No. 854,466. PATENTED MAY 21, 1907.

T. H. COLE.

APPARATUS FOR GENERATING AND STORING PRODUCTS OF COMBUSTION UNDER PRESSURE.

APPLICATION FILED NOV. 19, 1906.

3 SHEETS—SHEET 1.

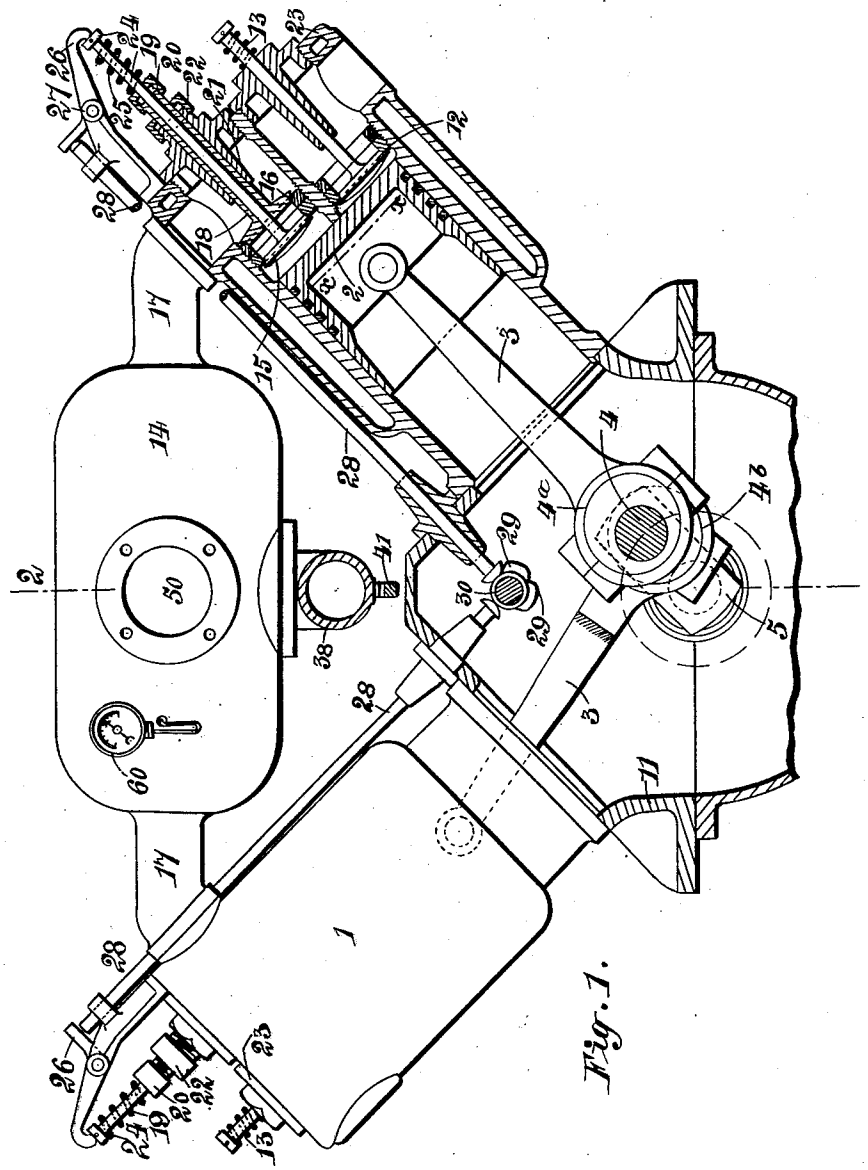

Fig. 1.

