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(54) **Actuator with a counter compression means and pre compression means**

(57) An actuator comprising a reaction/combustion cylinder, a counter compression cylinder, advantageously a pre compression cylinder, a rod connecting the pistons of said cylinders, and a connecting means for connecting the rod to the element to be tested.

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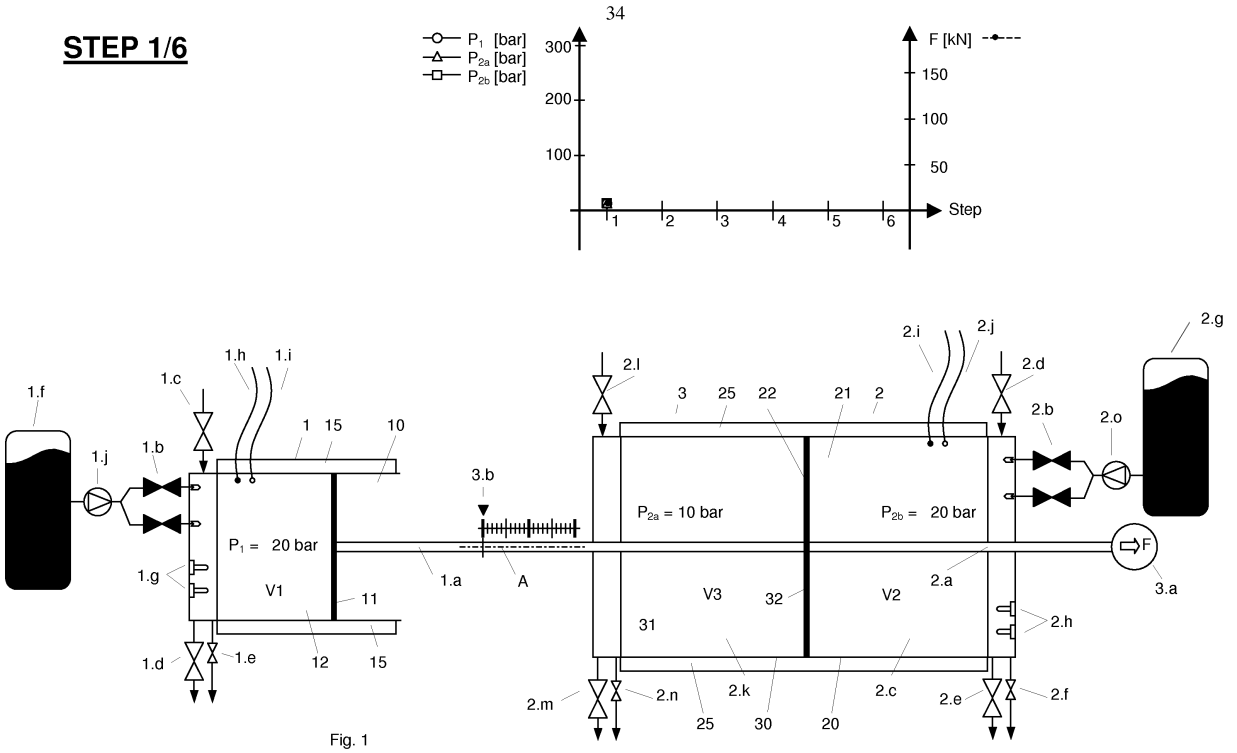

Fig. 1

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Description

[0001] The invention relates to an actuator provided with a counter compression means, adapted to control at least part of the movement of the combustion cylinder.

[0002] US 5303631 discloses a damped-action pyrotechnic actuator. Said actuator has a body containing a piston, a pyrotechnic material combustion chamber, and a counter pressure chamber between a piston head and a mobile end of the actuator, also including an intermediate compression chamber between the combustion chamber and the piston head, the intermediate compression chamber being connected to the combustion chamber by a hole, and a gas passage by-passing the piston head of the piston to connect the intermediate chamber to the counter pressure chamber.

[0003] Such a device is adapted for reducing the movement of the rod actuating on an element to be tested. Furthermore such a device is not suitable for controlling the return movement of the actuator.

[0004] The invention relates to an actuator suitable for generating very rapid action or force on the element to be tested, for example in less than 1 second, advantageously less than 500 milliseconds, for example between 1 millisecond and 200 milliseconds, while enabling to limit the force applied to the element after a predetermined displacement of the piston of the combustion chamber or of the reaction chamber. The element suitable to be tested are for example cylinders working in extreme conditions, valves to be closed or opened in very short times, pieces submitted to a rapid movement before having to return back to its initial position, etc

[0005] The invention relates to an actuator comprising :

- a first reaction cylinder 1 with a hollow body 10 containing a piston 11, said piston 11 defining with said hollow body 10 a reaction chamber 12 adapted for the reaction of at least one first (advantageously gaseous) component with a second component (advantageously gaseous or liquid of in the form of a vapour or droplets), said reaction generating heat and/or gases, whereby said piston is movable in an axis direction A along the inner face or faces of the reaction chamber 12 in function of the pressure within the reaction chamber 12, whereby the said piston 11 is provided with means for ensuring a substantially gas-tight seal with the inner face or faces of the reaction chamber when the piston 11 is moving in the reaction chamber, and whereby the portion of the reaction chamber 12 in which the piston 11 is movable in substantially gas tight way has a first cross section measured perpendicular to the said axis direction A ;
- a counter compression cylinder 2 comprising a hollow body 20 defining a chamber 21, and a piston 22 moving in said chamber 21 in a direction substantially perpendicular to the axis direction A or in a direction corresponding substantially to the axis direction A, whereby the said piston 22 is provided with means for ensuring a substantially gas-tight seal with the inner face or faces of the chamber 21 when the piston 22 is moving in the chamber 21, and whereby the portion of the chamber 21 in which the piston 22 is movable in substantially gas tight way has a second cross section measured perpendicular to the said axis direction A, whereby said second cross section is greater than 1.1 times the first cross section, advantageously greater than 1.5 times the first cross section, preferably greater than 2 times the first cross section;
- optionally, but advantageously, a pre compression cylinder 3 comprising a hollow body 30 defining a chamber 31, and a piston 32 moving in said chamber 31 in a direction substantially perpendicular to the axis direction A or in a direction corresponding substantially to the axis direction A, whereby the said piston 32 is provided with means for ensuring a substantially gas-tight seal with the inner face or faces of the chamber 31 when the piston 32 is moving in the chamber 31, and whereby the portion of the chamber 31 in which the piston 32 is movable in substantially gas tight way has a third cross section measured perpendicular to the said axis direction A, whereby said second cross section is greater than 1.1 times the first cross section, advantageously greater than 1.5 times the first cross section, preferably 2 times the cross section, and
- connecting means for connecting the piston 11 of the reaction chamber 12 to the piston 22 of the counter compression cylinder 2, and for connecting the piston 32 of the pre compression cylinder 3 to the piston 22 of the counter compression and/or the piston 12 of the reaction chamber 12.

[0006] The reaction chamber is for example a catalytic chamber suitable for catalysing a reaction with a nitro containing compound, for example nitromethane. The reaction chamber can also be a chamber in which a solid or liquid is reacted with a gas or a liquid. The reaction chamber is however advantageously a combustion chamber.

[0007] More specifically, the invention relates to an actuator comprising :

- a combustion cylinder 1 with a hollow body 10 containing a piston 11, said piston 11 defining with said hollow body 10 a combustion chamber 12 adapted for burning at least a fuel in an oxygen containing gas, whereby said piston is movable in an axis direction A along the inner face or faces of the combustion chamber 12 in function of the pressure within the combustion chamber 12, whereby the said piston 11 is provided with means for ensuring a substantially gas-tight seal with the inner face or faces of the combustion chamber when the piston 11 is moving

in the combustion chamber, and whereby the portion of the combustion chamber 12 in which the piston 11 is movable in substantially gas tight way has a first cross section measured perpendicular to the said axis direction A ;

- a counter compression cylinder 2 comprising a hollow body 20 defining a chamber 21, and a piston 22 moving in said chamber 21 in a direction substantially perpendicular to the axis direction A or in a direction corresponding substantially to the axis direction A, whereby the said piston 22 is provided with means for ensuring a substantially gas-tight seal with the inner face or faces of the chamber 21 when the piston 22 is moving in the chamber 21, and whereby the portion of the chamber 21 in which the piston 22 is movable in substantially gas tight way has a second cross section measured perpendicular to the said axis direction A, whereby said second cross section is greater than 1.1 times the first cross section, advantageously greater than 1.5 times the first cross section, preferably greater than 2 times the first cross section;
- optionally, but advantageously, a pre compression cylinder 3 comprising a hollow body 30 defining a chamber 31, and a piston 32 moving in said chamber 31 in a direction substantially perpendicular to the axis direction A or in a direction corresponding substantially to the axis direction A, whereby the said piston 32 is provided with means for ensuring a substantially gas-tight seal with the inner face or faces of the chamber 31 when the piston 32 is moving in the chamber 31, and whereby the portion of the chamber 31 in which the piston 32 is movable in substantially gas tight way has a third cross section measured perpendicular to the said axis direction A, whereby said second cross section is greater than 1.1 times the first cross section, advantageously greater than 1.5 times the first cross section, preferably greater than 2 times the cross section (for example 3, 4, 5 times the first cross section), and
- connecting means for connecting the piston 11 of the combustion chamber 12 to the piston 22 of the counter compression cylinder 2, and for connecting the piston 32 of the pre compression cylinder 3 to the piston 22 of the counter compression and/or the piston 12 of the combustion chamber 12.

