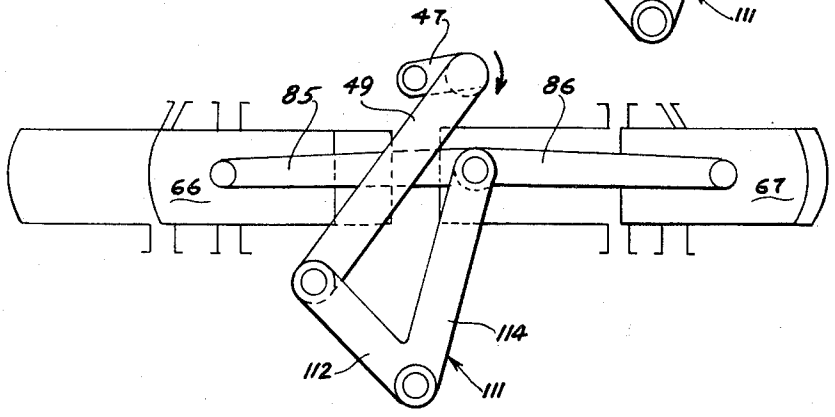


Fig. 12

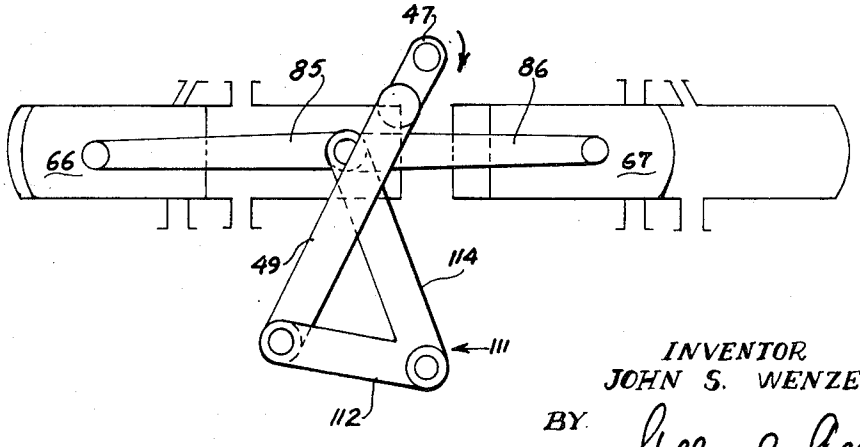


Fig. 13

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SELF-CHARGING AND -SCAVENGING LEVER ENGINE

BACKGROUND OF THE INVENTION

1. Field of the Invention

Internal combustion engines.

2. Description of the Prior Art

The use of lever-type engines dates back to the early days of automotive and internal combustion engine development. Historic advances in engine design necessarily include the brainchild of Alvah A. Powell, who saw advantages in changing long-stroke piston travel to shorter crank throw through leverage. More recent improvements include opposed cylinder two-cycle engines such as the type disclosed in U.S. Pat. No. 2,445,720 to Wenzel.

Known engines, however, include many undesirable features which designers in the art have unsuccessfully sought to overcome. Relatively complicated linkages with long connecting rods are characteristic of engines known to the art. In addition, vibration problems created by imbalance of moving parts result in a loss of engine efficiency as well as ever-increasing engine wear. The use of flywheels mounted on the ends of crankshafts and equipped with counterbalance weights have only added to already complicated engine structures.

SUMMARY OF THE INVENTION

This invention relates to internal combustion engines of the two-stroke-cycle type, and more particularly to a lever-type stepped piston engine having opposed stepped cylinder assemblies.

It is an object of the present invention to provide a lever-type engine including two or more pairs of opposed piston and cylinder assemblies each of which is connected to the effort end of a lever assembly of the bellcrank type, and in which piston strokes are considerably lengthened relative to the bore diameter.

Another object is to increase piston dwell time at each end of the piston stroke in an engine as described, thereby increasing mixing and igniting times of air fuel mixtures at any given crankshaft speed.

A further object of this invention is to provide a lever-type engine in which improved scavenging of burned gases is accomplished.

A further object is to provide improved means for homogenization of the fuel-air mixture both in compression ignition and spark ignition design.

Yet another object is to provide an engine such as described, in which the angle of thrust of the piston assemblies is decreased and maintained substantially equal in opposed piston assemblies, such that greater in-line thrust is experienced with minimized piston and cylinder wear.