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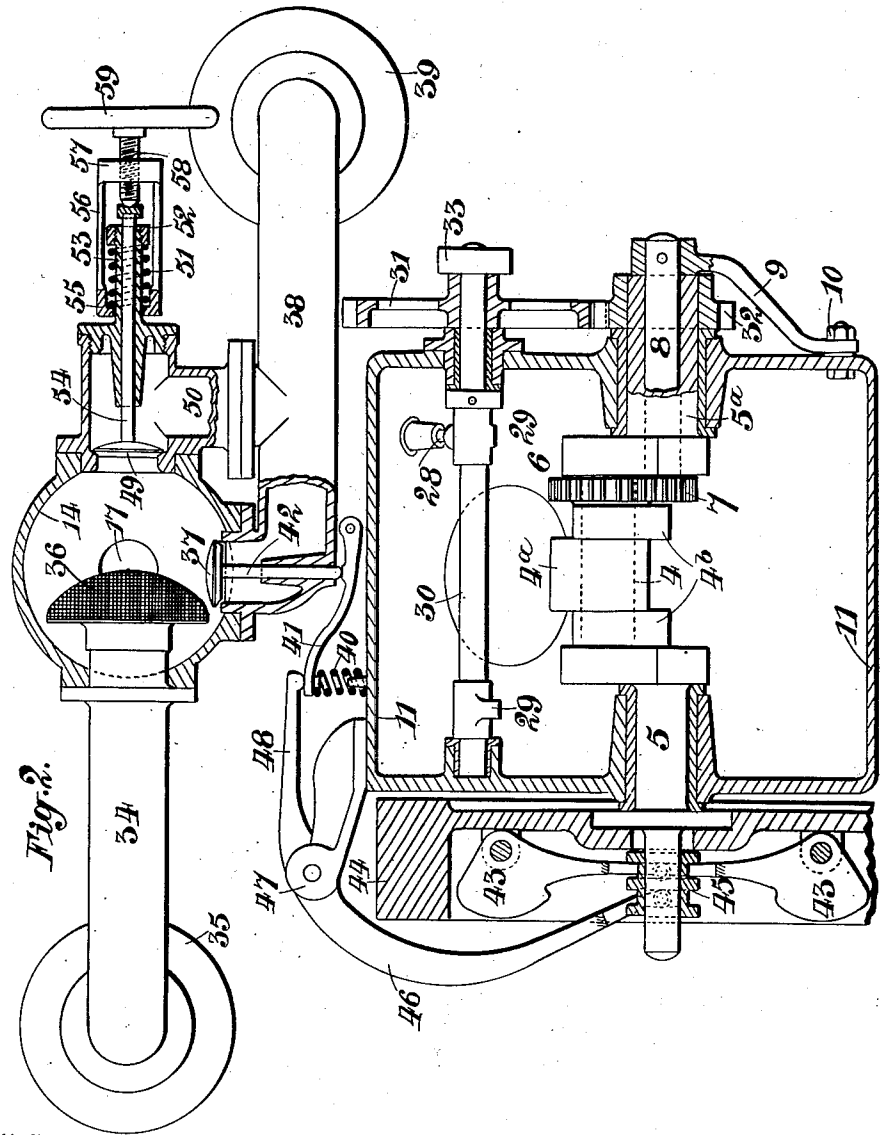

Fig. 2.

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3 SHEETS—SHEET 3.

Fig. 4.

