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FREE-PISTON ENGINE

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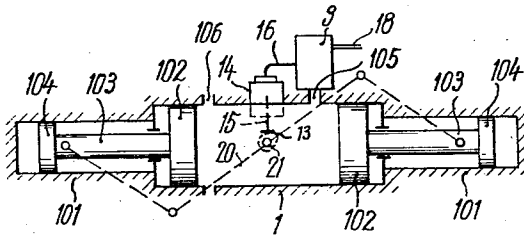


Fig. 1

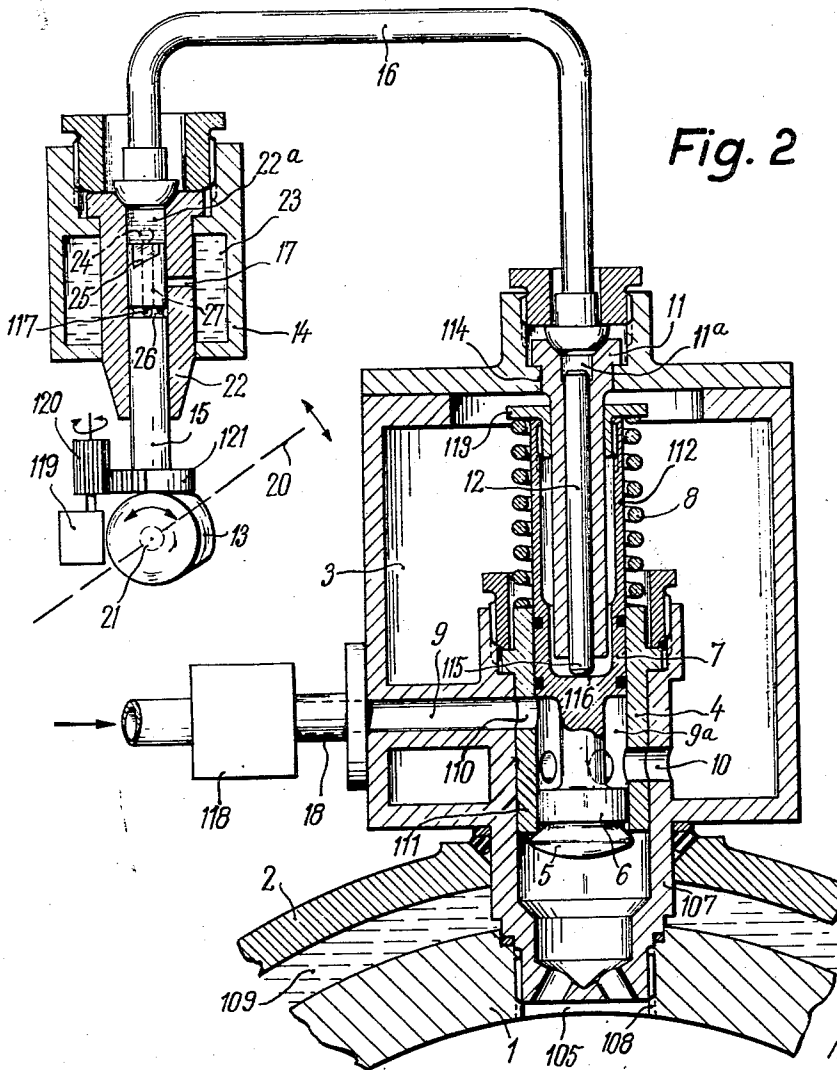


Fig. 2

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FREE-PISTON ENGINE

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In free-piston engines the stroke of the piston is not mechanically limited. Care must therefore be taken not to supply excessive quantities of fuel to the engine, which would increase the piston stroke beyond the admissible limit and in some cases might even cause the pistons to strike against the cylinder heads. When the engine is operated on liquid fuel, the quantity of fuel to be injected can be exactly metered by suitably dimensioning and adjusting the fuel pump.

