(19) Europäisches Patentamt
European Patent Office
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(11) EP 2 194 261 A1

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
09.06.2010 Bulletin 2010/23

(51) Int Cl.:
F02M 53/02 (2006.01) *F02M 63/00* (2006.01)

(21) Application number: **09174659.4**

(22) Date of filing: **30.10.2009**

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO SE SI SK SM TR

(30) Priority: **02.12.2008 BR 08054843**

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(54) Fuel rail equipped with an axial heater device layout for engine cold start operation with ethanol

(57) The present invention relates to a primary fuel rail (10) of the return-less type equipped with a particular axial heater device layout to increase the heat flux homogeneity in the fuel rail for an Ethanol Cold Start (ECS) system. The fuel rail (10) has one or more heating elements (12a, 12b) inserted therein in such a way that the heating part (100) of each element is oriented along or parallel to the main symmetry axis of the principal cavity of the said fuel rail (10) and each heating element is composed of two parts, an inactive support part (101) and an active heating part (100) having lengths (La, X), which can be individually tuned to obtain a maximum homogeneity of the heat flux along the rail towards the fuel injectors (11a-11d).

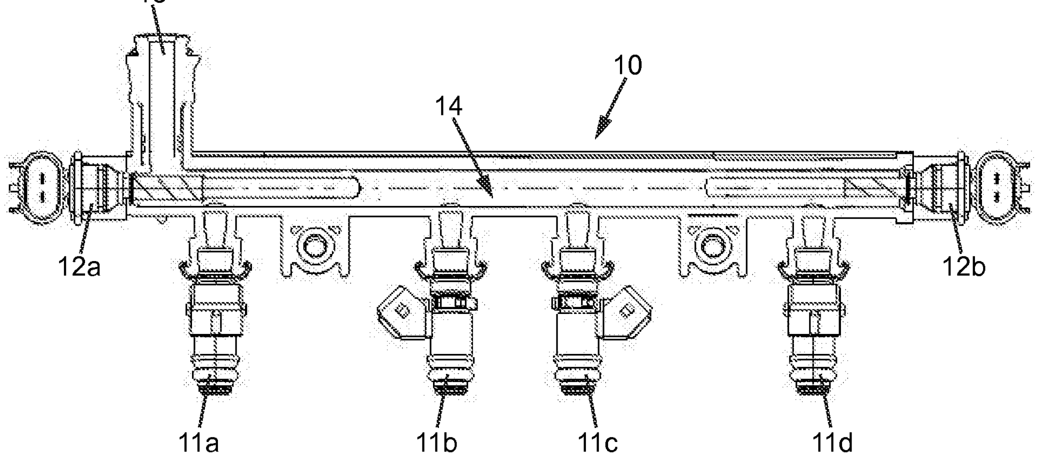

FIG. 3a

EP 2 194 261 A1

Description

[0001] The present invention relates to a fuel rail equipped with a particular axial heater device layout to increase the heat flux homogeneity in a primary returnless fuel rail for an Ethanol Cold Start (ECS) system.

Prior art

[0002] It is a well-known fact that when using fuels different from classic gasoline in an Internal Combustion (IC) engine several functions of the engine may be affected. In a modern IC-engine (figure 1), comprising a combustion chamber (1) with a spark ignition device (2), an exhaust (3) and inlet (4) manifold with a gas flow regulating (5) throttle body and an electronically controlled (6) mixture preparation system with Port Fuel Injectors (PFI) (7), a classic gasoline fuel with a typical chemical structure of C_8H_{18} enables a cold start performance, which allows the engine to start and warm-up at temperatures down to approximately 30°C below zero without use of auxiliary add-on devices. Figure 1 shows a layout of a speed/density (Manifold Absolute Pressure (MAP) and engine speed sensor input), but this layout is not mandatory. The layout can use any kind of strategy as long as it supplies the necessary data to enable the Engine Control Unit (ECU) to compute the relevant data for injector and ignition control.

[0003] In the case of a different low vaporizing fuel for example ethanol (C_2H_5OH) or a mixture between gasoline or ethanol (example: gasohol or E85) the cold start performance is strongly affected by the vaporization and surface tension parameters of the ethanol component, which are notably different from those of a pure gasoline. Fuelling the engine by pure ethanol creates the most difficult situation. In that case the cold start and warm up becomes very delicate below ambient temperatures of about 10° to 12°C.

[0004] The main reason for which not only the cold start but also the warm-up phase is of major interest is that for pollutants control (mainly the HC-content in the exhaust gas) in the time period during which the oxygen-sensor is not functioning (open-loop control strategy) a very precise injector control enables a decrease in unburned HC emission.

[0005] In recent years the presence of the ethanol cold start problem has led to several suggestions of add-on devices, which introduce either a separate high-vaporizing fuel (gasoline) or one or more heating devices, which are not positioned according to the present invention in the normal fuel rail on the upstream side of the fuel injectors. Both approaches have major inconveniences.

