

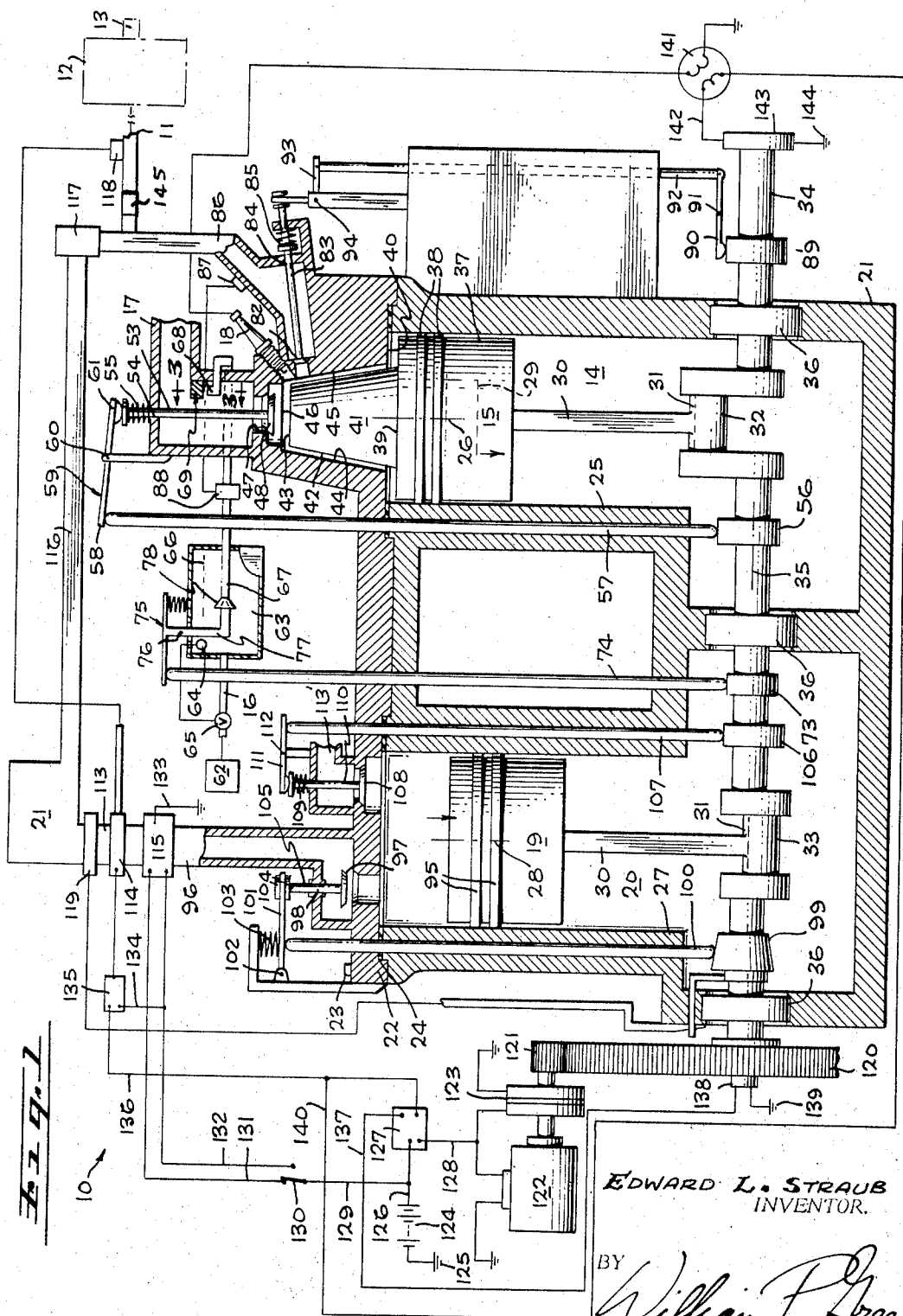
Feb. 11, 1969

E. L. STRAUB
HOT GAS GENERATOR

3,426,524

Filed Oct. 31, 1966

Sheet 1 of 2



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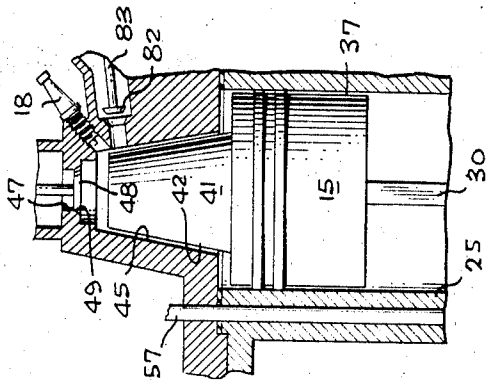


