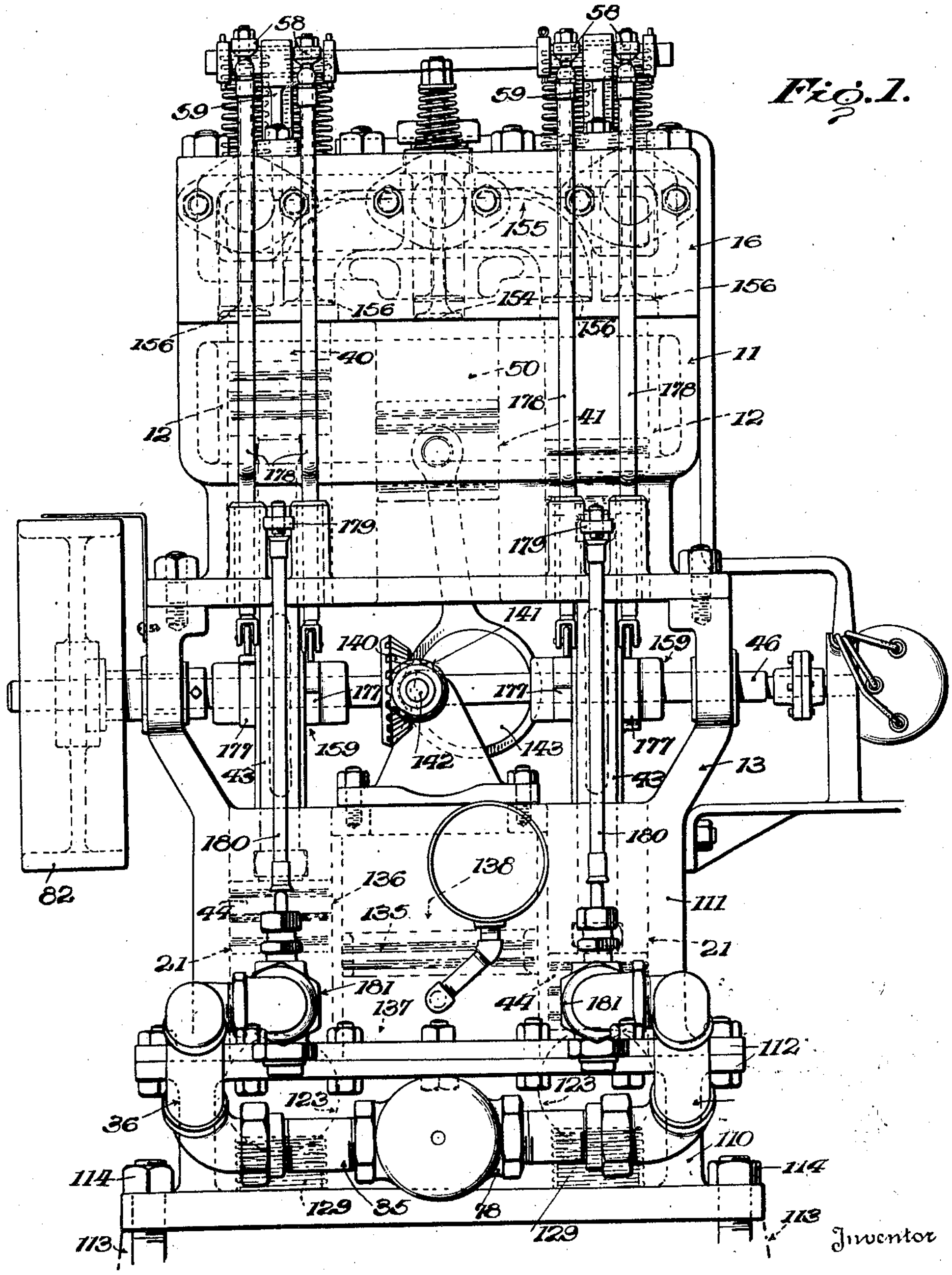
ENGINE

Filed April 20, 1933 6 Sheets-Sheet 1

Fig. 1.



Inventor

William F. Logan

By Cameron, Kerkam + Sutton

Attorneys

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Fig. 6.

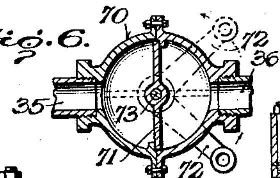


Fig. 2.

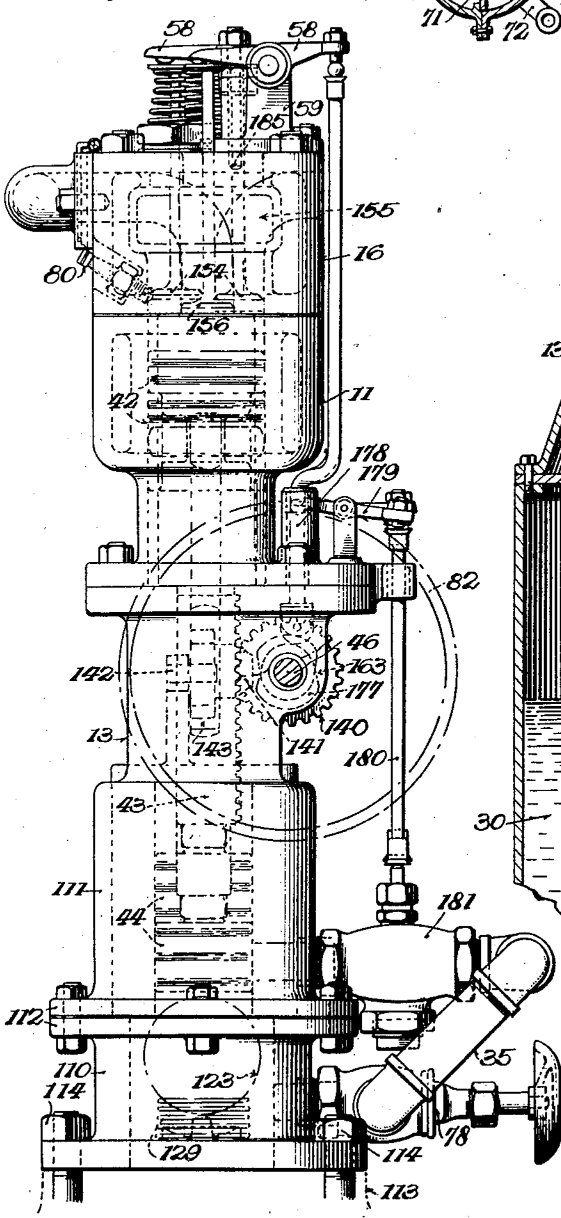
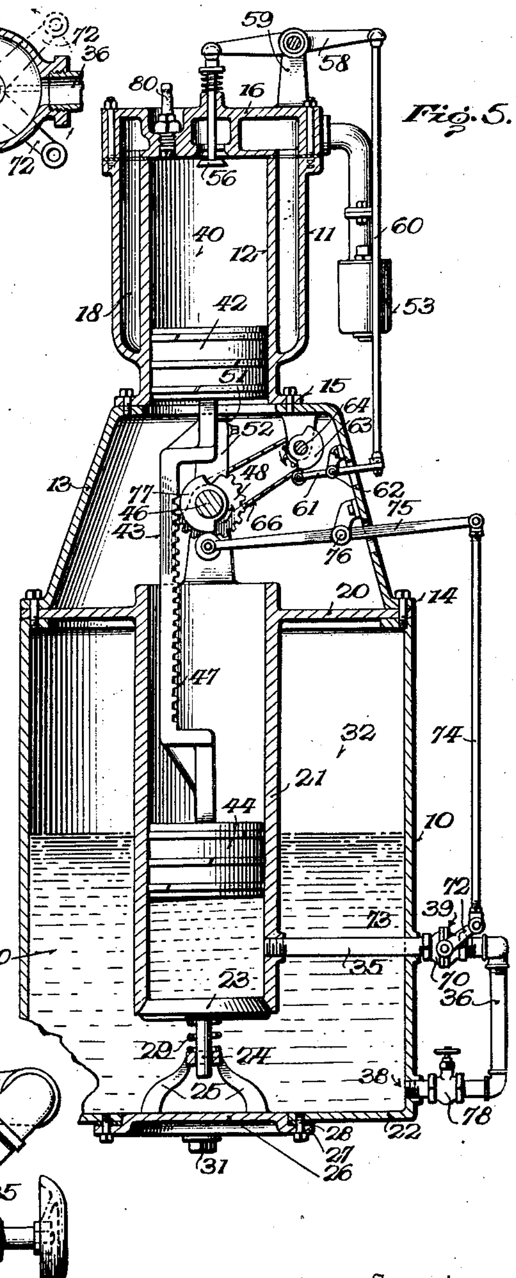


Fig. 5.