[0008] Advantageously, the reaction/combustion chamber 12 and the counter compression cylinder 2 are adapted the one with respect to the other, so that before a reaction/combustion phase in the reaction/combustion chamber 12, the combustion chamber 12 has a first minimal volume V1 and the counter compression cylinder 2 has a second minimal volume V2 with a ratio V1/V2 before combustion phase lower than 0.9, advantageously lower than 0.75, especially lower than 0.5, most advantageously lower than 0.35, preferably lower than 0.25.

[0009] According to an advantageous embodiment, the reaction/combustion chamber 12 and the pre compression cylinder 3 are adapted the one with respect to the other, so that before a combustion phase in the reaction/combustion chamber 12, the reaction/combustion chamber 12 has a first minimal volume V1 and the pre compression cylinder 3 has a third minimal volume V3 with a ratio V1/V3 before combustion phase lower than 0.9, advantageously lower than 0.75, especially lower than 0.5, advantageously lower than 0.35, preferably lower than 0.25.

[0010] According to further advantageous details of embodiments, the actuator comprises one or more of the following characteristics :

- the connecting means is a rod to which are attached the piston 11 of the reaction/combustion chamber 12, the piston 22 of the counter compression chamber, and the piston 32 of the pre reaction/combustion chamber, and/or
- the piston 22 of the counter chamber and the piston 32 of the pre reaction/combustion chamber form one single piston moving within a cylinder, whereby said single piston defines in said cylinder from one side, the chamber 21 of the counter compression cylinder 2, and from the opposite side, the chamber 31 of the pre compression chamber, and/or
- the counter compression cylinder 2 is adapted for the reaction/combustion of at least one reactant / fuel, and/or
- the reaction/combustion chamber and/or the counter compression cylinder is provided with one or more controlled fuel injectors, at least one means for filling the reaction/combustion chamber with oxygen containing gas at a pressure higher than 2 10^5 Pa, advantageously more than 5 10^5 Pa, preferably more than 10 10^5 Pa, one or more means for igniting a reaction/combustion, advantageously in the form of one or more preheaters (for example for preheating all the gas contained in the combustion chamber and/or counter compression chamber up to a temperature of 750°C, such as up to temperature comprised between 100°C and 600°C, advantageously between 200°C and 500°C) and/or one or more spark plugs optionally provided with a preheater, and one or more exhaust valves, and/or
- the combustion chamber and/or the counter compression cylinder 2 comprises one or more fast exhaust valves, and/or one or more slow exhaust valves. For example, the fast exhaust valve(s) are adapted when fully opened for reducing the pressure within the reaction/combustion chamber by at least 10 10^5 Pa, advantageously at least 20 10^5 Pa, preferably at least 50 10^5 Pa in a period corresponding to less than 0.2 times, advantageously less than 0.1 times, preferably less than 0.05 times the period required by the slow exhaust valves when fully opened for reducing the pressure within the reaction/combustion chamber by at least 10 10^5 Pa, advanta-

geously at least 20 10^5 Pa, preferably at least 50 10^5 Pa, with a pressure within the counter compression chamber higher than 50 10^5 Pa with its valves in closed position, and/or the fast exhaust valve(s) of the counter compression chamber 1 being adapted when fully opened for reducing the pressure within the counter compression chamber by at least 10 10^5 Pa, advantageously at least 20 10^5 Pa, preferably at least 50 10^5 Pa in a period corresponding to less than 0.2 times, advantageously less than 0.1 times, preferably less than 0.05 times the period required by the slow exhaust valves when fully opened for reducing the pressure within the counter compression chamber by at least 10 10^5 Pa, advantageously at least 20 10^5 Pa, preferably at least 50 10^5 Pa, with a pressure within the reaction/combustion chamber higher than 50 10^5 Pa with its valves in closed position.
and/or

- the reaction/combustion chamber and/or the counter compression cylinder 2 further comprises one or more temperature probes or sensors and one or more pressure probes or sensors (the sensors advantageously sent data to a control system or a computer system, said system controlling then the working of the injectors and/or the opening of one or more valves. Said sensors ensure then a feedback of the process, and enable then to better follow a pressure/force path applied to the element to be tested), and/or
- the actuator comprises a series of reaction/combustion cylinders placed in parallel or in series the one with respect to the other, each reaction/combustion cylinder 1 with a hollow body 10 containing a piston 11, said piston 11 defining with said hollow body 10 a reaction/combustion chamber 12 adapted for burning at least a fuel in an oxygen containing gas, whereby said piston is movable in an axis direction A along the inner face or faces of the reaction/combustion chamber 12 in function of the pressure within the combustion chamber 12, whereby the said piston 11 is provided with means for ensuring a substantially gas-tight seal with the inner face or faces of the reaction/combustion chamber when the piston 11 is moving in the reaction/combustion chamber, and whereby the portion of the reaction/combustion chamber 12 in which the piston 11 is movable in substantially gas tight way has a first cross section measured perpendicular to the said axis direction A, and/or
- the reaction/combustion cylinder is connected to or provided with one or more pre reaction/combustion chambers for igniting a reaction/combustion, said pre reaction/combustion chamber(s) being provided with (a) one or more controlled fuel injectors, (b) optionally at least one means for filling the reaction/combustion chamber with oxygen containing gas at a pressure higher than 2 10^5 Pa, advantageously more than 5 10^5 Pa, preferably more than 10 10^5 Pa, (c) one or more means for igniting a combustion, advantageously in the form of one or more preheaters and/or spark plugs optionally provided with a preheater, and (d) further optionally one or more exhaust valves, and/or
- the fuel injectors for the reaction/combustion chamber or a prechamber thereof is a piezzo injection valves, and/or
- the fuel injector(s) of the reaction/combustion chamber or pre reaction/combustion chamber is / are adapted for injecting fuel in the form of liquid, liquid spray, gas, vapour, and in the form of a mix fuel - oxygen containing gas, and/or
- the fuel injector(s) is/are associated to a preheater or cooler, for preheating or cooling the reactant / fuel or the mix fuel - oxygen containing gas to be injected, and/or
- the reaction/combustion chamber(s) has/have an envelope provided with means for controlling the temperature of the envelope, advantageously at least prior to a reaction/combustion phase, and/or
- the pre compression cylinder 3 is provided with filling means adapted to be connected to a gas source under pressure, one or more fast exhaust valves, and/or one or more slow exhaust valves. For example, the fast exhaust valve(s) are adapted when fully opened for reducing the pressure within the pre compression chamber by at least 2 10^5 Pa, advantageously at least 4 10^5 Pa, preferably at least 10 10^5 Pa in a period corresponding to less than 0.2 times, advantageously less than 0.1 times, preferably less than 0.05 times the period required by the slow exhaust valves when fully opened for reducing the pressure within the pre compression chamber by at least 2 10^5 Pa, advantageously at least 4 10^5 Pa, preferably at least 5 10^5 Pa, and/or
- the combustion cylinder and/or the counter compression cylinder has/have an envelope provided with means for controlling the temperature of the envelope, advantageously at least prior to a reaction/combustion phase, and/or

[0011] The actuator of the invention is advantageously associated to a control system or a computer system adapted to receive data from one or more sensors, advantageously pressure sensors and/or temperature sensors, said system being adapted for controlling the working of one or more injectors for following a pressure and/or force curve applied to the element to be tested. Said control system or computer system can also be adapted for controlling the filling valves of the various chambers, for enabling a progressive filling of the chambers, for example for enabling a filling of the chambers while remaining substantially at the initial state for the pistons within the cylinders. Moreover, the control system or computer system can be adapted for controlling the exhaust valves, so as to control the exhaust of gases from the various chambers, for example so as to achieve

at the end of the exhaust step a position of the pistons close or corresponding to the initial state.

[0012] The invention relates also to a testing device for an element, said device comprising an actuator according to the invention, the connecting means being provided with a means for linking the connecting means with the element to be tested at least for partial movement of the piston of the combustion cylinder, a system for measuring and/or determining at least partly the movement of the piston of the combustion chamber, and optionally a system for determining at least one parameter of the element to be tested at least during and/or after the element is submitted to the action of the connecting means.

Preferably the testing device is a non destructive testing device for the element to be tested, but enabling to determine the response(s) of at least one parameter of the element subjected to one or more forces during different time periods of less than 5 seconds, for example less than 3 seconds, advantageously less than 2.5 seconds, preferably for time periods comprised between 1 milliseconds and 1000 milliseconds (such as for time period of 1, 2, 5, 8, 10, 15, 20, 25, 50, 75, 100, 200, 250, 300, 400, 500, 600, 700, 750, 800, 900 and 1000 milliseconds), for one or more different displacements. By analysing said response(s), the destruction limit or the workability limit for said parameter(s) and thus of the element will be determined. In case, said determined destruction limit or workability limit is within a range considered as unsafe with respect the maximum theoretical destruction limit or workability limit, the element tested will not be considered as suitable for further use, while in case said determined destruction limit is away and below from the range considered as unsafe with respect the maximum theoretical destruction limit, the element tested will be considered as suitable for further use.