Fig. 1

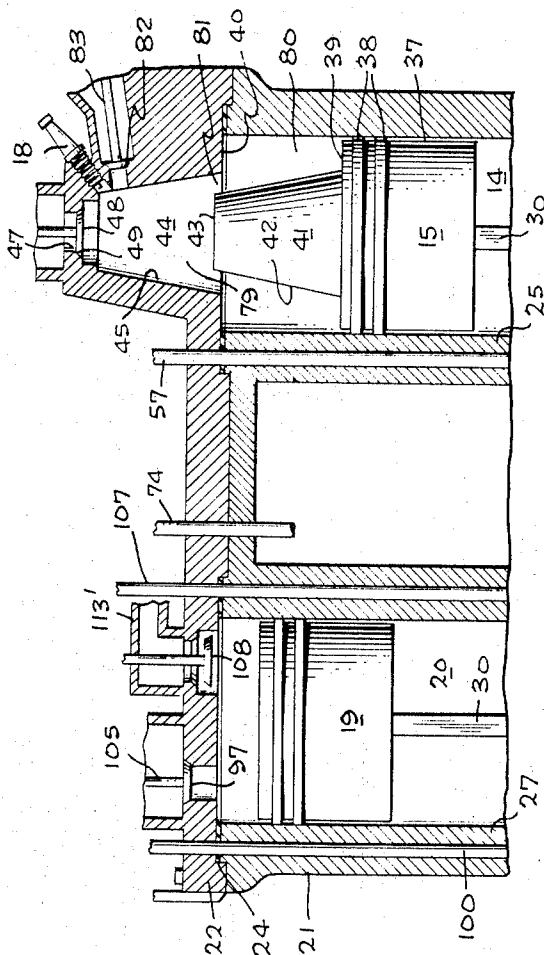


Fig. 2

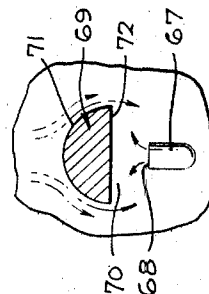


Fig. 3

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3,426,524

HOT GAS GENERATOR

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21 Claims

ABSTRACT OF THE DISCLOSURE

A hot gas generator for producing heated gases to be used in driving an engine, or for other purposes, said generator including a piston reciprocable within a cylinder to compress air in the cylinder, together with means for igniting fuel in the compressed air and then discharging the resultant heated gases from the cylinder, with the piston having a projection extending into an end recess in the cylinder in a relation dividing the cylinder into a first region for receiving a burnable air-fuel mixture, and a second partially isolated region for receiving primarily air. Some of the mixed air and burned gases from the cylinder may be taken to a second piston and cylinder mechanism which acts as a motor to drive the first piston.

Some of the subject matter of the present invention has been disclosed in my co-pending application Ser. No. 589,728, filed Oct. 26, 1966, on "Engine With Compression Braking System."

This invention relates to improved apparatus for generating a supply of hot pressurized gases, which it is contemplated may be utilized for any of various different purposes, but which are in certain respects especially useful for and intended for driving an engine of the external combustion hot-gas type. The invention will be discussed primarily as applied to the production of gases for driving such an engine.

Conventional internal combustion engines, such as those operating on the Otto or diesel cycles, are notoriously very low in efficiency, and have other disadvantages in use. Greater efficiency and improved operational characteristics should be attainable with an engine of the non-internal combustion type, operating on heated gases produced by burning of a fuel externally of the engine proper, with the products of combustion then being delivered to the engine to drive it. However, though numerous different types of gas generators for supplying pressurized gases of this type to an engine have been proposed in the past, none of those with which I am familiar has been entirely satisfactory, and as a result engines of the hot gas or hot air type have not achieved any wide popularity. Perhaps the most successful gas generator to date has been the "bounce piston" type of unit, in which freely moving unrestrained pistons oscillate reciprocally within a cylinder or cylinders in a manner developing pressurized gases at the outlets from the cylinders. These freely moving pistons have unfortunately had the decided disadvantage of functioning effectively within only very limited speed range, and have been very inflexible and uncontrollable for supplying varying volumes of gases.

A major object of the present invention is to provide a gas generating unit which is capable of very efficiently producing heated pressurized gases by combustion of fuel in the unit, and which can regulate these gases in volume between a maximum flow condition and an extremely low rate of flow, to thus satisfy the requirements of an engine for driving at high speed, very slow speed, or any intermediate velocity. Preferably, the gas generator varies its rate of gas production completely automatically, in response to variations in the demand for gases by the engine or other gas utilizing unit, so that an operator may

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regulate the speed of the engine freely and within wide limits, with the generator automatically providing heated gases as needed for any desired speed.

A further object of the invention is to provide a system which, in spite of its above discussed flexibility for providing varying rates of flow of the discharged gases, can always maintain those gases as delivered to the engine at essentially a predetermined optimum pressure, and desirably also at a predetermined optimum temperature, so that the highest thermodynamic efficiency may be attained by thus predetermining and regulating the conditions of the gases which flow to the engine.

A further feature of the invention resides in the completeness with which the fuel may be burned by the gas generator, in order that as much as possible of the available energy in the fuel may be converted to useable form, and further to prevent the ultimate emission from the engine of unburned gases which would otherwise contribute to air pollution.

Structurally, a unit embodying the invention includes a piston which is reciprocable relative to and within a cylinder, and which instead of being of the freely movable unrestrained "bounce piston" type, is positively driven by a source of energy other than any gas force which may be applied directly to the piston. This piston acts to compress air in the cylinder, following which a charge of fuel is burned in the air, with the products of combustion then being discharged from the cylinder for delivery to the driven engine or its equivalent. Preferably, the piston and cylinder are so constructed as to draw an excess of air into the cylinder upon each cycle of operation, but with a burnable mixture of fuel and air being located in a predetermined portion of the cylinder, and excessive air being present in another portion, so that the burnable mix may be ignited easily and burn readily, while the excessive air will act to assure complete ultimate burning of all of the fuel present in the cylinder. This result may be obtained by admitting fuel into the air stream during only a portion of the inlet cycle, and by shaping the piston to have a projection which extends into a cavity or recess in the cylinder head, in a manner dividing the cylinder into two at least partially isolated compartments or regions for receiving the burnable mix and the excessive air mixture respectively.

The piston within the burning cylinder is preferably driven by another piston and cylinder mechanism, which in turn is powered by a suitably pressurized fluid, desirably pressurized gases, at least a portion of which may be taken from the heated gases produced by the burning cylinder itself. An automatic control may respond to the pressure of the gases discharged from the burning cylinder in relation to controlling the rate at which the driving piston is operated in accordance with the requirements of the system. Also, the temperature may be regulated by controlling the admission of fuel into the incoming air fed to the burning cylinder in accordance with changes in the temperature of the gases discharged from that cylinder.

Another object of the invention is to provide a starting system which will initially commence operation of the gas producing apparatus by the actuation of a simple electrical switch, but which will thereafter enable automatic starting and stopping of the system in accordance with the requirements of the engine.

