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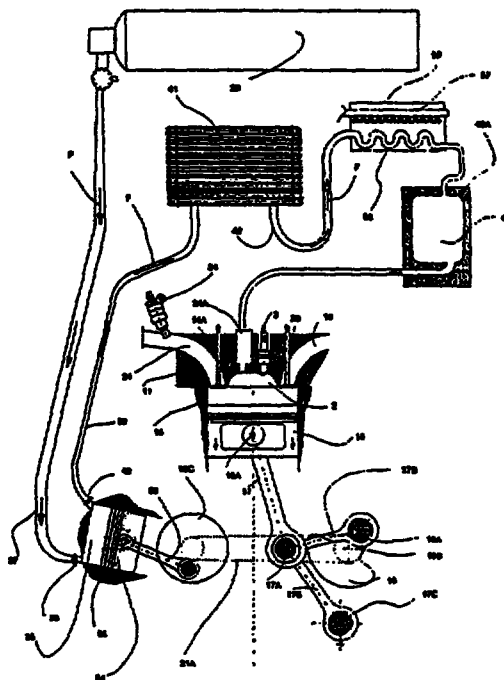
(54) Titre: PROCEDE DE FONCTIONNEMENT ET DISPOSITIF DE MOTEUR A INJECTION D'AIR COMPRIME ADDITIONNEL FONCTIONNANT EN MONO-ENERGIE, OU EN BI-ENERGIE BI OU TRI MODES D'ALIMENTATION

(57) Abstract

The invention concerns an engine method with suction-compression chamber (1) and/or expansion-exhaust chamber (4) operating by means of reciprocating pistons with an independent and twinned compression chamber (2) - the three chambers being separated with a device controlling the stroke causing, over a long period of engine rotation, said piston (15) to stop at the upper dead centre which in that position separates the combustion chamber and the expansion-exhaust chamber, also comprising a high-pressure compressed air chamber (23) and additional systems for recuperating ambient thermal energy and additional heating, capable of operating in mono-energy air plus supplementary compressed air or in bi-energy, or with conventional fuel in internal or external combustion, or by injection of a dose of compressed air thereby producing three operating modes depending on the type of use. The invention is useful for all types of engine methods.

(57) Abrégé

Procédé de moteur à chambre d'aspiration-compression (1) et/ou chambre de détente-échappement (4) fonctionnant à l'aide de pistons alternatifs avec une chambre de combustion indépendante et jumelée (2) - les trois chambres étant séparées - avec un dispositif de contrôle de la course provoquant, sur une longue période de rotation moteur, l'arrêt au point mort haut dudit piston (15) qui dans cette position sépare la chambre de combustion et la chambre de détente-échappement, comportant également un réservoir d'air comprimé haute pression (23) et des systèmes de récupération d'énergie thermique ambiante et de réchauffe additionnel, pouvant fonctionner en mono-énergie air plus air comprimé additionnel ou en bi-énergie, soit avec un carburant traditionnel en combustion interne ou externe, soit avec l'injection d'une dose d'air comprimé additionnel réalisant ainsi trois modes de fonctionnement selon l'utilisation. Toutes applications de moteurs.



OPERATING METHOD AND DEVICE FOR SUPPLEMENTARY
COMPRESSED AIR INJECTION ENGINE OPERATING WITH MONO-
ENERGY OR BI-ENERGY IN TWO OR THREE POWERING MODES

5 The invention relates to land vehicles and more particularly those which operate with an injection of supplementary compressed air, comprising a high-pressure compressed-air reservoir.

 Cyclic internal combustion engines with
10 independent combustion chamber and compression and expansion chambers such as those described in French patents 2319769 or alternatively 2416344 allow a certain number of operating improvements over conventional engines, but the time given over to the
15 transfer and combustion of gases is very short and does not allow for good efficiency.

 In his published patent application WO 97/39232, the author has described a method for a cyclic internal combustion engine with an independent
20 constant-volume combustion chamber in which the induction-compression chamber, the combustion chamber, and the expansion-exhaust chamber consist of three separate and entirely independent parts, and in which the cycle of the induction-compression chamber is in
25 advance of that of the expansion-exhaust chamber so as to allow long combustion times. One of the main advantages of this method is that the mixture burns at truly constant volume for a longer length of time than in a conventional engine.

30 One of the difficulties with this kind of engine is the time to establish the pressure in the expansion chamber when transferring gases between the combustion chamber and the expansion chamber.

 To solve this problem, and in another French
35 patent application 97/13313, the author has described a method for controlling the movement of the pistons of machines such as engines or compressors, characterized in that at its top dead center, the piston is halted in

its movement and kept in its top dead center position for a long period of time and therefore over a large angular sector during the rotation, so that the following can take place at constant volume:

- 5 - the ignition and combustion operations, in the case of conventional engines,
- the operations of injecting fuel, in the case of diesel engines,
- the operations of transferring gas and/or
- 10 compressed air, respectively, in the case of engines with independent combustion and/or expansion chambers,
- the operations at the end of exhaust, start of induction, in all cases of engines and other compressors.

15 The piston may be stopped at top dead center and kept there by any means known to those skilled in the art, for example using cams, pinions, etc, but as a preference, to allow the piston to be stopped at its top dead center, the piston is controlled using a

20 pressure lever device itself controlled by a connecting rod and crank system. The term "pressure lever" is given to a system of two articulated arms, one of which has a stationary end, or pivot, and the other of which can move about an axis. If a force is exerted

25 approximately at right angles to the axis of the two arms, when they are aligned, on the articulation between these two arms, then the free end is made to move. This free end may be connected to the piston and cause it to move. The top dead center of the piston

30 occurs when the two articulated rods are practically one in the continuation of the other (at about 180°).

 The crankshaft is connected by a control connecting rod to the axis of articulation of the two arms. The position of the various elements in space and

35 their sizes make it possible to alter the kinetic characteristics of the assembly. The position of the stationary end determines an angle between the axis of movement of the piston and the axis of the two arms

when they are aligned. The position of the crankshaft determines an angle between the control connecting rod and the axis of the two arms when they are aligned. The variation in size of these angles and in the lengths of the connecting rods and arms, determines the angle of rotation of the crankshaft for which the piston is stationary at its top dead center. This corresponds to the piston dwell time.

In this kind of engine, the transfer of gases and, in particular, in thermal mode, of burnt gases, from the combustion chamber to the expansion chamber takes place at high temperature, and producing a system for opening and closing at these temperatures is a tricky prospect.

The present invention sets out to solve this problem of the transfer of pressure from the combustion chamber to the expansion chamber in a different way by proposing an engine method involving separate chambers, for induction-compression, expansion-exhaust and combustion and/or expansion at constant volume which are separate, and in which method a device for controlling the stroke of the piston to allow the latter to be stopped at its top dead center is mounted at least on the expansion-exhaust chamber. The combustion and/or expansion chamber is mounted twinned without any shutter on the upper part of the expansion-exhaust chamber, the piston practically separating the combustion chamber from the expansion-exhaust chamber at its top dead center. Furthermore, the operating cycle of the induction-compression cylinder may have some retard with respect to the cycle of the expansion-exhaust cylinder so that the top dead center of the piston of the expansion-exhaust cylinder is, as the engine rotates, in advance of the top dead center of the piston of the induction-compression cylinder. As soon as the piston of the expansion cylinder has reached its top dead center, where it partially closes off the combustion chamber, it is in advance of the top

dead center of the piston of the induction-compression chamber and remains at its top dead center during the following operations:

- communication between the combustion chamber
5 and the induction-compression chamber,
- filling of said combustion chamber with the air-fuel mixture compressed by the piston of the induction-compression chamber reaching its top dead center,
- 10 - closure of the communication between the combustion chamber and the induction-compression chamber,
- ignition and combustion of the mixture which generates an increase in pressure,
- 15 then, as soon as it begins its downstroke, produces work brought about by the increase in pressure. Combustion takes place at truly constant volume because the mixture is expanded directly without transfer into the expansion chamber, producing the motive power right
20 from the start of the downstroke of the expansion-exhaust piston.

The term "truly constant" which has just been used, goes back to the state of the art which, in common parlance, uses the term "combustion at constant
25 volume" even though in a conventional engine the piston is always in motion and the volume is therefore never really constant.

These advantages, combined with a long combustion time in a compact combustion chamber make it
30 possible to obtain far lower emissions of pollutants in the exhaust than can be achieved in conventional engines.

According to a particular embodiment of the method according to the invention, it is possible to
35 form between the compression chamber and the combustion chamber a buffer volume in which compressed air is accumulated which will make it possible to avoid surge effects and pressure drops due to the dead transfer

volumes and expansion during the filling of the combustion chamber.

The mode of operation of the induction-compression chamber can thus vary without this in any way changing the principle of the invention: while in common practice it would seem convenient to use a piston-type compressor, any other means of producing compressed air may be used - single or multi-stage compressor of the piston, rotary vane, gear (Roots, Lyshom) type or turbocompressor driven by the exhaust gases; just as in certain applications it is possible to use a reserve of air in a cylinder (or any other container) which would be expanded in the combustion chamber, or even compressed air from a network (in the example of a stationary engine used in a factory using compressed air from a network).

As a preference, the twinned combustion chamber is of a shape similar to that of a sphere with no roughnesses or corners for better combustion, and similarly it is thermally insulated by being coated with a thermal barrier made of ceramic or other lagging insulating materials to ensure that there is no heat energy lost through the walls which may thus be kept at very high temperatures and therefore ensure that the flame is not quenched on said walls, thus avoiding the production of unburned hydrocarbons in the exhaust gases. This combination makes it possible to appreciably improve the emissions of pollutant gases.

The method of operation of the engine according to the invention makes it possible to use homogeneous air-fuel mixtures and the mixture may be achieved by a carburetor prior to the induction-compression stage, although an injection (electronic or mechanical) system is preferred. However, direct injection into the combustion chamber may also be used without in any way altering the principle of operation of the invention.

The method of operation of the engine according to the invention also allows the use of heterogeneous

self-igniting mixtures like in diesel engines. In this case, the spark plug fitted in the combustion chamber is omitted and a direct injector of diesel fuel supplied from a pump and its equipment of the kind
5 commonly used in diesel engines, is fitted in said combustion chamber.

The invention can be applied to operation in dual-energy operation according to two modes of supply. In his published patent application WO 96/27737, the
10 author has described a method for an engine with an independent internal combustion chamber, operating on a dual-mode principle with two types of energy using either conventional fuel such as gasoline or diesel fuel on the highway (operating in single mode on air-
15 fuel), or, at low speed, particularly in towns and suburbs, injection of compressed air into the combustion chamber (or any other non-polluting gas) to the exclusion of any other fuel (operating in the second mode on air plus supplementary compressed air).

20 According to another aspect of the present invention, the method of operation of an engine according to the invention adopts this dual-energy and dual-mode principle. In the air-fuel mode, the air-fuel mixture is drawn into and compressed in an independent
25 induction-compression chamber. This mixture is then transferred, still at pressure, into the combustion chamber which is twinned with the expansion-exhaust chamber. When the expansion-exhaust piston is stopped at its top dead center, the combustion chamber is at
30 constant volume and the mixture is ignited so as to increase its temperature and pressure. Combustion is continued while the piston is stationary at its top dead center and then this mixture is expanded directly without being transferred in the expansion and exhaust
35 chamber, to produce work therein. The expanded gases are then discharged to the atmosphere through an exhaust duct.

In the air plus supplementary compressed air

mode, at low power, the fuel injector is no longer operated; when the expansion-exhaust piston is stationary at its top dead center, the combustion chamber is at constant volume and there is introduced
5 into the combustion chamber, appreciably after the (fuel-free) compressed air from the induction-compression chamber has been introduced into this chamber, a dose of supplementary compressed air from an external reservoir in which the air is stored at high
10 pressure, for example 200 bar, and ambient temperature. This dose of compressed air at ambient temperature will heat up upon contact with the mass of air at high temperature contained in the combustion chamber, which in this case becomes an expansion chamber, will expand,
15 and the mixture of the two masses of air increases the pressure obtaining in the chamber to allow motive power to be delivered during expansion.

The invention may also apply to operation in single-energy air plus supplementary compressed air
20 mode. In his published patent application WO 97/4884, the author described the installation of this type of engine operating in single mode, with air plus supplementary compressed air, on service vehicles, for example town buses, taxis, delivery vans and the like.

25 This type of dual-mode or dual-energy (air and gasoline or air and supplementary compressed air) engine may in fact be converted for preferential use in towns, for example, on all vehicles and more particularly town buses or other service vehicles
30 (taxis, garbage trucks, etc), in air-supplementary compressed air single mode by omitting all the elements which are specific to the operating of the engine with a conventional fuel, such as the tank, the fuel circuit, injectors, etc.