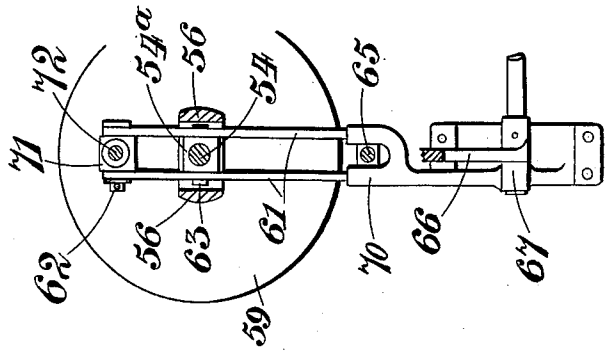
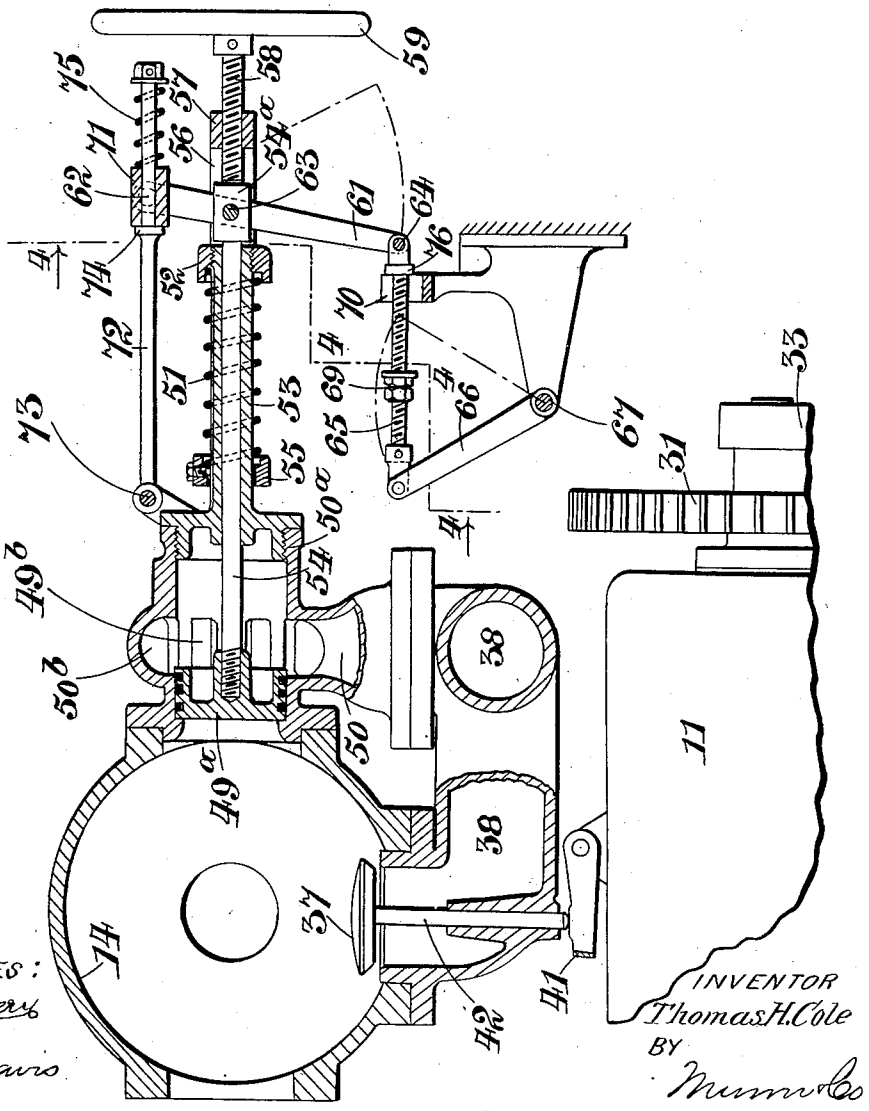


Fig. 5.



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APPARATUS FOR GENERATING AND STORING PRODUCTS OF COMBUSTION UNDER PRESSURE.

No. 854,466. Specification of Letters Patent. Patented May 21, 1907.

Application filed November 19, 1906. Serial No. 344,095.

To all whom it may concern:

Be it known that I, THOMAS HENRY COLE, a subject of the King of Great Britain, residing at 54 Margate road, Southsea, in the county of Hants, England, insurance agent, have invented certain new and useful Improvements in Apparatus for Generating and Storing Products of Combustion Under Pressure, of which the following is a specification.

This invention relates to the generation of power by the combustion of a gas or vapor within a confined space, and it has for its object to provide means whereby the greatest practicable elasticity or flexibility may be obtained in the application of the power generated in an internal combustion motor.

According to this invention, the gaseous products of combustion from such a motor (which may for convenience be termed the primary motor), are rendered available for utilization as motive fluid in an engine of any kind (which may be termed the secondary motor) adapted to be worked by an elastic fluid under pressure; the primary motor serving exclusively as a pressure pump, whereby the gaseous products of combustion formed within it are forced into an intermediate receiver or reservoir, whence they are withdrawn as motive fluid to supply the secondary motor in the same manner as steam is drawn from a boiler to supply an ordinary steam engine. Consequently the arrangement as a whole may be said to combine the characteristic advantages of both an explosion engine, and a steam engine and boiler, while avoiding the principal defects of each.