The above and other features and objects of the invention will be better understood from the following detailed description of the typical embodiments illustrated in the accompanying drawings, in which:

FIG. 1 shows a gas producing unit constructed in accordance with the invention, with the pistons shown as they appear at the commencement of an air inlet portion of the cycle of the burning cylinder;

FIG. 2 is a fragmentary representation of the unit when the piston in the burning cylinder is in its bottom dead center position;

FIG. 3 is an enlarged fragmentary section taken on line 3—3 of FIG. 1; and

FIG. 4 is a fragmentary representation of the burning cylinder and piston during the burning portion of the cycle.

Referring first to FIG. 1, I have illustrated somewhat diagrammatically at 10 a unit embodying the invention and utilized for the purpose of producing hot compressed gases within a conduit 11 leading to an engine 12 which is driven by the gases in a manner turning the output shaft 13 of the engine. It is contemplated that this engine may be of any known type, such as a turbine, but is preferably a reciprocating gas driven engine as disclosed and claimed in my co-pending application Ser. No. 589,728 filed Oct. 26, 1966, on "Engine With Compression Braking System."

Unit 10 includes a burning cylinder 14 containing a piston 15, and within which fuel from an inlet line 16 burns in air from an air inlet line 17 when ignited by a spark plug 18. Piston 15 is driven positively by a second piston 19 within a motor or power cylinder 20. Piston 19 is driven by pressurized gases which are preferably taken from an accumulator tank 21 which receives and stores a portion of the gases produced in burning cylinder 14. As will be understood, there may be provided a number of the burning cylinders 14 and contained pistons, and/or a number of the power or engine cylinders 20 and contained pistons, in lieu of the single burning cylinder and single power cylinder illustrated.

The two cylinders 14 and 20 may be formed by and within a single unitary cylinder block 21 having a cylinder head structure 22 secured by bolts 23 to the block, with appropriate gaskets 24 therebetween. The block is appropriately bored to form the cylindrical side wall 25 of burning cylinder 14 centered about an axis 26, and the cylindrical side wall 27 of cylinder 20 centered about a second axis 28 which is parallel to axis 26. Each of the pistons is connected pivotally by a transverse wrist pin 29 to a connecting rod 30, which is in turn connected pivotally at 31 to a crank throw 32 or 33 of a shaft 34 which turns about an axis 35 disposed perpendicular to axes 26 and 28. Shaft 35 is suitably journaled in the engine block by bearings 36.

Piston 15 has a large diameter lower portion 37 which is essentially cylindrical externally and of a diameter only slightly smaller than side wall 25 of cylinder 14, and which carries piston rings 38 forming a gas seal between the cylinder wall 25 and the piston. At its upper extremity, portion 37 of the piston 15 has an annular upwardly or axially outwardly facing surface 39 disposed transversely of and centered about axis 26, and located opposite a corresponding transverse annular shoulder surface 40 formed on the cylinder head 22. Upwardly beyond shoulder 39, piston 15 integrally carries and forms an upwardly extending projection 41, which may be of circular cross section and centered about axis 26, and which has a frusto-conical side wall surface 42 tapering upwardly toward an upper transverse end surface 43 of the piston. The cylinder head 22 is shaped to form a recess 44 upwardly beyond transverse shoulder surface 40, which recess is shaped substantially the same as projection 41 of the piston, and which more particularly has a frusto-conical side wall surface 45 disposed at the same angle as piston surface 42 and similarly centered about axis 26. Also, the cylinder head 22 has transverse end wall surface 46 which is located opposite and dimensioned in correspondence with surface 43 of the piston, and which contains an opening 47 adapted to be closed by upward movement of a valve 48 against an annular valve seat surface 49 (see FIG. 2). Valve 48 may be so dimensioned and located as to be received within a small recess formed in the upper transverse wall of head 22 even in the FIG. 1 open position of the valve.

Inlet air enters the upper end of recess 44 through opening 47 from the previously mentioned air inlet line 17 into which there may of course be connected an appropriate air cleaner. Valve 48 is carried by a valve stem 53 which may be mounted slidably for only axial movement by a guide passage 54, and which is yieldingly urged to closed position by a spring 55. The valve 48 is opened in timed relation to the rotation of shaft 34 by a cam 56, which acts against an axially movable push rod 57, which in turn displaces upwardly a first end 58 of a rocker arm 59 pivoted to the cylinder head structure at 60, so that the second end 61 of the rocker arm will displace the valve downwardly in an opening direction against the influence of spring 55. Cam 56 is designed to open valve 48 in the top dead center position of piston 15, and to close that valve in the bottom dead center position, following which upward movement of the piston acts to compress the air thus taken into cylinder 14.

The fuel to be burned in cylinder 14 may be any appropriate liquid fuel, such as unleaded gasoline, high grade diesel fuel, or the like, and is supplied from an appropriate tank represented at 62 under enough pressure to pass through line 16 into a small float and valving chamber 63. A float 64 in chamber 63 may actuate a valve 65 automatically in a manner maintaining a predetermined level of fuel in chamber 63, as for instance at the level illustrated at 66. The fuel flows from chamber 63 through a line 67 which passes through an opening in a side wall of air inlet line 17 and has a discharge opening 68 at its end (see FIG. 3). This opening 68 faces upwardly as seen in FIG. 3, and is located directly beneath an air block member 69 rigidly secured to and projecting inwardly from and within air inlet line 17, so that this block member protects the fuel inlet opening 68 from the air stream, and causes the development of a vacuum in the area 70 of FIG. 3 to effectively draw fuel from opening 68 into the air stream. Air block member 69 may have an upper curved surface 71 of the illustrated streamlined configuration, and may have an essentially transverse or horizontal undersurface 72 facing the fuel inlet opening.