Still another object is to provide a lever-type engine in which forces created by piston motion are used to compress fluid such as air or air fuel mixtures, the compressed fluid being supplied to an adjacent cylinder combustion chamber with a resulting decrease in linkage wear as a result of the absorption or recovery of energy in compressing the fluid.

A further object of the present invention is to provide a one-piece stepped piston assembly fitted to a cylinder having a corresponding two-diameter configuration. Valves permit the intake of air or a gaseous mixture directly from the atmosphere or through a carburetor, as well as the discharge of same under pressure into associated cylinder assemblies.

The present invention fulfills the aforementioned and other objects and overcomes limitations and disadvantages of prior art solutions to problems by providing, according to one aspect of the invention, a two-cycle lever-type internal combustion engine having a crankshaft and including first and second opposed cylinder assemblies each formed with a combustion chamber, and a compression chamber of a diameter larger than that of the combustion chamber. A piston assembly is supported for reciprocable movement within each cylinder assembly and includes combustion and compression portions thereof of respective diameters which enable slidably

mating engagement of the piston assembly with the combustion and compression chambers.

Each piston assembly includes a connecting rod pivotally secured thereto at one end and having an inner end which extends into pivotal engagement with the connecting rod of its opposed piston assembly. A lever assembly housing or engine casing supports a shaft which extends perpendicularly with respect to the longitudinal axes of opposed cylinder assemblies. A first bellcrank lever assembly including a first sleeve supported by the shaft for rotary movement therearound additionally comprises first and second levers integral with and extending radially from the first sleeve. A second bellcrank lever assembly including a second sleeve supported coaxially with respect to the first sleeve by the shaft for rotary movement therearound further comprises third and fourth levers integral with and extending from said second sleeve.

The second and fourth levers are of a greater length than the first and third levers, respectively, and comprise the effort end of the bellcrank lever assembly. Thrust of the working piston assemblies is transmitted to the second and fourth levers, thereby imparting rotary movement to the bellcrank lever assemblies which in turn impart rotary movement to the crankshaft via suitable connecting rods.

During the working stroke of any given piston assembly, air or a gaseous mixture is compressed within the compression chamber by a piston compression portion. This compressed fluid is supplied via conduit means from this compression chamber to an adjacent cylinder assembly combustion chamber for further compression thereof during the compression stroke of the adjacent piston assembly combustion portion. Valving of the flow of fluid through the conduit means is described in more detail below.

BRIEF DESCRIPTION OF THE DRAWING

FIG. **1** is a plan view of two opposed pairs of piston and cylinder assemblies of a lever-type internal combustion engine according to the present invention.

FIG. **2** is a cross-sectional view as taken generally across line II–II of FIG. **1** with cross-cylinder conduits eliminated for simplicity.

FIG. **3** is a cross-sectional view taken across line III–III of FIG. **2** and showing cross-cylinder conduits.

FIG. **4** is a cross-sectional view taken across line IV–IV of FIG. **1**.

FIG. **5** is a cross-sectional view taken across line V–V of FIG. **1**.

FIGS. **6—9** are operating sequence FIGS. showing the positions of the pistons during various steps of the sequence of operation of the present invention together with a schematic showing of the fluid flows.

FIGS. **10—13** are schematic views of the positions of the levers during various steps in the sequence of operation. FIGS. **10—13** correspond in stages of operation to FIGS. **6—9** respectively.

DESCRIPTION OF PREFERRED EMBODIMENTS OF THE INVENTION

Referring now in more detail to the drawing, FIG. **1** shows a four-cylinder engine **10** which includes a first pair of opposed cylinder assemblies **11** and **12**, and a second pair of opposed cylinder assemblies **13** and **14**. Cylinder assemblies **11** and **13** are disposed in horizontal side-by-side relationship with respect to each other, as are cylinder assemblies **12** and **14**. Cylinder assemblies **11**, **12**, **13** and **14** each include combustion portions **15**, **16**, **17** and **18** respectively, integrally formed with compression portions **19**, **20**, **21** and **22**. Parallel radially extending heat exchanging fin assemblies **23**, **24**, **25** and **26** are integral with cylinder combustion portions **15**, **16**, **17** and **18** such that heat generated during operation of engine **10** will be transferred from these combustion portions to the surrounding environment by the combination of conduction, convection and radiation effects.