35 According to another feature of the invention, the method of operation of an engine according to the invention also uses the single-energy single-mode principle with the injection of supplementary

compressed air into the combustion chamber which thus becomes an expansion chamber. Furthermore, the air drawn in by the engine may be filtered and purified through one or more charcoal filters or using some
5 other mechanical or chemical method or molecular sieve, or some other filter so as to produce a pollution-reducing engine. In the current text, the use of the expression "air" should also be understood as covering "any non-polluting gas".

10 For operating in compressed-air mode, the present invention proposes another method of operation for the compressed-air engine, in which is mounted a device for controlling the stroke of the piston causing the latter to stop at its top dead center. The
15 induction-compression cylinder is isolated - either by disengagement or rendered inoperative by keeping its valves open or closed, or by omitting it when the engine is designed to operate only in single-mode compressed-air mode. The engine operates with an
20 expansion-exhaust cylinder which has an exhaust port and a twinned independent expansion chamber. During the upstroke of the piston of said expansion-exhaust chamber, during the exhaust cycle, the exhaust port is closed off so as to allow some of the expanded gases to
25 be recompressed to a high temperature and pressure in the expansion chamber into which, while the piston is stationary at its top dead center, a dose of supplementary compressed air from a storage reservoir is injected, thus causing an increase in pressure in
30 said chamber, producing work by driving the piston back in its downstroke.

The engine thus operates with an expansion (therefore a power stroke) on each revolution of the crankshaft in a cycle which, although fundamentally
35 different, could be compared with that of a two-stroke engine insofar as there is an expansion for every engine revolution.

As a preference, the method of operation of the

engine according to the invention comprises a system for recovering ambient thermal energy as described by the author in his patent application FR 97/00851, in which the compressed air contained in the storage
5 reservoir at very high pressure, for example 200 bar, and ambient temperature, for example 20°C, prior to its end use at a pressure below 30 bar, for example, is expanded to a pressure close to the pressure needed for its end use in a variable-volume system, for example in
10 a piston in a cylinder, producing work which can be recovered and used by any known means, mechanical, electrical, hydraulic or the like. This expansion with work consequently cools the compressed air which has been expanded to a pressure close to the usage pressure
15 to a very low temperature, for example -100°C. This compressed air, expanded to its usage pressure and at very low temperature, is then sent into an exchanger where it exchanges heat with the ambient air, and heats up to a temperature close to ambient temperature, and
20 thus increases in pressure and/or volume, recovering the heat energy taken from the atmosphere.

Also as a preference, the method of operation of the engine according to the invention comprises a thermal heater system as described by the author in his
25 patent application FR 98/00877, in which he proposes a solution which will increase the amount of energy that can be used and that is available, characterized in that the compressed air, before being introduced into the combustion and/or expansion chamber, from the
30 storage reservoir either directly or having passed through the air-air heat exchanger and before being introduced into the combustion chamber, is routed through a thermal heater in which its pressure and/or volume is increased further before being introduced
35 into the combustion and/or expansion chamber, thus considerably further increasing the performance that can be achieved by the engine.

The use of a thermal heater has the advantage

that clean continuous combustion that can be catalyzed or from which pollution can be reduced by any known means with a view to obtaining infinitely low levels of pollutant emissions can be achieved.

5 Another aspect according to the invention proposes another method which allows the engine to be operated in dual energy mode - operating on air plus supplementary compressed air in towns and operating on air plus conventional fuel on the highway - when the
10 induction-compression chamber has been omitted. The cycle for opening and closing the exhaust valve, which opens on every engine revolution over part of the piston upstroke, varies during operation to open during the piston upstroke every two revolutions. In addition
15 to this, the engine has an inlet for air and fuel such as gasoline, diesel oil or the like, allowing the introduction of a charge of carburetted mixture which is drawn in during the piston downstroke then compressed in the expansion chamber which then becomes
20 a combustion chamber, in which chamber the mixture is burnt and then expanded, producing work by driving back the piston and then discharged in the exhaust according to the conventional four-stroke engine cycle.

 According to another aspect of the invention,
25 the invention proposes a three-mode dual-energy method of operation in which the engine operates either with compressed air without additional heating, for example when driving in town with zero pollution, or with compressed air that has been heated by external
30 combustion in a thermal heater supplied with a conventional fuel, for example for running in the suburbs, with infinitely low pollution, or for running on the highway, with internal combustion and with the inlet of air and gasoline (or any other fuel) allowing
35 the introduction of a charge of carburetted mixture which is drawn in during the piston downstroke then compressed in the expansion chamber which thus becomes a combustion chamber, in which the mixture is burnt

and then expanded, producing work and discharged to the atmosphere according to the conventional four-stroke engine cycle.

The three modes of operation described
5 hereinabove - air plus supplementary compressed air, air plus supplementary compressed air heated by a burner and air plus fuel - may be used separately or in combination, the modes of opening and closing the exhaust and inlet ducts, the methods and devices for
10 switching from one mode to another, are controlled by electronic devices, electromechanical devices, mechanical devices or the like, and the fuels or gases used may vary without in any way changing the principle of the invention. Likewise, the inlet and exhaust
15 valves may advantageously be controlled by electrical, pneumatic or hydraulic systems controlled by an electronic computer according to operating parameters.

Other objects, advantages and features of the invention will become apparent from reading the
20 description, by way of non-limiting example, of a number of embodiments, this description being given with reference to some appended drawings, in which:

Figure 1 diagrammatically depicts a view in cross section of one embodiment of the engine according
25 to the invention in which the expansion-exhaust chamber is controlled by a system for controlling the stroke of the piston and comprises a twinned combustion chamber.

Figure 2 depicts this same engine after the air-fuel mixture has been introduced into the
30 combustion chamber at the time of ignition.

Figure 3 depicts this same engine at the start of the expansion phase.

Figure 4 depicts this same engine during exhaust and compression.

35 Figure 5 depicts another mode of operation viewed schematically in cross section in which a buffer volume for accumulating compressed air is installed between the compressor and the combustion chamber, at

the time of the inlet of the compressed air-fuel mixture into the combustion chamber.

Figure 6 depicts this same engine at the time of ignition.

5 Figure 7 depicts this same engine during expansion.

Figure 8 depicts this same engine at the end of exhaust.

10 Figure 9 depicts diagrammatically, viewed in cross section, an engine according to the invention equipped with a device for injecting supplementary air for operation in dual-mode dual-energy operation.

Figure 10 depicts this same engine at its bottom dead center at the start of the exhaust phase.

15 Figure 11 depicts diagrammatically, viewed in cross section, a compressed-air engine according to the invention depicted at its top dead center.

Figure 12 depicts this engine during exhaust.

20 Figure 13 depicts this engine during recompression.

Figure 14 depicts a view in cross section of this engine equipped with a device for recovering ambient heat energy and with a continuous combustion heat device.

25 Figure 15 depicts a view in cross section of a dual-energy internal combustion engine according to the invention, during induction.

Figure 16 depicts this engine at the time of ignition.

30 Figure 17 depicts this engine during expansion.

Figure 18 depicts it during exhaust.

35 Figure 19 depicts, diagrammatically, in longitudinal section, an engine according to the invention equipped to operate in dual-energy three-mode operation.

Figures 1 to 4 depict one embodiment of the engine according to the invention in which the induction and compression and expansion and exhaust

chambers are each controlled by a connecting rod and crank system and piston sliding in a cylinder, viewed in cross section, which shows the compression chamber 1, the constant-volume combustion chamber 2 in which
5 there is a spark plug 3, twinned with the expansion chamber 4. The compression chamber 1 is connected to the combustion chamber 2 by a duct 5, the opening and closure of which are controlled by a sealed shutter 6. The combustion chamber 2 is twinned with the expansion
10 chamber 4 and opens onto the latter at its upper part.

The compression chamber is supplied with compressed air by a conventional piston-compressor assembly: a piston 9 sliding in a cylinder 10 controlled by a connecting rod 11 and a crankshaft 12.
15 The fresh air-fuel mixture is let in through an inlet duct 13, the opening of which is controlled by a valve 14.

The expansion chamber controls an engine assembly with a piston equipped with a device for
20 controlling the stroke of the piston in which device the piston 15 (depicted at its top dead center), sliding in a cylinder 16, is controlled by a pressure lever. The piston 15 is connected by its axis to the free end 15A of a pressure lever consisting of an arm
25 17 articulated on a common axis 17A to another arm 17B fixed so that it can pivot on a stationary axis 17C. Attached to the axis 17A common to the two arms 17 and 17B is a control connecting rod 17D connected to the wrist 18A of a crankshaft 18 rotating on its axis 18B.
30 As the crankshaft rotates, the control connecting rod 17D exerts a force on the common axis 17A of the two arms 17 and 17B of the pressure lever, thus allowing the piston 15 to move along the axis of the cylinder 16, and in return transmits to the crankshaft 18 the
35 forces exerted on the piston 15 during the power stroke, thus causing it to rotate. The stationary axis 17C is positioned laterally with respect to the axis along which the piston 15 moves and determines an angle

A between the axis of movement of the piston and the axis of alignment X'X of the two arms 17 and 17B when they are aligned. The crankshaft is positioned laterally with respect to the axis of the cylinder and/or of the pressure lever and its position determines an angle B between the control connecting rod 17D and the axis of alignment X'X of the two arms 17 and 17B when they are aligned. By varying the angles A and B and the lengths of the various connecting rods and arms, the characteristics of the kinetics of the assembly are modified so as to obtain an asymmetric curve representing the stroke of the piston 1 and so as to determine the angle of rotation of the crankshaft for which the piston 15 is stationary at its top dead center. The burnt gases are discharged through an exhaust duct 19, the opening of which is controlled by a valve 20.

The crankshaft 18 drives the compressor at the same speed via a link 21 with an angular offset between the top dead centers of the expansion piston and of the compressor piston, the latter being retarded by an angle of rotation which is chosen according to the desired combustion time. The compressor may also be mounted on the same crankshaft in which the angular offset of the wrists makes it possible to achieve the offsetting of the top dead centers without in any way changing the principle of the device of the invention, which in this instance is shown with a link 21, making for a simpler drawing.

Figure 1 depicts the engine when the compressor piston 9 is close to its top dead center and the shutter 6 has just opened to allow the constant-volume combustion chamber 2 to be fed with fresh air-fuel mixture while the piston 15 of the expansion chamber 4 is at its top dead center and will remain there for a certain period of rotation of the engine, for example 110° .

Continuing the rotation in the clockwise

direction, in Figure 2, the compressor piston 9 has just passed its top dead center and is beginning its downstroke: the shutter 6 has just been closed and shuts off the duct 5, the inlet valve 14 opens to allow
5 replenishment with fresh air-fuel mixture from the compressor (intake). As soon as the shutter 6 closes, ignition is initiated by the spark plug 3 and the air-fuel mixture is combusted in the chamber twinned to the expansion-exhaust cylinder, at constant volume 2, while
10 the expansion piston 15 remains at its top dead center during the combustion period.

The crankshafts 12 and 18 continue their rotation - Figure 3 depicts the situation about 100° later - the expansion piston 15 has just begun its
15 downstroke and the gases under very high pressure contained in the twinned combustion chamber 2 are expanding in the expansion chamber 4, pushing back the piston 15 and thus providing the power stroke, while the compressor piston 9 is in the process of completing
20 the intake of fresh carburetted mixture and the inlet valve 14 closes.

Expansion will continue over about 180° of rotation of the crankshaft, Figure 4, the exhaust valve
20 opens and the piston 15 discharges the burnt and expanded gases into the exhaust duct 19, while the
25 compressor piston 9 will compress the air-fuel mixture in the compression chamber 1 and the shutter 6 will be opened to let fresh air-fuel mixture into the constant-volume chamber 2 once again, to recommence the cycle
30 (Fig. 1).

It will be readily understood that for each revolution of the crankshaft (engine and compressor) there is a corresponding expansion (or power stroke) and that the choice of offset between top dead center
35 of the compressor piston 9 and top dead center of the expansion piston 15, and the time the expansion piston 15 is stationary in its top dead center determines the combustion time of the mixture in the constant-volume

combustion chamber 2.

Furthermore, the expansion volume displaced by the expansion piston 15 may be greater than the volume displaced by the compressor 9. This difference can be
5 determined according to the differences in the polytropic compression and expansion curves with a view to obtaining the lowest possible pressure at the end of the expansion stage, this being the hallmark of good efficiency and low acoustic emissions.

10 Figures 5 to 8 depict, viewed diagrammatically in cross section, another embodiment of the engine according to the invention in which, between the compressor and the constant-volume combustion chamber 2, there is a compressed-air buffer volume 22 supplied
15 with compressed air by any appropriate means through a duct 22A, this volume being kept at practically constant pressure and having the effect of avoiding certain surge effects and the pressure drops which are due to the dead transfer volume and to the expansion
20 during filling of the combustion chamber 2. The duct 5, the opening and closure of which are controlled by the shutter 6, connects the compressed-air buffer volume 22 to the combustion chamber 2 twinned with the expansion and exhaust chamber (2) and comprises a fuel injector
25 24 intended to produce the air-fuel mixture appreciably before it is introduced into the combustion chamber 2. A shutter 25, also installed in this duct, allows the charge let into the combustion chamber to be adjusted (throttle).