[0013] The invention further relates to a method for testing an element, by using a testing device according to the invention or a actuator according to the invention. Said method comprises at least the following steps :

- filling the reaction/combustion chamber of the reaction/combustion cylinder with a reacting gas or an oxygen containing gas so that said chamber contains a first volume of gas, the chamber of the counter compression with a gas so that said chamber contains a second volume of gas, and the chamber of the pre compression cylinder with a gas so that said chamber contains a third volume of gas, whereby at the equilibrium following the filling of said chambers,
- injecting into the reaction/combustion chamber of a determined amount of liquid or gaseous fuel ;
- igniting, if not immediate burning after injection, for example due to the heat or temperature within the chamber, the reaction/combustion of the fuel in the reaction/combustion chamber, so as to increase the pressure in said chamber, whereby generating a force and/or a movement of the connecting means, causing an action on the element to be tested, as well as an eventually movement of the piston of the counter compression cylinder for increasing the pressure into the chamber of said counter compression chamber ;
- optionally opening of one or more valves of the reaction/combustion chamber so as to reduce the pressure into said reaction/combustion chamber, whereby generating a force and/or a movement of the connecting means, causing or ending an action on the element to be tested, a movement of the piston of the counter compression cylinder for reducing the pressure into the chamber of said counter compression, and optionally a movement of the piston of the pre compression chamber for increasing the pressure in the chamber of said pre compression chamber.

[0014] According to an embodiment, reactant/fuel is injected after and/or during initiation of the reaction/combustion. This enables a better control of the pressure increase in the reaction/combustion chamber, and to exert increased pressure step by step on the element to be tested, before the back pressure and/or movement of the piston of the reaction/combustion chamber.

[0015] Advantageously, a liquid or gaseous fuel is injected in the counter compression cylinder, while said fuel is ignited for accelerating the return movement of the piston of the reaction/combustion cylinder by accelerating the exhaust of gases from the reaction/combustion cylinder.

Optionally, after the return movement or during the return movement of the piston of the reaction/combustion cylinder, one or more valves of the counter compression cylinder is/are opened for reducing the pressure in the chamber of the counter compression chamber.

[0016] According to an embodiment, the ratio second volume / first volume is greater than 4, while the pressure at equilibrium in the chambers of the reaction/combustion cylinder and the counter compression cylinder is greater than 10 10^5 Pa, advantageously greater than 15 10^5 Pa, preferably at least equal to about or greater than 20 10^5 Pa

[0017] According to a further advantageous embodiment, the envelope of the reaction/combustion chamber is heat controlled so that the temperature thereof is up to a temperature of 750°C, such as up to temperature comprised between 100°C and 600°C, advantageously between 200°C and 500°C.

[0018] According to a preferred method of the invention, the fuel is burned in an oxygen containing atmosphere comprising more than 30% volume oxygen, advantageously more than 50% volume oxygen, preferably more than 80% oxygen. For example the burning of the fuel is carried out in an atmosphere containing more than 90% volume oxygen, most preferably more than 95% volume oxygen, or even more such as more than 99% volume oxygen.

[0019] After a first reaction/combustion, the atmos-

phere can be cooled, whereby the pressure within the combustion chamber will drop. Said atmosphere can be further be used, possibly after exhaust of gases, for burning an additional quantity of fuel, for carrying a further testing.

[0020] The oxygen containing atmosphere consists thus essentially of O_2, CO, CO_2 and H_2O, and N_2 when using for example air or a nitro containing fuel.

[0021] In the method of the invention using a combustion as reaction, butane, pentane, hexane, isooctane, nitroalkane, for example with 1 to 8 carbon atoms or more, such as nitromethane, nitroethane, etc. and mixtures thereof are preferably used as fuel, possibly as mixture thereof. Pentane and/or iso octane and/or nitromethane or gas mixtures containing more than 75% volume pentane or isooctane or nitromethane or mixtures thereof are preferred.

[0022] Details and characteristics of the invention will appear from the following description, in which reference is made to the attached drawings.

[0023] In said drawings,

- figure 1 is a schematic view of a device of the invention in which the combustion chamber and the counter compression chamber are filled with oxygen;
- figure 2 is a view of the device of figure 1, after injecting a first quantity of pentane or isooctane or nitromethane or mixtures thereof in the combustion chamber and after the burning of said quantity ;
- figure 3 is a view of the device of figure 2, after injecting an additional quantity of pentane or isooctane or nitromethane or mixtures thereof in the combustion chamber and after the burning of said additional fuel quantity ;
- figure 4 is a view of the device of figure 3, after injecting a quantity of pentane or isooctane or nitromethane or mixtures thereof in the counter compression chamber and after burning of said quantity,
- figure 5 is a view of the device of figure 4, after injecting an further additional quantity of pentane or isooctane or nitromethane or mixtures thereof in the counter combustion chamber and after the burning of said further additional fuel quantity; and
- figure 6 is a view of the device of figure 5, after opening of all exhaust valves, and.

[0024] The device of figure 1 is an actuator comprising :

- a combustion cylinder 1 with a hollow body 10 containing a piston 11, said piston 11 defining with said hollow body 10 a combustion chamber 12 adapted for burning at least a fuel in an oxygen containing gas, whereby said piston is movable in an axis direction A along the inner face or faces of the combustion chamber 12 in function of the pressure within the combustion chamber 12, whereby the said piston 11 is provided with means for ensuring a substantially gas-tight seal with the inner face or faces of the combustion chamber when the piston 11 is moving in the combustion chamber, and whereby the portion of the combustion chamber 12 in which the piston 11 is movable in substantially gas tight way has a first cross section measured perpendicular to the said axis direction A ;
- a counter compression cylinder 2 comprising a hollow body 20 defining a chamber 21, and a piston 22 moving in said chamber 21 in a direction substantially perpendicular to the axis direction A or in a direction corresponding substantially to the axis direction A, whereby the said piston 22 is provided with means for ensuring a substantially gas-tight seal with the inner face or faces of the chamber 21 when the piston 22 is moving in the chamber 21, and whereby the portion of the chamber 21 in which the piston 22 is movable in substantially gas tight way has a second cross section measured perpendicular to the said axis direction A, whereby said second cross section is greater than 1.1 times the first cross section, advantageously greater than 1.5 times the first cross section, preferably greater than 2 times the first cross section ;
- a pre compression cylinder 3 comprising a hollow body 30 defining a chamber 31, and a piston (22 = 32) moving in said chamber 31 in a direction substantially perpendicular to the axis direction A or in a direction corresponding substantially to the axis direction A, whereby the said piston 32 is provided with means for ensuring a substantially gas-tight seal with the inner face or faces of the chamber 31 when the piston 32 is moving in the chamber 31, and whereby the portion of the chamber 31 in which the piston 32 is movable in substantially gas tight way has a third cross section measured perpendicular to the said axis direction A, whereby said second cross section is greater than 1.1 times the first cross section, advantageously greater than 1.5 times the first cross section, preferably greater than 2 times the first cross section, and
- connecting means (1a, 2a) for connecting the piston 11 of the combustion chamber 12 to the piston 22 of the counter compression cylinder 2, and for connecting the piston 32 of the pre compression cylinder 3 to the piston 22 of the counter compression and/or the piston 12 of the combustion chamber 12.

[0025] The combustion chamber 12 and the counter compression cylinder 2 are adapted the one with respect to the other, so that before a combustion phase in the combustion chamber 12, the combustion chamber 12 has a first minimal volume V1 and the counter compression cylinder 2 has a second minimal volume V2 with a ratio V1/V2 before combustion phase lower than 0.9, for example a ratio V1/V2 of 0.9, 0.8, 0.7, 0.6, 0.5, etc. Said ratio is measured after filling the combustion chamber and the counter compression cylinder with oxygen con-

taining gas at a same pressure, for example 20 10^5 Pa, while the pre compression chamber is filled with a gas at a pressure lower than the pressure of the gas in the combustion chamber, for example at 10 10^5 Pa.

[0026] The combustion chamber 12 and the pre compression cylinder 3 are adapted the one with respect to the other, so that before a combustion phase in the combustion chamber 12, the combustion chamber 12 has a first minimal volume V1 and the pre compression cylinder 3 has a third minimal volume V3 with a ratio V1/V3 before combustion phase lower than 0.9, advantageously lower than 0.75, especially lower than 0.5, advantageously lower than 0.35, preferably lower than 0.25.

[0027] The connecting means 1a, 2a is one common rod to which are attached the piston 11 of the combustion chamber 12, the piston 22 of the counter compression chamber, and the piston 32 of the pre compression chamber.

[0028] The piston 22 of the counter chamber 2 and the piston 32 of the pre compression chamber form one single piston 22,32 moving within one common cylinder 20,30, whereby said single piston 22,32 defines in said cylinder from one side, the chamber 21 of the counter compression cylinder 2, and from the opposite side, the chamber 31 of the pre compression chamber. The piston 22,32 is provided with a gas tight seal.

[0029] The counter compression cylinder 2 is adapted for the combustion of at least one fuel.