While engine 10 may be either a compression ignition or spark ignition type, for purposes of illustration engine 10 will be described as a two-stroke cycle, compression ignition engine. Fuel lines 27, 28, 29 and 30 each supply a combustible fluid from an external source (not shown) to fuel jet injection assemblies 31, 32, 33 and 34 which, in turn, are secured within openings 35, 36, 37 and 38 formed in the ends of cylinder combustion portions 15, 16, 17 and 18, respectively.

An engine casing 39 includes a removable cover 40 secured by headed bolts 41 to the main portion of the casing, and houses a portion of a crankshaft assembly 42. Crankshaft assembly 42 is journaled within bearings 43 and 44, which are fixedly supported by engine casing 39. Crankshaft assembly 42 includes opposed crankshaft throws 45 and 46 each of which is fixedly secured to the main crankshaft 47.

Crankshaft connecting rods 48 and 49 are each secured at their respective upper ends to crankshaft throws 45 and 46 by means of bracket assemblies 50, which hold connecting rods 48 and 49 to the throws by means of headed bolts 51.

Engine casing 39 further supports a shaft 52 held within the casing by end hubs 53. Shaft 52 extends beneath, equidistant from and perpendicularly with respect to the coaxial longitudinal axes of opposed cylinder assemblies 11 and 12, and 13 and 14, respectively (FIG. 2).

FIG. 3 shows cylinder combustion portions 15—18 formed with internal combustion chambers 54, 55, 56 and 57 each communicating with openings 35—38 respectively. Compression portions 19—22 of cylinder assemblies 11—14 are each formed with cylinder compression chambers 58, 59, 60 and 61, each of these compression chambers communicating with their associated combustion chambers. Cylinder assemblies 11—14 are further formed with annular flanges 62, 63, 64 and 65 against which engine casing 39 is fixedly disposed.

The inside diameters of compression chambers 58, 59, 60 and 61 are each larger than the inside diameters of combustion chambers 54, 55, 56 and 57, respectively. Piston assemblies 66, 67, 68 and 69 are supported for reciprocable sliding movement within cylinder assemblies 11, 12, 13 and 14, respectively. These piston assemblies may be hollow, being formed with cavities 70, 71, 72 and 73, respectively, and include piston combustion portions 74, 75, 76 and 77 integrally formed in a one-piece construction with larger diameter compression portions 78, 79, 80 and 81, respectively. Piston rings 82 encircle piston compression portions 74—77, thereby forming a fluidtight seal between the respective piston combustion portions and the walls of the respective cylinder assembly combustion chambers. Similarly, piston rings 83 encircle piston compression portions 78—81, thereby forming a fluidtight seal between these compression portions and the walls of the respective cylinder assembly compression chambers.

A relatively short transversely extending shaft 84 is fixedly supported within the cavities of each of the piston assemblies. Piston connecting rods 85, 86, 87 and 88 are each pivotally secured to shaft 84 within piston assemblies 66, 67, 68 and 69, respectively. Connecting rods 85—88 are each formed with longitudinally extending slots 89 formed therethrough for purposes of minimizing the weight of these rods without adversely affecting their load transmitting capabilities. Opposed connecting rods 85 and 86 extend toward and into pivotal engagement with one another at a transverse pivot axis 90. Similarly, opposed connecting rods 87 and 88 extend toward and into pivotal engagement with one another at transversely extending pivot axis 91.

Referring now to FIG. 4, a lever assembly 116 of the bellcrank-type is shown including a first lever 92 integrally formed with an extending radially from a first cylindrical sleeve 93 which is supported for rotary movement about shaft 52. Lever assembly 116 is further formed with a second lever 94 which is integrally formed with and extends radially from first cylindrical sleeve 93 at a predetermined angle with respect to lever 92. An end portion 95 of second lever 94 is hingedly secured at pivot axis 91 to piston connecting rods 87 and 88 such that each of these members is free to pivot with respect to the others. A transversely extending pin 96 holds piston connecting rods 87 and 88 in engagement with second lever 94.

An end portion 97 of first lever 92 is pivotally secured by a pin 98 to a lower end portion 99 of crankshaft connecting rod 48. Connecting rod 48 may similarly be formed with a longitudinally extending slot 100 therethrough for purposes of eliminating undesirable weight. Connecting rod 48 is transversely offset from piston connecting rod 87 so as not to interfere therewith during movement of piston assemblies 68 and 69.