30 Figure 5 depicts the engine when the shutter 6 has just been opened to allow compressed air mixed with fuel atomized by the injector 24 into the constant-volume combustion chamber 2 via the duct 5 while the expansion piston 15 is at its top dead center after its
35 upstroke during which it has driven out into the atmosphere via the duct 19 (the exhaust valve 20 having been opened) the gases which were burnt and expanded in the previous cycle.

As soon as the mixture has been introduced into the twinned and independent combustion chamber 2, Figure 6, the shutter 6 is closed again and the independent combustion chamber 2 is isolated, then the
5 spark plug 3 is used to initiate ignition and the air-fuel mixture is burnt in the constant-volume combustion chamber 2 while the expansion piston 15 remains at its top dead center.

The crankshaft 18 continues its rotation,
10 Figure 7, and the expansion piston 15 performs its downstroke and the gases under very high pressure contained in the twinned combustion chamber 2 expand in the expansion chamber 4 pushing back the piston 15 and thus providing the power stroke.

15 Expansion continues over approximately 180° of rotation of the crankshaft 18 as far as bottom dead center and then the exhaust valve 20 opens and the piston 15 in its upstroke, Figure 8, discharges the burnt and expanded gases in the exhaust duct 19, as far
20 as top dead center. After that, the shutter 6 is opened to allow a new charge of fresh air-fuel mixture into the constant-volume chamber 2 and to recommence the cycle (Fig 5).

It will be observed that with the introduction
25 of a compressed-air buffer volume, the principle of operation of the engine remains the same. However, the air compressor becomes completely independent, no longer has to have particular angular timing with respect to the engine crankshaft 18, and the choice of
30 its principle is thereby facilitated and, for example, rotary compressors may thus be used. Furthermore, the greater the size of this buffer volume, the greater the attenuation of the effects of the surge and pressure drops in the transfer volume and on expansion during
35 the filling of the combustion chamber.

Figures 9 and 10 depict an engine according to the invention equipped, for dual-energy dual-mode operation, with a supplementary air injector 24A and a

very-high-pressure compressed-air storage reservoir 23 to allow it to operate without pollution in urban areas in which the engine operates without injecting fuel but by injecting a dose of supplementary compressed air into the combustion chamber 2 (which thus becomes an expansion chamber) to produce an increase in pressure. In these figures of a cyclic internal combustion engine, the twinned combustion chamber 2 is supplied by a buffer volume of compressed air 22, itself supplied with compressed air by any appropriate means via a duct 22A, and kept at practically constant pressure and which has the effect of avoiding certain effects of surge and the pressure drops due to the dead transfer volume and the expansion during the filling of the combustion chamber 2. The duct 5, the opening and closure of which are controlled by the shutter 6, connects the compressed-air buffer volume 22 to the combustion chamber 2 twinned with the expansion and exhaust chamber 4 and comprises a fuel injector 24 intended to produce the air-fuel mixture appreciably before it is introduced into the combustion chamber 2. A shutter 25, also installed in this duct, makes it possible to regulate the charge let into the combustion chamber (throttle).

In these same Figures 9 and 10, the engine is also equipped with a device for controlling the stroke of the piston, in which device the piston 15, sliding in a cylinder 16, is controlled by a pressure lever, the operation and description of which are identical to what was described for Figure 1.

In operation on the highway with a conventional fuel, the engine operates as described in Figures 5 to 8.

In operation at low power, the fuel injector 24 is no longer operated and when, in its rotation, the engine is at top dead center of the piston of the expansion cylinder 16, Figure 9, only the supplementary air injector 24A is operated and introduces into the

chamber a dose of supplementary compressed air from the high-pressure storage cylinder 23, expanded to a pressure slightly higher than the pressure obtaining in the combustion chamber 2 so as to allow it to be transferred, this mass of supplementary compressed air will heat up on contact with the compressed air contained in the chamber and the mixture of these two masses of air brings about an appreciable rise in pressure so as to produce work during expansion. Expansion continues over approximately 180° of rotation of the crankshaft 18 as far as bottom dead center then the exhaust valve 20 opens and the piston 15, in its upstroke, Figure 10, discharges the expanded gases into the exhaust duct 19 until it reaches its top dead center.

Figures 11 to 13 show diagrammatically in cross section a single-energy air engine according to the invention equipped with a device for controlling the stroke of the piston in which the piston 15 (depicted in Figure 11 at its top dead center), sliding in a cylinder 16, is controlled by a pressure lever. The piston 15 is connected by its axis to the free end 15A of a pressure lever consisting of an arm 17 articulated on a common axis 17A to another arm 17B which is fixed so that it can pivot on a stationary axis 17C. Attached to the axis 17a common to the two arms 17 and 17B is a control connecting rod 17D connected to the wrist 18A of a crankshaft 18 rotating about its axis 18B. As the crankshaft rotates, the control connecting rod 17D exerts a force on the common axis 17A of the two arms 17 and 17B of the pressure lever, thus allowing the piston 15 to move along the axis of the cylinder 16 and in return transmits to the crankshaft 18A the forces exerted on the piston 15 during the power stroke, thus causing it to rotate. The stationary axis 17C is positioned laterally with respect to the axis of movement of the piston 15 and determines an angle A between the axis of movement of the piston and the axis

of alignment X'X of the two arms 17 and 17B when they are aligned. The crankshaft is positioned laterally with respect to the axis of the cylinder and/or of the pressure lever and its position determines an angle B
5 between the control connecting rod 17D and the axis of alignment X'X of the two arms 17 and 17B when they are aligned. By varying the angles A and B and the lengths of the various connecting rods and arms, the characteristics of the kinetics of the assembly are
10 modified to obtain an asymmetric curve of the stroke of the piston 15 and to determine the angle of rotation of the crankshaft for which the piston is stationary at its top dead center. Positioned over this collection of pistons, connecting rods and crankshafts is a cylinder
15 head 11 comprising, on the one hand, an exhaust port 19, the opening and closure of which are performed by an exhaust valve 20 and, on the other hand, an expansion chamber 2 which, having just been supplied with supplementary compressed air by an injector 24A,
20 is thus under pressure, Figure 11. During rotation, the compressed air contained in the expansion chamber 2 expands, driving back the piston 15 as far as its bottom dead center, thus producing its power stroke, the exhaust valve 20 remaining closed during this
25 phase. At practically bottom dead center, the exhaust valve 20 opens and the piston 15 in its upstroke, Figure 12, pushes out to the atmosphere, through the exhaust duct 19, some of the compressed air which was expanded in the previous cycle. During the upstroke of
30 the piston 15 and at a given moment, for example halfway through said stroke, Figure 13, the exhaust valve is closed again and the piston will recompress the remainder of the gases still in the cylinder, creating a high pressure and high temperature (hot
35 mass) in the expansion chamber 14. As soon as the piston stops at its top dead center as per Figure 11, the injector 15 is then actuated to allow a dose of supplementary compressed air from the high-pressure

storage reservoir 23 to be injected and to create an increase in pressure in the expansion chamber so as to repeat the cycle during expansion, producing motive power.

5 Those skilled in the art may choose the time at which the exhaust closes to suit the desired and chosen parameters such as the final temperature and pressure at the end of compression without in any way changing the principle of the invention.

10 Figure 14 shows an engine according to the invention equipped with systems for recovering ambient heat energy and for heating. The engine is equipped with a device for recovering ambient heat energy in which expansion with work of the high-pressure
15 compressed air stored in the reservoir 23 is performed in a connecting rod 53 and working piston 54 assembly coupled directly to a crankshaft 18C connected to the engine crankshaft 18 by a transmission device 21A. This piston 54 slides in a blind cylinder 55 and determines
20 a working chamber 35 into which there open, on the one hand, a high-pressure air inlet duct 37, the opening and closure of which are controlled by an electrically operated valve 38 and, on the other hand, an exhaust duct 39 connected to an air-air heat exchanger or
25 radiator 41 itself connected by a duct 42 to a buffer volume at a practically constant end-use pressure 43. During operation when the working piston 54 is at its top dead center, the electrically operated valve 38 is opened then closed again so as to let in a charge of
30 very-high-pressure compressed air which will expand, driving back the piston 54 as far as its bottom dead center, produce work, and drive the crankshaft 18C via the connecting rod 53 and drive the engine crankshaft 18 via the transmission device 21A. During the upstroke
35 of the piston 54, the electrically operated exhaust valve 40 is then opened and compressed air practically expanded to the usage pressure and at very low temperature contained in the working chamber is

discharged (in the direction of arrow F) into the air-air exchanger or radiator 41. This air will thus heat up to a temperature close to ambient temperature and increase in volume as it enters the buffer volume 43
5 having recovered a not insignificant amount of energy from the atmosphere.

Also installed on the duct 42 between the air-air exchanger 41 and the buffer volume 43 is a thermal heater 56, consisting of burners 57 which will
10 considerably increase the temperature and therefore the pressure and/or the volume of the compressed air originating (in the direction of the arrows F) from the air-air exchanger 41 as it passes through the heat exchange coil 58.

15 Figures 15 to 18 depict the engine according to another aspect of the invention, viewed diagrammatically in cross section and modified to operate according to the invention on a dual-mode principle using two types of energy, employing either a
20 conventional fuel such as gasoline or diesel oil on the highway (single-mode operation on air-fuel) or, at low speed, particularly in urban and suburban areas, using an addition of compressed air to the combustion chamber, the piston 15, sliding in a cylinder 16, is
25 controlled by a pressure lever, the description and operation of which are identical to what was described in Figure 1.

Positioned over this collection of pistons, connecting rods and crankshafts is a cylinder head 11
30 comprising, on the one hand, an exhaust port 19, the opening and closure of which are performed by an exhaust valve 20, the twinned combustion chamber 2 and, on the other hand, an inlet port 13A, the opening and closure of which are controlled by a valve 14A. When
35 the engine is operated in air plus supplementary compressed air mode, the inlet valve 13A is not operated and remains closed and the engine therefore operates as described in Figures 11 to 13, above a

certain speed of, for example, 60 km/h on switching to thermal mode with an air-fuel mixture, the cycle governing the opening and closure of the exhaust valve 20 is altered so that this valve opens during the upstroke of the piston only every two engine revolutions whereas the inlet valve 13A is made to open also every two revolutions during the downstroke of the piston 15, the engine can thus switch mode and cycle, during the downstroke of the piston 15, Figure 15, the inlet valve 13A is open and the piston draws in a mixture of air and gasoline delivered by the injector 24, this mixture is then compressed during the upstroke of the piston 15, Figure 16, in the combustion chamber 2 where it is ignited during ignition initiated by the spark plug 3 then expanded, driving back the piston 15 during the power stroke, Figure 17, as far as bottom dead center where the exhaust valve 20 is opened and the mixture is then discharged to the atmosphere through the exhaust duct 19 on the upstroke of the piston 15, Figure 18. When the piston is at its top dead center, the inlet valve 13A opens to recommence a further cycle (as per Figure 15). The engine thus operates on a conventional four-stroke cycle.

Figure 19 depicts a dual-energy, three-mode engine assembly according to the invention, capable of operating either on air plus supplementary compressed air at light load, or on compressed air plus supplementary compressed air heated by a thermal heater, the above two modes being on a cycle with one power stroke per revolution, or alternatively still, in a thermal air plus fuel with internal combustion mode with one power stroke every two revolutions. It is possible in this figure to see all of the elements compatible with such an operation, namely a piston 15 sliding in a cylinder 16 controlled by a pressure lever, the operation and description of which are identical to what was described in Figure 1.

Positioned over this collection of pistons,

connecting rods and crankshafts is a cylinder head 11 comprising, on the one hand, an exhaust port 19, the opening and closure of which are performed by an exhaust valve 20, the twinned combustion chamber 2 and, on the other hand, an inlet port 13A, the opening and closure of which are controlled by a valve 14A. The engine is equipped with a device for recovering ambient heat energy in which the expansion, with work, of the high-pressure compressed air stored in the reservoir 23 is performed in a connecting rod 53 and working piston 54 assembly coupled directly to a crankshaft 18C connected to the engine crankshaft 18 by a transmission device 21A. This piston 54 slides in a blind cylinder 55 and determines a working chamber 35 into which there open, on the one hand, a high-pressure air inlet duct 37, the opening and closure of which are controlled by an electrically operated valve 38 and, on the other hand, an exhaust duct 39 connected to the air-air heat exchanger or radiator 41 itself connected by a duct 42 to a buffer volume at practically constant end-use pressure 43. During operation when the working piston 54 is at its top dead center, the electrically operated valve 38 is opened then closed again so as to let in a charge of very-high-pressure compressed air which will expand, driving the piston 54 back as far as its bottom dead center and drive the crankshaft 18C via the connecting rod 53 and drive the engine crankshaft 18 via the transmission device 21A. During the upstroke of the piston 54, the electrically operated exhaust valve 40 is then opened and compressed but expanded and very-low-temperature air contained in the working chamber is discharged (in the direction of the arrow F) into the air-air exchanger or radiator 41. This air will thus heat up to a temperature close to ambient temperature and increase in volume as it enters the buffer volume 43 having recovered a not insignificant amount of energy from the atmosphere.