When gaseous fuels are used, it is known to admix a predetermined quantity of gas to the induction air before it enters the engine cylinder. In the case of the two-stroke cycle which is the only one applicable to free-piston engines, this entails the disadvantage that during scavenging and charging of the cylinder with gas/air mixture, it is difficult to avoid that a part of the mixture escapes unused through the exhaust ports.

It is further known to inject or blow into the engine cylinder during the compression stroke thereof a predetermined volume of gas from a conduit in which prevails a certain pressure, through a positively controlled valve. Since the gas volume depends not only on the pressure and on the valve cross-section, but also on the time during which the valve is open, it may happen that due to changes in the stroke of the pistons, in the pressure in the compression cylinder, or in the frequency, the time available for injection is changed in spite of the fact that the piston stroke for the injection is maintained constant, and thus an inadmissibly great quantity of fuel may be supplied to the engine cylinder.

In connection with gas-operated crankshaft-type engines it is also known to provide upstreams of the engine cylinder a reservoir which during the filling thereof with gas, is closed off from the engine cylinder. This reservoir serves to compensate pressure variations and has a correspondingly great volume which may, for example, be a multiple of the swept volume of the engine cylinder.

It would also be possible to provide the engine, in a manner analogous to engines having a pump for liquid fuel, with a gas pump which aspirates the fuel gas and supplies it to the engine cylinder with a predetermined pressure. Apart from the fact that the gas volume aspirated and supplied by the pump is varied by changes in the stroke of the pistons, such pumps, in the case of the available gas pressure or the calorific value of the fuel gas being low, require very large dimensions, which increases the weight as well as the overall dimensions of the engine.

It is the object of the present invention to supply to the engine cylinder an exactly metered quantity of gas with simple means, and to control this quantity in the case of desired changes in performance. This is achieved by means of a gas reservoir mounted on the engine cylinder and provided with a valve positively controlled by the engine, which receives an exactly metered gas volume and upon opening of the valve discharges it into the engine cylinder, the valve being so constructed that when it is open towards the engine cylinder it cuts off the supply of gas from the supply conduit to the reservoir, and when it is closed towards the engine cylinder it opens the supply of gas to the reservoir. Thus, the quantity of gas supplied to the engine cylinder can never exceed the exactly metered volume contained in the storage reservoir.

The control of the gas quantity to be supplied may be

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effected in various ways. If the fuel gas is available with a sufficiently high pressure, the control of the gas quantity may, according to the present invention, be effected in such a manner that a pressure reducing valve which is responsive to a control variable, for example to the supply pressure, to the induction pressure, or to the filling or charging pressure in the case of compressors, etc., and is arranged in the supply conduit to the gas reservoir. The volume of the gas reservoir being constant, this causes the gas quantity supplied to the engine cylinder to be controlled in dependence on the filling or charging pressure of the reservoir.

However, the control can also be effected in such a manner that the compression pressure which increases in the engine cylinder during injection or blowing-in, is used for varying the gas quantity, the filling pressure of the reservoir remaining constant. Even in the case of quickest discharge, the pressure in the reservoir can drop only to a value which corresponds to the compression pressure which at this moment prevails in the engine cylinder. When a normal fuel pump, the volume control of which also changes simultaneously with the beginning of the fuel injection, is used for driving the aforementioned positively controlled valve, the valve, with the pump adjusted to a large volume, is opened already at a time at which the compression pressure in the engine cylinder is still low, while with the pump adjusted to a small volume, the valve is opened later at a time at which the compression pressure is higher, so that then the gas reservoir can be emptied only until its filling pressure reaches a value corresponding to this compression pressure. For this purpose, the pump piston must be provided with an upper oblique or bevelled control edge. The valve is closed by spring pressure when the pump is relieved in the usual manner by the return flow of the pressure fluid. Since this causes the effective stroke of the pump, and therewith the opening period of the valve, to be reduced, the valve cross section must be laid out in correspondence with the smallest pump stroke, respectively the shortest opening period employed.