FIG. 4 shows engine casing 39 including a bulge plate 101 formed with a relief area 102 which will be occupied by end portion 97 of first lever 92 during rotary movement of bellcrank lever assembly 116. Thus, reciprocatory movement of piston assemblies 68 and 69 will result in thrust being transmitted from the respective piston assemblies during their working stroke into piston connecting rods 87 and 88 via shafts 84 and thereafter into end portion 95 of second lever 94, thereby resulting in pivoting of second lever 94 about the axis of shaft 52. This pivoting of second lever 94 results in an identical angular pivoting of first lever 92, thereby resulting in rotation of crankshaft throw 45 about the axis of crankshaft via connecting rod 48. In this way, crankshaft 47 is caused to turn and energy is thereby supplied to remote means such as an automotive transmission, etc.

It is to be noted that the linkage of the present invention as shown in FIG. 4 includes piston connecting rods 87 and 88 being connected and pivoting with respect to each other about pivot axis 91 such that the longitudinal axes of connecting rods 87 and 88 intersect the coaxial longitudinal axes of opposed cylinder assemblies 13 and 14 at identical angles. This angle of intersection or angle of thrust is reduced as compared to known linkages wherein piston connecting rods are offset and do not meet and pivot with respect to each other at a common axis nor in a common plane.

Looking now at cylinder assemblies 13 and 14 as illustrated in FIG. 4, cylinder combustion portions 17 and 18 are formed with radially extending charge ports 103 and 104, respectively, each of which communicates with combustion chambers 56 and 57, respectively. Combustion portions 17 and 18 are further formed with exhaust ports 105 and 106, respectively, each of which communicates with their respective combustion chambers. In a preferred embodiment of this invention, the diameters of exhaust ports 105 and 106 are larger than the diameters of the charge ports 103 and 104. In addition, the centerline of exhaust port 105 is, longitudinally of the cylinder axis, offset from the axis of the charge port 103 outwardly from the compression chamber 60 such that movement of piston assembly 68 to the right (as shown in FIG. 4) will result in an uncovering of exhaust port 105 prior to the uncovering of charge port 103. Further movement of piston assembly 68 will result in uncovering of charge port 103 as well as exhaust port 105 such that complete and more efficient scavenging of burned fluids may occur.

Cylinder assembly compression portions 21 and 22 are formed with inlet ports 107 and 108, respectively, as well as diametrically opposed outlet ports 109 and 110, respectively.

It is to be noted here that while this description is directed toward opposed cylinder assemblies 13 and 14 as shown in FIG. 4, opposed cylinder assemblies 11 and 12 possess an identical structure. Thus, looking now at FIG. 5, a lever assembly 111 of the bellcrank-type is shown including a lever 112 integrally formed with and extending radially from a cylindrical sleeve 113. A lever 114 having a length greater than the lever 112 is similarly integrally formed with and extends radially from cylindrical sleeve 113 at an angle with respect to lever 112. Lever 114 is pivotally secured to piston connecting rods 85 and 86 at pivot axis 90 via a pin 117 which holds end portion 115 in pivotal engagement with connecting rods 85 and 86. Thus, reciprocatory movement of piston assemblies 66 and 67 within cylinder assemblies 11 and 12 will result in a transfer of the thrust of the working piston assembly into lever 114 such that lever 114 constitutes the effort lever

of bellcrank lever assembly **111**. The result will be a pivoting of lever **114** about the axis of shaft **52** which, in turn, will result in rotary movement of lever **112** and sleeve **113** about the same axis.

An end portion **118** of lever **112** is pivotally connected via a pin **119** to a lower end portion **120** of crankshaft connecting rod **49**. Connecting rod **49** is formed with a longitudinally extending slot **121** therethrough similar to slot **100** in the case of crankshaft connecting rod **48**. The aforedescribed pivoting of lever **114**, therefore, will result in lever **112** imparting rotary movement to crankshaft throw **46** about the axis of crankshaft **47**, thereby causing rotation of crankshaft **47**.

Cylinder assembly combustion portions **15** and **16** are formed with charge ports **122** and **123**, respectively. Combustion portions **15** and **16** are further formed with exhaust ports **124** and **125**, respectively, the diameters of the exhaust ports being larger than the diameters of the charge ports. As in the case of charge ports **103** and **104**, and exhaust ports **105** and **106**, exhaust ports **124** and **125** are, longitudinally of the cylinder axis, offset from charge ports **122** and **123** such that, for example, movement of piston assembly **66** to the right (as shown in FIG. **5**) will result in an uncovering of exhaust port **124** prior to an uncovering of charge port **122**. Further movement of piston assembly **66** to the right will result in uncovering of both charge port **122** and exhaust port **124**. The same applies in the case of charge port **123** and exhaust port **125**. Ports **122**, **123**, **124** and **125** communicate with their respective cylinder combustion chambers.