Inventor

William F. Logan

By Cameron, Kerkam & Sutton

Attorneys

Nov. 3, 1936. W. F. LOGAN 2,059,802

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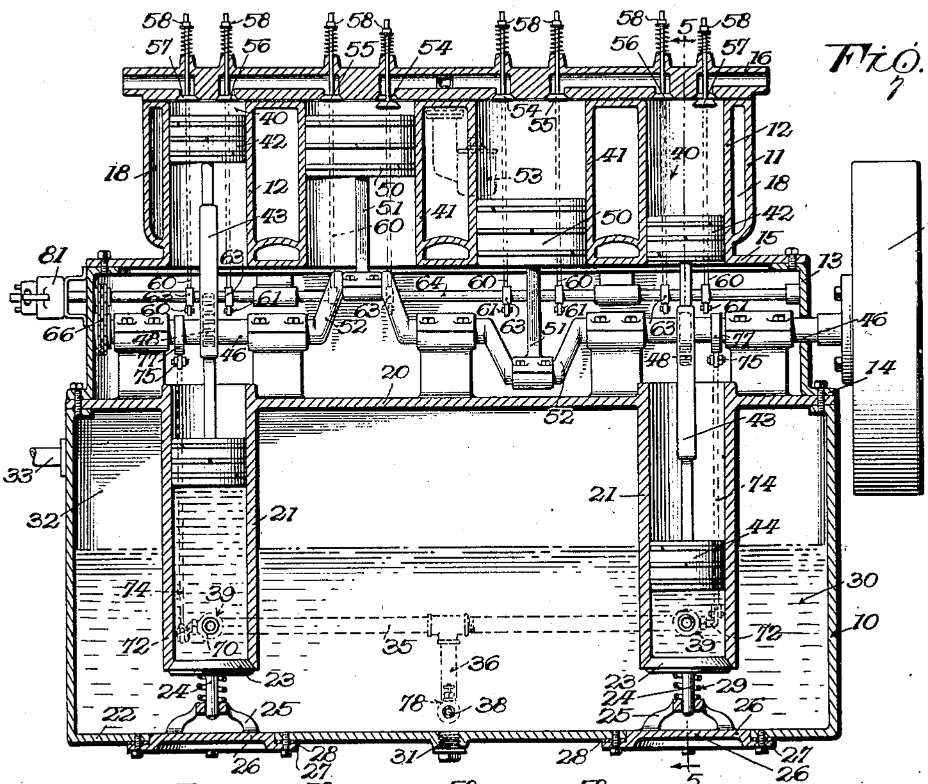

Fig. 4

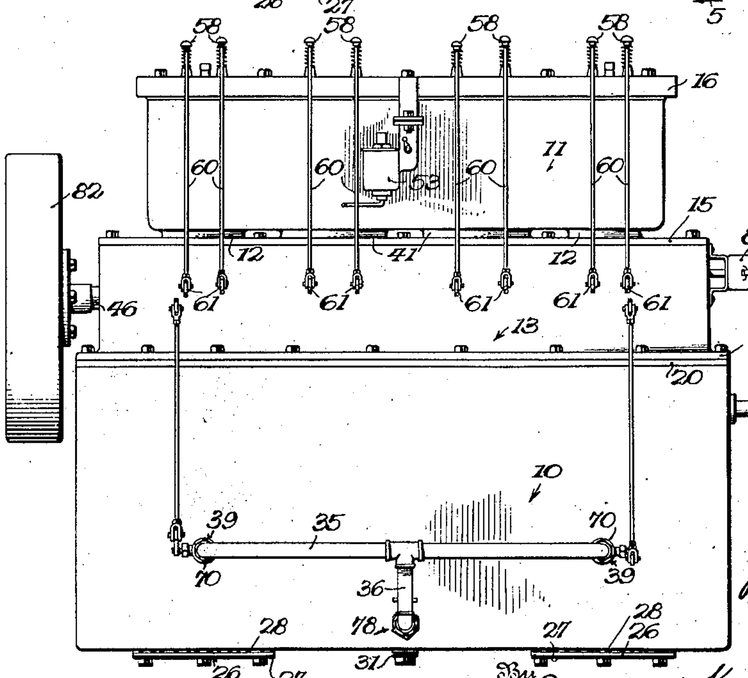

Fig. 3

Inventor

William F. Logan

By Cameron, Kerkam & Sutton

Attorneys

Nov. 3, 1936.

W. F. LOGAN

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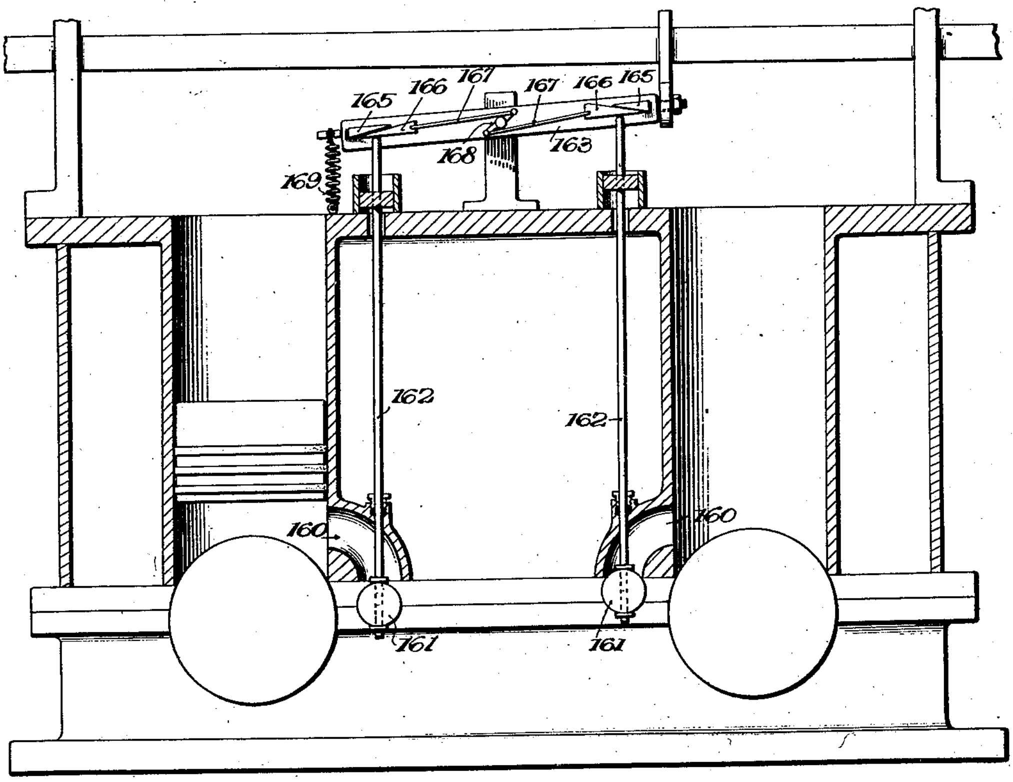

Fig. 7.

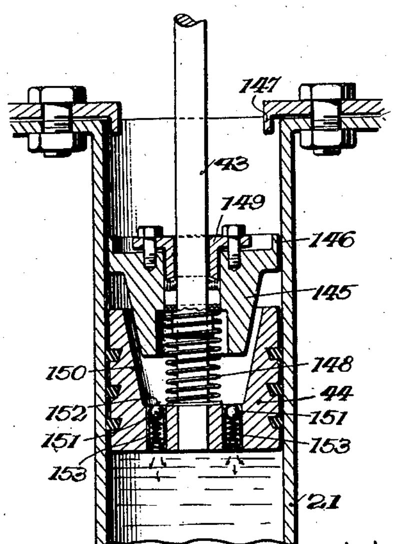

Fig. 8.

Inventor

William F. Logan

By Cameron, Kerkam & Sutton

Attorneys

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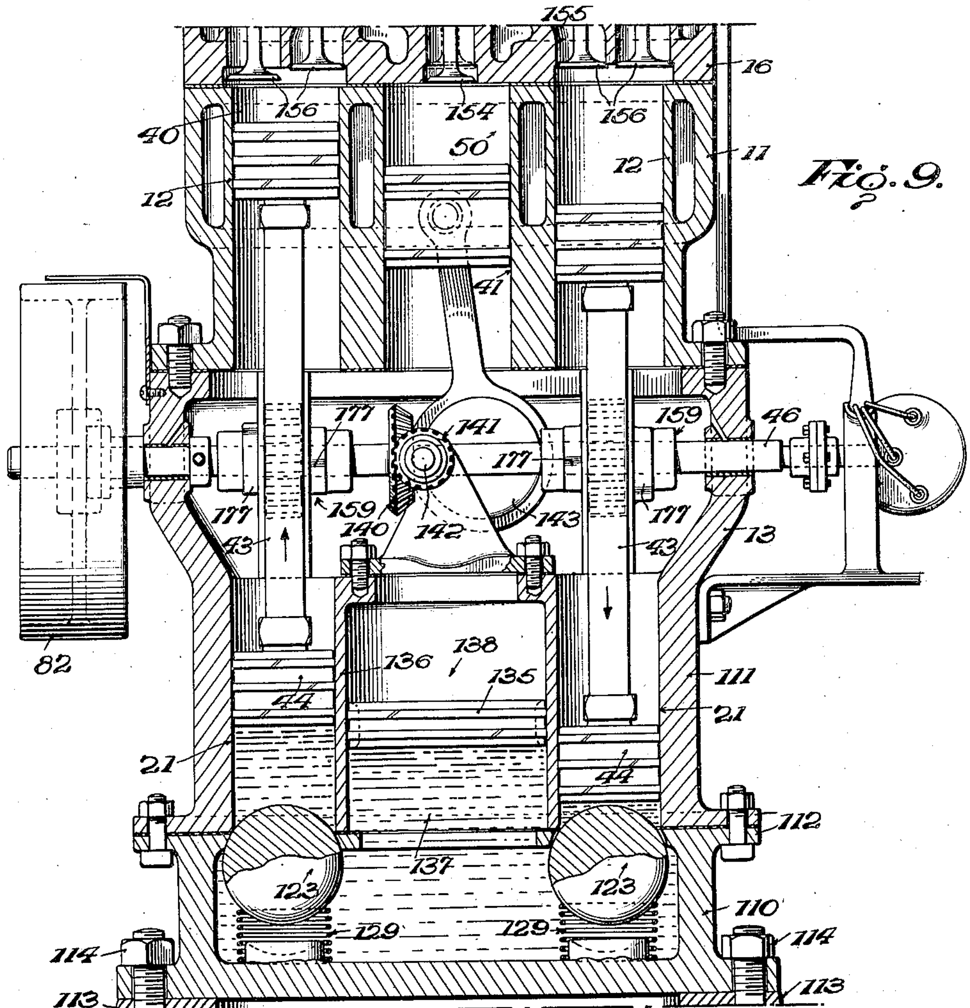

Fig. 9.