The timing of the delivery of fuel through line 67 into the air stream is controlled by a cam 73 (FIG. 1), carried and driven by shaft 34, and which acts to displace upwardly a push rod 74 which pivots a valving element 75 about a fulcrum point 76. Element 75 carries a valve proper 77 which coacts with a tapered valve seat end portion 78 of conduit 67 to open and close the left end of tube 67 in accordance with the actuation of push rod 74 by cam 73. Cam 73 maintains valve 77 closed during the initial portion of the downstroke of piston 15, and thus during the initial portion of the open interval of air valve 48, so that pure air without fuel is first drawn into the cylinder 14. At a predetermined point during the downstroke of piston 15, preferably about 90 degrees after top dead center, valve 77 opens to admit fuel into the air thereafter inducted into the cylinder, so that the final portion of the air contains fuel in a proper air-fuel ratio or mix to burn readily and thoroughly. This burnable mixture is contained within the upper portion or region 79 of the cylinder chamber (FIG. 2) located within cylinder head recess 44 and above the upper transverse end surface 43 of the piston, while the initially inducted essentially pure air is contained within a lower annular portion or region 80 of the cylinder chamber, beneath shoulder surface 40 of the cylinder head and between that surface and transverse surface 39 of the piston. The more restricted annular area 81 between these two compartments or regions (which area has a smaller horizontal cross section than either of the regions 79 or 80) acts to isolate these regions sufficiently to maintain the proper burnable mix in the upper compartment 79 and the less burnable mix or pure air in region 80. The opening of valve 77 is so controlled by cam 73 as to separate the burnable and unburnable mixes in this manner, under optimum operating conditions. The pis-

ton and cylinder head are so constructed that, in the top dead center position of piston 15, both of the compartments 79 and 80, as well as the space 81, and therefore the entire cylinder chamber, are reduced to substantially zero volume, or as near thereto as is practical.

On its upstroke, piston 15 compresses both the air within compartment 80 and the air-fuel mixture within compartment 79. A few degrees before top dead center, say for example about 12 degrees, the fuel-air mixture is ignited by spark plug 18, which as seen in FIG. 1 is so located as to have its spark exposed directly to the reduced dimension upper compartment 79. A few degrees later, say for example about five degrees before top dead center, the burned gases are allowed to discharge from the cylinder past an exhaust or discharge valve 82, carried by a stem 83 which is slidably mounted at 84, and is yieldingly urged by a spring 85 to closed position. The discharging gases flow through an outlet conduit 86 which communicates with the line 11 leading to engine 12. On the side of conduit 86 there is mounted a thermostatic control element 87, to which changes in temperature of the exhausting gases are transmitted through the metal side wall of conduit 86. The thermostatic element 87 in turn controls the setting of a variable opening valve 88 connected into fuel line 67, to regulate the opening of valve 88 in a manner tending to compensate for any change in temperature. That is, valve 88 closes slightly in response to an increase in temperature of the exhaust gases, and opens slightly in response to a decrease in temperature of the gases, to thus maintain the gas temperature in conduit 86 substantially uniform. This temperature control functions to maintain the desired temperature regardless of the volume of gases which may be passing through the system, and regardless of the speed of operation of piston 15 and the rest of the apparatus.

Spring 85 is so designed as to maintain valve 82 closed until the burning gases within cylinder 14 have reached a predetermined pressure in excess of the system pressure within line 11. For example, if the system pressure is 125 pounds per square inch within line 11, for operating engine 12, spring 85 may be of a strength to maintain valve 82 closed until the burning gases within cylinder 14 have increased the pressure within that cylinder to a value of about 200 pounds per square inch. This pressure will of course be developed almost instantaneously after commencement of the burning, say about five to seven degrees after commencement of that burning, so that at that instant, and just prior to arrival of piston 15 at top dead center, valve 82 will momentarily open to allow the heated gases to discharge from the cylinder and into conduit 86, with valve 82 closing at about top dead center. In conjunction with this pressure actuation of valve 82 there may be provided a cam 89 on shaft 35, which acts through a rocker arm or lever 90 pivoted at 91, and a rod 92 which is pivotally connected to lever 90, to swing a bell crank 93 (also pivotally connected to rod 92) about a fulcrum point 94 in a manner opening valve 82 for an interval of a few degrees just prior to top dead center. It is noted that spark plug 18 is located near the air inlet valve 48, and also near discharge valve 82, and preferably substantially between these two valves.

As indicated previously, the pumping and compressing piston 15 within burning cylinder 14 is driven positively by piston 19 within power cylinder 20. This piston 19 may be essentially conventional in construction, having rings 95 engaging and sealed with respect to the side wall of cylinder 20. Heated gases for driving the piston downwardly within the cylinder are admitted into the upper end of the cylinder through an inlet line 96 past a valve 97 which is mounted slidably at 98 for axial movement, and which is controlled by a cam 99 on shaft 34. Cam 99 actuates a push rod 100, which pivots a rocker arm 101 upwardly about a fulcrum point 102 against the resistance of a spring 103, with the second end of the rocker arm being confined between two shoulders 104 on

stem 105 of valve 97, to move the valve upwardly in response to actuation of the push rod 100 by cam 99. Similarly, a cam 106 acts through a push rod 107 to open an exhaust valve 108 downwardly against the tendency of a spring 109. Stem 110 of valve 108 is actuated by a rocker arm 111 which is fulcrumed at 112, and which engages the stem and push rod 107 at its opposite ends. The discharging gases are vented to atmosphere through an outlet conduit 113'.