The primary motor is adapted to work on a four-phase cycle, each of its pistons being arranged to so operate during the exhaust stroke as to expel the entire volume of the products of combustion (or as much thereof as practicable) from the cylinder. Under normal working conditions the exhaust gases, thus expelled, are stored in the reservoir under pressure, means being provided however for relieving the piston of this back pressure so long as the speed of the primary motor at starting remains, and also whenever it happens to fall, below a certain limit.

This device may be combined with or supplemented by means for preventing the pressure within the reservoir from exceeding the maximum against which the primary motor is adapted to deliver the products of combustion, so that the motor shall not be liable to become choked by back pressure.

The invention will be described with reference to the accompanying drawings which illustrate in an elementary form an arrangement comprising a primary motor having two cylinders each adapted to work on a four-phase cycle.

In the drawings Figure 1 is a side elevation of the primary motor partly in section on the common plane of the axes of the two cylinders, and Fig. 2 is a section on line 2—2 of Fig. 1. Fig. 3 illustrates a modification of part of the arrangement shown in Fig. 2, and Fig. 4 is a section on line 4—4 of Fig. 3.

In each of the figures portions are omitted or broken away in order the better to show the construction.

Each cylinder 1 of the primary motor has a single-acting piston 2 fitted to work within it and coupled by a connecting rod 3 to the crank 4 on a crank shaft 5, the cylinders being (in the arrangement illustrated) set with their axes intersecting one another perpendicularly at the axis of the crank shaft, and their pistons and piston rods being coupled to the same crank.

It will be obvious that whereas at the termination of the compression stroke there must remain behind the piston (as in any ordinary internal combustion engine) sufficient clearance to accommodate the compressed charge; on the other hand at the termination of the exhaust stroke there should be as little clearance left behind the piston as possible, since otherwise the complete expulsion of the products of combustion against the pressure existing in the reservoir could not be effected. In order to meet this requirement, each piston may have a stroke of varying length, the piston on the compression stroke stopping short of the rear end of the cylinder so as to leave the necessary space for the compressed explosive charge, and on the exhaust stroke being brought as near as is practicable to the cylinder cover. In the arrangement illustrated, the periodic variation in the length of the stroke is effected by a corresponding variation in the effective throw of the crank, the construction being as follows.

Upon the crank pin 4 a pair of eccentrics 4^a 4^b are mounted to turn side by side as one,

the two connecting rods 3 working not directly upon the crank, but each upon the corresponding eccentric 4^a or 4^b, whose throw corresponds to the required difference between the lengths of the compression and exhaust strokes of the piston. In the construction shown, one of the connecting rods 3 is understood to be forked, the corresponding eccentric 4^b being duplicated at opposite sides of the other eccentric 4^a as indicated in Fig. 2, wherein both connecting rods are omitted for the sake of clearness. Means are provided for communicating to the eccentrics a movement of rotation about the crank pin 4 at such a speed that the eccentricity of each will be directed from and toward the rear end of the corresponding cylinder at the moments when the piston in that cylinder arrives at the end of its compression and exhaust strokes respectively. For this purpose the eccentrics have attached to or integral with them a spur wheel 6 which gears with a pinion 7 (of one-half the diameter of the wheel 6) fast on a stationary spindle 8 extending axially through the crank shaft at one side of the crank, this portion 5^a of the shaft being made tubular, and the spindle 8 being conveniently prevented from rotating by means of a spanner 9 fast on the outer end of the spindle and having its end anchored as at 10 to the frame 11 of the motor.

In Fig. 1 the right-hand piston 2 (which is in section) is shown as having reached the end of its exhaust stroke, at which moment the clearance behind the piston is virtually *nil*, while the dotted line *x*—*x* indicates the position attained by the rear end of the piston at the termination of the compression stroke, at which moment the corresponding eccentric 4^a will of course be at the opposite extremity of its throw although the crank 4 will again be in the position shown.

The valve through which the combustible charge is admitted to each cylinder may be of any convenient type adapted to be worked either automatically by the difference of pressure on its opposite sides, or mechanically by means of tappet or other gear actuated from the crank shaft. In the arrangement illustrated the fuel inlet valve 12 is shown as adapted to work automatically and normally held closed by a spring 13.