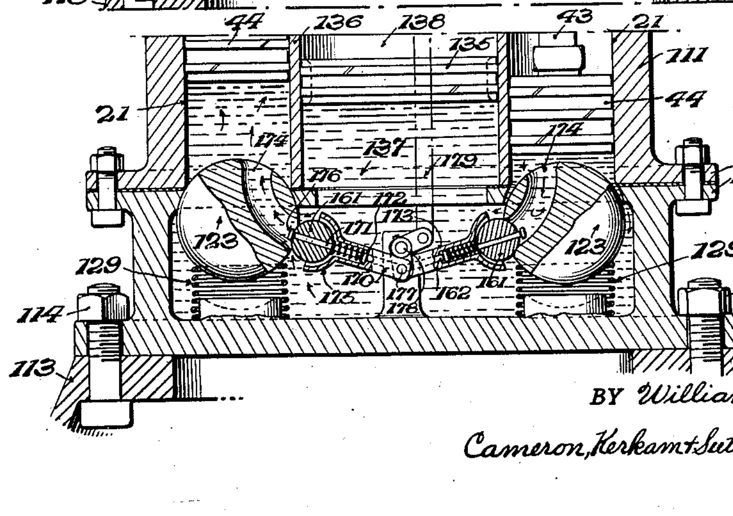

Fig. 10.

INVENTOR

BY William F. Logan

Cameron, Kerkam & Sutton ATTORNEYS

Nov. 3, 1936.

W. F. LOGAN

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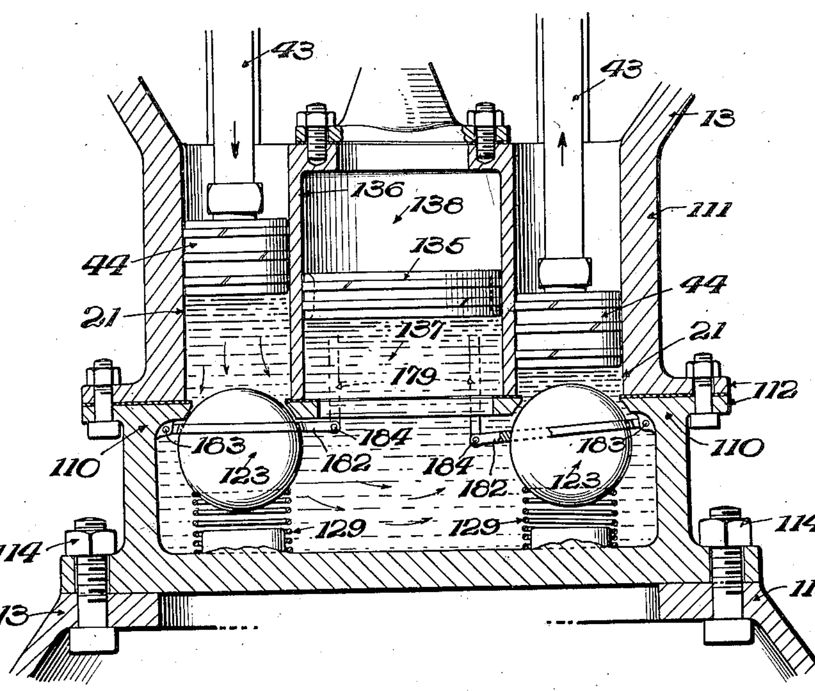
Fig. 11.



Inventor

William F. Logan

By Cameron, Kerkam & Sutton

Attorneys

Patented Nov. 3, 1936

2,059,802

UNITED STATES PATENT OFFICE

2,059,802

ENGINE

William F. Logan, Cape May, N. J., assignor to Logan-Newville Motors, Inc., Wildwood, N. J., a corporation of New Jersey

Application April 20, 1933, Serial No. 667,096

29 Claims. (Cl. 123—46)

This invention relates to engines, and more particularly to engines of the type employing what are known as "floating" pistons. While in its broader aspects the invention has utility when applied to steam and air engines, the invention is of particular utility when embodied in an internal combustion engine, and it will therefore be more particularly described with reference to such use. The present application is a continuation in part of my application Serial No. 580,176, filed December 10, 1931, entitled Gas engines, and of my application Serial No. 498,189, filed November 25, 1930, entitled Gas engines.

It is an object of this invention to provide a novel engine which employs floating pistons so combined with energy delivering means that a highly efficient, accurately controllable and smoothly operating engine is provided.

Another object of the present invention is to provide a novel internal combustion engine of the type characterized in which the energy derived from the combustion of a fuel mixture is utilized with a minimum loss through dissipation in heat.

Another object of the present invention is to provide an engine wherein the energy derived from the motive fluid is converted into the kinetic energy of a moving column of substantially incompressible liquid and the potential energy of an elastic means under conditions which permit the development and use of said energy with high efficiency.

Another object of this invention is to provide an engine of the type just characterized wherein the delivery of the kinetic and potential energy is so controlled as to secure a smooth and uniform delivery of power and wherein vibrations and irregularities of operation are substantially eliminated.

Another object of the present invention is to provide an engine of the type first characterized wherein the delivery of power is under the control of parts whose speed is regulated independently of any fluctuations in speed of the floating piston during its power stroke.

Another object of this invention is to provide an internal combustion engine of the type employing a floating piston wherein the compression of the fuel mixture and the time of its ignition as well as its admission to and discharge from the combustion chamber are controlled independently of fluctuations in speed of the floating piston during its combustion stroke.

Another object of this invention is to provide an engine of the type first characterized which avoids the tendency of the floating piston to rebound at the end of its power stroke.

Another object of this invention is to provide an engine of the type employing a floating piston wherein the use of a crank mechanism is avoided and wherein power is delivered to the driving shaft substantially at right angles thereto at all times.

Another object of this invention is to provide an engine of the type employing a floating piston which avoids the conditions consequent on the occurrences of dead centers, and which avoids irregularities of speed, vibrations, shocks, jars and the like.

Another object of this invention is to provide a novel internal combustion engine wherein compression of the fuel mixture after ignition with the resultant energy losses is entirely avoided.

Another object of this invention is to provide a novel internal combustion engine which enables the cylinder clearance to be materially reduced with substantial increase in efficiency.

Another object of this invention is to provide a novel internal combustion engine wherein it is practicable to furnish each charge of fuel with such a quantity of oxygen as will obtain substantially a complete combustion of said fuel in the combustion chamber with the resultant elimination of fuel losses.

Another object of this invention is to provide a novel engine which enables the production of high power at relatively low speed or high speed at relatively low R. P. M. at the engine.

Another object of this invention is to provide a novel engine in which there is a substantially smooth and uniform delivery of power to the driving shaft throughout the operation of the same.

Another object of this invention is to provide a novel engine which facilitates close regulation of the speed and delivery of power and which also provides flexibility of design in securing desired rates of power delivery and desired rates of revolution through a wide range.

Another object of this invention is to provide a novel engine whereby increased power per unit of fuel consumed and increased thermal efficiency can be obtained.

Another object of the present invention is to provide a novel engine wherein the heat losses are so reduced that a cooling system is generally unnecessary, although one may be used if preferred.

Another object of this invention is to provide a novel internal combustion engine which enables the maintenance normally of a constant air and fuel mixture irrespective of variations of load on the engine, but which also enables variations of mixture for variations of load or speed if preferred.

Another object of this invention is to provide a novel internal combustion engine wherein a low exhaust temperature and pressure can be obtained and also efficient scavenging of each combustion chamber effected.

Another object of this invention is to provide a novel engine which has low weight per unit of power delivered and which therefore readily lends itself to use in airplanes, automobiles and the like.

Another object of this invention is to provide a novel engine which is simple in construction, strong and rugged in service, and economical in operation and maintenance, and which readily lends itself to a wide range of control and use.

Another object of this invention is to provide a novel method for controlling and utilizing the energy developed by a floating piston.

Other objects will appear as the description of the invention proceeds.

The invention is capable of receiving a variety of mechanical expressions, two of which are illustrated on the accompanying drawings, but it is to be expressly understood that the drawings are for purposes of illustration only, and are not to be construed as a definition of the limits of the invention, reference being had to the appended claims for that purpose.

Referring in detail to the drawings, wherein the same reference characters are employed to indicate corresponding parts in the several figures,

Fig. 1 is an elevation of a preferred embodiment of the present invention;

Fig. 2 is a side elevation of the embodiment of Fig. 1;

Fig. 3 is a front elevation on a smaller scale of another embodiment of the present invention;

Fig. 4 is a longitudinal section through the embodiment of Fig. 3 on a slightly enlarged scale;

Fig. 5 is a vertical section, on a still further enlarged scale, taken on the line 5—5 of Fig. 4;

Fig. 6 is a detailed sectional view of one of the mechanically operated by-pass valves;

Fig. 7 is a somewhat schematic view illustrating another arrangement and location of the valves;

Fig. 8 is a detail of the stop for each piston unit as used in the embodiment of Figs. 1 and 2;

Fig. 9 is a sectional view of the embodiment shown in Fig. 1;

Fig. 10 is a somewhat schematic view illustrating an arrangement and location of the valves, and

Fig. 11 is a vertical section of another embodiment.

Referring first to the embodiment illustrated in Figs. 3 to 6, inclusive, and particularly to Fig. 4, a base section 10, of any suitable size and construction, is mounted on any suitable foundation or frame and provides a receptacle or tank. Suitably mounted above said receptacle 10 is a cylinder block 11, here shown as including two cylinders 12 providing combustion chambers, but it is to be expressly understood that the invention is not restricted to the use of only two cylinders as will hereinafter appear. As shown, a shaft housing 13 is interposed between receptacle 10 and cylinder block 11 and is suitably secured to each, as by bolts, screws, welding, etc., at the flanges 14 and 15. The cylinder block 11 is provided with a suitable head 16 attached to the body thereof in any suitable way and in the form shown a water jacket 18 is provided for the cylinders and head, although as hereinafter noted, the present invention enables the omission of water jackets if desired.

