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Girodin

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[54] **COMBUSTION ENGINE WITH REDUCED EMISSIONS**

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[30] **Foreign Application Priority Data**

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[52] **U.S. Cl.** **60/39.63**

[51] **Int. Cl.** **F02g 3/02**

[58] **Field of Search** 60/39.63

[56] **References Cited**

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Primary Examiner—Clarence R. Gordon

[57] **ABSTRACT**

An external combustion engine wherein air compressed in a plurality of cylinders is delivered to a common combustion chamber is disclosed. The hot exhaust gases exiting the combustion chamber of the present invention are returned directly to the cylinders at a pressure which approximates the compressed air delivery pressure. In a preferred embodiment the combustion chamber is divided into two portions and control over the engine output power is achieved either by varying the time of opening of the valves which return the exhaust gases to the cylinders or by means of a variable pressure drop fuel delivery device which operates in combination with a variable delivery fuel pump.

9 Claims, 12 Drawing Figures

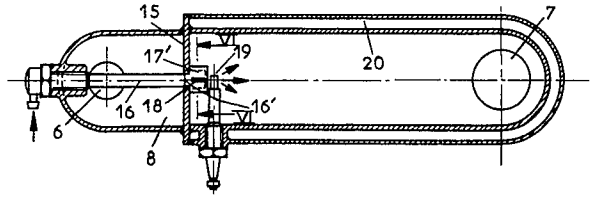


FIG. 1

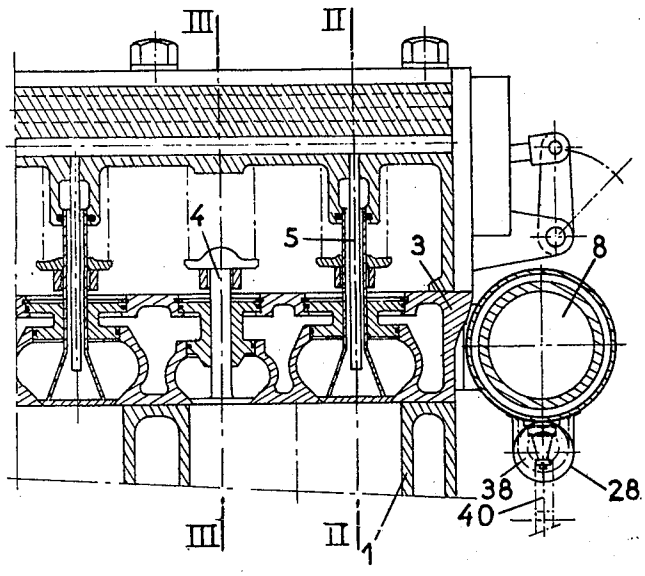


FIG. 2

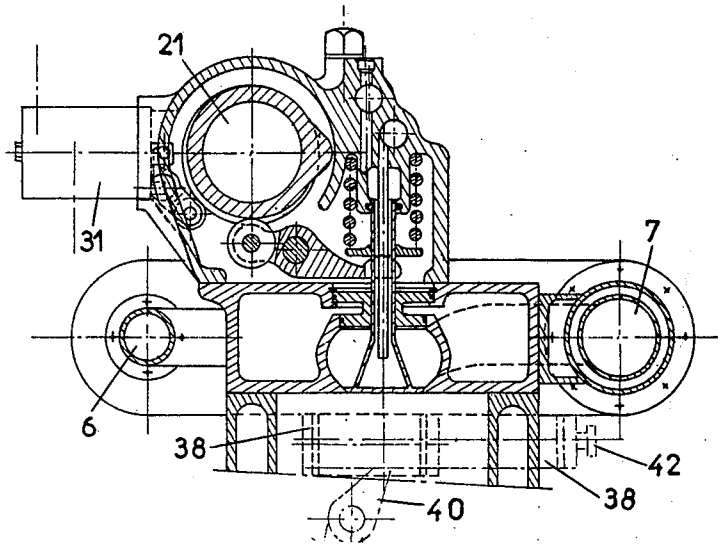


FIG. 4

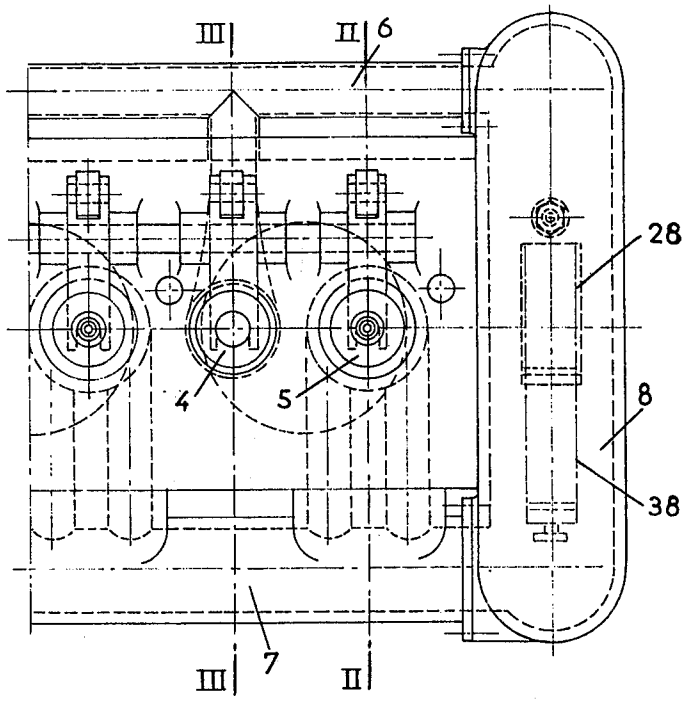


FIG. 3

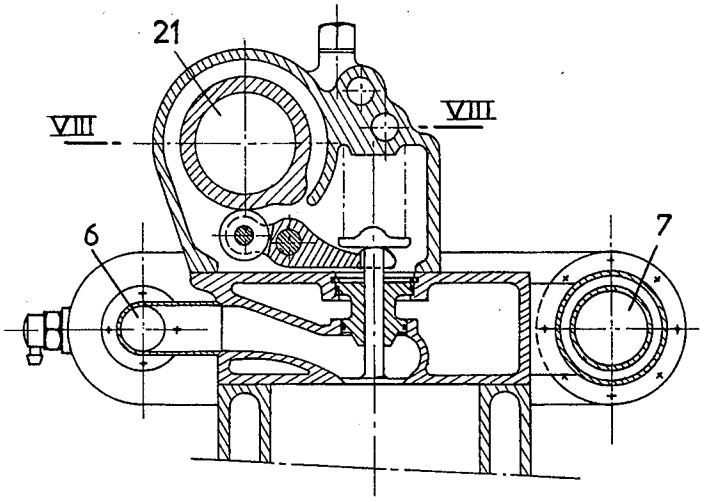


FIG. 5

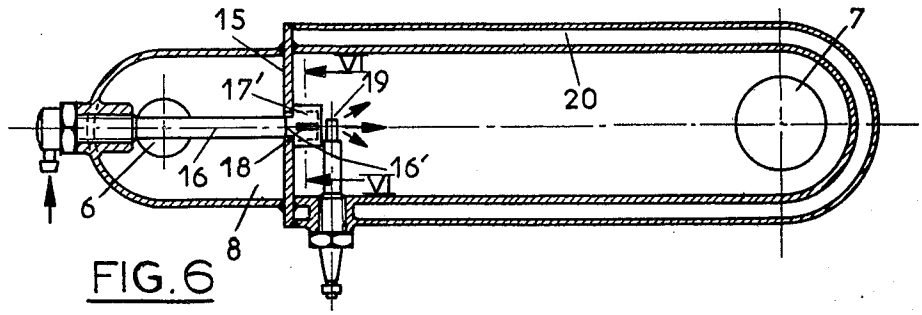


FIG. 6

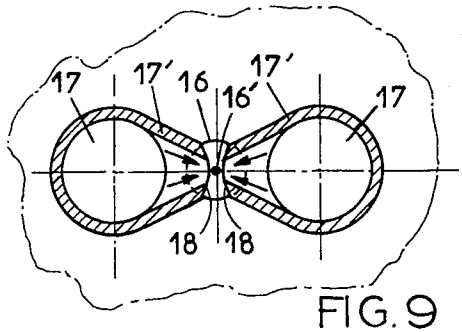


FIG. 7

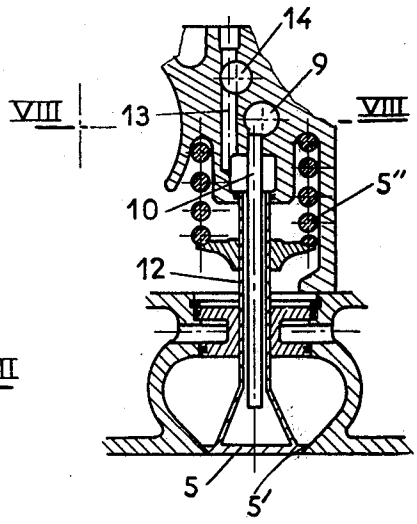


FIG. 9

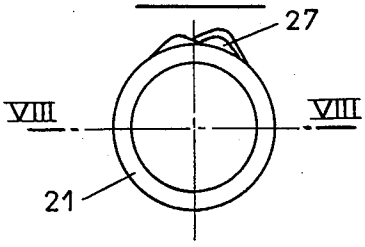


FIG. 8

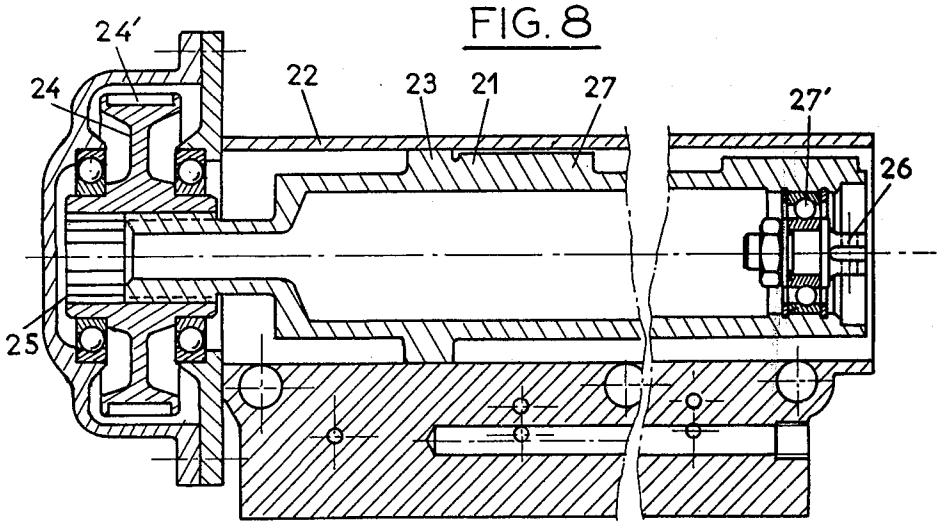


FIG. 10

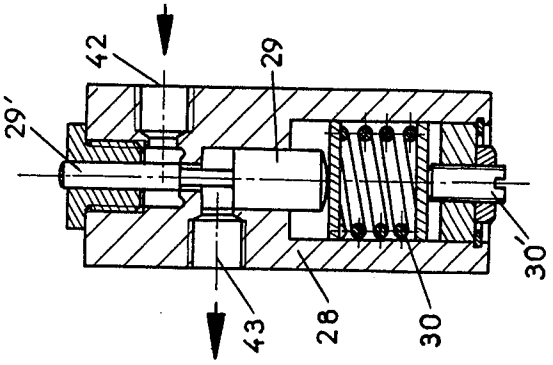


FIG. 11

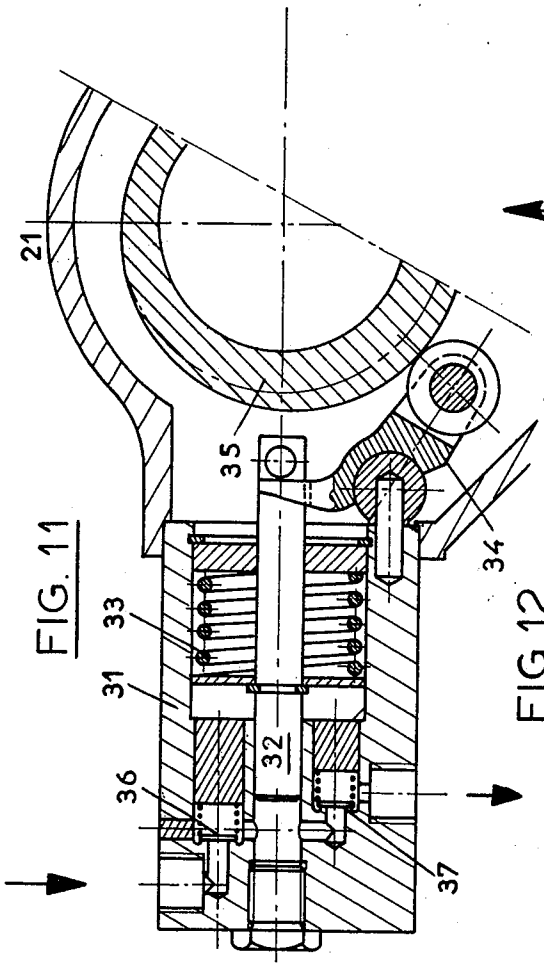
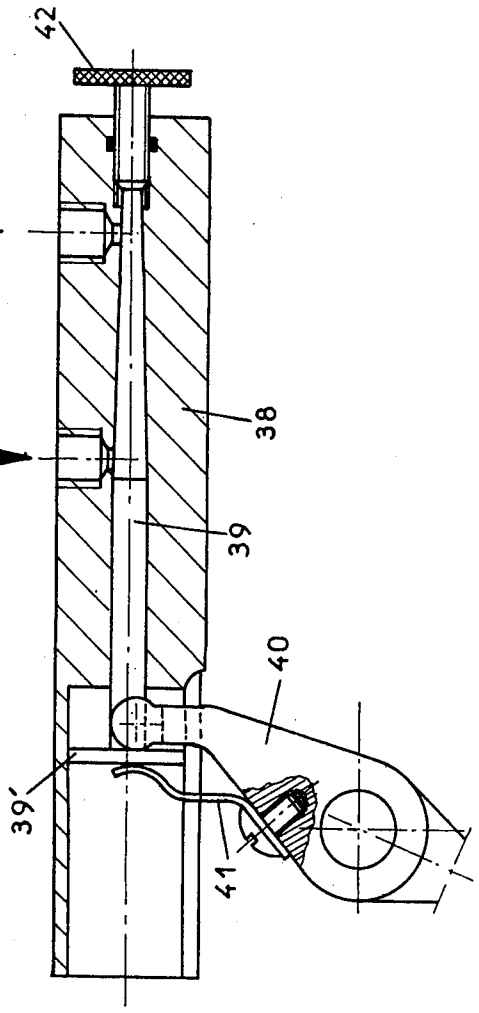


FIG. 12



COMBUSTION ENGINE WITH REDUCED EMISSIONS

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to the reduction of the pollutants carried by the exhaust gases of fuel burning engines. More specifically, this invention is directed to an external combustion type engine. Accordingly, the general objects of the present invention are to provide novel and improved methods and apparatus of such character.