Cylinder compression portions **19** and **20** are formed with radially extending inlet ports **126** and **127**, respectively, as well as diametrically opposite and radially extending outlet ports **128** and **129**, respectively.

In a preferred embodiment of the present invention, a reed-type valve assembly **130** is secured by bolts **131** to cylinder assembly **14**. Similarly, a reed-type valve assembly **132** is secured with bolts **133** to cylinder assembly **12**. Valve assemblies **130** and **132** cover inlet ports **108** and **127** respectively such that only when pressure external of these valve assemblies exceeds the pressure in inlet ports **108** and **127** will the respective valve assemblies permit the flow of fluid into the compression chambers of the cylinder assemblies **14** and **12**. Of course, it is within the scope of the present invention to provide any suitable valve means known to the art.

Referring again to FIG. **1**, conduits **134**, **135**, **136** and **137** are shown. More specifically, conduit **134**, which may be made from any suitable heat-resistant material, interconnects outlet port **109** of the compression portion **121** of cylinder assembly **13** with charge port **122** of the combustion portion **15** of cylinder assembly **11**. Conduit **135** interconnects outlet port **128** of the compression portion **19** of cylinder assembly **11** with charge port **103** of the combustion portion **17** of cylinder assembly **13**. Similarly, conduit **136** interconnects outlet port **110** of the compression portion **22** of cylinder assembly **14** with charge port **123** of the combustion portion **16** of cylinder assembly **12**. Conduit **137** interconnects outlet port **129** of the compression portion **20** of cylinder assembly **12** with charge port **104** of the combustion portion **18** of cylinder assembly **14**. It is within the scope of the present invention to include any variety of valving devices in or associated with conduits **134**, **135**, **136** and **137** to control the flow of fluid therethrough in a selected or predetermined manner.

As already stated, the lever-type engine of the present invention may be used as a compression ignition engine or as a spark ignition engine. In either case, energy from the burning of an air fuel mixture inside a cylinder is extracted in order to produce an output or work. It is well known that the main difference between engines operating on spark ignition and compression ignition is in the method of admitting and igniting the fuel. In the spark ignition engine, the fuel and air are mixed before they enter the cylinder, while in the compression ignition engine, fuel and air enter separately and the mixing occurs within the cylinder. For purposes of illustration only, the structure illustrated in the aforedescribed FIGS. has been described in terms of a compression ignition engine. In other preferred embodiments of this invention, a spark plug, for example, designated numeral **138** and shown in phantom lines in FIG. **3**, is added to cylinder assemblies **11**, **12**, **13** and **14**, and an air fuel mixture is supplied through a carburetor to respective combustion chambers, thereby converting the engine from a compression ignition engine to a spark ignition engine.

OPERATION OF PREFERRED EMBODIMENTS OF THE INVENTION

In operation, any one of the described piston assemblies will be caused to move in a working stoke upon firing or ignition of a fuel-air mixture within the associated combustion chamber. For purposes of illustration and starting at the point of ignition, piston assembly **66**, for example, will be caused to move to the right (as shown in FIG. **6**) as a result of combustion in chamber **54**. It is the force due to combustion against piston combustion portion **74** of piston assembly **66** that results in thrust being transmitted from piston assembly **66** into piston connecting rod **85**. This thrust is thereafter transmitted into piston connecting rod **86** via the interconnection at pivot axis **90**, and thence into opposed piston assembly **67**. Thus, both piston assembly **66** and piston assembly **67** move to the right.

During this movement to the right, a pressure differential across inlet port **126** is experienced such that valve assembly **132** opens, permitting a flow of air from the atmosphere, for example, into inlet port **126**. Further movement of piston assembly to the right results in uncovering of exhaust port **124** such that burned gases under pressure flow therethrough and out from combustion chamber **54**. Still further movement of piston assembly **66** to the right causes charge port **122** to be opened. Compressed air from compression chamber **60** of cylinder assembly **13** flows at high velocities through outlet port **109**, through conduit **134** and thereafter through charge port **122** into combustion chamber **54**.