Further advantages and details of the present invention will become apparent from the following description of embodiments which are given by way of example only, in conjunction with the accompanying drawings, in which:

FIG. 1 is a diagrammatic view of a free-piston internal combustion engine with a gas reservoir and control valve according to the present invention, and

FIG. 2 is a sectional view of the gas reservoir provided on the engine cylinder, and of the valve control mechanism.

Referring now to the drawings, and more particularly to FIG. 1, which schematically illustrates a free-piston internal combustion engine of a type known per se, it may be seen that this engine comprises an engine cylinder 1, pump cylinder 101, engine pistons 102 and pump pistons 104 each of which is connected with an engine piston 102 by means of a connecting rod 103, and operates in a pump cylinder 101.

The pump pistons are provided for compressing a gaseous medium which is the usual arrangement in free piston machines. Of course, each pump cylinder is provided with an inlet valve and an outlet valve. These valves are not shown in FIGURE 1 of the drawing which is a schematic view.

The engine cylinder is provided with inlet port 105 and exhaust ports 106.

For the purpose of synchronizing the two halves or sides of the engine, the connecting rods 103 of both cylinder groups are coupled to each other by means of an articulated linkage 20, in a manner known per se. This linkage is connected in the middle part thereof in known manner with a shaft 21 which is arranged outside the en-

gine cylinder 1 and the axis of which vertically intersects the cylinder axis. When the engine is in operation, this shaft 21 is rotated in an oscillatory movement through a predetermined angle by the linkage 20.

Also shown schematically in FIG. 1 is the gas reservoir 3 which is provided according to the present invention, and the interior space of which is connected with the inlet opening 105 of the engine cylinder through a valve system which is to be described later. A gas supply conduit 18 opens into the gas reservoir 3.

FIG. 1 further shows schematically a control device 14 which will be described in more detail in the following, in connection with FIG. 2. This control device 14 is connected with the gas reservoir 3 by a hydraulic conduit 16. The control device is operated by a cam 13 which is mounted on the shaft 21 and acts on a piston 15 of the control device 14 so as to effect an axial displacement of this piston.

As may be seen from FIG. 2, the gas reservoir 3 is screwed into a thread 103 of the inlet port 105 by means of a threaded socket 107. This socket 107 sealingly extends through a cooling jacket 2 surrounding the engine cylinder 1. The space between engine cylinder 1 and cooling jacket 2 accommodates a coolant 109.

The gas reservoir 3 houses a valve mechanism which controls the gas flow between the gas supply conduit 18 and the inlet port 105. This valve mechanism comprises a sleeve 4 which is inserted into the socket 107 and slidingly receives a valve body 5. This valve body 5 presents piston-like extensions 6 and 7 which are guided by the sleeve 4. An annular groove 9a is provided between the piston-shaped extensions 6 and 7 which act as control slide valves. In the closed position of the valve body 5 illustrated in FIG. 2, this annular groove 9a communicates through a bore 110 of sleeve 4 and through a conduit 9 with the gas supply conduit 18, and is connected with the interior space of the gas reservoir 3 through a plurality of radial bores 10 of sleeve 4, respectively of socket 107. In its closed position shown in FIG. 2, the valve body 5 makes sealing contact against a valve seat 111 on the lower end face of sleeve 4.

On its upper end the valve body 5 is formed with a sleeve extension 112 over which is slid a coil spring 8. This compression coil spring 8 abuts with its lower end against the end face of the sleeve 4 which is stationary in relation to the gas reservoir 3, and with its upper end bears against a flanged nut 113 which is screwed into the sleeve extension 112. This arrangement causes the valve body 5 to be urged into the closed position illustrated in FIG. 2, by the action of spring 8.