The pressurized hot gases which are fed to power cylinder 20 come from accumulator 21 through a line 113, under the control of an automatically actuated pressure responsive throttle 114, and with an electrically controlled stop valve 115 being also connected into the line. The gases reach accumulator 21 from the discharge conduit 86 of burning cylinder 14 through a line 116, into which there is connected a check valve 117 which will allow heated pressurized gases to flow into the accumulator from conduit 86, but will not allow reverse flow. The throttle valve 114 is controlled automatically by a pressure responsive element 118 connected into communication with the system pressure within line 11, to regulate the rate of gas flow to power cylinder 20 in a manner maintaining a substantially constant pressure in line 11 leading to engine 12. That is, if the pressure in line 11 falls off from a determined desired value, pressure control 118 opens throttle 114 to increase the rate of operation of piston 19 just sufficiently to return the pressure in line 11 to its desired value. Conversely, if the pressure in line 11 rises to an excessive value, automatic control 118 throttles valve 114 to a more restricted condition to reduce the rate of operation of piston 19 and its driven piston 15, just sufficiently to return the pressure in line 11 to the desired value. Thus, the pressure in line 11, like the temperature in that line, remains constant.

Cam 99 opens valve 97 at the top dead center position of piston 19, at which position valve 108 is closed, so that the pressurized high temperature gases enter cylinder 20 above piston 19 and force the piston downwardly. Valve 97 closes at a point during the downstroke of piston 19 which is predetermined to assure expansion of all of the gases to nearly atmospheric pressure before exhaust valve 108 opens a few degrees prior to the bottom dead center position of the piston. Thus, a maximum amount of energy is extracted from the heated gases, with minimum losses to the atmosphere. The exhaust valve 108 then remains open during the upstroke of the piston to assure full exhaustion of all of the gases from the cylinder in preparation for closure of that valve at top dead center, and reopening of valve 97 for the next successive stroke.

In the event that the gases within cylinder 20 expand to atmospheric pressure before piston 19 reaches its bottom dead center position, and further movement of the piston then develops a sub-atmospheric pressure within cylinder 20, valve 108 will automatically open against the tendency of spring 109, and without operation by cam 106, to avoid requiring the piston to do negative work against the vacuum in the cylinder. During such opening of the valve, valve stem 110 simply moves away from its contact with rocker arm 111, even though cam 106 has not actuated the valve. It is also noted that cam 99 may be tapered and be shiftable axially in a manner opening valve 97 to different extents in accordance with any variations which may occur in the pressure of gases in line 113, with this automatic response desirably being under the control of an automatic sensing element represented at 119 in FIG. 1. Thus, if at the commencement of operation of the apparatus, the pressure in accumulator 21 is somewhat below the pressure normally and automatically maintained in that accumulator, control 119 will actuate cam 99 axially along the shaft in a manner such that it will adjust the closing point of valve 97 and therefore compensate for the reduced pressure of the gases.

To maintain the rate of rotation of shaft 34 uniform,

the shaft may carry a fly wheel 120, typically having external gear teeth which engage mating teeth on a pinion gear 121 designed to drive the fly wheel and shaft for starting. Gear 121 is in turn driven by a starter motor 122 through a magnetic clutch represented at 123, with power being supplied to the starter motor from a battery 124. The battery is grounded at one side 125, and has a lead 126 from its opposite terminal which connects through the secondary side of a starter relay 127 to a lead 128 connecting in parallel to the starter motor 122 and magnetic clutch 123. The opposite sides of the starter motor and magnetic clutch are both connected to ground, as shown in FIG. 1. Another lead 129 from the battery passes through a two position switch 130, whose movable contact can connect selectively to either of two leads 131 and 132. When switch 130 supplies current to lead 131, that current passes through a typically solenoid type electrically operated stop valve 115, and to the ground terminal 133 at the opposite side of that valve, to actuate the valve to closed position. When switch 130 is turned to close the circuit to lead 132, this lead passes current through stop valve 115 in a manner opening that valve. Also, the lead 132 is connected to a circuit which includes a lead 134, a switch 135 connected to pressure controlled throttle 114, a lead 136 connecting to the primary coil of starter relay 127, from which current flows through a lead 137 to a switch 138, and ultimately to ground at 139. Switch 135 is actuated by valve 114, in a relation such that when valve 114 is open, switch 135 is closed, and vice versa. Switch 138 is actuated and driven by fly wheel 120, and is closed when the fly wheel is stationary and until the fly wheel reaches a speed in excess of cranking speed, at which time switch 138 is automatically opened to halt the cranking operation. Another circuit from lead 132 extends through lead 134, switch 135, and a line 140 leading to the primary side of an ignition coil 141. After passing through this ignition coil, current flows through a lead 142 to breaker points 143, and then to ground 144, with the breaker points being driven by shaft 34 and acting to close the ignition circuit to coil 141 at the proper time for firing spark plug 18 during each cycle of operation of the apparatus. Breaker points 143 are desirably of the speed responsive type, acting to automatically advance the spark as the speed increases. The secondary side of ignition coil 141 is connected to spark plug 18, to deliver high voltage impulses to the spark plug at the desired timed intervals.

To now describe a cycle of operation of the apparatus illustrated in the figures, assume that the pistons and the rest of the apparatus are initially at rest, and that no pressure is present in accumulator 21. Also, assume that the starting switch 130 is connected to lead 131, so that stop valve 115 is closed to prevent the admission of any pressurized gases to the power cylinder 20. The gas generator may then be started by simply moving the movable contact of switch 130 to its position of engagement with lead 132, to supply energizing current from battery 124 to that lead. Such energization of lead 132 supplies current to the opening side of stop valve 115, to open that valve in preparation for the delivery of pressurized gases to cylinder 20. The electricity is also supplied to switch 135 through lead 134, and since it is assumed that there is no pressure at any point in the system, valve 114 is fully opened, and the connected switch 135 is closed. Thus, the electrical circuit from leads 132 and 134 is completed through switch 135 to the ignition system through lead 140, and in parallel to starter relay 127 through lead 136. Switch 138 is closed because of the stationary condition of fly wheel 120, to complete the circuit to the starter relay, so that secondary current from the starter relay passes to the starter motor 122 and magnetic clutch 123. Energization of the clutch mechanically connects the starter motor to fly wheel driving gear 121, and energization of the motor commences its rotation to drive the fly wheel and commence rotation of shaft 34. As the shaft