The reservoir into which the products of combustion are forced during the exhaust stroke of each piston is indicated at 14. Owing to the pressure necessarily maintained in this reservoir during the ordinary working of the secondary motor, the communication between each cylinder and the reservoir is controlled by a valve or valves adapted to combine the functions of a non-return valve with those of the positively operated exhaust valve of an internal combustion engine of the usual type. In the arrangement illustrated, the control is effected by means of a pair of lift valves 15, 16 opening in opposite directions. These valves close the same passage 17 leading from the exhaust port of the cylinder to the reservoir, the inner valve 15 opening inward (*i. e.* toward the cylinder) under the action of cam or tappet gear in opposition to spring pressure and the pressure of the gases within the cylinder, while the outer valve 16 opens outward, also in opposition to spring pressure, but automatically under the pressure of the gases during their expulsion.

In the arrangement illustrated, the outer valve 16 has a stem 18 fitted to work as a sleeve upon the stem 19 of the inner valve 15, the stem 19 passing through a stuffing box 20 on the outer end of the stem 18, which works through a guide 21 and stuffing box 22 carried by the cylinder cover 23. The spindle 19 is prolonged some distance beyond the stuffing box 20 between which and a head 24 on the spindle 19, a spring 25 is interposed, this spring being constantly under compression. The outer end of the spindle 19 is pressed upon at the proper moment by a lever 26 fulcrumed at 27 and actuated through a tappet rod 28 by means of a cam 29 fast on a shaft 30, the latter being rotated from the crank shaft 5 by means of gear wheels 31, 32 at such speed as to cause the valve 15 to be held open during approximately the whole of the exhaust stroke of the piston. The valve 15 being held open during the exhaust stroke, the valve 16, which during usually the greater part of the exhaust stroke will be held closed by the pressure within the reservoir, will open (against the stress of the spring 25) under the pressure within the cylinder when this latter pressure begins to exceed that in the reservoir, and so will permit the escape of the products of combustion from the cylinder. At other times each of the valves 15 and 16 will shield one another from pressure (acting from within the cylinder and reservoir respectively) tending to open them, and each will simultaneously on the other hand be held closed by the pressure from which it shields the other.

The ignition may be effected by means of an electric sparking device under the control of a commutator mounted as at 33 on the cam shaft 30.

From the reservoir 14 a pipe 34 leads to the secondary motor, which is indicated diagrammatically at 35 and which may be an engine of any type best suited for the work required to be done. The entrance to the pipe 34 should be protected as at 36 by a screen of gauze or equivalent material adapted to arrest the solid impurities carried over into the reservoir 14 by the exhaust gases from the primary motor.

In an arrangement such as that illustrated, wherein the primary motor is shown as exhausting directly into the reservoir, the pressure in the latter must be relieved when the

speed of the primary motor falls below a certain limit, and should in fact be *nil* when the primary motor is at rest, so that this motor may start free from any load save that due to its own internal friction. The means whereby these conditions are secured in the construction shown, consist of a governor-actuated valve 37 controlling a connection 38 from the reservoir 14 to the exhaust silencer 39 through which the products of combustion may be discharged to the atmosphere when not delivered to the secondary motor. The valve 37 closes outward and (so long as the primary motor is at rest or runs at a speed which is below a predetermined minimum limit) is held open by the pressure of a spring 40 acting through a lever 41 upon the end of the stem 42 of the valve. Upon the primary motor attaining a speed above the minimum limit, a pair of centrifugally acting weighted levers 43 pivoted to the flywheel 44 which is fast on the crank shaft 5, move so as to cause a collar 45 upon said shaft to slide thereon and in turn impart movement to one arm 46 of a lever which is fulcrumed as at 47 to a fixed point, the other arm 48 of this lever operating the lever 41 in opposition to the spring 40 so as to permit the valve 37 to close. In consequence of this arrangement, the exhaust from the primary motor will be discharged directly to the silencer 39 (or atmosphere) at starting, and until the motor has attained the predetermined speed, after which the valve 37 will close and the pressure within the reservoir 14 will rise to the degree required, this pressure being again relieved if at any time the speed of the primary motor should fall below the predetermined minimum limit, which may obviously be varied by adjusting the speed limit at which the governor-controlled valve is permitted to come into operation.