The gas reservoir 3 comprises in its cover portion an opening 114 concentric with sleeve 4, into which a hollow cylinder 11 is sealingly inserted. This hollow cylinder 11 projects into the sleeve extension 112 of the valve body, the sleeve extension 112 with its flanged nut 113 being slidable on the hollow cylinder 11. Guided in the cylinder 11 is a plunger 12 the lower extremity 115 of which bears against the bottom 116 of the sleeve extension 112. The interior space 11a of cylinder 11 communicates with the conduit 16.

The hydraulic control device 14 is constructed in the manner of a fuel pump of known kind, such as are generally installed in automobiles. It comprises a cylinder 22 to the interior space of which is connected the conduit 16, and in which the piston 15 operated by the cam 13 is arranged for sliding movement. The hydraulic control device 14 further comprises a reservoir 23 for the hydraulic fluid, e.g. oil. The cylinder 22 extends through this reservoir 23 and is surrounded by the fluid contained therein. Furthermore, the cylinder 22 comprises two radial bores 24 and 17 which are adapted to co-operate with a bevelled control edge 25, respectively an annular groove 26, of piston 15. The annular groove 26 communicates with the upper surface of the piston through a

radial bore 117 and an axial bore 27 communicating with said radial bore.

The piston 15 may be rotated either manually or through a regulator 119 through a pinion 120 and a gear 121 in such a manner that during the movement of piston 15 effected by cam 13, the bevelled control edge 25 closes opening 24 sooner or later, depending on the relative rotational position of piston 15.

The apparatus described in the foregoing operates as follows:

With the parts in the position shown in FIG. 2, the interior space of gas reservoir 3 is connected with the gas supply conduit 18 through the radial bores 10, the annular groove 9a, the bore 110 and the conduit 9. Consequently, the gas reservoir 3 is filled with the pressure prevailing in the conduit 18. After the filling of the gas reservoir 3, the valve mechanism arranged inside the gas reservoir is operated in the following manner:

Cam 13 in its rotational movement lifts piston 15, displacing it in the cylinder 22. Before the control edge 25 reaches opening 24, the hydraulic fluid is fed into reservoir 23 through opening 24. After the opening 24 has been closed by the piston 15, a pressure is built up in the cylinder space 22a, which propagates through conduit 16 into the space 11a in gas reservoir 3, and acts on the plunger 12 in the sense of displacing it in the axial direction. As may easily be seen from FIG. 2, the piston 12 displaces the valve body 5 downwardly, whereby the latter is lifted off its seat 111. However, the connection between gas reservoir 3 and engine cylinder 1 is still kept closed by the piston-shaped extension 6, until the piston extension 7 has completely closed the bore 110. Upon further displacement of the valve body 5, the gas reservoir 3 is opened towards the inlet port 105 of engine cylinder 1, through radial bores 10 and annular groove 9a, so that the gas may flow from the gas reservoir 3 into the engine cylinder 1 until the pressure in the gas reservoir 3 has dropped to a value corresponding to the compression pressure prevailing at that moment in the engine cylinder.

In the meantime, the piston 15 has been further displaced in the cylinder 22 by cam 13, and its annular groove comes into register with the bore 17. At this moment, the conduit 16 and the cylinder space 11a are relieved of pressure, since the pressure fluid may flow back into the reservoir 23 through the conduit 16, the axial bore 27, the radial bore 117, and the annular groove 26. The valve body 5 is then returned to the position shown in FIG. 2, by the action of spring 8.

When the cam 13 returns into the position shown in FIG. 2, the piston 15 is also returned to its original position illustrated in the drawing.

Controlling of the quantity of gas to be supplied may be effected in various ways, e.g. by inserting a pressure relief valve 118 into the supply conduit 18 to the gas reservoir, said pressure relief valve being influenced by a control pulse, e.g. by the supply pressure or the induction pressure or the filling or charging pressure of the collector of compressors. Alternately said controlling may be done by varying the valve actuation time. For this purpose it is possible e.g. to control the fuel gas volume with constant pressure in the gas supply conduit by arranging the hydraulic control device 14 to cooperate with a regulator 119 turning the pump piston 15 by means of a gearing, illustrated as comprising a pinion 120 and a gear 121 which also serves as a cam follower in conjunction with cam 13, with an angle corresponding to the arc length of the bevelled control surface 25 of the piston 15. Thereby the time for the initiation of the actuation of valve 5 may be advanced or retarded, because the bevelled control surface 25 closes the opening 24 sooner or later according to its position, so that the blowing-in of gas is effected at a lower or a higher compression pressure in the engine cylinder, and consequently the gas reservoir is discharged more or less.