Tank or receptacle 10 is provided with a removable or fixed cover 20 and mounted on or integrally attached to said cover 20 are a plurality of cylinders 21, hereinafter referred to as work cylinders, which correspond in number to the cylinders 12 providing combustion chambers, and hence here shown as two. Said cylinders 21 communicate with and are here shown as projecting into the interior of the tank 10, and suitably mounted on the bottom of said tank 10 are valves 23 which normally close the bottom of the cylinders 21. Said valves may be of any suitable construction and as hereinafter pointed out in conjunction with the embodiment of Fig. 1 preferably take the form of elastic balls, but as here shown, the valves are in the form of disks provided with stems 24 which are reciprocably mounted in spiders 25 formed on or attached to the bottom member 22. If desired said spiders may be mounted on removable plates 26 suitably secured over openings in the bottom member 22, said openings being sufficiently large to permit the withdrawal of the spiders with the valve members mounted thereon. Said removable plates 26 may be secured in position in any suitable way, as by bolts passing through flanges 27 with interposed gaskets 28. Any other suitable means, however, may be provided for gaining access to the valves. Each valve 23 is normally urged into its position for closing the bottom of its opposed cylinder 21, and to this end, a helical spring 29 surrounds each valve stem 24 and reacts between the spider 25 and the valve disk 23 to normally urge the latter into its seating position.

Although it is possible to operate the engine using a compressed gas in the tank above described, it is preferred to use a liquid subjected to the pressure of an elastic medium because of the relative incompressibility of liquid. Tank 10 is accordingly partly filled with a liquid 30, such as oil, the volume of liquid therein being sufficient to assure that under no conditions of operation will the lower open ends of the cylinders 21 be uncovered. Said liquid may be introduced into the tank 10 through any suitable filling opening, and a drain opening is indicated at 31. Cooperating with the surface of the liquid 30, either directly or through an interposed plate or plunger as hereinafter explained, is an elastic medium which is under a substantial initial compression and which may be further compressed when liquid is forced from the cylinders 21 into the tank 10. Said medium thereby acts as a storer of potential energy and subsequently delivers said stored energy as hereinafter explained. While said elastic medium may take the form of springs or equivalent elements, the preferred elastic medium is a gas, such as air, filling the space 32. Said air is under a substantial initial pressure, and may be introduced through any suitable pipe as 33. The initial pressure of the air employed is determined by the pressure required to bring each piston to rest at the end of its combustion stroke, and for a given size of piston in the combustion chamber, the initial pressure of the air may be said to vary inversely with variations in the area of the piston acting on the liquid.

The interior of said tank 10 is in communication with the cylinders 21, and the connections therebetween may take a variety of forms. As here shown, a by-pass conduit 35 of any suitable construction, shown as a pipe which leads to the interior of each cylinder 21 adjacent the lower end thereof, projects to the exterior of the tank, through suitable fluid-tight joints, as shown in Fig. 3. Pipe 35 also communicates with the interior of the tank 10 at a point below the surface of the liquid therein, sufficiently below the minimum liquid level so that its inlet will never be uncovered by said liquid under any condition of operation. As here shown a pipe section 36 leads from said conduit 35 and opens into the tank at 38 adjacent the bottom thereof. Said by-pass conduit 35 is provided with a valve mechanism 39 for each cylinder as hereinafter explained, said valve mechanism as shown being disposed exteriorly of the tank, but the valves as well as the connections or conduits between the tank and work cylinders may be within the tank as will hereinafter appear.

Cylinder block 11, in addition to the two cylinders 12 providing combustion chambers 40, includes a pair of cylinders 41 providing compression chambers, although as hereinafter explained in conjunction with the embodiment of Fig. 1, a single compression chamber can be used for both cylinders 12, or compression chambers may be formed within the cylinders 12 below the pistons thereof or within the cylinders 21 above the pistons thereof. Each cylinder 12 is substantially in alignment with a cylinder 21, and in the form here shown the cylinders 12 and 41 are also arranged in longitudinal alignment, but this is not essential, as the cylinders 12 and 41 may be otherwise arranged and the compression cylinders 41 may if preferred be disposed laterally with respect to the cylinders 12.

Each cylinder 12 is provided with a piston 42 which is connected through a piston rod 43 of any suitable size and construction with a piston 44 disposed in the associated cylinder 21, or a single cylinder and piston combining the functions of cylinders 12 and 21 and pistons 42 and 44 could be used. In the form here shown (see Fig. 5) piston rod 43 is provided with an offset to pass around the driving shaft 46, but as shown in the embodiments of Figs. 1 and 2, the driving shaft may be disposed laterally with respect to the piston rods 43 so that the latter may extend in right lines. The driving connection from each piston rod 43 to the driving shaft 46 is such that there is a right angle delivery of power from the piston rod to the driving shaft throughout the work stroke, and as the present invention employs pistons which are to float when moving under the expansion due to combustion of the fuel mixture, the construction is such that during the stroke of each piston pair, 42 and 44, under the propulsion due to the combustion of the fuel mixture no driving relation exists between the piston rods 43 and the driving shaft 46, but during the return or work stroke of each piston pair a driving relation is established between each piston rod and the driving shaft. The mechanism for effecting the foregoing functions can be of any suitable character, constituting in effect a one-way clutch between each piston rod and the driving shaft; as here shown each piston rod 43 is provided with a rack 47 which cooperates with a segmental gear 48 that has teeth for slightly over 180°, so that there is at least one tooth more than 180° of teeth for a purpose hereinafter explained. Said segmental gears 48 are suitably secured to the shaft 46, and each gear is so disposed that their teeth mesh with the corresponding rack 47 only during the up stroke of the piston pair, while during the down stroke of the piston pair the cutaway portion of the segmental gear is opposed to the rack 47, or the segmental gear may be constantly in mesh with the rack and a one way clutch be interposed between the gear and the shaft. The diameter of the gears 48 is selected to effect the desired lever ratio suitable for the particular length of stroke and timing employed.

Each compressor cylinder 41 is provided with a piston 50 driven from the driving shaft 46 in any suitable way, here shown as through a piston rod 51 and crank 52. Compressor 41 may operate to compress only the air to support the combustion of the fuel, after which the fuel may be injected into the compressed air, as by an injector of any suitable construction, opening for example into the combustion chamber, or the fuel as well as the air may be mixed in the compressor and subjected to compression in advance of introduction into the combustion chamber. The compressed air from the compressor may be introduced after the piston 42 has made its scavenging stroke or the air may be introduced to help purge the combustion chamber of burnt gases. The fuel used may be either gaseous or liquid or solid. As here shown a liquid fuel is introduced into each compressor from any suitable carbureting device 53. Each compressor is provided with a suitable inlet valve 54 and outlet valve 55, and each cylinder is also provided with a suitable inlet valve 56 and outlet valve 57. Said inlet and outlet valves are operated in any suitable way in timed relation with the movement of the pistons, and as here shown said valves are tappet valves operated by rocker arms 58 suitably pivoted on brackets 59 and in turn operated by rods 60 and rocker arms 61 suitably pivoted on brackets 62. Rocker arms 61 are operated from cams 63 mounted on a cam shaft 64 driven in any suitable way as by a chain drive 66 from the driving shaft 46. It will be understood that the cranks 52 and cams 63 are so constructed and arranged as to effect the introduction of the charge into the compressor chambers 41, the compression of the charge therein, the transfer of the charge to the combustion chambers 40, and the exhaust of the burnt gases from said combustion chambers in proper timed sequence with the operation of the parts to effect the cycle of operation hereinafter explained.

As before noted each cylinder 21 is provided, in the by-pass conduit 35 associated therewith, with a suitable valve mechanism 39 for opening and closing communication between said by-pass and the interior of said cylinder. Said valve mechanism may be of any suitable construction and operated in any suitable way from the driving shaft or cam shaft. As here shown, the conduit leading from each cylinder 21 has a valve housing 70 which, as shown in the enlarged detail of Fig. 6, contains a butterfly valve disk 71 operable by a crank arm 72 disposed exteriorly of the housing 70 and mounted on the pivotal axis 73 of said valve member. Each crank arm 72 is connected through rod 74 to a rocker 75 pivoted at 76 on a suitable bracket and operated by a cam 77 here shown as mounted on the driving shaft 46. Said cams are so arranged as to effect the operation of the valves 71 in the timed sequence hereinafter described. By-pass 35 is also preferably provided with a suitable valve 78 whereby the size of the passage for fluid flow may be varied. This valve may be manually or automatically operated.

Any suitable means are provided for igniting the fuel mixture in the combustion chambers 40, spark plugs 80 being diagrammatically indicated and controlled through a distributor 81 of any suitable character and construction driven from driving shaft 46. Driving shaft 46 is also shown as provided with a pulley 82 as indicative of any suitable driving connection from said shaft 46 to the means to be driven, or a flywheel may be provided if desired.

The cycle of operation of the engine is as follows: The fuel mixture, or the air alone if a fuel injector is used, is drawn into a compressor 41 and compressed therein, and the charge is then transferred to a combustion chamber 40. Compressor 41 is of such size that a sufficient quantity of air is drawn thereinto to effect a substantially complete combustion of the fuel, whether gaseous or liquid and whether introduced into the compressor or into the combustion chamber itself. When the piston 42 has reached the top of its stroke and after the fuel mixture is introduced into the combustion chamber, said mixture is ignited. As said ignition occurs only after the piston 42 has reached its uppermost position, there is no compression of the mixture after ignition, and therefore the entire force of expansion arising from the combustion of the fuel mixture is directly applied to the piston 42. Piston 42 being a floating piston, it is forced downwardly at precisely the rate at which expansion of the mixture occurs under combustion, it being remembered that during this stroke of piston 42 there is no mechanical connection between the piston and the driving shaft. Hence there is no mechanical restraint upon said piston to cause the normal expansion of the mixture under combustion to be retarded, and therefore the tendency for the energy to be dissipated in heat to the engine walls is materially reduced. Moreover, as there is no compression of the mixture after combustion starts, the heat losses characteristic of the compression of ignited charges is avoided. Also, as the amount of air initially provided is sufficient for complete oxidation of the fuel, the heat losses incident to delayed burning of the gases are largely avoided. In other words, the piston 42 is free to move at the variable rate at which the mixture tends to expand naturally when combustion is free and complete.