[0030] The combustion chamber and/or the counter compression cylinder is provided with one or more controlled fuel injectors 1.b (fuel supplied from a fuel tank 1.f with interposition of one or more high pressure pumps, for example one pumps per injector), at least one means 1.c for filling the combustion chamber 12 with oxygen containing gas at a pressure for example of 20 10^5 Pa, one or more means 1.g for igniting a combustion, advantageously in the form of one or more spark plugs optionally provided with a preheater, and one or more exhaust valves1.d, 1.e. The igniting of the combustion can be immediate after the injection, for example due to the heat or temperature within the chamber

[0031] The combustion chamber 12 and the counter compression cylinder 21 comprises optionally one or more fast exhaust valves (1.d 2.e) and one or more slow exhaust valves (1.e, 2.n). For example, the fast exhaust valve(s) (1.d) being adapted when fully opened for reducing the pressure within the combustion chamber 12 by at least 10 10^5 Pa, advantageously at least 20 10^5 Pa, preferably at least 50 10^5 Pa in a period corresponding to less than 0.2 times, advantageously less than 0.1 times, preferably less than 0.05 times the period required by the slow exhaust valves(1.e) when fully opened for reducing the pressure within the combustion chamber by at least 10 10^5 Pa, advantageously at least 20 10^5 Pa, preferably at least 50 10^5 Pa with a pressure within the counter compression chamber higher than 50 10^5 Pa with its valves in closed position, while the fast exhaust valve (s) of the counter compression chamber 21 is/are adapted when fully opened for reducing the pressure within the counter compression chamber by at least 10 10^5 Pa, advantageously at least 20 10^5 Pa, preferably at least 50 10^5 Pa in a period corresponding to less than 0.2 times, advantageously less than 0.1 times, preferably less than 0.05 times the period required by the slow exhaust valves when fully opened for reducing the pressure within the counter compression chamber by at least 10 10^5 Pa, advantageously at least 20 10^5 Pa, preferably at least 50 10^5 Pa, with a pressure within the combustion chamber higher than 50 10^5 Pa with its valves in closed position.

[0032] The combustion chamber 1 and/or the counter compression cylinder 2 further comprises one or more temperature probes or sensors 1.h 2.i and one or more pressure probes or sensors 1.i, 2.j.

[0033] The actuator can possibly comprise a series of combustion cylinders placed in parallel or in series the one with respect to the other, each combustion cylinder 1 with a hollow body 10 containing a piston 11, said piston 11 defining with said hollow body 10 a combustion chamber 12 adapted for burning at least a fuel in an oxygen containing gas, whereby said piston is movable in an axis direction A along the inner face or faces of the combustion chamber 12 in function of the pressure within the combustion chamber 12, whereby the said piston 11 is provided with means for ensuring a substantially gas-tight seal with the inner face or faces of the combustion chamber when the piston 11 is moving in the combustion chamber, and whereby the portion of the combustion chamber 12 in which the piston 11 is movable in substantially gas tight way has a first cross section measured perpendicular to the said axis direction A.

[0034] The combustion cylinder 1 can also possibly be connected to or provided with one or more precombustion chambers for igniting a combustion, said prechamber (s) being provided with (a) one or more controlled fuel injectors, (b) optionally at least one means for filling the combustion chamber with oxygen containing gas at a pressure higher than 10 10^5 Pa, (c) one or more means for igniting a combustion, advantageously in the form of one or more spark plugs optionally provided with a preheater, and (d) further optionally one or more exhaust valves. The igniting of the fuel can also be immediate after the injection within the chamber, for example due to the heat or temperature within the chamber.

[0035] The fuel injectors 1.b,2.b for the combustion chamber or a prechamber thereof or for the counter compression cylinder 2 are advantageously piezzo injection valves connected to the reservoirs 1.f, 2.g via one or more high pressure pumps.

[0036] Said fuel injector(s) of the combustion chamber or precombustion chamber and/or counter compression cylinder is / are adapted for injecting fuel in the form of liquid, liquid spray, gas, vapour, and in the form of a mix fuel - oxygen containing gas.

[0037] The fuel injector(s) is/are advantageously associated to a preheater or cooler, for preheating or cooling the fuel or the mix fuel - oxygen containing gas to be

injected.

[0038] The combustion chamber(s) 1 has/have an envelope 15 provided with means for controlling the temperature of the envelope, advantageously at least prior to a combustion phase. Said envelope 15 is for example adapted for the flow of at least one liquid medium, such as a cooling or preheating medium. Said medium is up to a temperature of 750°C, such as up to temperature comprised between 100°C and 600°C, advantageously between 200°C and 500°C.

[0039] The pre compression cylinder 3 is provided with filling means 2.1 adapted to be connected to a gas source under pressure, one or more fast exhaust valves 2.m, and/or one or more slow exhaust valves 2.n. for example, the fast exhaust valve(s) 2.m are adapted when fully opened for reducing the pressure within the pre compression chamber by at least 2 10^5 Pa, advantageously at least 4 10^5 Pa, preferably at least 10 10^5 Pa in a period corresponding to less than 0.2 times, advantageously less than 0.1 times, preferably less than 0.05 times the period required by the slow exhaust valves 2.n when fully opened for reducing the pressure within the combustion chamber by at least 2 10^5 Pa, advantageously at least 4 10^5 Pa, preferably at least 10 10^5 Pa. The pre compression cylinder can be filled with any type of gas, such as air, nitrogen oxygen, etc.

[0040] The counter compression cylinder 2 has an envelope 25 provided with means for controlling the temperature of the envelope, advantageously at least prior to a combustion phase. Said envelope 25 is for example adapted for the flow of at least one liquid medium, such as a cooling or preheating medium. Said medium is up to a temperature of 750°C, such as up to temperature comprised between 100°C and 600°C, advantageously between 200°C and 500°C.

[0041] More preferably the temperature of the envelope 25 is maintained at a temperature substantially equal to the temperature of the envelope 15.

[0042] The connecting means or rod 1.a, 2.a is provided with a means 3.a for linking the connecting means 1.a, 2.a with the element to be tested at least for partial movement of the piston 11 of the combustion cylinder 1. A system 3.b measures and/or determines at least partly the movement of the piston 11 of the combustion chamber The means 3.a can optionally be provided with a system for determining at least one parameter of the element to be tested at least during and/or after the element is submitted to the action of the connecting means, for example a pressure sensor.

[0043] A method for testing an element, by using a testing device according to figure 1 will now be described. Said method comprises for example the following steps :

- filling the combustion chamber 12 of the combustion cylinder with an oxygen containing gas (for example substantially pure oxygen) so that said chamber 12 contains a first volume of gas (pressure of 20 10^5 Pa) , the chamber 21 of the counter compression cylinder 2 with a gas(for example oxygen) so that said chamber 21 contains a second volume of gas V2 (pressure of 20 10^5 Pa), and the chamber 31 of the pre compression cylinder 3 with a gas so that said chamber 31 contains a third volume of gas (for example oxygen or air with a pressure of 20 10^5 Pa). The filling of the chambers 12, 21 and 31 is advantageously progressive and/or simultaneous, so that the device / pistons remain substantially at the equilibrium position in their respective chamber. For example, at the equilibrium following the filling of said chambers, the ratio second volume V2 / first volume V1 is greater than 2, even 3 or 4 or 5 or more. (see figure 1) Possibly, one or more means are used for blocking the rod 1.a, 2.a during the filling operation. This is advantageous for safety purpose during the filling operation of the chamber with gas.
- injecting into the combustion chamber 12 a determined amount of liquid or gaseous fuel, namely of pentane or isooctane or nitromethane or mixtures thereof;
- igniting the combustion of the fuel in the combustion chamber 12, so as to increase the pressure in said chamber 12 to about 100 10^5 Pa, whereby generating a force and/or a movement of the connecting means or rod 1.a,2.a, causing an action or force F on the element to be tested, as well as a movement of the piston of the counter compression cylinder 2 for increasing the pressure into the chamber 21 of said counter compression cylinder 2 (see figure 2) The pressure in said counter compression chamber 20 is increased to about 23 10^5 Pa, while the pressure of the chamber 31 is decreased to 9 10^5 Pa. Possibly, the pressure into the chamber 31 can be maintained to the initial pressure of 10 10^5 Pa.

When the ignition is generated due to the preheating of the oxygen containing gas in which the fuel is injected, the auto ignition of fuel is carried out at the injection step, as the fuel as soon as injected is burned.

- optionally waiting a time sufficient for adapting one or more parameters of the process and/or for determining one or more parameters of the process, for example for controlling the pressure and/or the movement;
- injecting into the combustion chamber 12 a further determined amount of liquid or gaseous fuel, namely of pentane or isooctane or nitromethane or mixtures thereof;
- igniting the combustion of the fuel in the combustion chamber 12, so as to increase the pressure in said chamber 12 to about 200 10^5 Pa, whereby generating a further movement of the connecting means or rod 1.a,2.a, causing a further action or force F on the element to be tested, as well as a movement of the piston of the counter compression cylinder 2 for increasing the pressure into the chamber 21 of said

counter compression cylinder 2 (see figure 3) The pressure in said counter compression chamber 20 is increased to about 27 10^5 Pa, while the pressure of the chamber 31 is decreased to 8 10^5 Pa. Possibly, the pressure into the chamber 31 can be maintained to the initial pressure of 10 10^5 Pa.

When the ignition is generated due to the preheating of the oxygen containing gas in which the fuel is injected, the auto ignition of fuel is carried out at the injection step, as the fuel as soon as injected is burned.