2. Description of the Prior Art

It is, of course, well known that the exhaust gases from "heat" engines of both the internal combustion and "explosion" types are characterized by a composition commensurate with incomplete burning. While theoretical solutions to the problems associated with cleansing the exhaust gases emanating from fuel burning engines have been proposed, apparatus in accordance with such theoretical solutions are believed to be prohibitive from the standpoint of both manufacturing cost and operating expense.

The advantages of external combustion engines; i.e., engines in which combustion takes place in a separate chamber at virtually constant pressure; are well known. Unfortunately, previously proposed engines of the external combustion type have not been applicable to use in the automotive field.

SUMMARY OF THE INVENTION

The present invention overcomes the above briefly discussed and other deficiencies and disadvantages of the prior art by providing a novel external combustion engine particularly well suited for use in automobiles. An engine in accordance with the present invention can be both manufactured and operated at reasonable cost.

The external combustion heat engine of the present invention is characterized by an operational mode wherein, at the end of the compression phase, each cylinder delivers the air compressed therein to a common combustion chamber. The hot gases leaving the combustion chamber are subsequently delivered to the cylinders at a pressure close to the delivery pressure. Thus, disregarding pressure losses occurring in the combustion chamber, an engine in accordance with the present invention operates upon a diesel cycle.

Structurally, each cylinder head of an engine in accordance with the present invention includes a pair of control valves respectively for delivering compressed air to the combustion chamber and for receiving hot gases from the combustion chamber. This arrangement will be employed whether the engine is of the two or four stroke type. Also in accordance with the invention, the hot gas inlet valve associated with each cylinder is cooled by a continuous flow of a suitable coolant; the valve head and its stem being hollow to permit coolant flow.