turns, it causes piston 15 to pump air and fuel into cylinder 14, in which fuel is burned, with the resultant gases of combustion being discharged into conduits 86 and 11, and with some of the gases passing through conduit 116 back to accumulator 21. After the piston 15 has turned through a very few cycles, sufficient pressure is developed in accumulator tank 21 to commence powered reciprocation of piston 19 within cylinder 20, for driving shaft 34 at an increased speed sufficient to open switch 138 and thus de-energize the starting motor and magnetic clutch. Pressure controlled throttle 114, under the control of regulator element 118, then becomes effective to automatically regulate the volume of gases passing to cylinder 20 in a manner generating within cylinder 14 just enough pressurized gases to maintain the desired predetermined pressure in line 11.

If engine 12 is stopped, the pressure in line 11 will increase to a value completely closing throttle 114 by its control 118, to thus stop the operation of piston 19 and its driven piston 15. Such closing of throttle 114 opens switch 135 to de-energize ignition circuit 140 and thus prevent damage to the points of breaker 143. When engine 12 again commences to draw pressurized gases from the system, throttle 114 will open automatically and switch 135 will close automatically, to supply gases to drive piston 19 and recommence the generation of gases within cylinder 14. At the same time, the closure of switch 135 will resupply current to the ignition circuit 140, and will energize starter 122 and clutch 123 to assist in starting piston 19. Thus, if piston 19 happens to have stopped at a position in which the gases can not start it (as during the upstroke of the piston), the starter will drive the piston until the gases take over and until speed responsive switch 138 breaks the starter circuit. Similarly, the starter will start the piston if for any reason the system has lost pressure.

When it is desired to stop the engine completely, switch 130 is turned to its position of engagement with lead 131, to close stop valve 115 in a manner positively preventing leakage of any of the gases from accumulator 21. Such actuation of switch 130 also prevents energization of the starting circuit. When the switch 130 is subsequently returned to its position of energization of lead 132, the starter motor and gases will again function together to start the gas generator and recommence the production of heated gases. As will be apparent, the energization of starter 122 on each start enables the use of only a single piston 19 for driving the gas generator, rather than a series of cylinders. If only the gases has to be relied on for starting the generator, it would be necessary to employ enough pistons to assure the positioning of at least one piston in a position to be driven by the gases at all times.

To discuss a cycle of operation of the pistons themselves, assume first of all that the pistons are in the FIG. 1 condition, and that piston 19 is being forced downwardly by gases entering cylinder 20 past the open inlet valve 97. As piston 19 turns shaft 34, it forces piston 15 downwardly from the top dead center position, with valve 48 opening at top dead center to admit air (initially without fuel) into cylinder 14 from conduit 17. When the piston 15 reaches a predetermined point in its downward travel, as for instance 90 degrees after top dead center, cam 73 opens valve 77 to admit fuel into the air stream through conduit 67, and in a proper mixture for effective burning. When the piston reaches bottom dead center (FIG. 2), the initially introduced air is present in lower compartment 80, while the air-fuel mixture is present in upper compartment 79, with the two compartments being isolated to a large extent by the restriction offered at 81. Valve 48 closes at bottom dead center, and on the upstroke of piston 15, the piston compresses both the air in compartment 80 and the air-fuel mixture in compartment 79. Just prior to top dead center, spark plug 18 ignites the mixture in compartment 79. Valves 48 and 82 are of course closed at the time of ignition (typically 12 degrees prior to top dead center of piston 15). When the

developed gases reach a high enough pressure, they force valve 82 to open, very rapidly and for a very short interval, to discharge most of the gases into conduit 86, and then allow closure of valve 82 before the piston reaches top dead center. The compressed air in lower compartment 80 also discharges rapidly through the outlet with the gases, and assists in scavenging the burned gases from the cylinder while maintaining a substantial excess of oxygen acting to assure very complete burning of all of the fuel. The piston then commences its next cycle of operation to draw another charge of air and fuel into the cylinder, compress it, and burn and then discharge it into line 86.

The positioning of the discharge opening 68 of fuel conduit 67 near the right hand side of the air inlet passageway causes the fuel to enter past valve 48 at a location closely adjacent spark plug 18, to thus maximize the opportunity for effective burning at the spark plug location. Such positioning of the fuel inlet opening 68 also positions this opening near the location of discharge valve 82.

Desirably, a pressure control valve 145 is connected into the gas discharge line 11 leading to engine 12, with valve 145 preferably being located in line 11 upstream of pressure responsive element 118, valve 145 may be of any conventional type adapted to prevent the flow of gases rightwardly past this valve until the development of a predetermined normal operating gas pressure at the left side of the valve. The purpose of this pressure control valve is to assure the development at the left side of valve 145 of sufficient pressure to enable proper starting and operation of the gas generating system, prior to delivery of any of the produced gases to engine 12.

I claim:

1. A hot gas generator comprising a cylinder, inlet means for admitting air and fuel into said cylinder, a piston in the cylinder reciprocable relative thereto and operable to compress said air, means for igniting said fuel in the cylinder to burn in said compressed air and produce heated gases, outlet means for then discharging said heated gases from the cylinder, and motor means driven by a source of power other than gas force applied directly to said piston by the burning of said fuel in said cylinder and operable to positively drive said piston relative to said cylinder for compressing said air, said cylinder and piston being shaped to define a cylinder chamber having two regions which are partially separated one from the other by said piston, said inlet means being constructed and positioned to introduce a burnable air-fuel mixture into one of said regions and to introduce a greater percentage of air into the other region.