- optionally waiting a time sufficient for adapting one or more parameters of the process and/or for determining one or more parameters of the process, for example for controlling the pressure and/or the movement;
- injecting in the counter compression chamber 21 of a determined amount of pentane or isooctane or nitromethane or mixtures thereof, as well as optionally injecting into the combustion chamber 12 of a further determined amount of liquid or gaseous fuel, namely of pentane or isooctane or nitromethane or mixtures thereof;
- igniting the fuel(pentane or isooctane or nitromethane or mixtures thereof) in the counter compression chamber 21, as well as optionally the fuel in the combustion chamber 12, so as to increase the pressure in said chamber 12 to about 250 10^5 Pa and in the counter compression chamber to a pressure of about 98 10^5 Pa, whereby generating a movement of the connecting means or rod 1.a,2.a, causing a decrease of the action or force F on the element to be tested, as well as a movement of the piston of the counter compression cylinder 2 for reducing the volume thereof V1, while increasing the volume V2 of the counter compression chamber 21 (see figure 4) The pressure in said counter compression chamber 20 is increased to about 98 10^5 Pa, while the pressure of the chamber 31 is increased to 9 10^5 Pa. Possibly, the pressure into the chamber 31 can be maintained to the initial pressure of 10 10^5 Pa. When the ignition is generated due to the preheating of the oxygen containing gas in which the fuel is injected, the ignition of fuel is carried out at the injection step, as the fuel as soon as injected is burned.
- optionally waiting a time sufficient for adapting one or more parameters of the process and/or for determining one or more parameters of the process, for example for controlling the pressure and/or the movement;
- injecting into the combustion chamber 12 of a still further determined amount of liquid or gaseous fuel, namely of pentane or isooctane or nitromethane or mixtures thereof, as well as injecting in the counter compression chamber 21 of a further determined amount of pentane or isooctane or nitromethane or mixtures thereof;
- igniting the combustion of the fuel in the combustion chamber 12, as well as in the counter compression chamber 21, so as to increase the pressure in said chamber 12 to about 300 10^5 Pa and in the counter compression chamber to a pressure of about 160 10^5 Pa, whereby generating a force and/or movement of the connecting means or rod 1.a,2.a, causing a decrease of the action or force F on the element to be tested, as well as a movement of the piston of the counter compression cylinder 2 for reducing the volume thereof V1, while increasing the volume V2 of the counter compression chamber 21 (see figure 5) The pressure in said counter compression chamber 20 is increased to about 160 10^5 Pa, while the pressure of the chamber 31 is increased to 10 10^5 Pa. When the ignition is generated due to the preheating of the oxygen containing gas in which the fuel is injected, the auto ignition of fuel is carried out at the injection step, as the fuel as soon as injected is burned.
- optionally waiting a time sufficient for adapting one or more parameters of the process and/or for determining one or more parameters of the process, for example for controlling the pressure and/or the movement;
- optionally, but advantageously one or more cooling system for the injectors, preferably for avoiding vaporization of the fuel within the injectors, but possibly well in the chamber (combustion or counter compression);
- optionally opening of one or more valves 1.d, 2.m, 2.e (but preferably opening first of the valves 1.e, 2.n and 2.f) of the various chambers so as to reduce the pressure into said chambers, whereby at least, ending an action on the element to be tested, a movement of the piston of the counter compression cylinder for reducing the pressure into the chamber of said counter compression, and a movement of the piston of the pre compression chamber for increasing the pressure in the chamber of said pre compression chamber. Advantageously, the valves are open in a way for ensuring substantially no movement of the rod and pistons in the chambers.

[0044] In said figures, P1 is the pressure within the combustion chamber in bars (1 bar = 10^5 Pa), P2a is the pressure in the counter compression chamber, P2b is the pressure in the pre compression chamber, and the force expressed in kN is represented in dashed lines.

[0045] By adapting the quantity of fuel (pentane or isooctane or nitromethane or mixtures thereof) injected in the chambers 12 and 21, as well by adapting the ignition time, it is possible to follow several pressure paths and force paths, in conjonction with eventually different movement.

[0046] In said figures, the pressure and force are given for the various steps 1/6 to 6/6.

[0047] In said figures, a method comprising two for-

ward movement steps or two increasing forces followed by two back pressure and/or movement steps is shown. However, it is obvious that the device of the invention enables various methods comprising successive forward movement steps (3, 4, or more, 10, 20, etc.) of the rod, followed by successive back pressure and/or movement steps of the rod (for example, 3, 5, 10 or even more). Moreover between a first series of successive forward movement steps of the rod and a second series of successive forward movement steps of the rod, there can be one or more back pressure and/or movement steps of the rod. On the same way, between a first series of successive back pressure and/or movement steps of the rod and a second series of successive back pressure and/or movement steps of the rod, there can be one or more forward movement steps of the rod. The movements (back, forward) are controlled by the injection of fuel with the chambers 12 and 21.

As the injection steps with ignition step can be carried out substantially the one after the other, the general movement of the rod 1.a, 2.a is continuous or substantially continuous.

[0048] The injector(s) are advantageously piezzo injection nozzles, such as the injectors used in diesel common rails, or magnetic injectors, with continuous, substantially continuous working, and/or with pulsed working or intermittent working. When more than one injector is used, the injectors can be the same or different, advantageously different, for example one for injecting large fuel quantity or one specific fuel, and another for injecting smaller quantity of fuel or one different fuel or fuel mixture. The injectors can be connected to one or more pumps, for example pumps suitable for increasing the pressure of the injection above 300 10^5 Pa, for example 500 10^5 Pa, 1000 10^5 Pa, 1500 10^5 Pa, 2000 10^5 Pa.

[0049] The injector(s) are advantageously suitable for injecting the quantity of fuel in less than 0.01 second, advantageously less than 0.005 second, for example less than 0.002 second, such as 0.001 second, 0.0005 second or even less.

[0050] The device of the invention enables to have for testing purposes huge instantaneous power or force or speed of movement, even if only very low quantity of fuel is used.

[0051] The device enables to test complete cycles, comprising a path of increased pressure and a path with lowering pressure.

Claims

1. An actuator comprising :

- a first reaction cylinder 1 with a hollow body 10 containing a piston 11, said piston 11 defining with said hollow body 10 a reaction chamber 12 adapted for the reaction of at least one first (advantageously gaseous) component with a second component (advantageously gaseous or liquid of in the form of a vapour or droplets), said reaction generating heat and/or gases, whereby said piston is movable in an axis direction A along the inner face or faces of the reaction chamber 12 in function of the pressure within the reaction chamber 12, whereby the said piston 11 is provided with means for ensuring a substantially gas-tight seal with the inner face or faces of the reaction chamber when the piston 11 is moving in the reaction chamber, and whereby the portion of the reaction chamber 12 in which the piston 11 is movable in substantially gas tight way has a first cross section measured perpendicular to the said axis direction A ;
- a counter compression cylinder 2 comprising a hollow body 20 defining a chamber 21, and a piston 22 moving in said chamber 21 in a direction substantially perpendicular to the axis direction A or in a direction corresponding substantially to the axis direction A, whereby the said piston 22 is provided with means for ensuring a substantially gas-tight seal with the inner face or faces of the chamber 21 when the piston 22 is moving in the chamber 21, and whereby the portion of the chamber 21 in which the piston 22 is movable in substantially gas tight way has a second cross section measured perpendicular to the said axis direction A, whereby said second cross section is greater than 1.1 times the first cross section, advantageously greater than 1.5 times the first cross section, preferably greater than 2 times the first cross section;
- optionally, but advantageously, a pre compression cylinder 3 comprising a hollow body 30 defining a chamber 31, and a piston 32 moving in said chamber 31 in a direction substantially perpendicular to the axis direction A or in a direction corresponding substantially to the axis direction A, whereby the said piston 32 is provided with means for ensuring a substantially gas-tight seal with the inner face or faces of the chamber 31 when the piston 32 is moving in the chamber 31, and whereby the portion of the chamber 31 in which the piston 32 is movable in substantially gas tight way has a third cross section measured perpendicular to the said axis direction A, whereby said second cross section is greater than 1.1 times the first cross section, advantageously greater than 1.5 times the first cross section, preferably greater or equal 2 times the cross section, and
- connecting means for connecting the piston 11 of the reaction chamber 12 to the piston 22 of the counter compression cylinder 2, and for connecting the piston 32 of the pre compression cylinder 3 to the piston 22 of the counter compression and/or the piston 12 of the reaction chamber

12.

2. The actuator of claim 1 comprising :

- a combustion cylinder 1 with a hollow body 10 containing a piston 11, said piston 11 defining with said hollow body 10 a combustion chamber 12 adapted for burning at least a fuel in an oxygen containing gas, whereby said piston is movable in an axis direction A along the inner face or faces of the combustion chamber 12 in function of the pressure within the combustion chamber 12, whereby the said piston 11 is provided with means for ensuring a substantially gas-tight seal with the inner face or faces of the combustion chamber when the piston 11 is moving in the combustion chamber, and whereby the portion of the combustion chamber 12 in which the piston 11 is movable in substantially gas tight way has a first cross section measured perpendicular to the said axis direction A ;
- a counter compression cylinder 2 comprising a hollow body 20 defining a chamber 21, and a piston 22 moving in said chamber 21 in a direction substantially perpendicular to the axis direction A or in a direction corresponding substantially to the axis direction A, whereby the said piston 22 is provided with means for ensuring a substantially gas-tight seal with the inner face or faces of the chamber 21 when the piston 22 is moving in the chamber 21, and whereby the portion of the chamber 21 in which the piston 22 is movable in substantially gas tight way has a second cross section measured perpendicular to the said axis direction A, whereby said second cross section is greater than 1.1 times the first cross section, advantageously greater than 1.5 times the first cross section, preferably greater than or equal to 2 times the first cross section;
- optionally, but advantageously, a pre compression cylinder 3 comprising a hollow body 30 defining a chamber 31, and a piston 32 moving in said chamber 31 in a direction substantially perpendicular to the axis direction A or in a direction corresponding substantially to the axis direction A, whereby the said piston 32 is provided with means for ensuring a substantially gas-tight seal with the inner face or faces of the chamber 31 when the piston 32 is moving in the chamber 31, and whereby the portion of the chamber 31 in which the piston 32 is movable in substantially gas tight way has a third cross section measured perpendicular to the said axis direction A, whereby said second cross section is greater than 1.1 times the first cross section, advantageously greater than 1.5 times the first cross section, preferably greater than 2 times the first cross section, and
- connecting means for connecting the piston 11 of the combustion chamber 12 to the piston 22 of the counter compression cylinder 2, and for connecting the piston 32 of the pre compression cylinder 3 to the piston 22 of the counter compression and/or the piston 12 of the combustion chamber 12.