In order to prevent the pressure within the reservoir becoming at any time so high as to choke the exhaust of the primary motor, a second means of escape for the gases within the reservoir may be provided, this device being adjustable so as to open a communication from the reservoir to the silencer (or atmosphere) upon any predetermined maximum limit of pressure being exceeded. In the arrangement illustrated, the second escape valve 49 (which controls a passage 50 leading from the reservoir to the pipe 38 which connects the valve 37 with the silencer 39) opens outward in opposition to a spring 51 interposed between a shoulder 52 on the guide 53 (through which the stem 54 of the valve 49 works) and a collar 55 fitted to slide upon said guide, the collar 55 having attached to it (through the medium of a stirrup 56) a boss 57, through a screw-threaded hole in which a screwed spindle 58 is adjusted (by means for example of a hand wheel 59) so as to bear with any required pressure against the end of the valve spindle 54. Upon the pressure within the reservoir 14 rising beyond the predetermined maximum limit to which the spring 51 has been adjusted by rotating the hand-wheel 59 and screw spindle 58, the valve 49 will be forced open, the thrust which it exerts through its spindle 54 being transmitted by the screw 58 and stirrup 56 to the sliding collar 55 and thence through the spring 51 to the shoulder 52.

It will be obvious that the movement of the spindle 54 or collar 55 might be utilized to control the supply of fuel to the primary motor, the mechanism being designed so that the supply of fuel would be diminished upon the pressure within the reservoir exceeding a predetermined limit. A convenient arrangement for this purpose would consist in the substitution of a piston valve for the ordinary lift valve shown at 49, the piston valve having a relatively long travel before opening communication between the reservoir 14 and passage 50, and this travel being utilized to transmit the necessary movement to the mechanism controlling the fuel supply to the primary motor. An example of such an arrangement is illustrated in Figs. 3 and 4, wherein 49^a is a piston valve which replaces the lift valve 49 shown in Fig. 2. The valve 49^a when moved outward by pressure from within the reservoir 14, eventually uncovers a series of lateral ports 49^b connecting the interior of the valve chamber 50^a with an annular passage 50^b surrounding said chamber and communicating with the branch pipe 50 which leads to the exhaust pipe 38 as before. The movements of the spindle 54 of the valve 49^a are transmitted to a duplex lever 61 mounted to rock about a fulcrum 62, the lever engaging a pair of trunnions 63 on the cap 54^a through the medium of which the regulating screw 48 bears upon the end of the spindle 54. The lever 61 is jointed at 64 to one end of a rod 65 whose other end is jointed to a lever 66 fulcrumed at 67 and connected by any convenient means to the spindle of the throttle valve which controls the fuel supply to the primary motor; the arrangement being such that any movement of the piston valve 49^a in the direction of opening will tend to cause the throttle valve to close, and vice versa, as hereafter more fully explained.

The rod 65 is screw-threaded and carries a nut (and lock-nut) 69 whereby the movement of the rod, and therefore the stroke of the levers 61 and 66, may be adjustably limited, as desired, by the nut encountering a stationary stop 70. In order to avoid the breakage which might otherwise result from the obstruction offered to the movement of the lever 61 (and therefore of the valve 49^a) in consequence of such limitation of the stroke of the rod 65 when the valve 49^a opens to a greater extent than is permitted by the

nut 69, the fulcrum 62 is carried by a block 71 which is fitted to slide on a rod 72 extending alongside of the valve spindle 54, the rod 72 being pivoted as at 73 to a fixed point so as to be capable of angular movement in the plane of the valve spindle. The block 71 is normally (*i. e.* so long as the valve 49ª remains closed) held against a shoulder 74 by a spring 75 which, when the nut 69 encounters the stop 70, yields so as to permit of the lever 61 thereafter turning about the pivot 64 as a fulcrum, the rod 72 meanwhile moving (about its pivotal support 73) toward the valve spindle 54.