Also fitted on the duct 42A between the air-air

exchanger 41 and the buffer volume 43 is a thermal heater 56 consisting of burners 57 which will considerably increase the temperature and therefore the pressure and/or the volume of the compressed air
5 originating (in the direction of the arrows F) from the air-air exchanger 41 as it passes through the heat exchange coil 58.

Furthermore, also formed in this cylinder head 11 is an inlet port 13A, the opening and closure of
10 which are controlled by a valve 14A. When the engine operates in air plus supplementary compressed air mode, the inlet valve 13A is not operated and remains in the closed position, and the engine therefore operates as described in Figures 11 to 13, and the device for
15 recovering ambient heat energy preferably operates in this mode. Above and beyond a certain speed of, for example, 50 km/h, the heater device may be set into operation by lighting the burners 57 so as to allow an increase in performance while at the same time
20 remaining very low on pollution because of the continuous catalyzed combustion, and thereafter, beyond a higher speed, for example of 70 km/h, the supplementary compressed-air injector 24A is no longer operated, the burner 57 is extinguished and there is a
25 switch to thermal (internal combustion) mode using an air-fuel mixture and the cycle governing the opening and closure of the exhaust valve 20 is altered so that it opens during the upstroke of the piston only every two engine revolutions whereas the inlet valve 13A is
30 made to open also every two revolutions during the downstroke of the piston 15, the engine can thus change cycle, during the downstroke of the piston 15, Figure 15, the inlet valve 13A is opened and the piston draws in a mixture of air and gasoline and this mixture is
35 then compressed during the upstroke of the piston 15, Figure 16, in the combustion chamber 2 where it is ignited during the ignition initiated by the spark plug 3 then expanded, driving the piston 15 back during the

power stroke, Figure 17, as far as bottom dead center where the exhaust valve 20 is opened and the mixture is then discharged to the atmosphere through the exhaust duct 19 during the upstroke of the piston 15, Figure 5 18. The inlet valve then opens to recommence a further cycle as per Figure 15. The engine thus operates on a conventional four-stroke cycle.

Of course the invention is not in any way restricted to the embodiments described and depicted; 10 it is liable to numerous variations accessible to those skilled in the art, depending on the envisaged application and without in any way departing from the spirit of the invention.



CLAIMS

1. Operating method for an engine with an induction-compression chamber, an expansion-exhaust
5 chamber, both operating using reciprocating pistons, and with a combustion chamber, the three chambers being separate, characterized in that there is provided, at least on the expansion-exhaust chamber, a device for controlling the stroke of the piston of said chamber
10 causing this piston to stop at its top dead center, and in that the combustion chamber is mounted twinned with no shutter on the top part of the expansion-exhaust cylinder, the piston practically separating the combustion chamber from the expansion-exhaust chamber
15 at its top dead center.

2. Engine operating method according to claim 1, characterized in that the operating cycle of the induction-compression chamber is retarded with respect to the cycle of the expansion-exhaust chamber so that
20 the piston of the latter, reaching its top dead center, is in advance of the top dead center of the piston of the induction-compression chamber and remains at its top dead center during the following operations:

- communication between the combustion chamber
25 and the induction-compression chamber,

- filling of said combustion chamber with the air-fuel mixture compressed by the piston of the induction-compression chamber reaching its top dead center,

- closure of the communication between the
30 combustion chamber and the induction-compression chamber,

- ignition and combustion of the mixture which generates an increase in pressure,

35 then, as soon as it begins its downstroke, produces work brought about by the increase in pressure.

3. Engine operating method according to claims 1 and 2, characterized in that the engine operates with



heterogeneous self-igniting mixtures, in which method a fuel injector is actuated to bring about combustion as soon as the combustion chamber is isolated from the induction-compression chamber.

5 4. Engine operating method according to claims 1 to 3, characterized in that the combustion chamber is a portion of a sphere twinned with the expansion and exhaust chamber.

5. Engine operating method according to any one of
10 claims 1 to 4, characterized in that at least one of the chambers - combustion and expansion - is coated with a thermal barrier made of lagging insulating material.

6. Engine operating method according to any one of
15 claims 1 to 5, characterized in that fitted between the chamber for the induction and compression of fresh gases and the twinned independent combustion chamber is a buffer volume for the gases thus compressed so as to avoid surge effects and pressure drops which are due to
20 the dead transfer volume between the chambers, and to the partial expansion of the gases while the combustion chamber is filling, a connecting duct and its system of controlled opening and closure therefore being located between the buffer volume and the combustion chamber.

25 7. Engine operating method according to any one of claims 1 to 6 used in dual energy and dual mode operation, characterized in that when operating at low power, for example in urban traffic, the induction-compression chamber is no longer supplied with fuel and
30 in that there is introduced into the combustion chamber, appreciably after the (fuel-free) compressed air from the induction-compression chamber has been let into this chamber, a dose of supplementary compressed air from an external reservoir in which the air is
35 stored under an initial high pressure, for example 200 bar and at ambient temperature, this dose of supplementary compressed air at ambient temperature, on contact with the mass of air at high temperature

contained in the combustion chamber which in this case becomes an expansion chamber, heating up, expanding and increasing the pressure prevailing in the combustion chamber so as during expansion to allow the delivery of motive power, and in that when operating at high power, for example on the highway, the engine is supplied with fuel and operates according to any one of claims 1 to 6.

8. Engine operating method according to any one of claims 1 to 6 used in single energy and single mode air plus supplementary compressed air operation, characterized in that all the elements needed for supplying the engine with a conventional fuel are omitted, and in that there is introduced into the combustion chamber, appreciably after (fuel-free) compressed air from the induction-compression chamber has been let into this chamber, a dose of supplementary compressed air from an external reservoir in which air is stored under initial high pressure, for example 200 bar and ambient temperature, this dose of supplementary compressed air at ambient temperature, on contact with the mass of air at high temperature contained in the combustion chamber which in this case becomes an expansion chamber, heating up, expanding and increasing the pressure prevailing in the combustion chamber to allow motive power to be delivered upon expansion.

9. Single-mode compressed-air operating method for an engine, comprising an expansion-exhaust chamber operating with the aid of a piston sliding in a cylinder, and equipped with an exhaust port and a twinned independent expansion chamber, characterized in that the expansion-exhaust chamber is equipped with a device for controlling the stroke of the piston causing the latter to stop at its top dead center, in which the induction-compression cylinder has been omitted and in that, during the upstroke of the piston of the expansion-exhaust chamber, during the exhaust cycle, the exhaust port is closed off to allow some of the



previously expanded gases to be recompressed to a high temperature and high pressure in the expansion chamber into which, while the piston is stationary at its top dead center, a dose of supplementary compressed air
5 from a storage reservoir is injected, thus causing an increase in pressure in the expansion chamber, this producing work by driving the piston back in its downstroke.

10. Engine operating method according to any one of
10 claims 7 to 9, characterized in that, before being introduced into the expansion chamber, the compressed air contained in the high-pressure storage reservoir is expanded with work producing a drop in its temperature and is then sent into an exchanger to exchange heat
15 with the ambient air to heat it up and thus increase its pressure and/or its volume by recovering ambient heat energy.

11. Engine operating method according to any one of
claims 7 to 10, characterized in that before being
20 introduced into the expansion chamber, the compressed air from the storage reservoir is routed either directly or having passed through the air-air heat exchanger, into a thermal heater where its pressure and/or its volume can increase still further.

25 12. Engine operating method according to claim 9, used in dual energy operation, characterized in that the cycle for the opening and closure of the exhaust valve which opens on every engine cycle over part of the piston upstroke varies during operation to open
30 during the piston upstroke every two revolutions and in that the engine is equipped with an air and fuel inlet which introduces into the cylinder a charge of carburetted mixture which is drawn in during the piston downstroke and then compressed in the twinned expansion
35 chamber, which then becomes a combustion chamber, in which the mixture is burnt and then expanded, producing work by driving the piston back and is then discharged in the exhaust according to the conventional four-



stroke engine cycle.

13. Engine operating method according to any one of claims 1 to 11, in three-mode use, characterized in that the engine operates either with compressed air
5 without heat and with zero pollution, or with a compressed air that has been heated by external combustion in a thermal heater supplied with a conventional fuel with practically zero pollution, or with internal combustion by letting in air and fuel,
10 allowing a charge of carburetted mixture to be introduced into the expansion chamber, in which the mixture is burnt and then expanded, producing work and discharged in the exhaust according to the conventional four-stroke engine cycle, thus achieving three-mode
15 operation.

14. Engine operating method in three-mode use according to claim 13, characterized in that the three operating modes described hereinabove - air plus supplementary compressed air, air plus supplementary
20 compressed air heated by a burner, air plus fuel - may be used separately or in combination.

15. Engine operating method according to any one of claims 7 to 13, characterized in that the air drawn in by the engine is filtered and purified through one or
25 more filtration stages chosen from active-charcoal methods, mechanical methods, chemical methods and molecular sieves, so as to achieve a pollution-reducing engine.

16. Engine device for implementing the method according to one of claims 1 and 2, characterized in that it comprises a combustion chamber (2) which is
30 twinned with the expansion chamber (4) which itself comprises a piston (15) controlled by a device for controlling the piston stroke, causing the piston to stop at its top dead center for a period of angular
35 rotation which may be as much as 150°, and consisting of a pressure lever (17, 17A, 17B, 17C) itself controlled by a connecting rod (17D) connected to the



wrist (18A) of an engine crankshaft (18) rotating about its axis (18B) and driving, via a compressor crankshaft (12) and a connecting rod (11), an induction-compression piston (9) in a compression chamber (1) connected to the combustion chamber (2) by a duct (5), the opening and closure of which are controlled by a sealed shutter (6), and characterized in that the crankshaft (12) of the induction-compression chamber is driven through a mechanical link (21) by the engine crankshaft (18) and timed with a retard in the cycle so that the expansion-exhaust piston (15) arrives and remains at its top dead center while:

- the shutter (6) opens,
- the combustion chamber fills with the mixture compressed by the compression piston (9) reaching its top dead center,
- the shutter (6) closes,
- the spark plug (3) causes ignition,
- and combustion takes place, generating an increase in pressure in the chamber (2) and driving back the expansion piston (15), producing work known as the power stroke.

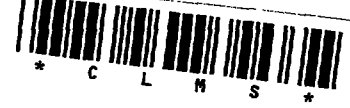
17. Engine device for implementing the method according to claim 3, characterized in that it comprises a combustion chamber (2) which is twinned with the expansion chamber (4) which comprises a piston (15) controlled by a device for controlling the piston stroke, causing the piston to stop at its top dead center for a long period of angular rotation, this control device consisting of a pressure lever (17, 17A, 17B, 17C) itself controlled by a connecting rod (17D) connected to the wrist (18A) of an engine crankshaft (18) rotating about its axis (18B) and driving, via a compressor crankshaft (12) and a connecting rod (11), an induction-compression piston (9) in a compression chamber (1) connected to the combustion chamber (2) by a duct (5), the opening and closure of which are controlled by a sealed shutter (6), in that a buffer



volume (22) is placed between a compressor which is connected to this volume by a duct (23), in that a throttle valve (25) is inserted between this buffer volume and the duct (5) comprising a fuel injector (24), and in that as soon as the piston (15) reaches its top dead center, and while it is stationary in this position, the shutter (6) is opened and the fuel injector (24) is actuated to introduce a charge of compressed mixture into the chamber (2), then the shutter is closed again and ignition is initiated by a spark plug (3) to cause combustion which will generate an increase in pressure in the chamber (2) and drive the expansion piston (15) back, producing work known as the power stroke.

18. Engine device for implementing the method according to claim 7, characterized in that the combustion chamber (2) takes a supplementary compressed air injector (24A) fed from a high-pressure storage reservoir (23), and which, during low-power operation, injects a dose of supplementary compressed air while the fuel injector (24) is not actuated, and causes an increase in pressure in the combustion chamber (2) which produces work by expanding during the piston downstroke.