The combustion chamber, preferably a single such chamber being operatively associated with several cylinders and there possibly being a plurality of combustion chambers, in a preferred embodiment of the invention is characterized by division into two compartments which are in communication with one another through a restriction designed to produce a pressure loss. The volume of the two compartments of the combustion

chamber is such that the intermittent arrival of compressed air and the intermittent discharge of hot gases produces only a small variation in pressure relative to the main operating pressure. A continuous fuel-feed jet is positioned in the combustion chamber adjacent to the restriction by which communication between the two compartments is established thereby permitting the utilization of the pressure drop produced by the restriction to effect the mixing of the fuel and air.

Also in accordance with the present invention, engine output power control may be effected by varying the time of opening of the hot gas inlet valves. Control over the time of opening of the inlet valves is accomplished by means of a camshaft associated with each row of cylinders; the camshaft being axially displaceable and carrying cams having profiles of evolute form.

The delivery of fuel to the combustion chamber or chambers of an engine in accordance with the present invention is controlled by a regulator so that fuel flow increases when chamber pressure decreases and decreases when combustion chamber pressure increases. This mode of fuel control permits the variation of engine power by means of the axially displaceable camshaft, as described above, since the feed pressure of the cycle in the cylinders is maintained substantially constant.

In accordance with a second embodiment of the invention, power control is achieved more simply, albeit at the expense of a slight reduction in efficiency, by a pressure drop producing device arranged between the fuel injection nozzle in the combustion chamber and a variable fuel pump. The pressure drop producing device, which may be a needle valve, will not permit fuel delivery beyond a given pressure; the maximum pump pressure corresponding to the maximum cycle pressure in the cylinders and the opening time of the valves being constant.

BRIEF DESCRIPTION OF THE DRAWING

The present invention may be better understood and its numerous objects and advantages will become apparent to those skilled in the art by reference to the accompanying drawings which depict a two-stroke engine and in which:

FIG. 1 is a partial side elevation cross-sectional view of an engine in accordance with a first embodiment of the present invention;

FIG. 2 is a cross-sectional view of the embodiment of FIG. 1 taken along the axis II—II of an exhaust valve;

FIG. 3 is a cross-sectional view of the embodiment of FIG. 1 taken along the axis III—III of a compressed gas delivery valve;

FIG. 4 is a plan view of the first embodiment of the invention with the rocker box cover removed to reveal the camshaft;

FIG. 5 is an axial section view through a combustion chamber of the embodiment of FIG. 1;

FIG. 6 is an enlarged partial section view, taken along line VI—VI, of the combustion chamber of FIG. 5;

FIG. 7 is an enlarged fragmentary view of the valve of FIG. 2;

FIG. 8 is a cross-sectional view through the axis of a camshaft; line VIII—VIII of FIG. 9, taken in a plane parallel to the cylinder head joint plane, FIG. 8 showing the apparatus which controls the camshaft axial position;

FIG. 9 is a sectional view through the camshaft of the disclosed embodiment of the invention;

FIG. 10 is a cross-sectional view of a constant-pressure fuel-flow regulator in accordance with the invention;

FIG. 11 is an axial section through a fuel feed pump which may be employed with the present invention; and

FIG. 12 is an axial section through a needle-valve fuel-flow control device which may be employed in a second embodiment of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring jointly to FIGS. 1–4, the cylinder block 1 of an engine in accordance with the present invention defines a plurality of cylinders conventionally arranged and terminating, at their upper ends, at a cylinder head 3. The cylinder head 3 defines, for each cylinder, the housing for a controllable delivery or compressed air discharge valve 4 and a controllable hot gas inlet valve 5. Both of valves 4 and 5 open into head 3; i.e., the valves open away from the cylinders.

The compressed air discharge valves 4 are connected to a delivery manifold 6 in the manner shown in FIGS. 3 and 4. The inlet valves 5 are connected to a hot gas manifold 7 in the manner depicted in FIGS. 2 and 4. The manifolds 6 and 7 are connected to a combustion chamber 8, common to all of the cylinders in a single bank, by means of flanges and gasketing. The relationship of combustion chamber 8 to the remaining engine structure may be seen from a joint consideration of FIGS. 1 and 4.