3. The actuator of claim 1 or 2, in which the reaction/combustion chamber 12 and the counter compression cylinder 2 are adapted the one with respect to the other, so that before a reaction/combustion phase in the reaction/combustion chamber 12, the combustion chamber 12 has a first minimal volume V1 and the counter compression cylinder 2 has a second minimal volume V2 with a ratio V1/V2 before combustion phase lower than 0.9, advantageously lower than 0.75, especially lower than 0.5, advantageously lower than 0.35, preferably lower than 0.25.

4. The actuator of any one of the claims 1 to 3, in which the reaction/combustion chamber 12 and the pre compression cylinder 3 are adapted the one with respect to the other, so that before a reaction/combustion phase in the combustion chamber 12, the reaction/combustion chamber 12 has a first minimal volume V1 and the pre compression cylinder 3 has a third minimal volume V3 with a ratio V1/V3 before combustion phase lower than 0.9, advantageously lower than 0.75, especially lower than 0.5, advantageously lower than 0.35, preferably lower than 0.25.

5. The actuator of any one of claims 1 to 4, in which the connecting means is a rod to which are attached the piston 11 of the reaction/combustion chamber 12, the piston 22 of the counter compression chamber, and the piston 32 of the pre compression chamber, the piston 22 of the counter chamber and the piston 32 of the precombustion chamber form one single piston moving advantageously within a cylinder, whereby said single piston defines in said cylinder from one side, the chamber 21 of the counter compression cylinder 2, and from the opposite side, the chamber 31 of the pre compression chamber.

6. The actuator of any one of the preceding claims, in which the counter compression cylinder 2 is adapted for the reaction/combustion of at least one reactive/fuel.

7. The actuator of any one of the claims 1 to 6, in which the reaction/combustion chamber and/or the counter compression cylinder is provided with one or more controlled fuel injectors, at least one means for filling the reaction/combustion chamber with oxygen containing gas at a pressure higher than $2\ 10^5$ Pa, advantageously more than $5\ 10^5$ Pa, preferably more than $10\ 10^5$ Pa, one or more means for igniting a

reaction/combustion, advantageously in the form of one or more preheaters and/or spark plugs optionally provided with a preheater, and one or more exhaust valves.

8. The actuator of claim 7, in which the reaction/combustion chamber and/or the counter compression cylinder 2 comprises one or more fast exhaust valves, and/or one or more slow exhaust valves. For example, the fast exhaust valve(s) of the reaction/combustion chamber 1 are adapted when fully opened for reducing the pressure within the combustion chamber by at least 10 10^5 Pa, advantageously at least 20 10^5 Pa, preferably at least 50 10^5 Pa in a period corresponding to less than 0.2 times, advantageously less than 0.1 times, preferably less than 0.05 times the period required by the slow exhaust valves when fully opened for reducing the pressure within the reaction/combustion chamber by at least 10 10^5 Pa, advantageously at least 20 10^5 Pa, preferably at least 50 10^5 Pa, with a pressure within the counter compression chamber higher than 50 10^5 Pa with its valves in closed position, and/or the fast exhaust valve(s) of the counter compression chamber 1 being adapted when fully opened for reducing the pressure within the counter compression chamber by at least 10 10^5 Pa, advantageously at least 20 10^5 Pa, preferably at least 50 10^5 Pa in a period corresponding to less than 0.2 times, advantageously less than 0.1 times, preferably less than 0.05 times the period required by the slow exhaust valves when fully opened for reducing the pressure within the counter compression chamber by at least 10 10^5 Pa, advantageously at least 20 10^5 Pa, preferably at least 50 10^5 Pa, with a pressure within the reaction/combustion chamber higher than 50 10^5 Pa with its valves in closed position.

9. The actuator of any one of the preceding claims, which comprises a series of reaction/combustion cylinders placed in parallel or in series the one with respect to the other, each reaction/combustion cylinder 1 with a hollow body 10 containing a piston 11, said piston 11 defining with said hollow body 10 a reaction/combustion chamber 12 adapted for burning at least a fuel in an oxygen containing gas, whereby said piston is movable in an axis direction A along the inner face or faces of the reaction/combustion chamber 12 in function of the pressure within the reaction/combustion chamber 12, whereby the said piston 11 is provided with means for ensuring a substantially gas-tight seal with the inner face or faces of the combustion chamber when the piston 11 is moving in the reaction/combustion chamber, and whereby the portion of the reaction/combustion chamber 12 in which the piston 11 is movable in substantially gas tight way has a first cross section measured perpendicular to the said axis direction A.

10. The actuator of any one of the preceding claim, in which the reaction/combustion cylinder is connected to or provided with one or more pre reaction/combustion chambers for igniting a combustion, said prechamber(s) being provided with (a) one or more controlled fuel injectors, (b) optionally at least one means for filling the reaction/combustion chamber with oxygen containing gas at a pressure higher than 2 10^5 Pa, advantageously more than 5 10^5 Pa, preferably more than 10 10^5 Pa, (c) one or more means for igniting a reaction/combustion, advantageously in the form of one or more spark plugs optionally provided with a preheater, and (d) further optionally one or more exhaust valves.

11. The actuator of any one of the preceding claims, in which the reactant(s)/fuel injectors for the reaction/combustion chamber or a prechamber thereof is a piezzo injection valves.

12. The actuator of any one of the preceding claims, in which the pre compression cylinder 3 is provided with filling means adapted to be connected to a gas source under pressure, one or more fast exhaust valves, and/or one or more slow exhaust valves, the fast exhaust valve(s) being advantageously adapted when fully opened for reducing the pressure within the reaction/combustion chamber by at least 2 10^5 Pa, advantageously at least 4 10^5 Pa, preferably at least 10 10^5 Pa in a period corresponding to less than 0.2 times, advantageously less than 0.1 times, preferably less than 0.05 times the period required by the slow exhaust valves when fully opened for reducing the pressure within the reaction/combustion chamber by at least 2 10^5 Pa, advantageously at least 4 10^5 Pa, preferably at least 5 10^5 Pa.

13. The actuator of any one of the preceding claims, which is associated to a control system or a computer system adapted to receive data from one or more sensors, advantageously pressure sensors and/or temperature sensors, said system being advantageously adapted for controlling the working of one or more injectors for following a pressure and/or force curve applied to the element to be tested.

14. Testing device for an element, said device comprising an actuator according to any one of the preceding claims, the connecting means being provided with a means for linking the connecting means with the element to be tested at least for partial movement of the piston of the reaction/combustion cylinder or partial force exerted by said reaction/combustion chamber, a system for measuring and/or determining at least partly the movement of the piston of the reaction/combustion chamber, and optionally a system for determining at least one parameter of the element to be tested at least during and/or after the element

is submitted to the action of the connecting means.

15. Method for testing an element, by using a testing device according to the preceding claim, comprising at least the following steps :

- filling the reaction/combustion chamber of the reaction/combustion cylinder with an oxygen containing gas so that said chamber contains a first volume of gas, the chamber of the counter compression with a gas so that said chamber contains a second volume of gas, and optionally, but advantageously the chamber of the pre compression cylinder with a gas so that said chamber contains a third volume of gas, whereby at the equilibrium following the filling of said chambers,
- injecting into the reaction/combustion chamber of a determined amount of liquid or gaseous reactant/fuel ;
- igniting, if not being immediate following the injection step, the combustion of the fuel in the reaction/combustion chamber, so as to increase the pressure in said chamber, whereby generating a movement of the connecting means, causing an action on the element to be tested, as well as optionally a movement of the piston of the counter compression cylinder for increasing the pressure into the chamber of said counter compression chamber; and
- optionally opening of one or more valves of the reaction/combustion chamber so as to reduce the pressure into said reaction/combustion chamber, whereby at least ending an action on the element to be tested, a movement of the piston of the counter compression cylinder for reducing the pressure into the chamber of said counter compression, and optionally a movement of the piston of the pre compression chamber for increasing the pressure in the chamber of said pre compression chamber.