The movement so imparted to piston 42 by the expanding gases in the combustion chamber 40 is transmitted through piston rod 43 to the associated piston 44 in cylinder 21. As soon as the pressure per square inch on piston 44 is sufficient to overcome the pressure per square inch of the compressed air on the oil 30, valve 23 is opened and the oil is driven from the cylinder 21 by the advancing piston, the entire end of the cylinder being preferably open so as to offer the minimum resistance to the flow of the oil. If the piston in the other work cylinder were held against movement, or if the invention be embodied in a single cylinder engine, this displacement of oil from the cylinder 21 to the tank 10 is converted into potential energy in the form of an additional compression of the gas in the space 32. As a matter of practice, however, and during normal operation where a plurality of cylinders are used, the flow of oil from one cylinder 21 is taking place simultaneously with the flow of oil from the tank 10 into a second cylinder 21. Simultaneously with or immediately after the initiation of the combustion stroke of the piston 42, the butterfly valve 72 for the opposite cylinder 21 is opened and the oil flows into said cylinder 21 to move the corresponding piston 44 upwardly. As the maximum rate of flow of the oil into said cylinder 21 is controlled by the size of the by-pass, or the adjustable by-pass valve 78 when used, the rate at which the energy is delivered from the tank 10 to said piston 44 is controlled and substantially uniform. As the flow of oil from the first cylinder 21 is at a varying rate, however, because of the varying rate of movement of the piston in the combustion chamber, there is the development of both potential energy in the compressed gas and kinetic energy in the flowing oil, the former conserving the energy that would otherwise be lost if there were a controlled rate of development of pressure on the oil in the first cylinder 21. In other words substantially all of the energy developed by the expansion of the fuel mixture under combustion and the inertia of the moving pistons is captured by the moving oil and compressed gas in the tank, the latter acting as a reservoir for the energy developed in excess of the controlled rate of output through the oil and delivering said stored energy to maintain a uniform rate of output throughout the work stroke. But the piston 44 makes its work stroke at a substantially uniform pressure, because the actual variation in pressure in the compressed gas in the tank 10 is in fact relatively small.

During this work stroke of the piston 44 the rack 47 is in mesh with the teeth on the segmental gear 48, and the driving shaft 46 is therefore being driven. The piston 42 which is connected to the piston 44 that is making the work stroke is at this time scavenging its corresponding combustion chamber 40, and as the next charge is being compressed in the chamber of the associated compressor 41 it is possible to hold the outlet valve of said combustion chamber open for a major portion of the stroke and effect a satisfactory scavenging of the combustion chamber. During this same stroke the compressor piston 50 is making its compression stroke, its suction stroke having been made during the work stroke of the piston 44 first referred to, and as the working piston 44 approaches the end of its stroke, the outlet valve from the corresponding combustion chamber is closed and the inlet valve opened, while the outlet valve from the associated compressor chamber is opened simultaneously so that the compressed charge is transferred to the combustion chamber last referred to. When this piston 42 reaches the top of its stroke, the charge is ignited and the cycle is repeated, the oil now being driven from the second cylinder 21 into the tank 10 at the rate determined by the floating piston 42 in the combustion chamber, while the first referred to piston 44 is now performing its work stroke, and its associated piston 42 is scavenging its combustion chamber 40, and the related compressor 41 is simultaneously making its compression stroke. It will be understood that the two piston pairs 42 and 44 have their phases 180° apart.

As each segmental gear 48 extends for one or more teeth beyond 180° a driving relation is established between the first tooth of the second segmental gear to go into operation and its rack before the last tooth of the segmental gear that has been performing a work stroke becomes disengaged from its rack. Hence there is no interruption in the maintenance of the driving relation between the successively acting racks and the driving shaft, and the output of power is therefore smooth and continuous.

From the foregoing description the preferred embodiment of Figs. 1, 2, and 9 will be understood from a brief reference to the differences thereof from the embodiment of Figs. 3 to 6, corresponding parts being given the same reference characters as in the embodiments of Figs. 3 to 6. The embodiment of Figs. 1, 2, and 9 as shown has its tank or receptacle section 10 sub-divided into a base portion 110 and an upper portion 111, said two portions being suitably united as by bolts passing through flanges 112. Base portion 110 may be mounted on any suitable foundation 113 as by bolts 114. The provision of the joint at 112 permits the upper part of the engine to be lifted with respect to the lower portion 110 for access to the bottom of the tank and the valves therein, etc. If preferred, however, the tank may be made in one piece or in any other desired combination of sections. The portion 111 in this embodiment also includes the portion of the casing which houses the driving shaft and associated parts.

In place of disk valves 23 within the tank, the present invention employs spherical valves 123 mounted on coil springs 129. Said valves are preferably constructed of an elastic medium and constitute elastic balls that may give in the event that an undue pressure is imparted thereto.

In this embodiment the oil space within the tank 10 is separated from the compressed gas space therein by a plunger 135, the cylinders 21 in this embodiment having intermediate the same a centrally disposed cylinder 136 which opens at its botttom into the oil space 137 and has above the plunger 135 a space 138 for the compressed gas. Therefore, even though the engine be turned upside down, as may occur in use on an airplane, the oil in the space 137 cannot uncover the bottoms of the cylinders 21 and the inlets to the by-pass 35. It may here be noted that so long as the operating fluid is maintained in sealed contact with the pistons 44 it is unnecessary that said pistons work in or even project into the tank 10.

In this embodiment a single compressor 41 is provided, with suitable connections and valves for supplying compressed charges to the two combustion chambers 40, and the driving shaft 46, which is so positioned as to avoid any offset in the piston rods, is provided with a beveled gear 140 which meshes with a beveled gear 141 of one half the diameter of gear 140 on a stub-shaft 142 that carries an eccentric 143 for driving the piston 50 of said compressor. The outlet valve 154 of the compressor controls the admission of the compressed fluid into a storage space 155 which communicates with one or the other of the combustion chambers when one or the other of the inlet valves 156 of the latter is opened. As the compressor piston is operating twice as fast as the combustion and work pistons, a charge of compressed fluid from the compressor is transferred to and temporarily stored in the space 155 until the appropriate inlet valve 156 is opened. When the engine is started the pressure in chamber 155 is built up quickly and thereafter delivers the compressed fluid to the combustion chamber at the pressure developed in the compressor.

This embodiment also eliminates a separate cam shaft, all of the cams for operating the inlet and outlet valves being mounted directly on the driving shaft 46 as shown at 159. Likewise the cams 177 for operating the by-pass valves are mounted on said driving shaft 46 and said by-pass valves are operated from said cams through thrust rods 178, rockers 179 and rods 180 leading to valves of any suitable construction, here shown as of the balanced type, disposed within the valve casings 181.

In this embodiment only air is compressed in the compressor 41 and liquid fuel is injected directly into the charge of compressed air after it is transferred to each combustion chamber, an injector being generally indicated at 185 and communicating with any suitable source of fuel.

As shown in the fragmentary view of Fig. 8, each of the work pistons 44 may be provided with a cushioning or stop device in the event that the piston tends to move too far on its working stroke. As here shown each work piston 44 has mounted above and resiliently spaced from the same a stop member 145 which has an axially extending rim 146. The end of the cylinder is provided with an overhanging and inwardly directed rim member 147 spaced from the wall of the cylinder sufficiently to provide an annular recess that will receive the rim 146 and cooperate therewith to form in effect a dashpot. Stop member 145 is normally spaced from the piston proper 44 by a coil spring 148. A suitable gland may be provided around the piston rod as shown at 149.

If the piston 44 tends to overtravel the rim 146 will enter the annular space between the cylinder wall and the rim 147, acting as a dashpot and bringing stop member 145 to rest, while the spring 148, as member 145 is retarded, will oppose resiliently the relative approach of piston 44, but yielding until the piston is stopped. Hence the combined dashpot and spring action will bring the piston 44 to rest at the end of its stroke without shock or jar.

It is also preferred to provide means whereby any oil leaking past the piston 44 will be returned to the tank. As here shown the upper end of the piston 44 is recessed, and the body of the stop member 145 is so shaped as generally to conform and mate with said recess. At the bottom of said recess one or more check valves 151 control passages 152 in the piston, said valves being normally held closed by springs 153 as well as by the pressure existing at the under side of the piston. If oil should escape past the piston, however, it will flow into the recess 150 and collect therein. When the stop member 145 is arrested by the engagement of its rim 146 within the rim 147 and piston 44 continues to move against the tension of the spring 148, any oil trapped in recess 150 will be placed under sufficient pressure by the relative movement of the recess in the piston and the stop member to force the valve or valves 151 to open and return the oil to the interior of the tank. A suitable valve controlled passage may be similarly provided whereby the pressure of the air in the tank may be maintained at the desired value by the action of the piston and stop member.

Otherwise the construction and manner of operation will be apparent from the more detailed explanation of the embodiment of Figs. 3 to 6.