I claim:

1. A free piston engine adapted to be supplied with gaseous fuel comprising an engine cylinder having an inlet port and an outlet port and having disposed therein two oppositely reciprocating pistons defining between them an inner combustion chamber, each of said pistons at its outer side being rigidly connected to a compressor piston by means of a piston rod, the said compressor pistons being slidably mounted in compressor cylinders aligned with said engine cylinder, the compressor means being arranged symmetrically to said engine cylinder, said engine cylinder being supplied with gas by means of supply conduits and inlet orifices after opening of the inlet port and closing the outlet port; a gas reservoir between said inlet orifices and said gas supply, said gas reservoir comprising a single valve body controlling the connection from the gas supply to the gas reservoir and the connection between the gas reservoir and the inlet orifices respectively, so that only one of said connections is effective for supplying gas at any instant; said valve body being positively controlled in accordance with the position of the motor pistons; said gas reservoir being so dimensioned that its contents corresponds to the gas quantity needed for each one power stroke of the engine.

2. A free piston engine according to claim 1 wherein a synchronizing means is being provided to synchronize movement of said engine pistons, said synchronizing means comprising a linkage oscillating about an axis, said linkage having a shaft coincident with said axis, a cam fixed to said shaft, hydraulic means having a cylinder and a piston slidable therein, said cylinder of said hydraulic means being connected by a fluid conduit to said gas reservoir, bias means for urging said second piston towards a first direction; a valve body connecting said gas reservoir with said engine cylinder having slidably mounted therein a second piston, said second piston operating said valve body against said bias means, said piston of said hydraulic means including a cam follower co-operating with said cam, said valve body enabling the gas reservoir to communicate with said engine cylinder under control of said cam.

3. A free piston engine according to claim 1 wherein a synchronizing means is provided to synchronize movement of said engine pistons, said synchronizing means comprising a linkage oscillating about an axis, said linkage having a shaft coincident with said axis, a cam fixed to said shaft, a hydraulic means having a cylinder and

a piston slidable therein, said cylinder of said hydraulic means being connected by a fluid conduit to said gas reservoir having slidably mounted therein a second piston, bias means for urging said second piston towards a first direction; a valve body connecting said gas reservoir with said engine cylinder, said second piston operating said valve body against said bias means, said piston of said hydraulic means including a cam follower co-operating with said cam; said valve body enabling the gas reservoir to communicate with said engine cylinder under control of said cam; control means for controlling the quantity of the gas supplied to the engine cylinder, said control means being arranged in the fuel supply conduit to control the pressure of the gas supplied to the gas reservoir by means of said supply conduit.

4. A free piston engine according to claim 1 wherein a synchronizing means is being provided to synchronize movement of said engine pistons, said synchronizing means comprising a linkage oscillating about an axis, said linkage having a shaft coincident with said axis, a cam is fixed to said shaft, hydraulic means having a cylinder and a first piston slidable therein, said cylinder of said hydraulic means being connected by a fluid conduit to said gas reservoir having slidably mounted therein a second piston, bias means for urging said second piston towards a first direction; a valve body connecting said gas reservoir with said engine cylinder, said second piston operating said valve body against said bias means, said first piston of said hydraulic means including a cam follower co-operating with said cam; a control means for controlling the quantity of the gas supplied to said engine cylinder; said control means being adapted to vary the time relation between the movement of said engine pistons and the movement of said valve body in accordance with the desired gas supply.

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