This influx of air through port **122** plays a dual role. Firstly, the air causes a scavenging purging of combustion chamber **54** of burned gases, these gases flowing out of chamber **54** through exhaust port **124**. Secondly, this supply of fresh air fills chamber **54** and occupies this chamber until it will be compressed to ignition temperatures on the return stroke of piston assembly **66**.

Looking now at the return stroke of piston assembly **66**, as the piston moves to the left, the air within chamber **54** will be compressed since charge port **122** and exhaust port **124** will be sealed by piston combustion portion **74**. For each pound of pressure exerted on the air, there will be a temperature increase of about 2° F. At the top or end of this compression stoke (when pressure is highest) the temperature in the chamber may be about 1,000° F. This heat ignites fuel which is supplied to chamber **54** via fuel jet injection assembly **31** almost as soon as it is injected into the chamber, and the piston assembly, motivated by the expansion of burning gases, once again moves down on the power stroke. There is a continuous combustion during the entire length of the power stroke, and pressure resulting from combustion remains approximately constant throughout the stoke.

It should be noted that during the return stroke of piston assembly **66**, the air which entered chamber **58** via inlet port **126** is compressed and caused to flow under pressure through outlet port **128**, through conduit **135**, thence through charge port **103**, and then into combustion chamber **56** (see FIG. **9**).

What has just been described for piston and cylinder assemblies **66** and **11**, respectively, occurs for the remaining piston and cylinder assemblies at varying times during the overall engine cycle. Thus, in FIG. **6** it is seen that burned gases are escaping from chamber **54** through exhaust port **124**, while fresh air is entering compression chamber **58** through inlet port **126** due to the pressure drop in the latter chamber created by piston compression portion **78**. At the same time, scavenging of combustion chamber **57** of cylinder assembly **14**

is occuring as a result of the flow of compressed air from compression chamber 59 of cylinder assembly 12 through conduit 136 into chamber 57, thereby carrying exhaust out through exhaust port 106. A simultaneous intake of air through inlet port 108 occurs as a result of a pressure drop in chamber 61.

FIG. 7 shows piston assembly 68 at the very beginning of its work stroke with combustion commencing in chamber 56 as a result of the injection of fuel through injection assembly 33. At this time air in chamber 55 has been compressed to ignition temperatures and fuel is starting to enter chamber 55. FIGS. 8 and 9 illustrate the further progression of piston assemblies 67 and 68 during their work strokes, with the resulting cyclic charging and compression in the associated cylinder assemblies.

FIGS. 10, 11, 12 and 13 illustrate the respective positions of bellcrank lever assembly 111 at the stages of the engine cycle represented by FIGS. 6, 7, 8 and 9, respectively. It is a feature of the invention that piston dwell times are markedly increased at the top and bottom of each piston stroke, thereby improving the combustion process by increasing the time for air fuel mixing and ignition of the mixture, for any given crankshaft speed.

Once again, while a preferred embodiment of the invention illustrated and described relates to a compression ignition engine, the compression chambers are adapted to receive a gaseous mixture from a carburetor and discharge same into the combustion chamber of an adjacent cylinder assembly.

From the foregoing it will be appreciated that means have been provided for lengthening the piston stroke considerably beyond the dimension of the bore diameter without employing long connecting rods and crank throw radii.

The bellcrank lever provides a means for introducing a mechanical advantage between the pistons and the crankshaft in such a manner as to multiply the piston dwell time at top and bottom of each piston stroke thereby improving the combustion process by increasing the time for mixing and igniting the fuel-air mixture at any given crankshaft speed. That same increased dwell time at the bottom of the piston stroke improves scavenging of burned gases and admitting of a new charge of fuel and/or gaseous mixture for the succeeding combustion stroke.

Another advantage of this arrangement of components of this invention is the reduction in the angle of thrust of the pistons and their connecting rods. This same reduction in angle of thrust is reflected through the linkage to the connecting rod between the load end of the bellcrank lever and the crankshaft due to the reduced crank throw radius for any given piston stroke.

Additionally, the directly opposed cylinders provide a means for absorption of accelerating piston forces at the end of each piston stroke by means of the compression and ignition in the directly opposed cylinder, without imposing undue forces on the connecting linkages. Further, the utilization of these forces to accomplish the useful work of compressing the gaseous mixture in a nearly straight line thrust, results in improved efficiency over designs employing a direct connection between piston and crankshaft where the accelerating mass of these parts at the end of each work stroke must be absorbed by the crankshaft and the connecting linkages alone. The work of driving the piston or pistons through the compression stroke in the conventional design must be accomplished by reclaiming a part of the power previously imparted to the crankshaft and flywheel.