Fig. 7 illustrates an arrangement wherein the passages of communication between the tanks and work cylinders as well as the valves for controlling the same are disposed inside of the tank. As here shown, each work cylinder communicates with the tank 10 through a short passage 160 formed in the wall of the cylinder, thus eliminating the friction incident to the use of long passages. The by-pass valves are also now located in the tank, and may take any suitable form. As shown, each by-pass valve is in the form of a ball 161 operated by a valve rod 162 which projects through the top of the tank where a suitable gland or bellows seal is provided to prevent leakage around the valve rod. Each valve rod 162 is in operative engagement with a rocker 163 which in turn is operated by a thrust rod or a cam as in embodiments heretofore described. To provide for adjustment of the extent to which the valves 161 may be opened, and thereby to take the place of the separate adjustable valves 78 for varying the size of the by-pass in the embodiments of Figs. 1 to 6, lever 163 carries a pair of wedge-like stops 165 and a second pair of movable wedge members 166 connected by parallel links 167 and an intermediate link 168 so that said wedge members 166 may be protruded to a greater or less extent between the stops 165 and the ends of the valve rods 162. Link 168 can be operated manually or mechanically, and thereby the extent to which the valve rods are moved by the movement of the lever 163 may be adjusted manually or automatically. A coil spring 169 normally holds the lever 163 in operative relationship to its thrust rod or cam operating member. In place of providing the passages 160 in the walls of the cylinders, said passages may be provided in the ball valve members 123 provided the valve members 161 are so mounted as to cooperate with said passages without interfering with the proper opening of the valve members 123 under the pressure developed in the cylinders during the power strokes. Such an embodiment is shown in Fig. 10. The ball valve members 123 are provided with passages 174 of suitable shape designed to be closed at the appropriate times by valve members 161. Valve member 161 is slidable and rotatably engaged on pin 171, said pin being permanently mounted in arm 170 and extending centrally within the cup 175 formed on the arm 170. Spring 172 is designed and placed to hold valve member 161 against stop 176 formed on pin 171. When valve member 161 is closing orifice 174 it is forced away from stop 176 and further into cup 175. Spring 172 then acts to insure complete closure of said orifice. Arm 170 is rotatably mounted on rocker arm 173 by pin 177 such a connection allowing ball valve member 123 to open without hindrance when valve member 161 is closing orifice 174. Rocker arm 173 is rotatably mounted on pin 178 and is actuated by appropriate cams on shaft 46 working through push rod 179. The ball valve members themselves may be operated to admit the liquid to the work cylinders and provide the controlled admission of fluid thereto if also mounted so that they will open without resistance under the pressure developed in the cylinders during the power stroke while subject to operation by suitable valve operating rods extending into operative connection therewith when the oil is to be admitted to said cylinders. Such an embodiment is shown in Fig. 11. Base portion 110 has mounted on its upper portion near the lower outside edge of cylinder 21 stud 183. Ring member 182 engages stud 183 in such a way as to rotate thereon in a vertical plane. Ring member 182 is constructed to form a collar for ball valve member 123. Push rod 179 engages ring member 182 at pivot 184. Push rod 179 is actuated by an appropriate cam on shaft 46. At the correct time in the cycle of the engine as one piston nears the end of its power stroke push rod 179 is depressed. Ring member 182 is moved downwardly and engages ball valve member 123 of an associated cylinder forcing it downward a predetermined amount and allowing the liquid to flow into the associated cylinder for the commencement of the work stroke in that cylinder. At the correct time in the cycle the downward pressure on push rod 179 is released, spring 129 forces ball valve member 123 upward, carrying with it ring member 182 and push rod 179, and reseats ball valve member 123 in its seat at the lower end of cylinder 21 at which time ring member 182 is freed from engagement with ball valve member 123 and thereafter exerts no influence upon it until the next appropriate phase in the cycle.

It will therefore be perceived that a novel engine has been provided which employs a floating piston that is so combined with energy transferring means that a highly efficient, accurately controllable and smoothly operating engine is provided. Moreover, a combustible mixture is exploded under conditions whereby the energy derived is utilized with maximum efficiency, since the expansion of the mixture under combustion is converted into the kinetic energy of movement of piston 42 without the losses heretofore characteristic of engine cycles wherein compression of the charge continues after combustion begins, while the expansion of the burned mixture is substantially unrestrained as well as complete so that the development of heat by delayed combustion or restrained expansion, which heat is largely dissipated through the engine walls or in the exhaust gases, is kept to a minimum. While the dissipation of energy by heat is not entirely eliminated experience has demonstrated that the loss of energy by heat dissipation is so far reduced that the engine does not become overheated although no means are provided for circulating a cooling medium in heat interchanging relation with either the cylinder head or the cylinder walls. Hence a saving in the weight of the parts required for such cooling systems as have heretofore been employed is effected, and as the engine remains relatively cool in operation, there is less danger from the warpage and injury to the parts that arises from high heat, so that the engine can be made of lighter construction than heretofore considered feasible for like outputs of power.

The energy derived from the motive fluid is therefore largely converted into kinetic and potential energy, and the efficiency of the engine is therefore relatively high. Not only may the floating piston move at the rate determined by the natural tendency of the fluid to expand but in the case of a combustible mixture it moves at the rate determined by the tendency of the gases to expand under free combustion in the presence of an adequate supply of oxygen. Also full advantage is taken of the inertia of the moving piston to transfer energy to the fluid within the tank.

The pressure on the fluid within the tank is so selected as to assure that each floating piston will be brought to rest at the appropriate position for the end of its explosion stroke, which also assures that there is sufficient pressure on the liquid to effect the working stroke without any large change in relative pressure of the gas on the oil. As before noted, as soon as the pressure on the piston exceeds the pressure in the tank the outlet valve for the cylinder 21 is opened, and throughout the explosion stroke the oil is forced from the cylinder into the tank at the rate at which the piston moves under the action of the expanding gases. As soon as the plunger 44 comes to rest because of the drop in the pressure of the expanding gases that is driving piston **42**, and the momentum of the moving parts is overcome by the pressure on the oil, the valve closes because at this instant substantially atmospheric pressure is acting on the top of the piston pair **42**, **44**, while the pressure within the tank is acting to close the valve. As any oil remaining in the cylinder **21** is substantially incompressible and therefore inexpansible, and as the piston **44** cannot rebound without creating a vacuum at its under side, the piston **44** therefore tends to remain stationary at the bottom of its stroke until such time as the corresponding valve **71** is opened to admit oil under pressure into said cylinder **21**. Hence any rebound of the piston at the end of its stroke is effectively prevented.

As soon as the valve between the tank and a work cylinder is opened the oil under pressure flows into the work cylinder at the rate determined by the size of the passages, which may be controlled and adjusted by the valve mechanism provided. In fact the oil being forced from one cylinder **21** is, as to a considerable portion thereof, displacing an equal quantity of oil into the other cylinder **21**, so that one piston **44** is moving the other piston **44** indirectly through the intermediary of the oil in the tank **10**. But the inflow of oil into the second cylinder **21** is at a uniform rate and under a substantially uniform pressure, so that the piston **44** is caused to make its work stroke under substantially uniform conditions, while only that portion of the oil flowing from the first cylinder **21** in excess of what can enter the second cylinder **21**, because of the size of the connections, is acting to temporarily increase the pressure in the tank **10**, said increased pressure in the tank acting to maintain the pressure on the working piston **44** as it approaches the end of its working stroke. During this work stroke power is being delivered to the driving shaft at maximum efficiency, because throughout the stroke the delivery of energy from the rack **47** to the segmental gear **48** is substantially at right angles to the axis of the driving shaft, and therefore the power losses heretofore characteristic of crank mechanisms are avoided.

As one segmental gear comes into operation just prior to the preceding segmental gear going out of operation, the delivery of power to the driving shaft is smooth and regular, and without interruption, and hence there is an absence of shocks, jars, vibrations, etc. Also the force of expansion in the combustion chamber and acting on the liquid in the tank is equalized by the elastic medium in the tank, and any shocks and jars that would otherwise be created by the ignition of the charge as well as vibrations are eliminated by this cushioning effect. The admission of the liquid to each cylinder **21**, and also the admission and exhaust of the combustible charge to and from the combustion chambers, and the admission and exhaust of the air or charge to and from each compressor, and the ignition of the charge, are all under the control of the driving shaft, which in turn is moving at the controlled rate determined by the flow of oil into the cylinders **21**. Hence any irregularities in the rate of movement of the pistons in the combustion chambers are not reflected in the rate of movement of the driven parts. This enables the rate of power delivery to be nicely adjusted without loss of efficiency in the combustion chambers, because the pistons in the combustion chambers may move at a relatively high and varying speed in conformity with the efficient use and expansion of the gases therein, while the rate of work delivery may be controlled accurately since all of the other functions of the engine are under the control of the driving shaft moving at the controlled speed of the working pistons. On the other hand, the present invention makes possible the development of relatively high power or high speed although the number of explosions per minute are kept relatively low, because by varying the rate of delivery of the liquid into the work cylinders the rate of power delivery can be varied independently of the rate of which explosions occur, and therefore the present invention enables the development of power for speed or speed for power. Furthermore, while the fuel mixture may be maintained constant under variations or load, if preferred, the fuel mixture may be varied which will vary the length of the power strokes and therefore the power or speed developed.

The present invention further enables the clearance in the cylinder to be reduced with corresponding increase in efficiency. Thus in the embodiment of Figs. 1 and 2 wherein the fuel is injected into each power chamber after the compressed air is transferred thereto from the compressor and after the piston has reached the top of its stroke, the cylinder clearance can be reduced to that amount that is suitable to provide for the proper volume of air to combine with the injected fuel under such pressure as can be efficiently developed by the compressor, and a substantial increase in efficiency can thus be obtained in accordance with recognized principles governing increased pressure and decreased clearance. At the same time there is no danger of preignition because of the fact that the cylinder remains relatively cool and moreover, preignition would be without disadvantage because of the fact that the fuel is not introduced until the piston is ready to move on its power stroke. The manner herein employed in developing and transmitting power from the pistons to the driving shaft enables full advantage to be taken of the gain in efficiency so provided.

The pressure created in the compressor is partly effective in producing the power strokes of the pistons and therefore largely restored to the tank by the operation of the pistons moving on their power strokes. Hence this restored pressure largely compensates for the power needed to operate the compressor, while the compressor, in the embodiment of Figs. 1 and 2 particularly utilized for compression that part of the cycle where crank action is most efficient.

Furthermore, the present invention enables the heat units of the fuel consumed to be so utilized as work as to result in high thermal efficiency, and at the same time the engine is simple in construction, strong and rugged in service and readily lends itself to a wide flexibility in use and design, so that it may be applied to various services and deliver power under a wide variety of speeds and loads. Its weight per horse power is low, while its horse power per unit of fuel consumption is high.

While the embodiments illustrated on the drawings have been described with considerable particularity, it is to be expressly understood that the invention is not limited thereto. The principle underlying the present invention having been explained in detail, it will at once be apparent to those skilled in the art that considerable departure may be made from the embodiments illustrated and described without departing from the spirit of the invention. The invention can also be applied to steam or air engines with advantage. Although a liquid as well as an elastic medium are preferably used in the tank the invention as to certain features thereof can be used with advantage where the tank contains only a compressed gas, but with such a construction it is more difficult to prevent leakage around the pistons and more difficult to control the engine because of the compressibility of the operating fluid. Various other constructions of devices for compressing and introducing the fuel charge, transferring power from the pistons to the driving shaft, etc., may be used, various other forms of valves and valve operating mechanisms may be employed, other forms of elastic means may be used for cooperating with the liquid in the tank, etc., and engines may be built up of any suitable number of cylinders operating on the principle herein disclosed, or even a single cylinder may be used with some advantage, if a flywheel is also used, while changes may be made in the details of construction, materials, sizes, arrangements, and proportion of the various parts, and certain features used without other features, without departing from the spirit of this invention. Reference is therefore to be had to the appended claims for a definition of said invention.