19. Engine device for implementing the method according to claim 9, characterized in that the expansion chamber (2) is twinned with the expansion chamber (4) which comprises a piston (15) controlled by a device for controlling the piston stroke, causing the piston to stop at its top dead center for a long period of angular rotation and consisting of a pressure lever (17, 17A, 17B, 17C) itself controlled by a connecting rod (17D) connected to the wrist (18A) of an engine crankshaft (18) rotating about its axis (18B), said combustion chamber being supplied by an injector (24A) of supplementary compressed air from a high-pressure reservoir (23), and in that the exhaust valve (20) which closes off the exhaust duct (19) is made to open



at practically bottom dead center of the piston and to close again during the upstroke of said piston (15) so as to recompress in the expansion chamber (2) the remaining gas left there, producing a hot mass of compressed air into which, as soon as the piston stops at its top dead center, a fresh dose of supplementary compressed air is injected, causing the pressure in said chamber to rise and producing work during expansion right from the start of the downstroke of the piston (15).

20. Engine device for implementing the method according to claim 10 to 14, characterized in that located between the storage reservoir (23) and the supplementary compressed air injector (24A) is a piston (54) coupled directly to the drive shaft (18) and which slides in a blind cylinder (55) forming a work chamber (35) into which there open, on the one hand, a high-pressure air intake duct (37), the opening and closure of which are controlled by an electrically operated valve (38) and, on the other hand, an exhaust duct (39) connected to the air-air heat exchanger or radiator (41) itself connected by a duct (42) to a buffer volume (43) at a practically constant end-use pressure, and in that the very-high-pressure compressed air expands, driving back the piston and producing work with a lowering of the temperature and is then discharged (F) to the air-air exchanger (41) to heat up and increase in pressure and/or in volume.

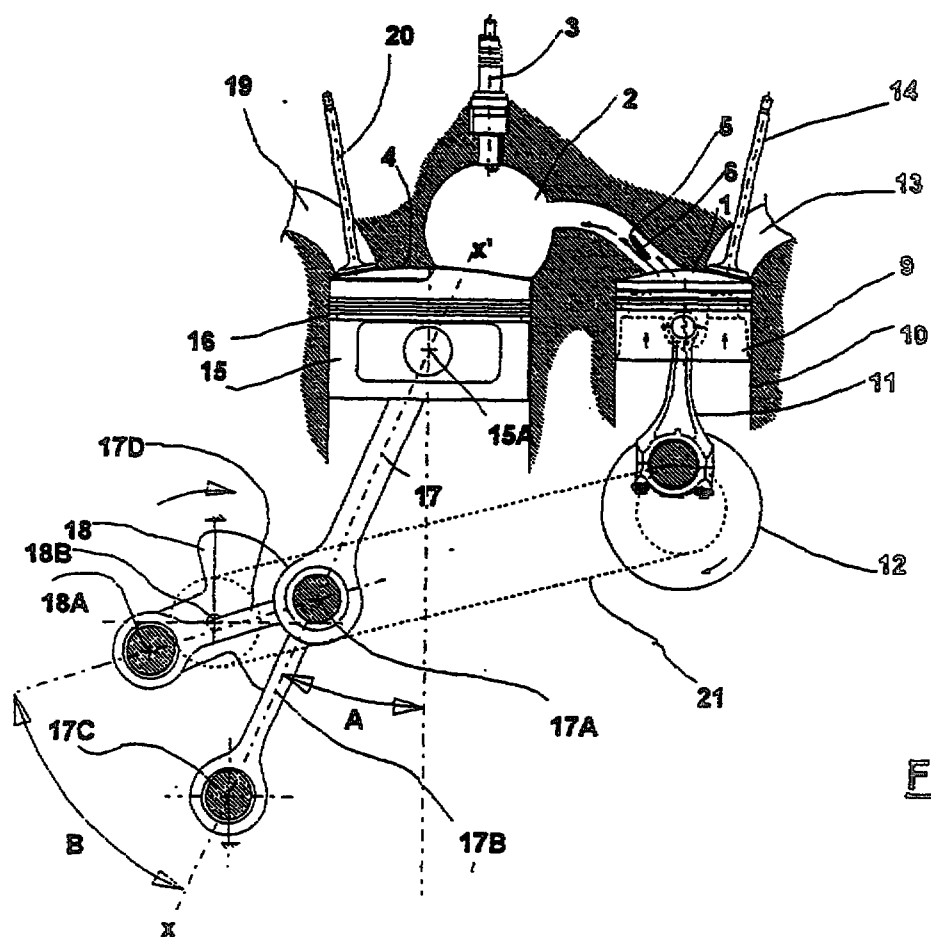
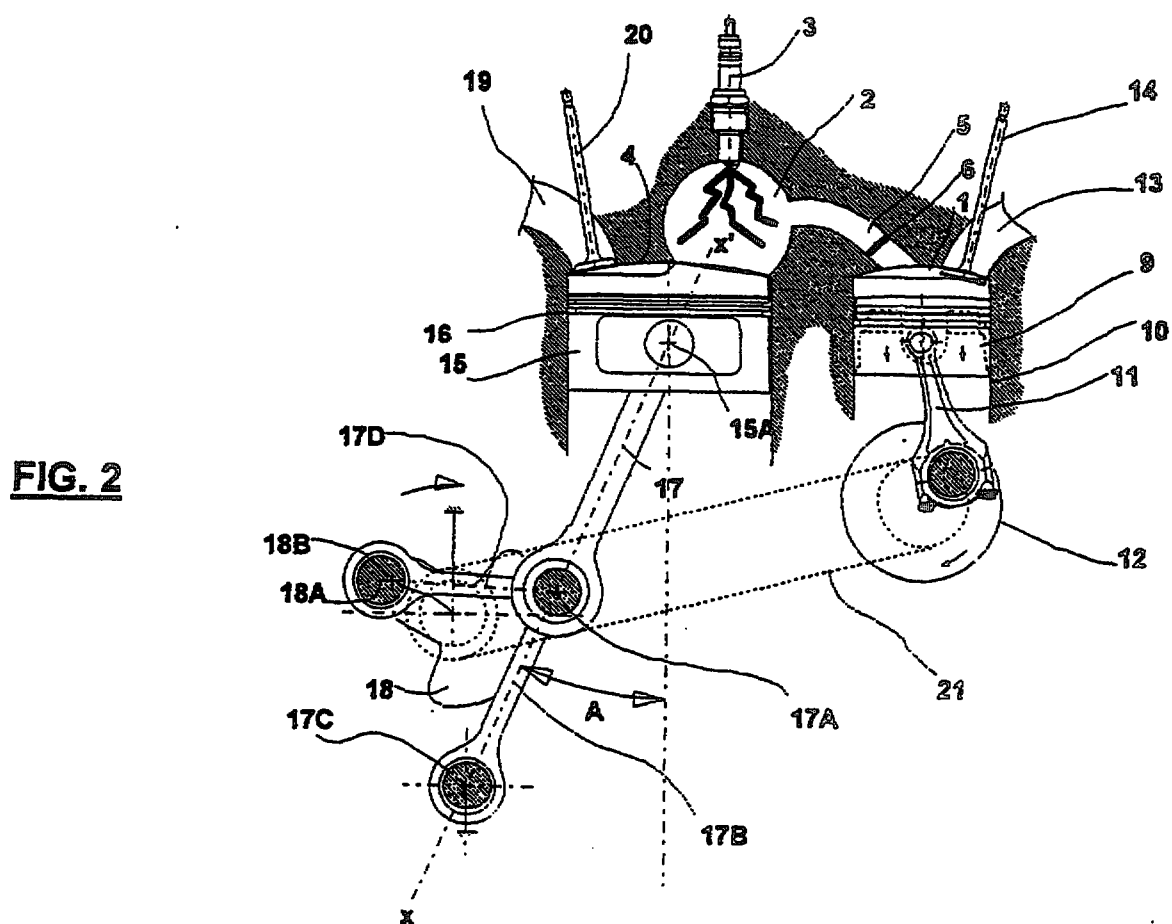
21. Engine device for implementing the method according to claim 10 to 14, characterized in that located between the high-pressure storage reservoir (23) and the supplementary compressed air injector (24A) is a thermal heater (56) consisting of burners (57) which increase the temperature and therefore the pressure and/or the volume of the compressed air originating (F) from the high-pressure reservoir (23) as it passes through the exchange coil (58).

22. Engine device according to claim 21,



characterized in that the compressed air from the high-pressure reservoir (23) passes through an air-air exchanger according to claim 20.

23. Engine device for implementing the method
5 according to claims 13 and 14, characterized in that the device for controlling the stroke of the piston, causing the piston to stop at its top dead center for a long period of angular rotation, consists of a pressure lever (17, 17A, 17B, 17C) itself controlled by a
10 connecting rod (17D) connected to the wrist (18A) of a crankshaft (18) rotating about its axis (18B) slides in a cylinder (16) topped by a cylinder head (11) comprising a twinned combustion chamber (2) into which there open, on the one hand, an intake duct itself
15 comprising a fuel injector (24), the opening and closure of which are controlled by a valve (14A) and, on the other hand, an exhaust duct (19), the opening and closure of which are controlled by a valve (20) which may, depending on the mode of operation, open
20 either every two engine revolutions during the piston upstroke or every revolution during just part of the piston upstroke, and a spark plug (3) and a supplementary compressed air injector (24A) supplied with compressed air by a high-pressure compressed air
25 storage reservoir (23), this assembly allowing the engine to be operated in two modes, either supplied with supplementary compressed air for low power, or supplied with a carburetted charge using conventional fuel, for higher powers.