2. A hot gas generator comprising a cylinder, inlet means for admitting air and fuel into said cylinder, a piston in the cylinder reciprocable relative thereto and operable to compress said air, means for igniting said fuel in the cylinder to burn in said compressed air and produce heated gases, outlet means for then discharging said heated gases from the cylinder, and motor means driven by a source of power other than gas force applied directly to said piston by the burning of said fuel in said cylinder and operable to positively drive said piston relative to said cylinder for compressing said air, said cylinder and piston being shaped to define a cylinder chamber having two regions which are partially separated one from the other by said piston, said inlet means being constructed and positioned to first admit primarily air into the cylinder, during an early portion of each cycle of operation, in a relation such that said air flows mainly into one of said regions, and to then admit an air-fuel mixture into the cylinder in a relation forming a burnable mix in said second region.

3. A hot gas generator comprising a cylinder, inlet means for admitting air and fuel into said cylinder, a piston in the cylinder reciprocable relative thereto and operable to compress said air, means for igniting said fuel

in the cylinder to burn in said compressed air and produce heated gases, outlet means for then discharging said heated gases from the cylinder, and motor means driven by a source of power other than gas force applied directly to said piston by the burning of said fuel in said cylinder and operable to positively drive said piston relative to said cylinder for compressing said air, said piston and cylinder having shoulders opposite one another and forming therebetween a first cylinder chamber region, said piston having a projection extending beyond said shoulders into a recess in an end of the cylinder in a relation forming a second region which is partially isolated by the piston from the first region.

4. A hot gas generator as recited in claim 3, in which said inlet means open essentially into said second region to introduce air and fuel thereinto.

5. A hot gas generator as recited in claim 3, in which said igniting means are located more in said second region than in said first region.

6. A hot gas generator as recited in claim 3, in which said inlet means include an air line containing a valve and positioned to admit air more into said second region than into said first region, and a fuel valve operable to open after said air valve so that on each cycle there flows into said cylinder first primarily air and then a burnable air-fuel mixture.

7. A hot gas generator as recited in claim 3, in which said outlet means are positioned to discharge gases from the cylinder at a location which in one position of the piston is intermediate said two regions and essentially laterally opposite said projection on the piston.

8. A hot gas generator as recited in claim 3, in which said projection on the piston and said recess in the cylinder taper to form a space therebetween through which said regions are in communication.

9. A hot gas generator as recited in claim 3, in which said projection on the piston and said recess in the cylinder taper to form a space therebetween through which said regions are in communication, said inlet means including an air inlet formed in an end of the cylinder within said recess and opposite an end of said projection of the piston, a valve for admitting a stream of air into the cylinder through said inlet, fuel valve means for introducing fuel into said air stream and operable to open in delayed relation to the opening of said air valve, said outlet means including a gas outlet which in one position of the piston is intermediate said two regions and essentially laterally opposite said projection on the piston which has an outlet valve, said igniting means including a spark plug positioned to ignite fuel primarily in said second region and located near said outlet and said inlet.

10. A hot gas generator as recited in claim 3, in which said projection on the piston and said recess in the cylinder taper to form a space therebetween through which said regions are in communication, said inlet means including an air inlet formed in an end of the cylinder within said recess and opposite an end of said projection of the piston, a valve for admitting a stream of air into the cylinder through said inlet, fuel valve means for introducing fuel into said air stream and operable to open in delayed relation to the opening of said air valve, said outlet means including a gas outlet which in one position of the piston is essentially intermediate said two regions and essentially laterally opposite said projection on the piston and which has an outlet valve, said igniting means including a spark plug positioned to ignite fuel primarily in said second region and located near said outlet and said inlet, said motor means including an engine having a cylinder and a piston driven by gases from said first mentioned cylinder, automatic pressure responsive control means operable to regulate the delivery of said gases to said second cylinder in response to changes in the pressure of said heated gases and in a relation tending to compensate for said changes, a thermostatic control responsive to changes in the tem-

perature of the gases from said first mentioned cylinder, and valve means operable by said thermostatic control to regulate the delivery of fuel to said first mentioned cylinder in response to variations in said temperature in a manner tending to compensate for said changes.

11. A hot gas generator comprising a cylinder, inlet means for admitting air and fuel into said cylinder, a piston in the cylinder reciprocable relative thereto and operable to compress said air, means for igniting said fuel in the cylinder to burn in said compressed air and produce heated gases, outlet means for then discharging said heated gases from the cylinder, motor means driven by a source of power other than gas force applied directly to said piston by the burning of said fuel in said cylinder and operable to positively drive said piston relative to said cylinder for compressing said air, and automatic pressure responsive control means operable to vary the rate of operation of said motor means in response to changes in the pressure of said heated gases in a relation tending to compensate for said changes and thereby regulate said gas pressure.

12. A hot gas generator comprising a cylinder, inlet means for admitting air and fuel into said cylinder, a piston in the cylinder reciprocable relative thereto and operable to compress said air, means for igniting said fuel in the cylinder to burn in said compressed air and produce heated gases, outlet means for then discharging said heated gases from the cylinder, and motor means driven by a source of power other than gas force applied directly to said piston by the burning of said fuel in said cylinder and operable to positively drive said piston relative to said cylinder for compressing said air, said motor means including an engine having a cylinder and a piston driven relative thereto by gases from said first mentioned cylinder, means for conducting said gases from said first mentioned cylinder to the second cylinder, and automatic pressure responsive control means operable to regulate the delivery of said gases to said second cylinder in response to changes in the pressure of said heated gases in a relation tending to compensate for said changes and thereby regulate said gas pressure.

13. A hot gas generator comprising a cylinder, inlet means for admitting air and fuel into said cylinder, a piston in the cylinder reciprocable relative thereto and operable to compress said air, means for igniting said fuel in the cylinder to burn in said compressed air and produce heated gases, outlet means for then discharging said heated gases from the cylinder, motor means driven by a source of power other than gas force applied directly to said piston by the burning of said fuel in said cylinder and operable to positively drive said piston relative to said cylinder for compressing said air, a thermostatic control responsive to changes in the temperature of the gases from said cylinder, and valve means operable by said thermostatic control to regulate the delivery of fuel to said cylinder in response to variations in said temperature in a manner tending to compensate for said changes.