On the pressure within the reservoir 14 falling below the predetermined limit, the valve 49ª is closed by the spring 51, as in the case of the arrangement previously described with reference to the lift valve 49, Fig. 2. At the same time the slide block 71 (if previously displaced as described) is restored by the spring 75 to normal position, and the lever 61 also returns to its normal position, which may be determined by a collar 76 on the rod 65 encountering that side of the stop 70 which is opposite to the nut 69.

The arrangement is such that so long as the piston valve 49ª remains closed the throttle valve stands fully open, whereas before the valve 49ª has reached its extreme open position, the throttle valve will have closed completely. Hence any excessive rise of pressure within the reservoir 14 will at once result in stoppage of the fuel supply to the primary motor, so that any needless waste of energy will be obviated. By suitably adjusting the nut 69 upon the rod 65, the actual extent to which the throttle valve closes may be limited as desired. For example, by initially setting the nut 69 close against the stop 70, the throttle valve will be prevented from closing at all, whereas by setting the nut toward the opposite end of the rod 65, the throttle valve will be allowed to close with a relatively short movement of the piston valve 49ª.

A pressure gage may be provided in connection with the reservoir 14 as indicated for example at 60, Fig. 1, and the reservoir may also be furnished with a safety valve if desired.

Claims.

1. Apparatus for generating and storing products of combustion under pressure, consisting essentially in the combination with an internal combustion motor adapted to work on a four-phase cycle and provided with means for causing the expulsion of practically the entire gaseous products of combustion at each exhaust stroke, of a reservoir for receiving the products of combustion so expelled, adapted to supply said products as motive fluid to an engine, and provided with outlet valves whereof the one is controlled by a governor actuated by the internal combustion motor so as to be adapted to relieve the working piston of said motor o back pressure so long as the speed of the motor is below a predetermined lim t, while the other outlet valve is adapted to relieve the pressure within the reservoir when said pressure exceeds the maximum pressure against which the nternal combustion motor is capable of delivering the products of combustion.

2. In apparatus for generating and storing products of combustion under pressure, the combination of an internal combustion motor adapted to work on a four-phase cycle and provided with means for imparting to the working piston a stroke of varying amplitude whereby on the compression stroke a combustion space is left in the working cylinder and on the exhaust stroke practically the entire gaseous products of combustion are expelled from the cylinder; a reservoir for receiving the products of combustion so expelled, adapted to supply said products as motive fluid to an engine, and provided with waste outlet valves whereof the one is controlled by a governor actuated by the internal combustion motor and adapted to relieve the working piston of said motor of back pressure so long as the speed of the motor is below a predetermined limit, while the other outlet valve is adapted to relieve the pressure within the reservoir when said pressure exceeds the maximum pressure against which the internal combustion motor is capable of delivering the products of combustion; and means for controlling the communication between the internal combustion motor and the reservoir, consisting of two lift valves situated in the rear end of the working cylinder of the motor and adapted to close toward one another under spring pressure, that valve which is next the reservoir being adapted to open under the pressure within the motor cylinder while that valve which is next the motor cylinder is carried by a spindle slidable longitudinally through the spindle of the other valve and is provided with means for causing it to open against the pressure within the motor cylinder, substantially as specified.

3. In apparatus for generating and storing products of combustion under pressure, the combination of an internal combustion motor adapted to work on a four-phase cycle and provided with means for causing the expulsion of practically the entire gaseous products of combustion at each exhaust stroke; a reservoir for receiving the products of combustion so expelled adapted to supply said products as motive fluid to an engine, and provided with waste outlet valves whereof the one is controlled by a governor actuated by the internal combustion motor and adapted to relieve the working piston of said motor of back pressure so long as the speed of the motor is below a predetermined limit, while the other outlet valve is adjustably loaded

by a yielding pressure and is adapted to relieve the pressure within the reservoir when said pressure exceeds the maximum pressure against which the internal combustion motor is capable of delivering the products of combustion; and means, operated by the opening movement of the last mentioned valve, for controlling the supply of fuel to the internal combustion motor, substantially as specified.

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