**FIG. 1****FIG. 2**

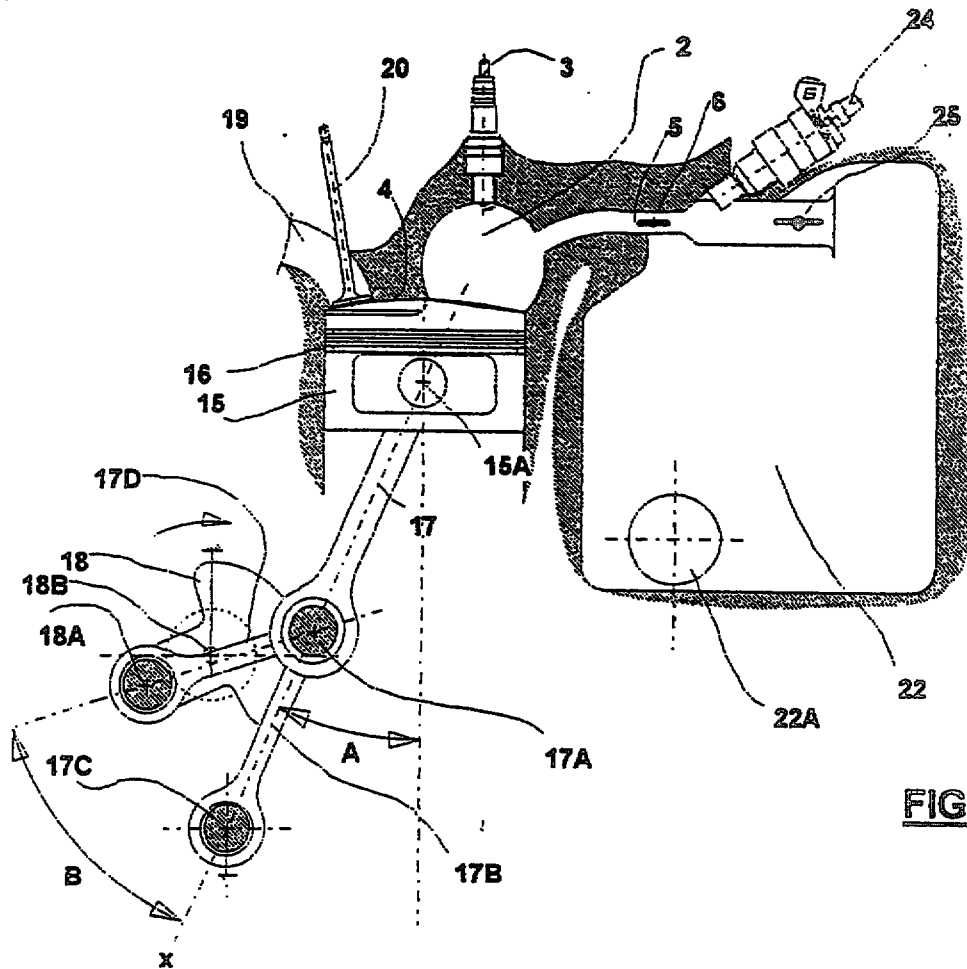


FIG. 5

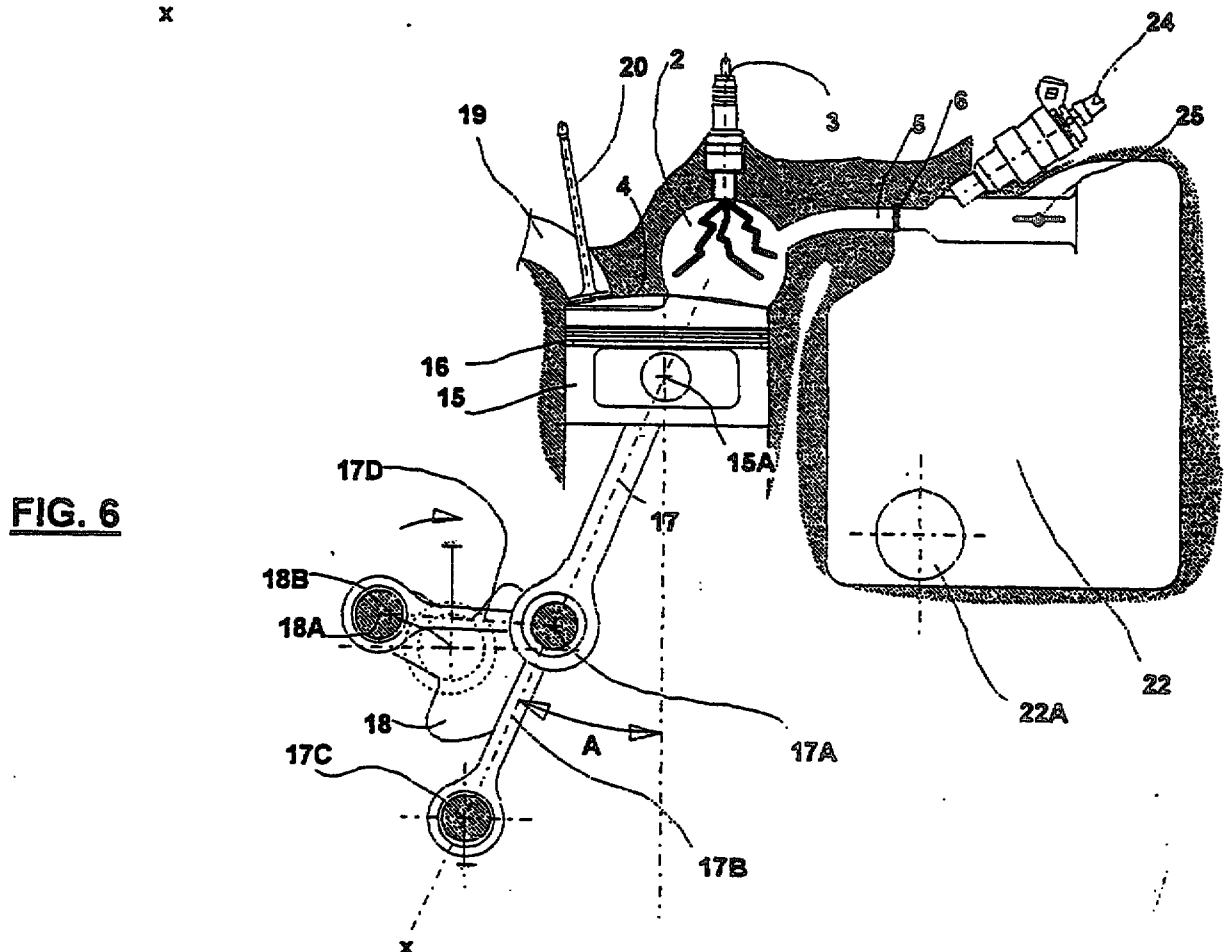


FIG. 6

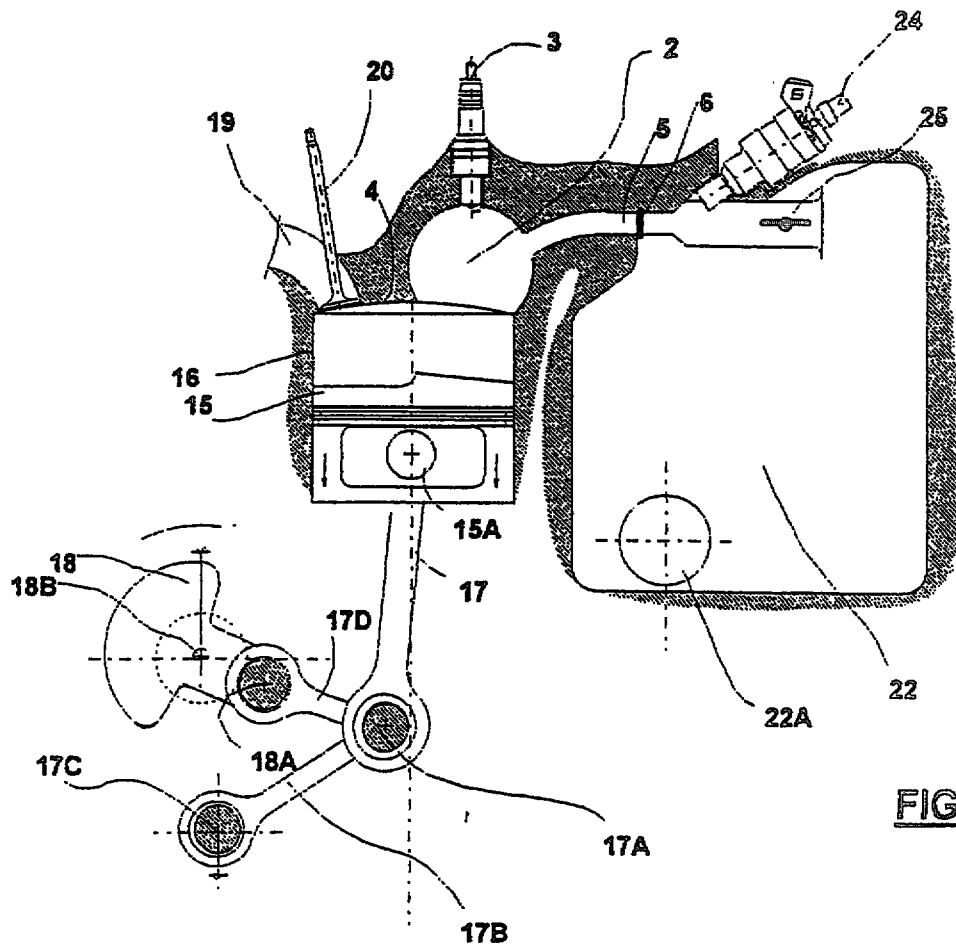
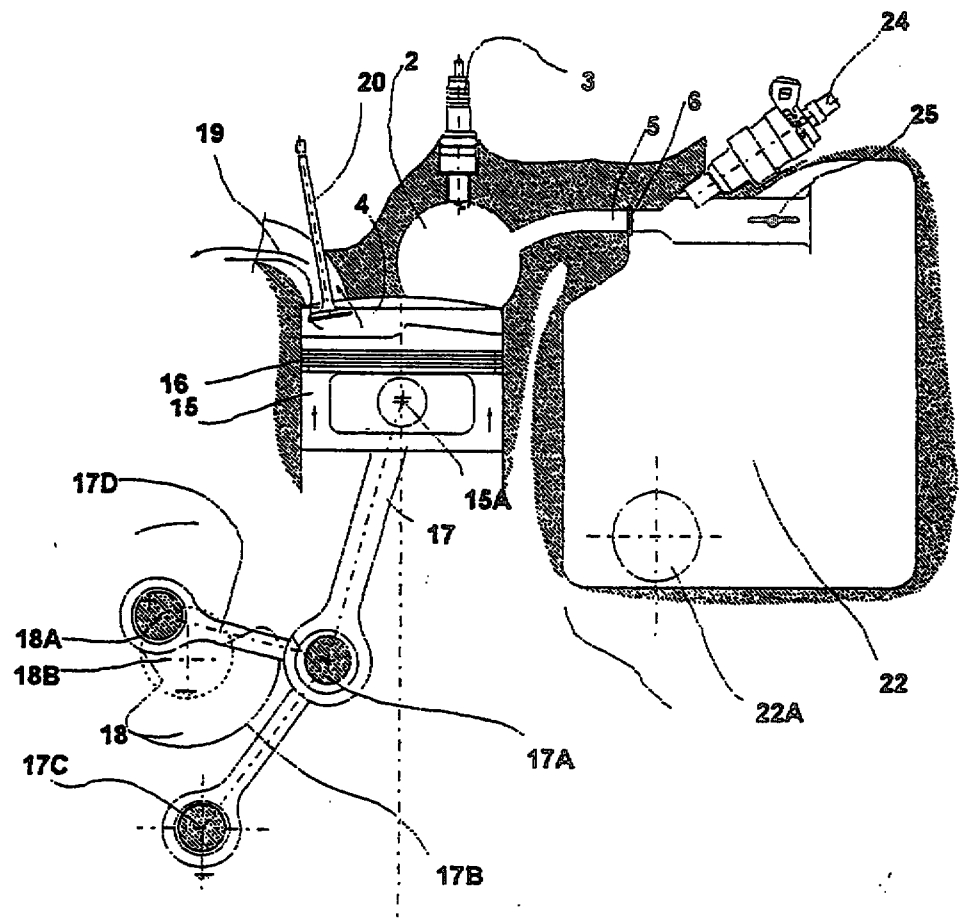
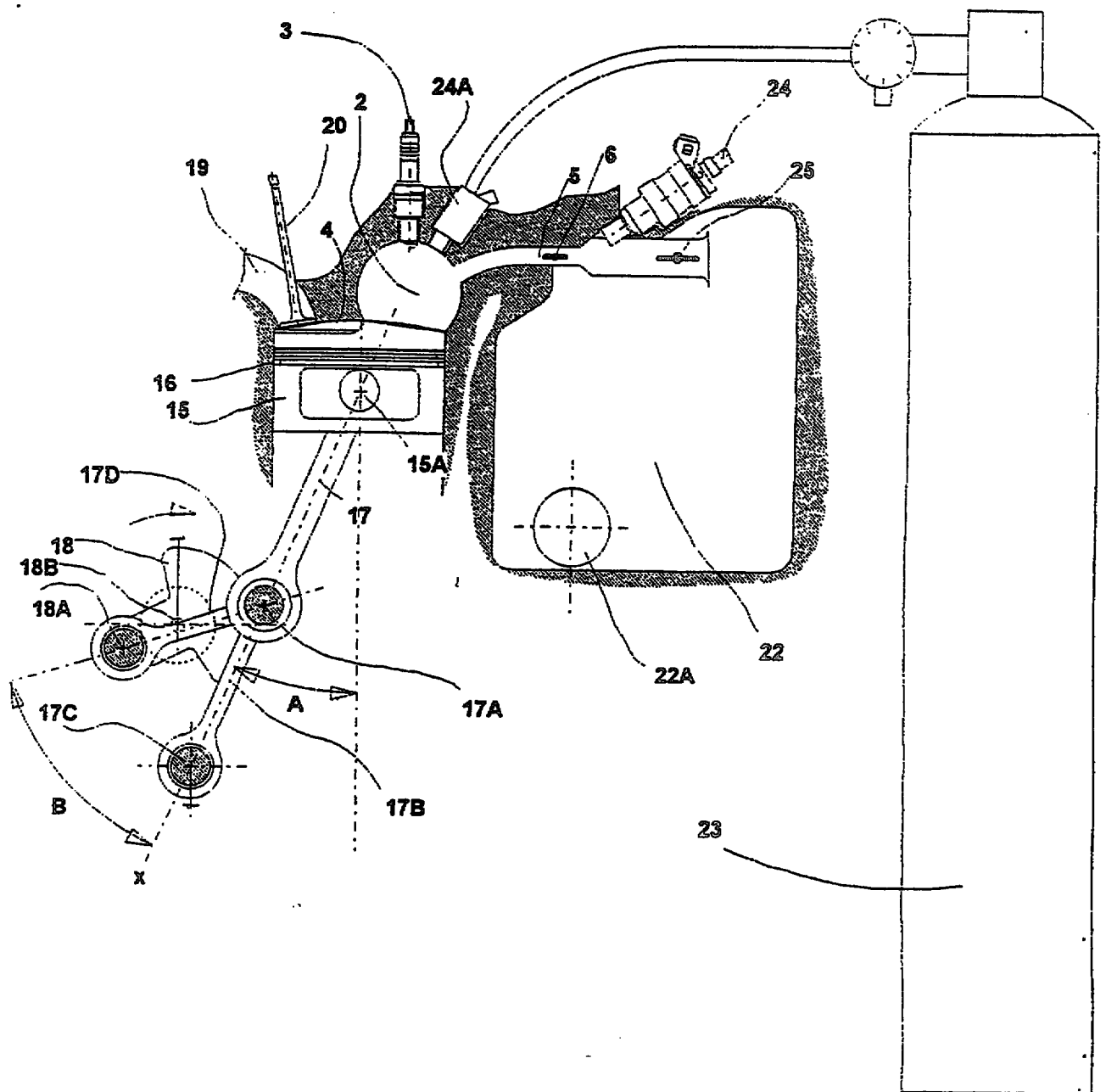
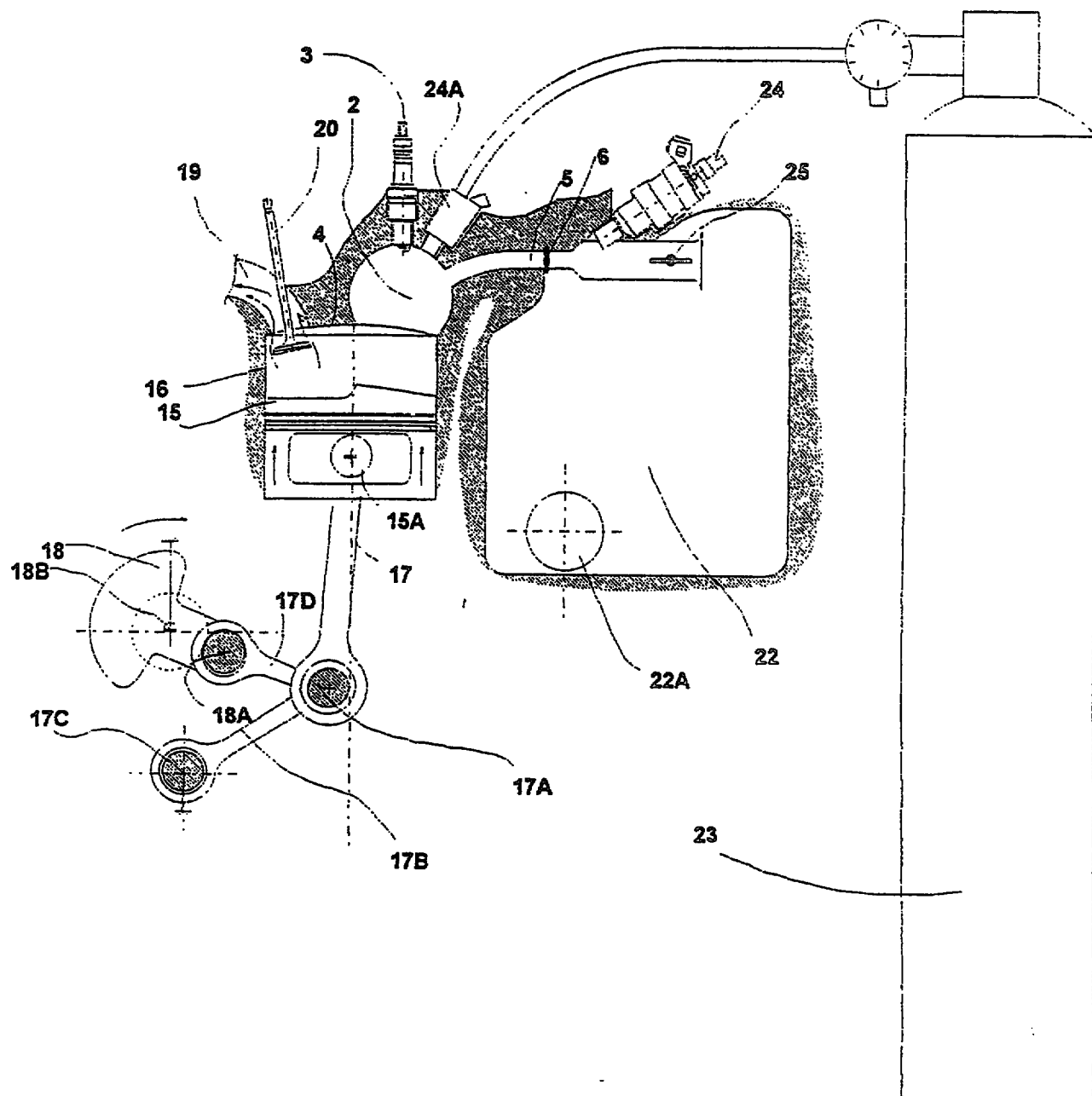