14. A hot gas generator comprising a cylinder, inlet means for admitting air and fuel into said cylinder, a piston in the cylinder reciprocable relative thereto and operable to compress said air, means for igniting said fuel in the cylinder to burn in said compressed air and produce heated gases, outlet means for then discharging said heated gases from the cylinder, motor means driven by a source of power other than gas force applied directly to said piston by the burning of said fuel in said cylinder and operable to positively drive said piston relative to said cylinder for compressing said air, and automatic pressure responsive control means operable to vary the rate of operation of said motor means in response to changes in the pressure of said heated gases in a relation tending to compensate for said changes and thereby regulate said gas pressure, said control means being operable upon the attainment of a predetermined pressure in said heated gases to automatically completely stop

said motor means and thereby halt the production of said heated gases, and being subsequently operable upon a predetermined drop in said pressure to automatically restart the motor means and recommence production of the heated gases.

15. A hot gas generator comprising a cylinder, inlet means for admitting air and fuel into said cylinder, a piston in the cylinder reciprocable relative thereto and operable to compress said air, means for igniting said fuel in the cylinder to burn in said compressed air and produce heated gases, outlet means for then discharging said heated gases from the cylinder, and motor means driven by a source of power other than gas force applied directly to said piston by the burning of said fuel in said cylinder and operable to positively drive said piston relative to said cylinder for compressing said air, said motor means including a piston and cylinder mechanism driven by pressurized gas, container means for holding a supply of pressurized gas and delivering it to said piston and cylinder mechanism to drive it, a starter operable to start said motor means, starting control means operable when actuated to a predetermined starting condition to admit pressurized gas from said container means to said piston and cylinder mechanism, and to also actuate said starter, and a speed responsive control unit operable to deactivate said starter upon attainment by said piston and cylinder mechanism of a predetermined speed greater than cranking speed.

16. A hot gas generator comprising a cylinder, inlet means for admitting air and fuel into said cylinder, a piston in the cylinder reciprocable relative thereto and operable to compress said air, means for igniting said fuel in the cylinder to burn in said compressed air and produce heated gases, outlet means for then discharging said heated gases from the cylinder, and motor means driven by a source of power other than gas force applied directly to said piston by the burning of said fuel in said cylinder and operable to positively drive said piston relative to said cylinder for compressing said air, said motor means including a piston and cylinder mechanism driven by some of said heated gases from said first mentioned cylinder, a throttle valve for regulating the flow of said heated gases to said motor means and actuable to a closed condition to stop the motor means, a pressure sensing unit operable to actuate said throttle valve automatically between open and closed positions in accordance with variations in the pressure of the heated gases produced by said mechanism and in a relation to admit gases to said motor means upon a predetermined drop in said pressure, a starter for starting said motor means, and a switch automatically operable in response to said drop in pressure to actuate said starter to drive the motor means.

17. A hot gas generator comprising a cylinder, inlet means for admitting air and fuel into said cylinder, a piston in the cylinder reciprocable relative thereto and operable to compress said air, means for igniting said fuel in the cylinder to burn in said compressed air and produce heated gases, outlet means for then discharging said heated gases from the cylinder, motor means driven by a source of power other than gas force applied directly to said piston by the burning of said fuel in said cylinder and operable to positively drive said piston relative to said cylinder for compressing said air, said motor means including an engine driving the piston relative to said cylinder and itself driven by gases from said cylinder, and means for conducting said gases from said cylinder to said engine, means for conducting said gases from said cylinder to an additional unit to be driven thereby, and a pressure control valve operable to prevent the discharge of any of said gases to said additional unit until attainment of a predetermined gas pressure to said engine.

18. A hot gas generator comprising a cylinder, inlet means for admitting air and fuel into said cylinder, a piston in the cylinder reciprocable relative thereto and operable to compress said air, means for igniting said fuel in the cylinder while said piston is nearer top dead center

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than bottom dead center on a particular cycle to burn the fuel in said compressed air and produce heated gases, outlet valve means for then discharging said heated gases from the cylinder and constructed and adapted to open and commence discharge of said gases while said piston still remains nearer top dead center than bottom dead center during the same cycle, and motor means driven by a source of power other than gas force applied directly to said piston by the burning of said fuel in said cylinder and operable to positively drive said piston relative to said cylinder for compressing said air.

19. A hot gas generator as recited in claim 18, in which said motor means include an engine having a cylinder and a piston driven relative thereto by gases from said first mentioned cylinder, and means for conducting said gases from said first mentioned cylinder to the second cylinder.

20. A hot gas generator as recited in claim 18, in which said igniting means act to ignite said fuel at approximately top dead center and said outlet valve means open to commence discharge of said gases a few degrees thereafter and still at approximately top dead center.

21. A hot gas generator comprising a cylinder, inlet means for admitting air and fuel into said cylinder, a piston in the cylinder reciprocable relative thereto and operable to compress said air, means for igniting said fuel in the cylinder to burn in said compressed air and produce heated gases, outlet means for then discharging said heated gases from the cylinder, and motor means driven by a source of power other than gas force applied directly to said piston by the burning of said fuel in said cylinder

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and operable to positively drive said piston relative to said cylinder for compressing said air, said motor means including a second piston and cylinder mechanism driven by said heated gases, container means for holding a supply of said heated gases and delivering them to said second piston and cylinder mechanism to drive it, a starter operable to start said motor means, and automatic starting control means responsive automatically to a predetermined drop in pressure in said container means to admit heated gases from said container means to said second piston and cylinder mechanism, and to also actuate said starter.

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