The reduced angle of thrust of the pistons and their connecting rods also makes possible a convenient method of adding a pump piston to each work piston for the purpose of transferring air or gaseous mixture to the work cylinders.

As shown in the attached drawing, a one-piece piston, comprised of two different diameters is fitted to a cylinder having a corresponding two diameter configuration.

The inner chamber (larger diameter) is a piston type reciprocating pump which supplies air (in a compression ignition engine) or a gaseous mixture (in a spark ignition engine) to the outer chamber (smaller diameter) of an adjacent cylinder, the crank throw of which cylinder is 180° from that of the pump cylinder.

In a four-cylinder engine as described above, the left front pump section would supply a charge to the left rear work section of the two diameter cylinders.

The pump sections of each cylinder are equipped with suitable check valves to permit intake of air or gaseous mixture directly from the atmosphere or through a carburetor and discharge of same into the connecting passage of the cylinder it charges.

The arrangement of the bellcrank levers described above also provides a means for attaching separate pump cylinders and their pistons directly below the work cylinders in such a manner as to provide charging of the work cylinders similar to the function of the pumps in a two-diameter cylinder.

The embodiments of the invention particularly disclosed are presented merely as examples of the invention. Other embodiments, forms and modifications of the invention come within the scope of the disclosure and of the appended claims.

I claim:

1. Apparatus for use with an engine having a crankshaft, comprising opposed first and second cylinder assemblies each including integral combustion and compression cylinder portions formed with inner diameters, a piston assembly reciprocable within each cylinder assembly and being formed with a plurality of outer diameters which slidingly mate with said inner diameters, and a lever assembly of the bellcrank-type interconnecting said piston assemblies to the crankshaft, said lever assembly including first and second lever arms integrally formed with and extending radially from a sleeve supported for rotary movement about a shaft, said second lever arm being offset axially of said sleeve from said first lever arm.

2. Apparatus according to claim 1, further comprising opposed third and fourth cylinder assemblies spaced from said first and second cylinder assemblies, and valve means for controlling charge pressures from compression cylinder portions.

3. Engine apparatus comprising at least two pairs of opposed substantially coaxial cylinder assemblies, each of said cylinder assemblies including a combustion cylinder portion formed with a charge port and an exhaust port, and a compression cylinder portion having an inner diameter larger than the inner diameter of said combustion cylinder portion; a piston assembly mounted for reciprocable movement within each of said cylinder assemblies, each of said piston assemblies including a combustion piston portion reciprocable within a respective combustion cylinder portion, and a compression piston portion integral with said combustion piston portion and reciprocable within a respective compression cylinder portion; valve means for controlling fluid flow through said ports; a crankshaft extending substantially perpendicularly with respect to longitudinal axes of the cylinder assemblies; and a lever assembly of the bellcrank-type interconnecting opposed piston assemblies with said crankshaft assembly, said lever assembly including first and second lever arms integrally formed with and extending radially from a sleeve supported for rotary movement about a shaft, said second lever arm being offset axially of said sleeve from said first lever arm.

4. Engine apparatus according to claim 3, wherein said two pairs of opposed cylinder assemblies include first, second, third and fourth cylinder assemblies, each combustion cylinder portion being formed with a combustion chamber and each compression cylinder portion being formed with a compression chamber, said first and second cylinder assemblies being opposed, each of said cylinder assemblies being formed with a fuel supply opening therethrough in an end portion of said combustion cylinder portion, and means for supplying fuel to each of said combustion chambers through said fuel opening.

5. Engine apparatus according to claim 4, wherein said fuel supply means includes a fuel injection nozzle disposed within said fuel supply opening.

6. Engine apparatus according to claim 3 wherein said two pairs of opposed cylinder assemblies include first, second, third and fourth cylinder assemblies each formed with a combustion chamber and a compression chamber, said chambers communicating with each other, said first and second cylinder assemblies being opposed, each of said cylinder assemblies being formed with an opening therethrough in an end portion of said combustion cylinder portion, and ignition means located in said opening for initiating combustion of fuel supplied to said combustion chamber.

7. Engine apparatus according to claim 4, further comprising valve means for permitting a charge to flow from the compression chamber of said third cylinder assembly to the combustion chamber of said first cylinder assembly during firing of said fourth cylinder assembly.