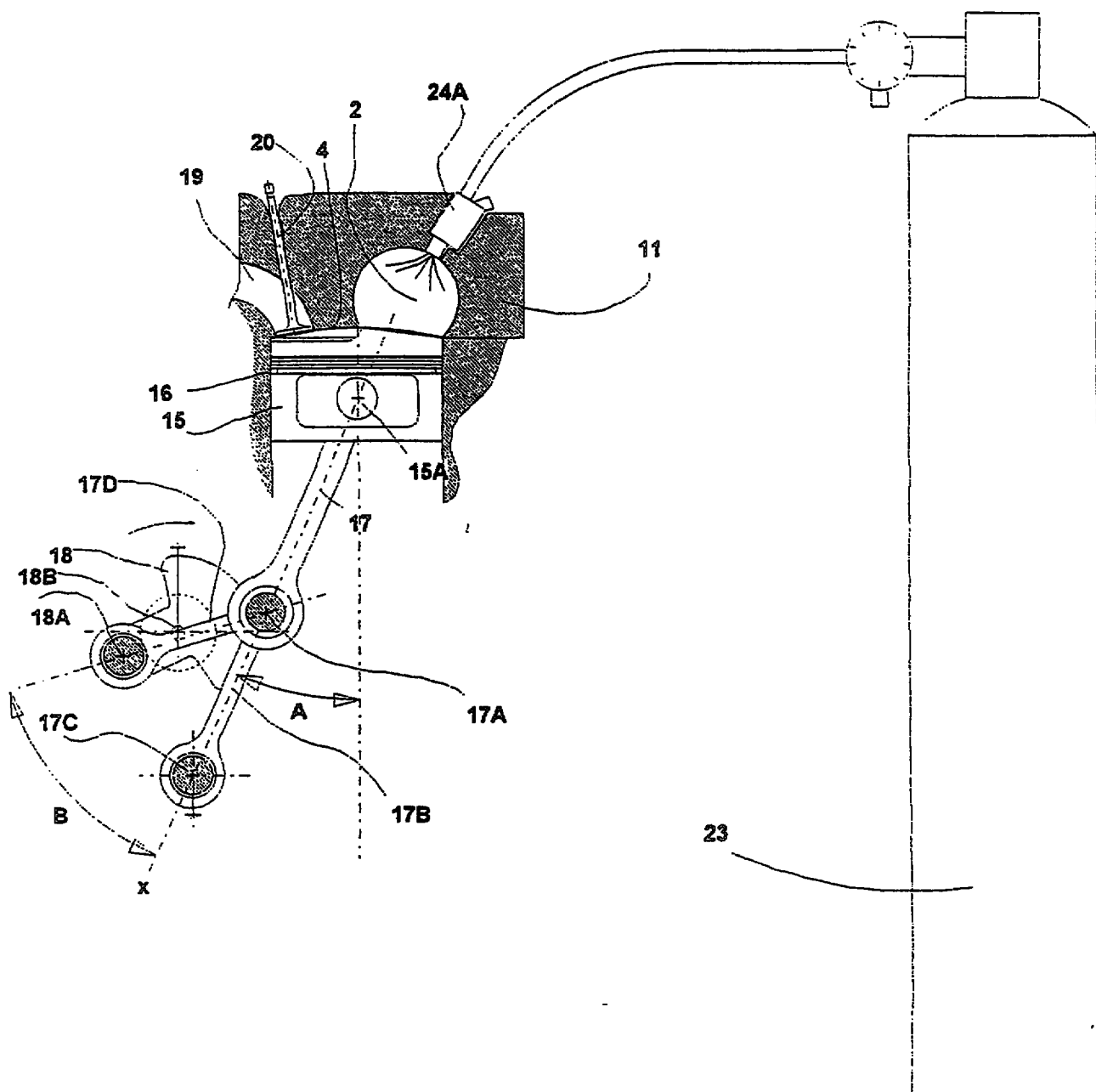
FIG. 7

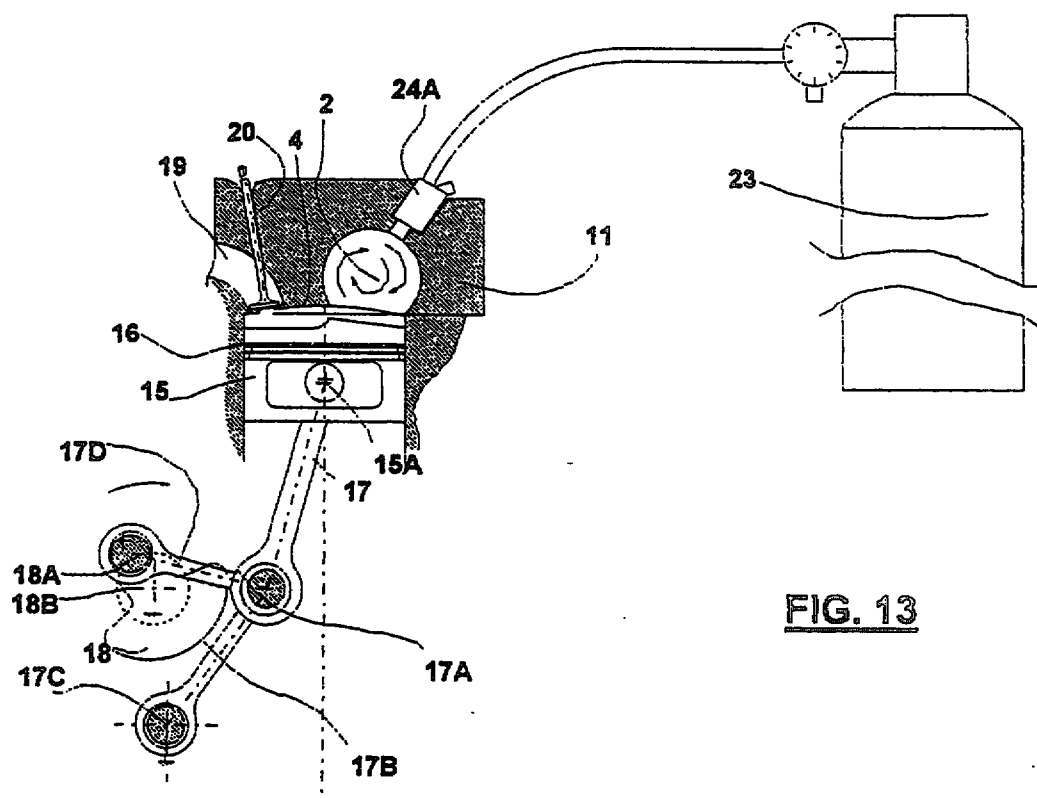
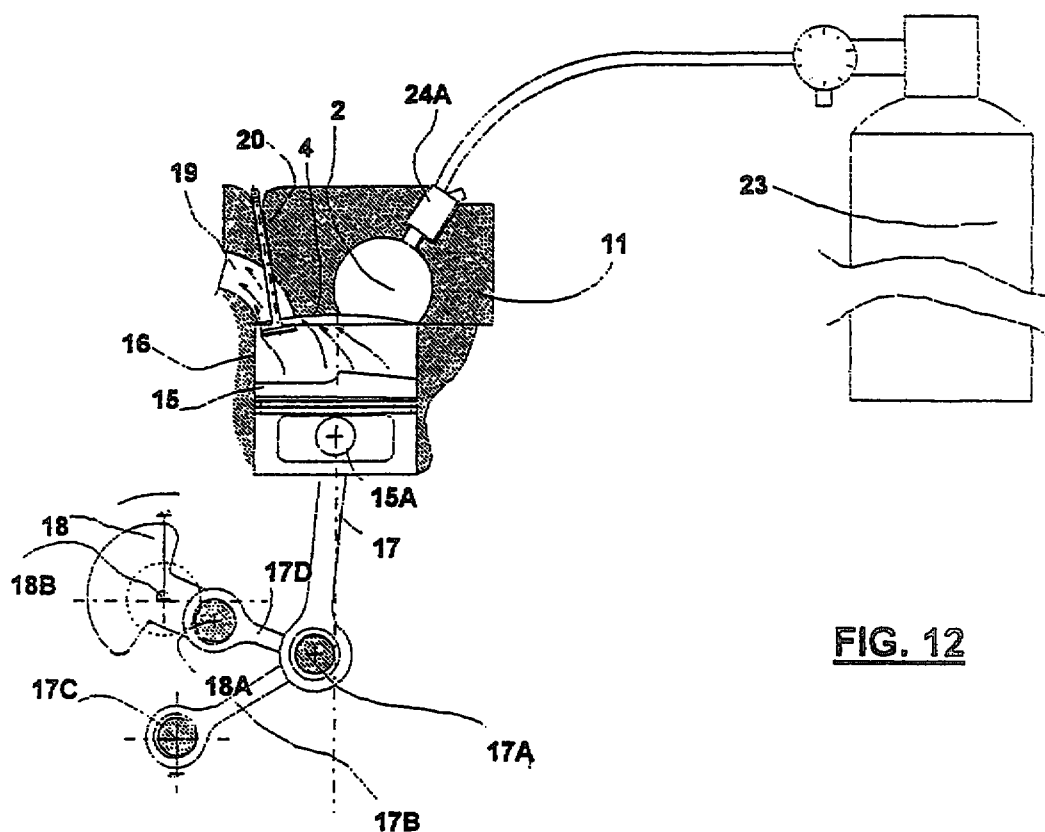
FIG. 8