The hot gas inlet valves 5, which may be most clearly seen from the enlarged view thereof which comprises FIG. 7, are fluid cooled. The circulating coolant is delivered to the valve through a passage 9 in the cylinder head cover and flows downwardly through a tube 10 which is coaxial with the hollow valve stem 12. The circulating coolant thereafter returns to a collector passage 14 through the annular space defined between the tube 10 and hollow stem 12. The collector passage 14 is typically arranged parallelly to the delivery passage 9 and communicates with the hollow valve stem via a further passage 13. During operation, the valve stem 12 reciprocates sliding in an annular seal. The head 5′ of the valve is biased against the valve seat by means of the spring 5″.

Referring now to FIGS. 5 and 6, the combustion chamber 8 receives, via the delivery manifold 6, compressed air from the cylinders. The hot gases exit the combustion chamber 8 through the hot gas manifold 7. Combustion chamber 8 is preferably of generally cylindrical shape and is divided into two portions by a partition 15 oriented perpendicularly to the geometrical axis of the chamber.

The introduction of liquid fuel into combustion chamber 8 is accomplished by a fuel injection conduit 16 having a discharge jet 16′ positioned at the center of the partition 15 in chamber 8. Compressed air arriving from delivery manifold 6 passes through partition 15 via a pair of openings 17 (FIG. 6) which are positioned symmetrically with respect to jet 16′. Considering FIG. 5, the compressed air is delivered via ports 17 to the interior of a housing 17′ in the right hand portion of the combustion chamber. Compressed air exits housing 17′ via a pair of oppositely disposed slots 18 which are symmetrical with and parallel to the fuel jet 16′. The slots 18 are designed to be of proper size to insure a sufficient pressure drop to maintain the virtually uniform air flow which mixes with the uniform fuel jet.

Ignition of the fuel-air mixture in combustion chamber 8 is achieved by means of a hot wire 19, a conventional device in diesel engines, positioned adjacent the discharge end of fuel jet 16′. In the manner well known in the art, hot wire 19 will cause initial ignition of the fuel-air mixture when electric current is passed therethrough and combustion will thereafter be maintained by virtue of the fact that wire 19 remains at the fuel-air mixture ignition temperature without external intervention through the combustion mechanism itself. The hot end of combustion chamber 8; i.e., the portion of the chamber to the right of partition 15 in FIG. 5, is cooled by causing a coolant to flow through the double wall 20 thereof.

Referring now to FIGS. 8 and 9, a camshaft 21 is mounted inside the bore of a rocker box cover by means of collars such as collar 23. The camshaft 21 is driven, at the crankshaft speed, via a pulley 24 by means of a toothed belt 24′. The camshaft 21 is affixed to pulley 24 by means of a splined connection which enables shaft 21 to translate axially. In accordance with the invention, the power produced by the engine may be varied by adjusting the opening time of the inlet valves 5. Such variation of the opening of the valves is achieved by translating camshaft 21 and thus the valve control cams 27 (see FIG. 9) with respect to the valve actuators by means of a yoke 26 while shaft 21 continues to rotate on bearing 27′. The cams 27 on shaft 21, which control the operation of inlet valves 5, are of evolute design in order to give the desired variable opening angle dependent upon the longitudinal position of camshaft 21.

In the interest of maintaining pressure within combustion chamber 8, a pressure regulator is employed for controlling the flow of combustible fuel to the chamber independently of the opening time of the inlet valves 5. Referring to FIG. 10, the pressure regulator may comprise a housing or body 28 having a differential area piston 29, 29′ disposed in a bore therein. The piston 29, 29′ is biased in the upward direction by a spring 30 and the amount of spring bias can be selected by means of an adjustment screw 30′. The pressure regulator is disposed in the fuel feed line and fuel enters housing 28 via an inlet port 42 and exits via a discharge port 43. If the pressure at port 43 of the pressure regulator is lower than the pressure corresponding to the setting of spring 30, the pressure regulator will open thereby permitting the delivery of fuel to the combustion chamber. As soon as the pressure within combustion chamber 8 reaches the pressure corresponding to the spring setting, the fuel flow will be interrupted.

FIG. 12 depicts a simplified control system in accordance with the invention wherein the camshaft 21 does not translate. In accordance with the embodiment of FIG. 12 power output control is accomplished by means of a fuel supply needle valve having a body 38 which defines a tapered cylindrical bore; the needle or valve element 39 being movable within said tapered bore. The position of the tapered needle 30 is controlled by a yoke lever 40 which is loaded into contact with the heel 39′ of needle 39 by means of a spring 41. In the case of an automotive application, the position of lever 40 is controlled by the accelerator pedal. A

screw **42** limits the displacement of the needle **39** and thus constitutes an idling adjustment.