8. Engine apparatus according to claim 7, further comprising valve means for permitting a charge to flow from the compression chamber of said second cylinder assembly to the combustion chamber of said fourth cylinder assembly during firing of said first cylinder assembly.

9. Engine apparatus according to claim 4, wherein said first and third cylinder assemblies are disposed in side-by-side relationship with respect to each other in a horizontal zone, said apparatus further comprising first conduit means interconnecting the outlet port of said third cylinder assembly with the charge port of said first cylinder assembly, said first conduit means further interconnecting the outlet port of said first cylinder assembly with the charge port of said third cylinder assembly.

10. Engine apparatus according to claim 9, further comprising second conduit means interconnecting the outlet port of said second cylinder assembly with the charge port of said fourth cylinder assembly, said second conduit means further interconnecting the outlet port of said fourth cylinder assembly with the charge port of the second cylinder assembly.

11. Engine apparatus, comprising:

a. first and second opposed substantially coaxial cylinder assemblies each being formed with a combustion chamber and a compression chamber, said compression chamber communicating with said combustion chamber and having a larger internal diameter than the latter;

b. a piston assembly reciprocable within each of said cylinder assemblies, said piston assembly including a combustion piston portion slidably supported within said combustion chamber, and a compression piston portion integral with said combustion piston portion and slidably supported within said compression chamber;

c. a piston connecting rod being pivotably connected at an outer end thereof to each of said piston assemblies, inner ends of said piston connection rods pivotably engaging each other at a first pivot axis;

d. a lever assembly housing;

e. a shaft supported by said housing and extending substantially perpendicularly with respect to the longitudinal axes of said cylinder assemblies; and

f. a first bellcrank lever assembly comprising a first sleeve supported by said shaft for rotary movement therearound, and first and second levers integral with and extending radially from said first sleeve, said second lever being offset axially of said sleeve from said first lever, an end of said second lever pivotably engaging said inner ends of said piston connecting rods at said first pivot axis such that linear movement of said piston assemblies will impart rotary movement to said first sleeve, said connecting rods extending at substantially identical angles from the longitudinal axes of said cylinder assemblies during movement of said piston assemblies.

12. Engine apparatus according to claim 11, further comprising a crankshaft, a rod interconnecting an end of said first lever with said crankshaft, said second lever being longer than said first lever.

13. Engine apparatus according to claim 11, wherein said combustion and compression piston portions are hollow, said outer ends of said connecting rods extending through said compression piston portion and into said combustion piston portion.

14. Engine apparatus according to claim 12, wherein said piston connecting rods and said crankshaft connecting rod are each formed with a longitudinal weight-saving slot therethrough.

15. Engine apparatus according to claim 11, further comprising:

a. third and fourth opposed substantially coaxial cylinder assemblies each being formed with a combustion chamber and a compression chamber, said first and third cylinder assemblies being disposed in horizontal side-by-side relationship with each other;

b. third and fourth piston assemblies being reciprocable within said respective third and fourth cylinder assemblies;

c. third and fourth piston connecting rods being pivotally connected at outer ends thereof to said respective third and fourth piston assemblies, inner ends of said third and fourth piston connecting rods pivotally engaging each other at a second pivot axis; and

d. a second bellcrank lever assembly comprising a second sleeve supported coaxially with respect to said first sleeve by said shaft for rotary movement therearound, and third and fourth lever integral with and extending from said second sleeve, said fourth lever being offset axially of said sleeve from said third lever, an end of said third lever pivotally engaging inner ends of said third and fourth piston connecting rods at said second pivot axis such that linear movement of said third and fourth piston assemblies will impart rotary movement to said second sleeve.

16. Engine apparatus according to claim 15, wherein said third and fourth piston connecting rods extend at substantially identical angles from the longitudinal axes of said cylinder assemblies during movement of said third and fourth piston assemblies.

17. Engine apparatus according to claim 16, wherein each of said cylinder assemblies is formed with inlet and outlet ports each communicating with said compression chamber, and charge and exhaust ports each communicating with said combustion chamber.

18. Engine apparatus according to claim 17, further comprising conduit means for supplying air from an outlet port of one cylinder assembly to the charge port of another.

19. Engine apparatus according to claim 18, further comprising valve means cooperating with said conduit means for controlling said air supply.

20. Engine apparatus according to claim 19, wherein said valve means includes a reed-type valve.