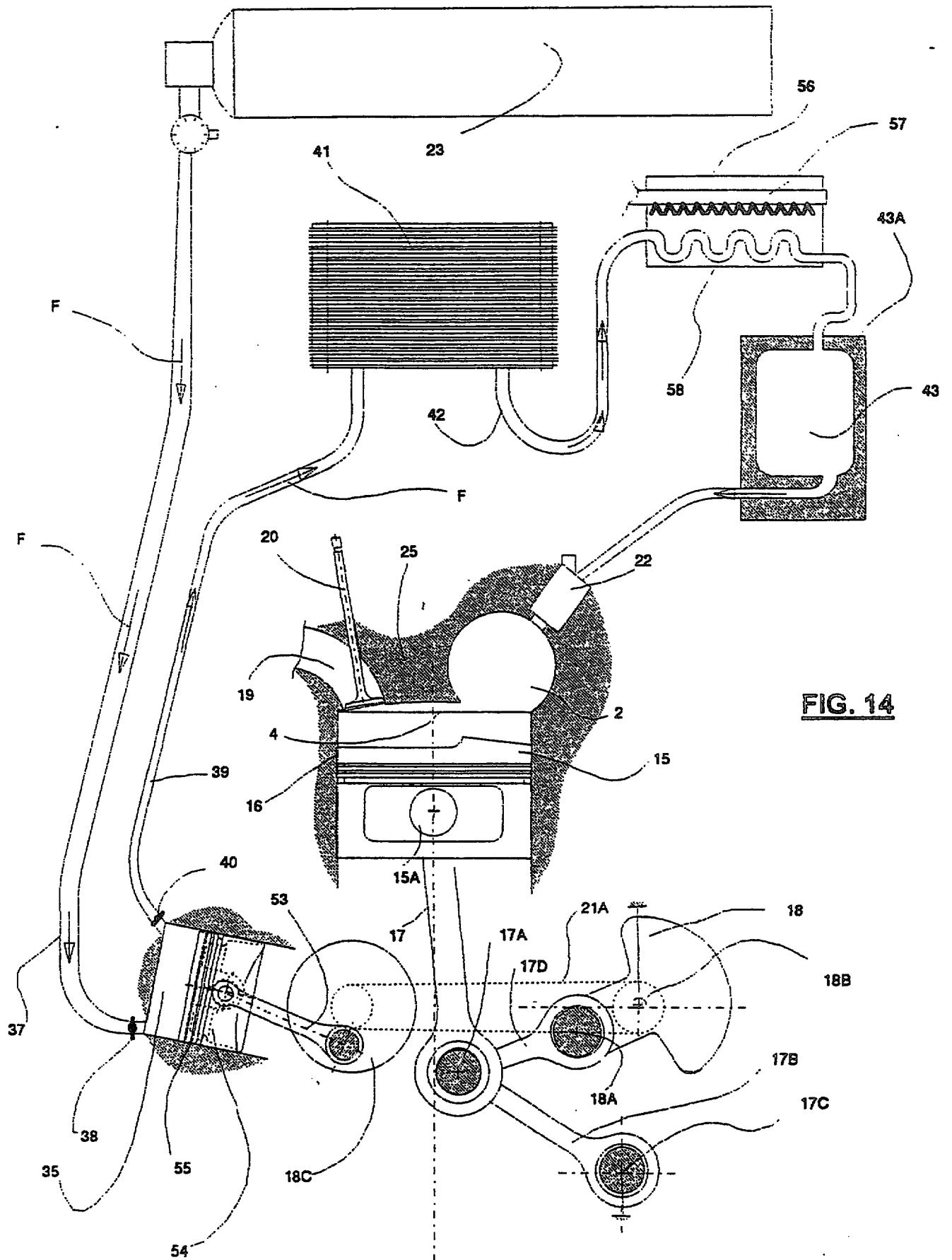


**FIG. 9**

**FIG. 10**

**FIG. 11**



**FIG. 14**

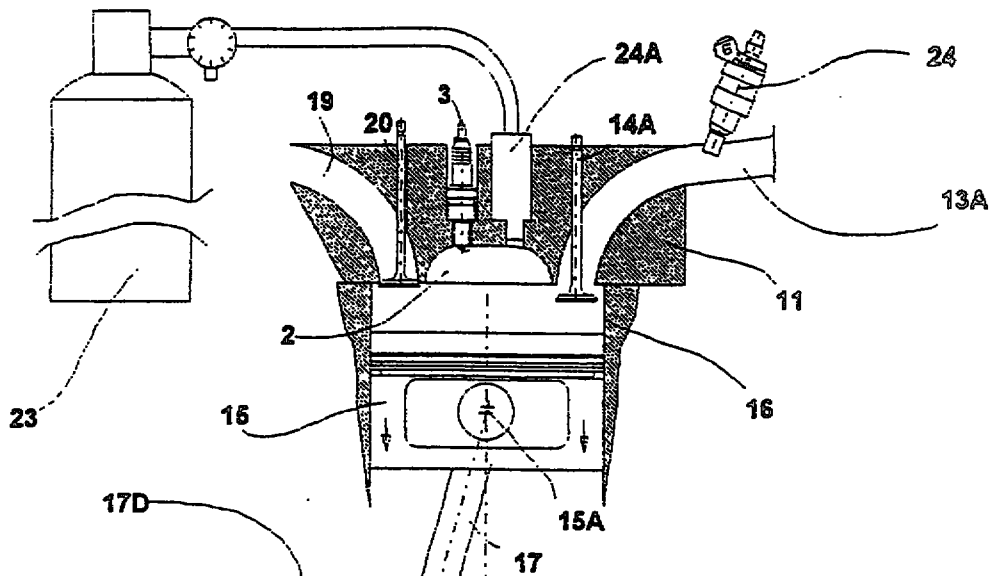


FIG. 15

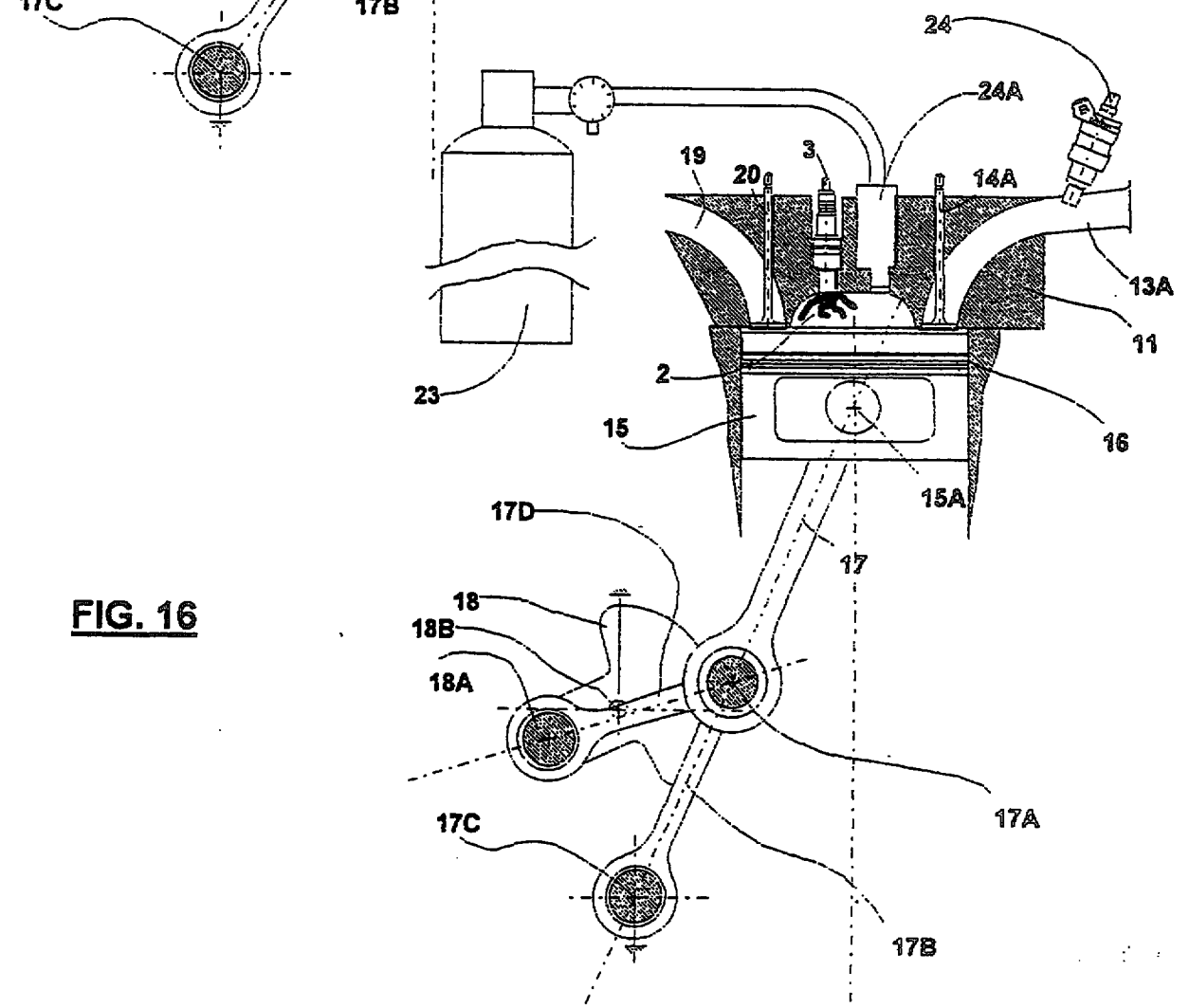


FIG. 16

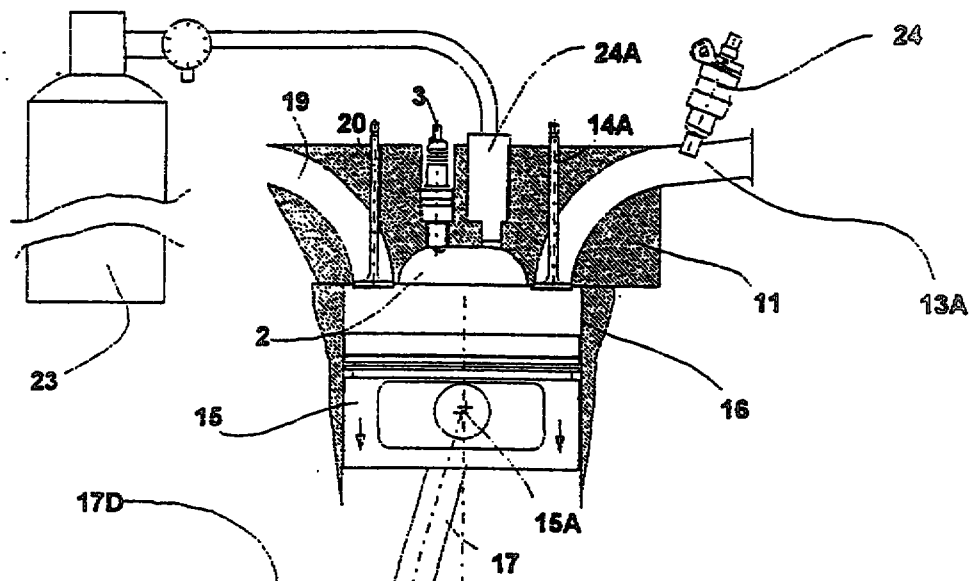


FIG. 17

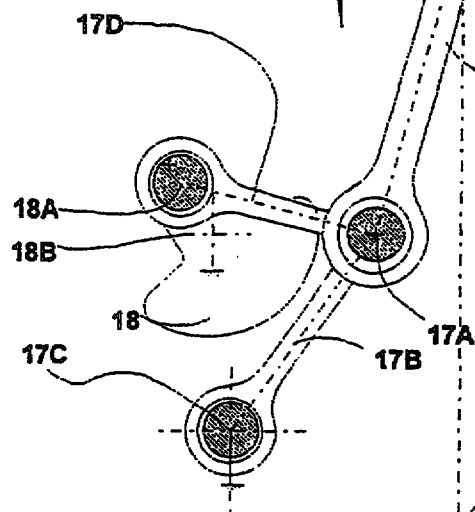


FIG. 18