Regardless of the control mode selected, an engine in accordance with the present invention will employ a variable-delivery fuel pump. The fuel pump should provide substantially constant delivery pressure with zero delivery beyond a certain maximum pressure. The pump depicted in FIG. **11** satisfies these conditions. In FIG. **11**, a pump body **31** defines a cylinder within which a piston **32** moves. The pump piston **32** is biased in the delivery direction by means of a spring **33** and the suction stroke is under the control of a rocker **34** operated by a cam **35** on camshaft **21**. Fuel enters the pump cylinder via a suction valve **36** and, after compression leaves the cylinder via a delivery valve **37**. The combination of the spring and rocker results in a controlled maximum pressure with the flow rate being an inverse function of said pressure.

While preferred embodiments have been shown and described, various modifications and substitutions may be made to the present invention without departing from the spirit and scope thereof. Accordingly, it is to be understood that the present invention has been described by way of illustration and not limitation.

What is claimed is:

1. An external combustion engine comprising:
- cylinder means, said cylinder means comprising a plurality of individual cylinders each having a piston and exhaust means associated therewith;
- a common combustion chamber, said combustion chamber being provided with fuel injection means and including internal means for causing a pressure drop of air delivered thereto to maintain substantially constant pressure therein while air is intermittently delivered thereto and exhaust products are intermittently withdrawn therefrom, said means for causing a pressure drop being juxtapositioned to said fuel injection means and the pressure drop resulting therefrom being sufficient to maintain uniform gas flow;
- means for delivering air compressed in each of said cylinders to said combustion chamber upstream of said pressure drop causing means; and
- means for delivering hot exhaust gases from said combustion chamber to said cylinders at a pressure which approximates the compressed air delivery pressure.

2. The apparatus of claim **1** wherein said delivering means each comprises:
- a controlled valve having a valve member and an actuator therefor located externally of the associated cylinder; and
- manifold means coupling the combustion chamber to the said associated cylinder via said valve.

3. The apparatus of claim **2** wherein the controlled valve of said exhaust gas delivering means each comprises:
- a valve member having a hollow sealing head and a hollow stem extending therefrom;
- a coolant delivery tube disposed within and coaxial with said hollow stem;
- means delivering coolant to said tube; and
- means connected to said stem for receiving coolant from said valve.

4. The apparatus of claim **2** wherein said combustion chamber comprises:
- a first compartment connected to receive compressed air from the manifold means of said air delivering means;
- a second compartment wherein combustion occurs, said first and second compartments being separated by a common partition, said compartments being sized to maintain substantially constant pressure in said combustion chamber as air is intermittently delivered thereto and exhaust gases withdrawn therefrom;
- means providing a restricted flow path through said partition for compressed air;
- means positioned adjacent said restricted flow path providing means for injecting fuel into said second compartment; and
- means for igniting the fuel-air mixture in said second compartment.

5. The apparatus of claim **4** wherein said fuel injecting means comprises:
- a fuel feed jet positioned adjacent the discharge end of said restricted flow path whereby the pressure drop imposed on the inflowing air results in fuel-air mixing.

6. The apparatus of claim **2** further comprising:
- means for varying the time of opening of said exhaust gas delivering means to thereby vary engine power output.

7. The apparatus of claim **6** wherein said valve timing varying means comprises:
- an actuator for each exhaust gas delivery means valve;
- an axially translatable camshaft;
- cams carried on said camshaft and cooperating individually with respective valve actuators, said cams being of evolute form; and
- means for imparting controlled axial movement to said camshaft.

8. The apparatus of claim **6** further comprising:
- pressure responsive fuel flow regulating means, said regulating means delivering fuel to said combustion chamber at a rate inversely proportional to the combustion chamber pressure, said regulating means interrupting fuel flow above a predetermined maximum combustion chamber pressure.

9. The apparatus of claim **2** further comprising:
- fuel pump means, said pump means including a variable-pressure variable-delivery pump having a maximum cut-off pressure; and
- fuel control valve means connected between said pump means and said combustion chamber, said fuel control valve means producing a variable pressure drop.

* * * * *