STEP 1/6

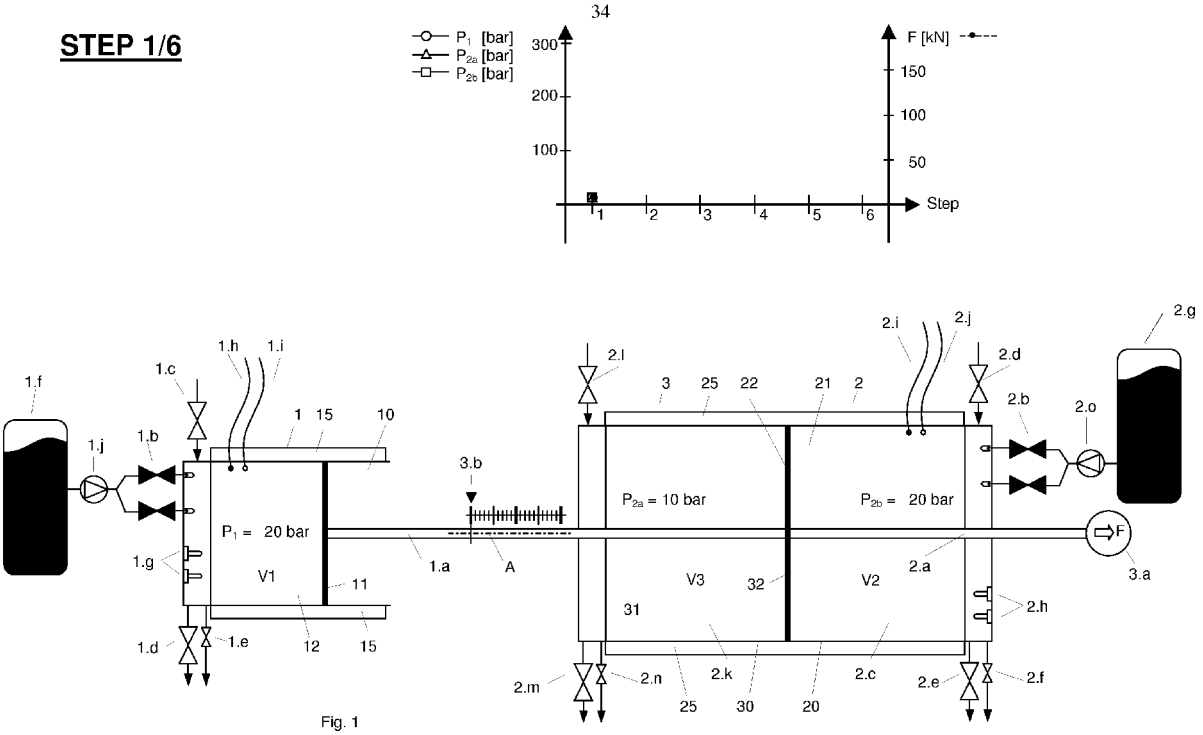

34
P1 [bar]
P2a [bar]
P2b [bar]
300
200
100
F [kN]
150
100
50
1
2
3
4
5
6
Step
1.f
1.j
1.b
1.c
1.h
1.i
1
15
10
1.g
P1 = 20 bar
V1
11
1.d
1.e
12
15
3.b
1.a
A
2.l
3
25
22
21
2
2.i
2.j
2.d
2.b
2.o
2.g
P2a = 10 bar
P2b = 20 bar
F
3.a
2.a
V3
32
V2
31
2.h
2.m
2.n
2.k
2.c
2.e
2.f
25
30
20

Fig. 1

STEP 2/6

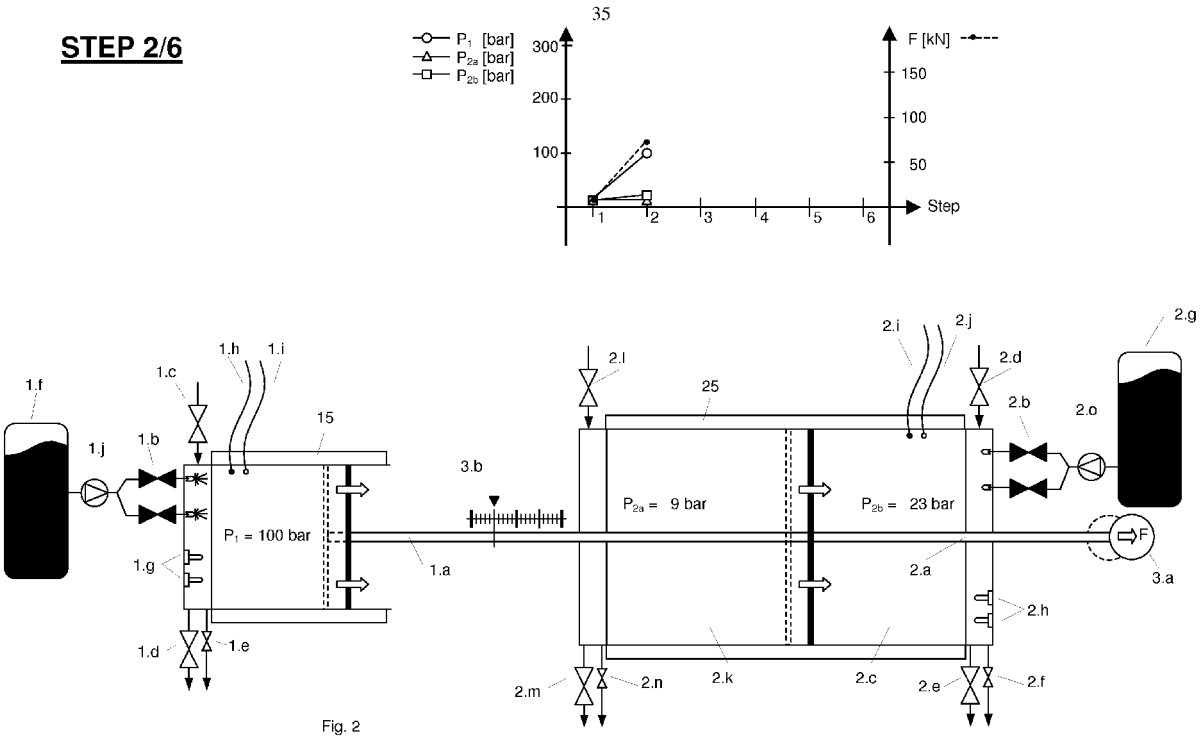

35
P1 [bar]
P2a [bar]
P2b [bar]
300
200
100
F [kN]
150
100
50
Step
1
2
3
4
5
6
1.f
1.j
1.b
1.c
1.h
1.i
15
1.g
1.d
1.e
P1 = 100 bar
3.b
1.a
2.l
25
P2a = 9 bar
P2b = 23 bar
2.i
2.j
2.d
2.b
2.o
2.g
F
3.a
2.a
2.h
2.m
2.n
2.k
2.c
2.e
2.f

Fig. 2

STEP 3/6

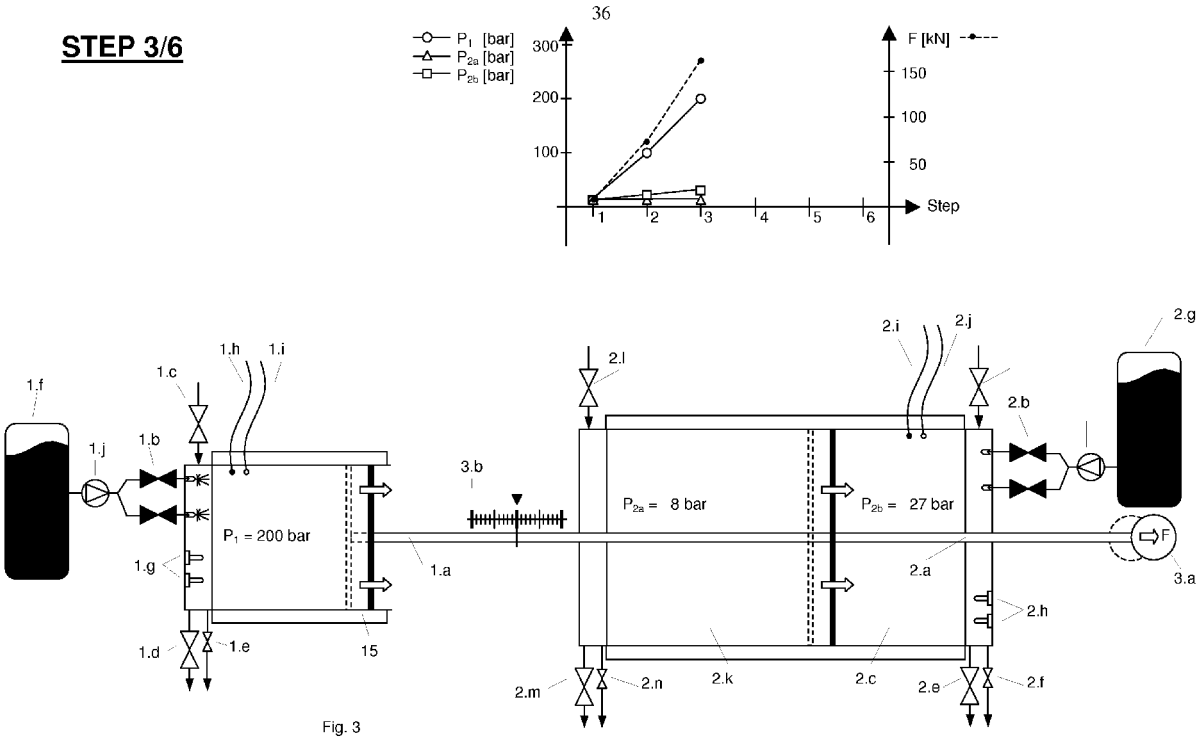

36
P1 [bar]
P2a [bar]
P2b [bar]
300
200
100
F [kN]
150
100
50
Step
1
2
3
4
5
6
1.f
1.j
1.b
1.c
1.h
1.i
1.g
1.d
1.e
15
P1 = 200 bar
3.b
1.a
2.l
P2a = 8 bar
P2b = 27 bar
2.i
2.j
2.b
2.g
2.a
2.h
2.m
2.n
2.k
2.c
2.e
2.f
F
3.a