What is claimed is:

1. In an internal combustion engine, cylinders providing a plurality of combustion chambers and a like plurality of work chambers, piston means in each associated pair of combustion and work chambers, a receptacle containing a liquid and an elastic medium under compression, connections between each work chamber and said receptacle, to carry said liquid, means for varying the rate of flow of said liquid in said connections, a driving shaft, and means for disconnecting said driving shaft from each piston means during the combustion stroke thereof and for connecting said shaft to said piston means during the return stroke thereof.

2. In an internal combustion engine, cylinders providing a plurality of combustion chambers and a like plurality of work chambers, piston means in each associated pair of combustion and work chambers, a receptacle containing a liquid and an elastic medium under compression, connections between each work cylinder and said receptacle to carry said liquid, means for controlling the rate of flow of said liquid in said connections, a driving shaft, means for disconnecting said driving shaft from each piston means during the combustion stroke thereof and for connecting said shaft to said piston means during the return stroke thereof, a separate compressor driven by said driving shaft, and valve controlled connections for transferring a charge from said compressor to the combustion chambers.

3. In an internal combustion engine, cylinders providing a plurality of combustion chambers and a like plurality of work chambers, piston means in each associated pair of combustion and work chambers, a receptacle containing a liquid and an elastic medium under compression, connections between each work cylinder and said receptacle to carry said liquid, means for varying the rate of flow of said liquid in said connections, a driving shaft, means for disconnecting said driving shaft from each piston means during the combustion stroke thereof and for connecting said shaft to said piston means during the return stroke thereof, and means controlled from said driving shaft for igniting the charge in each combustion chamber after the piston therein has completed its return stroke.

4. In an internal combustion engine, cylinders providing a plurality of combustion chambers and a like plurality of work chambers, piston means in each associated pair of combustion and work chambers, a receptacle containing a liquid and an elastic medium under compression, connections between each work chamber and said receptacle, a driving shaft, means for disconnecting said driving shaft from each piston means during the combustion stroke thereof and for connecting said shaft to said piston means during the return stroke thereof, means controlled by said driving shaft for opening and closing communication between each of said work chambers and said receptacle, and means for varying the size of said opening.

5. In an internal combustion engine, cylinders providing a plurality of combustion chambers and a like plurality of work chambers, piston means in each associated pair of combustion and work chambers, a receptacle containing a liquid and an elastic medium under compression, connections between each work chamber and said receptacle, a valve controlling the connection with each work chamber, a driving shaft, means for disconnecting said driving shaft from each piston means during the combustion stroke thereof and for connecting said shaft to said piston means during the return stroke thereof, and a pressure controlled valve for each work chamber for opening communication between said chamber and receptacle when the corresponding piston means starts on its combustion stroke.

6. In an internal combustion engine, cylinders providing a plurality of combustion chambers and a like plurality of work chambers, piston means in each associated pair of combustion and work chambers, a receptacle containing a liquid and an elastic medium under compression, valve controlled connections between each work chamber and said receptacle, means for controlling the time of opening of said valve, a driving shaft, and means for disconnecting said driving shaft from each piston means during the combustion stroke thereof and for connecting said shaft to said piston means during the return stroke thereof, said last named means providing substantially a right angle transmission of power to said driving shaft throughout the work stroke of each piston means.

7. In an internal combustion engine, cylinders providing a plurality of combustion chambers and a like plurality of work chambers, piston means in each associated pair of combustion and work chambers, a receptacle containing a liquid and an elastic medium under compression, valve controlled connections between each work chamber and said receptacle, means for controlling the time of opening said valve, a driving shaft, and means for disconnecting said driving shaft from each piston means during the combustion stroke thereof and for connecting said shaft to said piston means during the return stroke thereof, said last named means for one piston means remaining connected to said driving shaft until said connecting means for another piston means has become connected with said driving shaft.

8. In an internal combustion engine, in combination with a driving shaft, means providing a plurality of combustion chambers, a piston in each chamber adapted to be moved by the ex-

pansion of an ignited combustible mixture unrestrained by mechanical connection to said driving shaft, a receptacle containing a liquid and a compressed elastic medium, means providing a like plurality of work chambers adapted to communicate with said receptacle, piston means in each of said work chambers connected to one of said first named pistons and adapted to force liquid into said receptacles and another of said work chambers and to further compress said elastic medium during the combustion stroke of said piston, and means to connect the piston means in the cylinder into which liquid is being forced to said driving shaft while liquid is being forced thereinto.

9. In an internal combustion engine, in combination with a driving shaft, means providing a plurality of combustion chambers, a piston in each chamber adapted to be moved by the expansion of an ignited combustible mixture unrestrained by mechanical connection to said driving shaft, a receptacle containing a liquid and a compressed elastic medium, means providing a like plurality of work chambers adapted to communicate with said receptacle, piston means in each of said work chambers connected to one of said first named pistons and adapted to force liquid into said receptacle and another of said work chambers and to further compress said elastic medium during the combustion stroke of said piston, means for controlling the rate of flow of said liquid into said work chamber, and means to connect the piston means in the cylinder into which liquid is being forced to said driving shaft while liquid is being forced thereinto, said last named means applying torque to said driving shaft substantially at right angles thereto throughout the work stroke of said piston means.

10. In an internal combustion engine, in combination with a driving shaft, means providing a plurality of combustion chambers, a piston in each chamber adapted to be moved by the expansion of an ignited combustible mixture unrestrained by mechanical connection to said driving shaft, a receptacle containing a liquid and a compressed elastic medium, means providing a like plurality of work cylinders adapted to communicate with said receptacle, piston means in each of said work chambers connected to one of said first named pistons and adapted to force liquid into said receptacle and another of said work chambers and to further compress said elastic medium during the combustion stroke of said piston, means to connect the piston means in the cylinder into which liquid is being forced to said driving shaft while liquid is being forced thereinto, and valve means operated by said driving shaft for controlling the admission of liquid to each work chamber.

11. In an internal combustion engine, in combination with a driving shaft, means providing a plurality of combustion chambers, a piston in each chamber adapted to be moved by the expansion of an ignited combustible mixture unrestrained by mechanical connection to said driving shaft, a receptacle containing a liquid and a compressed elastic medium, means providing a like plurality of work cylinders adapted to communicate with said receptacle, piston means in each of said work chambers connected to one of said first named pistons and adapted to force liquid into said receptacle and another of said work chambers and to further compress said elastic medium during the combustion stroke of said piston, means to connect the piston means in the cylinder into which liquid is being forced to said driving shaft while liquid is being forced thereinto, and a pressure controlled valve for opening communication between each work chamber and said receptacle when a piston starts on its combustion stroke, said valve closing said communication as soon as said piston stops on its combustion stroke.

12. In an internal combustion engine, in combination with a driving shaft, means providing a plurality of combustion chambers, a piston in each chamber adapted to be moved by the expansion of an ignited combustible mixture unrestrained by mechanical connection to said driving shaft, a receptacle containing a liquid and a compressed elastic medium, means providing a like plurality of work chambers adapted to communicate with said receptacle, piston means in each of said work chambers connected to one of said first named pistons and adapted to force liquid into said receptacle and another of said work chambers and to further compress said elastic medium during the combustion stroke of said piston, means for controlling the time of flow of said liquid into said work chamber, means to connect the piston means in the cylinder into which liquid is being forced to said driving shaft while liquid is being forced thereinto, and a compressor operated by said driving shaft and communicating with the combustion chambers for compressing a charge of air sufficient to effect complete combustion of the fuel.

13. In an internal combustion engine, in combination with a driving shaft, means providing a plurality of combustion chambers, a piston in each chamber adapted to be moved by the expansion of an ignited combustible mixture unrestrained by mechanical connection to said driving shaft, a receptacle containing a liquid and a compressed elastic medium, means providing a like plurality of work chambers adapted to communicate with said receptacle, piston means in each of said work chambers connected to one of said first named pistons and adapted to force liquid into said receptacle and another of said work cylinders and to further compress said elastic medium during the combustion stroke of said piston, means for controlling the time and rate of flow of said liquid into said work chamber, and means to connect the piston means in the cylinder into which liquid is being forced to said driving shaft while liquid is being forced thereinto, said last named means remaining connected to said driving shaft until another piston means is connected to said driving shaft.

14. In an internal combustion engine, in combination with a driving shaft, means providing a plurality of combustion chambers, a piston in each chamber adapted to be moved by the expansion of an ignited combustible mixture unrestrained by mechanical connection to said driving shaft, a receptacle containing a liquid and a compressed elastic medium, means providing a like plurality of work chambers adapted to communicate with said receptacle, piston means in each of said work chambers connected to one of said first named pistons and adapted to force liquid into said receptacle and another of said work chambers and to further compress said elastic medium during the combustion stroke of said piston, means for controlling the time and rate of flow of said liquid into said work chamber, means to connect the piston means in the cylinder into

which liquid is being forced to said driving shaft while liquid is being forced thereinto, and means controlled by said driving shaft for igniting a fuel charge in each combustion chamber after the piston therein has reached the end of its return stroke.

15. In an internal combustion engine, in combination with a driving shaft, means providing a plurality of combustion chambers, a piston in each chamber adapted to be moved by the expansion of an ignited combustible mixture unrestrained by mechanical connection to said driving shaft, a receptacle containing a liquid and a compressed elastic medium, a plunger means in said receptacle separating said liquid and said compressed elastic medium, means providing a like plurality of work chambers adapted to communicate with said receptacle, piston means in each of said work chambers connected to one of said first named pistons and adapted to force liquid into said receptacle and another of said work chambers and to further compress said elastic medium during the combustion stroke of said piston, means to connect the piston means in the cylinder into which liquid is being forced to said driving shaft while liquid is being forced thereinto, and said plunger means in said receptacle retaining said liquid in operative position with respect to the piston means in said work cylinders irrespective of the vertical position of said liquid with respect to said receptacle.

16. In an internal combustion engine, in combination with a driving shaft, means providing a plurality of combustion chambers and a like plurality of work chambers a floating piston in each combustion chamber connected to a piston in an associated work chamber, a receptacle containing a liquid and a compressed elastic medium for maintaining said liquid under a substantial pressure, means of communication between the liquid in said receptacle and each of said work chambers, each floating piston being adapted to move its associated work piston to force liquid from its work chamber into said receptacle at the rate determined by the normal expansion of a fuel mixture under combustion, and means for controlling the rate at which said liquid under pressure in said receptacle flows into a second work chamber to move the piston therein on its work stroke.

17. In an internal combustion engine, in combination with a driving shaft, means providing a plurality of combustion chambers and a like plurality of work chambers, a floating piston in each combustion chamber connected to a piston in an associated work chamber, a receptacle containing a liquid and a compressed elastic medium for maintaining said liquid under a substantial pressure, means of communication between the liquid in said receptacle and each of said work chambers, each floating piston being adapted to move its associated work piston to force liquid from its work chamber into said receptacle at the rate determined by the normal expansion of a fuel mixture under combustion, and means normally closing communication between each work chamber and said receptacle but opened by the pressure generated by the combustion of the fuel charge in the corresponding combustion chamber, said last named means being closed by the pressure in said receptacle as soon as the pressure in said receptacle overcomes the inertia of the pistons being moved by the ignited fuel charge.

18. In an internal combustion engine, in combination with a driving shaft, means providing a plurality of combustion chambers and a like plurality of work chambers, a floating piston in each combustion chamber connected to a piston in an associated work chamber, a receptacle containing a liquid and a compressed elastic medium for maintaining said liquid under a substantial pressure, means of communication between the liquid in said receptacle and each of said work chambers, means for control of the rate of flow of said liquid in said means of communication, each floating piston being adapted to move its associated work piston to force liquid from its work chamber into said receptacle at the rate determined by the normal expansion of a fuel mixture under combustion, said pistons being disconnected from said driving shaft throughout the combustion strokes thereof, and means for connecting each work piston to said driving shaft throughout the period that liquid is being forced into the corresponding work chamber.

19. In an internal combustion engine, in combination with a driving shaft, means providing a plurality of combustion chambers and a like plurality of work chambers, a floating piston in each combustion chamber connected to a piston in an associated work chamber, a receptacle containing a liquid and a compressed elastic medium for maintaining said liquid under a substantial pressure, means of communication between the liquid in said receptacle and each of said work chambers, each floating piston being adapted to move its associated work piston to force liquid from its work chamber into said receptacle at the rate determined by the normal expansion of a fuel mixture under combustion, and means for controlling the time at which said liquid under pressure in said receptacle flows into a second work chamber to move the piston therein on its work stroke.

20. In an internal combustion engine, in combination with a driving shaft, means providing a plurality of combustion chambers and a like plurality of work chambers, a floating piston in each combustion chamber connected to a piston in an associated work chamber, a receptacle containing a liquid and a compressed elastic medium for maintaining said liquid under a substantial pressure, means of communication between the liquid in said receptacle and each of said work chambers, valve means in each of said means of a communication, each floating piston being adapted to move its associated work piston to force liquid from its work chamber into said receptacle at the rate determined by the normal expansion of a fuel mixture under combustion, means for controlling the time of opening of said valve means and the time of flow of said liquid under pressure in said receptacle into a second work chamber, and means for connecting each work piston to said driving shaft during its work stroke, said last named means delivering power to said driving shaft by a right angular application of torque thereto throughout the working stroke of said piston.

21. In an internal combustion engine, in combination with a driving shaft, means providing a plurality of combustion chambers and a like plurality of work chambers, a floating piston in each combustion chamber connected to a piston in an associated work chamber, a receptacle containing a liquid and a compressed elastic medium for maintaining said liquid under a substantial pressure, means of communication between the

liquid in said receptacle and each of said work chambers, means for controlling the time of flow of said liquid into each of said work chambers, each floating piston being adapted to move its associated work piston to force liquid from its work chamber into said receptacle at the rate determined by the normal expansion of a fuel mixture under combustion, means exterior of each combustion chamber for compressing a gaseous charge to be delivered to said chamber, means for transferring said charge to said chamber, and means for igniting a fuel mixture in said chamber when the piston thereof has reached the end of its return stroke.

22. In an engine, in combination with a driving shaft, means providing a plurality of power chambers and a like plurality of work chambers, a floating piston in each power chamber connected to a piston in an associated work chamber, a receptacle containing a fluid maintained under a substantial pressure, means of communication between said receptacle and each of said work chambers, means for controlling the rate of flow of said liquid into each of said work chambers, each floating piston being adapted to move its associated work piston to force fluid from its work chamber into said receptacle at the rate determined by the normal expansion of the motive fluid in said power chamber, said pressure fluid flowing from said receptacle into a second work chamber to move the piston in said work chamber on its working stroke, and means for connecting each work piston to said driving shaft only during its working stroke.

23. In an engine, in combination with a driving shaft, means providing a plurality of power chambers and a like plurality of work chambers, a floating piston in each power chamber connected to a piston in an associated work chamber, a receptacle containing a fluid maintained under a substantial pressure, means of communication between said receptacle and each of said work chambers, each floating piston being adapted to move its associated work piston to force fluid from its work chamber into said receptacle at the rate determined by the normal expansion of the motive fluid in said power chamber, said pressure fluid flowing from said receptacle into a second work chamber at a substantially uniform rate to move the piston in said work chamber on its working stroke, means for connecting each work piston to said driving shaft only during its working stroke, and means for determining the rate of flow of said fluid into each working chamber.

24. In an engine, in combination with a driving shaft, means providing a plurality of power chambers and a like plurality of work chambers, a floating piston in each power chamber connected to a piston in an associated work chamber, a receptacle containing a fluid maintained under a substantial pressure, means of communication between said receptacle and each of said work chambers, each floating piston being adapted to move its associated work piston to force fluid from its work chamber into said receptacle at the rate determined by the normal expansion of the motive fluid in said power chamber, said pressure fluid flowing from said receptacle into a second work chamber at a substantially uniform rate to move the piston in said work chamber on its working stroke, means for connecting each work piston to said driving shaft only during its working stroke, and a valve cooperating with each of said work chambers to permit flow of fluid therefrom and to prevent rebound of the piston therein at the end of the power stroke.

25. In an engine, in combination with a driving shaft, means providing a plurality of power chambers and a like plurality of work chambers, a floating piston in each power chamber connected to a piston in an associated work chamber, a receptacle containing a fluid maintained under a substantial pressure, means of communication between said receptacle and each of said work chambers, means for controlling the rate of flow of said liquid into each of said work chambers, each floating piston being adapted to move its associated work piston to force fluid from its work chamber into said receptacle at the rate determined by the normal expansion of the motive fluid in said power chamber, said pressure fluid flowing from said receptacle into a second work chamber at a substantially uniform rate to move the piston in said work chamber on its working stroke, and means for connecting each work piston to said driving shaft only during its working stroke, said last named means providing a right angle transmission of torque from each work piston to said driving shaft throughout the working stroke thereof.

26. In an engine, in combination with a driving shaft, means providing a power chamber and a work chamber, a floating piston in said power chamber connected to a piston in said work chamber, a receptacle containing a liquid and a compressed elastic medium maintaining said liquid under a substantial pressure, means of communication between said receptacle and said work chamber, said floating piston being adapted to move its associated work piston to force the liquid from its work chamber into said receptacle at the rate determined by the normal expansion of the motive fluid in said power chamber, means for controlling the rate at which the liquid under pressure flows from said receptacle to said work chamber, and means whereby said work piston is connected to said driving shaft only during the work stroke thereof.

27. The method of utilizing the energy developed by a motive fluid in a combustion engine which includes the steps of expanding the motive fluid by combustion, displacing a liquid medium by the action of said expanding motive fluid at a greater rate than it is to be utilized at the driven element, flowing said liquid medium by the action of said expanding motive fluid into driving relation with said driven element while simultaneously compressing an elastic medium by that displacement of the liquid medium which is in excess of that flowing to the driven element, and continuing the flow of said liquid medium to said driven element by the pressure of said compressed elastic medium.

28. The method of utilizing the energy developed by a motive fluid in a combustion engine which includes the steps of expanding the motive fluid by combustion at a rate which is determined by the rate of combustion, displacing a liquid medium by the action of said expanding motive fluid at the variable rate determined by the rate of expansion of said motive fluid and which is in excess of its rate of use by a driven element during a portion of the expansion period, flowing said liquid medium by the action of said expanding motive fluid into driving relation with said driven element and simultaneously compressing an elastic gaseous medium by that displacement of the liquid medium which is in ex-

cess of that flowing to the driven element, continuing the flow of said liquid medium to said driven element by the potential energy stored in said elastic medium, and controlling the rate of flow of said liquid medium to said driven element to determine the work function of the engine.

29. The method of utilizing the energy developed by a motive fluid in a combustion engine which includes the steps of expanding the motive fluid by combustion, displacing an element and a liquid medium in contact therewith by the action of said expanding motive fluid at the variable rate determined by the rate of expansion of said motive fluid and which for a portion of said period of expansion is in excess of the rate of use of said liquid medium by a driven element, flowing said liquid medium by the action of said expanding motive fluid into driving relation with said driven element and simultaneously compressing an elastic medium by that displacement of the liquid medium which is in excess of that flowing to the driven element, utilizing the potential energy of said compressed elastic medium to continue the flow of said liquid medium to said driving element after the rate of flow of the liquid medium by the expanding motive fluid has decreased, and then reversing the movement of said driven element by the combustion of said motive fluid to drive said first named element in the opposite direction by flowing said liquid medium and compressing said elastic medium as defined.

WILLIAM F. LOGAN.