Fig. 3

STEP 4/6

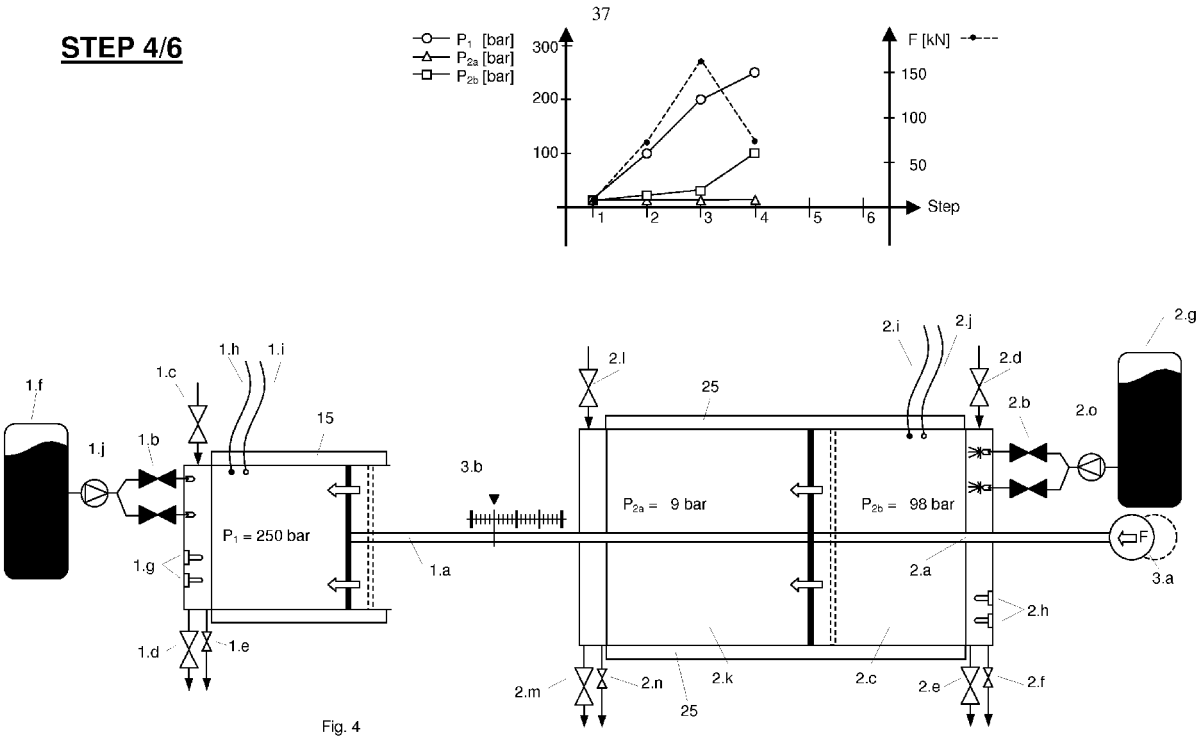
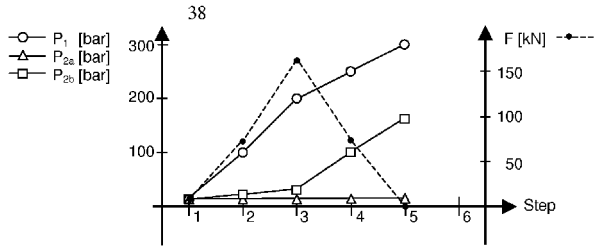

37
P1 [bar]
P2a [bar]
P2b [bar]
300
200
100
F [kN]
150
100
50
Step
1
2
3
4
5
6
1.f
1.j
1.b
1.c
1.h
1.i
15
1.g
1.d
1.e
P1 = 250 bar
3.b
1.a
2.l
25
P2a = 9 bar
P2b = 98 bar
2.i
2.j
2.d
2.b
2.o
2.g
F
3.a
2.a
2.h
2.m
2.n
25
2.k
2.c
2.e
2.f

Fig. 4

STEP 5/6


38
P1 [bar]
P2a [bar]
P2b [bar]
300
200
100
F [kN]
150
100
50
Step
1
2
3
4
5
6

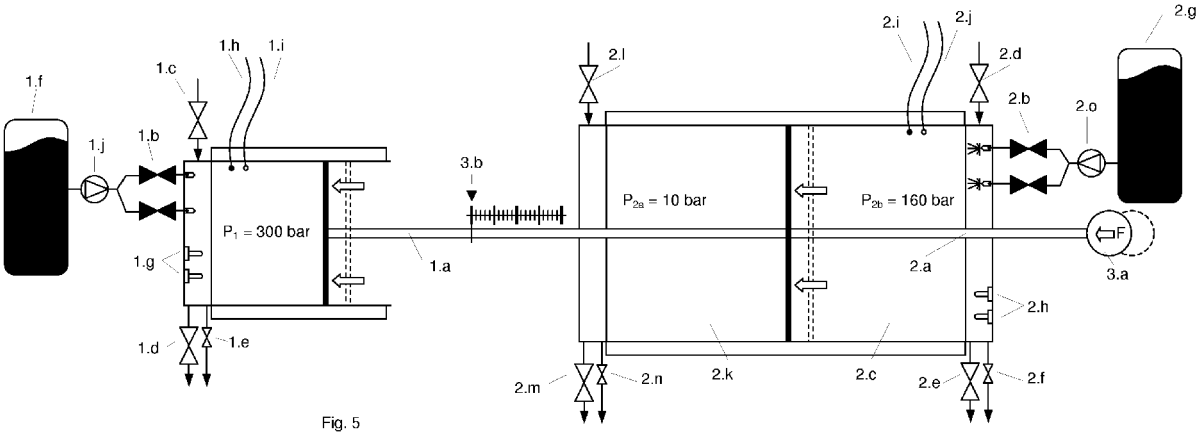
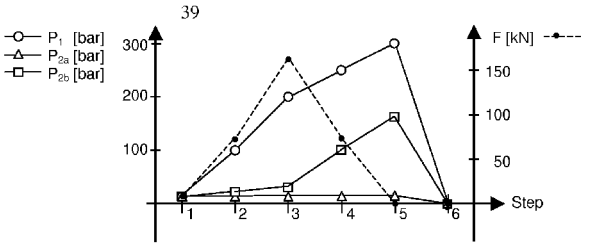

1.f
1.j
1.b
1.c
1.h
1.i
P1 = 300 bar
1.g
1.d
1.e
3.b
1.a
2.l
P2a = 10 bar
P2b = 160 bar
2.i
2.j
2.d
2.b
2.o
2.g
F
3.a
2.a
2.h
2.m
2.n
2.k
2.c
2.e
2.f

Fig. 5

STEP 6/6


39
P1 [bar]
P2a [bar]
P2b [bar]
300
200
100
F [kN]
150
100
50
Step
1
2
3
4
5
6

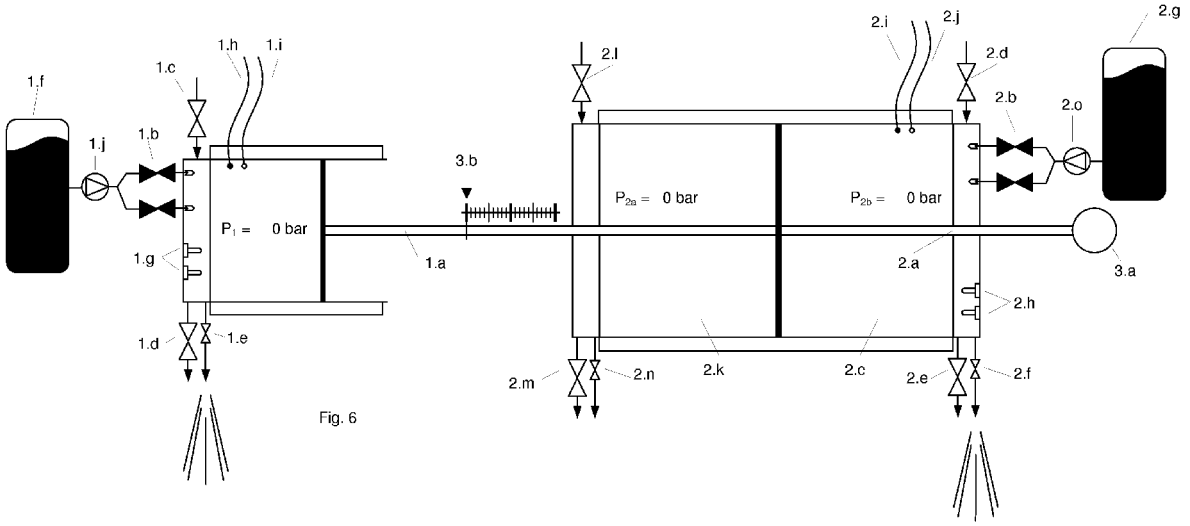

1.f
1.j
1.b
1.c
1.h
1.i
1.g
1.d
1.e
P1 = 0 bar
1.a
3.b
2.l
2.i
2.j
2.d
2.b
2.o
2.g
P2a = 0 bar
P2b = 0 bar
2.a
3.a
2.h
2.m
2.n
2.k
2.c
2.e
2.f

Fig. 6

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EUROPEAN SEARCH REPORT

Application Number
EP 09 16 8839

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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F15B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	21 January 2010	Krikorian, Olivier

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