[0006] Although functioning well for the cold start itself, the first approach is costly as a separate tank and fuel line for the high-vaporizing fuel must be installed on the vehicle and as the volume of this secondary system is limited (normally under-bonnet location) its capacity to be used during the warm-up period is very limited. The second type of approach can be used for the cold start, but an approach of this type, which does not follow the particular layout defined by the invention becomes totally unreliable for the warm-up period as the random introduction of a powerful heat source in the fuel-rail on the injector upstream side eventually leads to heat-conditioned cavitations in the liquid fuel.

[0007] Basically a fuel injector is designed to introduce a <u>metered amount</u> of liquid (non compressible) fuel in the intake system. Unfortunately heat-conditioned cavitations introduce gas bubbles into the liquid fuel and thereby change the state of the fluid from non-compressible to compressible. The basic fluid dynamics of compressible fluids is totally different from those of non-compressible fluids and therefore the metering function of the fuel injector designed for liquid fuel is not anymore controllable when a compressible fluid is passing through the metering area inside the injector.

[0008] The applicant has patented a solution, which enables, by a simple mechanical means without complicated electronic feed-back temperature control, to provide an asymptotic temperature stabilization of the fuel inside the fuel rail during the cold start phase (Brazilian Patent Application nr. PI 0705422-0).

Summary of the invention

[0009] The invention adds to the internal volume of a common fuel rail one or more electrically controlled heating elements. The heating elements are located in such a way that their active heating part is oriented along or parallel to the main axis of the fuel rail.

[0010] The distribution of the active heating surface along the rail cavity symmetry axis is favored by this particular axial layout, which increases significantly the homogeneity of the net heat flux in the lateral direction of the cavity and thereby decreases the hot fuel temperature difference between the fuel injectors connected to the rail.

[0011] The present invention presents several different installation layouts of the axial heaters within the perimeter of the fuel rail.

Brief description of the drawings

[0012] The objective of the present invention will be better understood by confronting the joined figures, which are presented as mere examples, which should in no way limit the scope of the invention.

- Figure 1 shows a conventional internal combustion engine with its associated injection system.
- Figure 2 shows the fuel rail with attached fuel injectors and the axial heaters located at each extremity of the rail.
- Figures 3a and 3b show the internal part of the fuel rail with the axial heaters located as well as the detailed layout of each heating element.

- Figures 4a, 4b, 4c, 4d and 4e show axial cuts of several different installation layouts in different fuel rail designs.
- Figure 5 shows a graphical representation of the stabilization versus time of the fuel temperature at each fuel injector (example 4 cylinder engine) by application of the present invention.

Preferred Embodiments

[0013] In conformity with the joined figures, and in particular with reference to figure 2 and figure 3a, the invention adds to the internal volume of a fuel rail one or more electronically controlled heating elements.

[0014] Figure 2 illustrates the principle of the invention. The common fuel rail (10) supplies pressurized fuel to a number of fuel injectors (11a to 11d) and as an example two heating elements (12a and 12b) are located on each side of the fuel rail. Each heating element is a fast acting device with a typical temperature rise- time of ~ 70°C/s (measured in still air at 1 mm from the heater surface). The total number of heating devices will typically absorb approximately 800 W at 10 V supply. The maximum heater temperature should typically be attained after approximately 6 s. The above-indicated numerical values are not limitative.

[0015] Figure 3a shows an example of the internal layout of the system. The active heating parts of the elements (12a and 12b) are located in a position, which is axial or co-axial with respect to the main axis (14) of the fuel rail. The example shows a layout with only one fuel entrance pipe (13), which connects the fuel rail to the fuel delivery pump.

[0016] Figure 3b shows details of the heating elements. An element is composed of a unit, which is axially located in the rail. This unit is divided in two parts, the active heating part (100) of the length L_a (typically between 35 and 70 mm) and an inactive support (101) of a length X (typically between 0 and 35 mm). The axial part is connected to a connector body (102) and an electrical connector (103). To comply with a large number of mounting requirements the connector body (102) and the connector (103) can be positioned at an angle α (between 0 and 90 °) with respect to the axial parts (100 and 101). The axial parts (100 and 101) of a heating element can be connected to a mechanical tubular heat dissipater, as suggested by the Brazilian Patent Application nr. PI 0705422-0.

[0017] Figures 4a, 4b, 4c, 4d and 4e show further variants of the installation layout for an axial heating element.

[0018] Figure 4a shows a variant with two fuel inlet pipes (201 and 202), which supply the cold fuel at symmetrical positions in the vicinity of the axial heating elements (12a, 12b). The precise position of the inlet pipes as well as the lengths X and L_a are tuned to provide the maximum equilibrium of heat flux towards the fuel injectors (11a-11d).

[0019] Figure 4b shows a variant by which the effect of heat flux homogeneity is obtained with only one cold fuel inlet pipe (203), which is connected to a transfer bore (204), located inside the fuel rail (10) with outlets in the vicinity of the heating elements (12a, 12b).

[0020] Figure 4c shows a layout, which adds a separate compartment (300), which enables the introduction of a third co-axial heating element (301) to provide a supplementary heat flux directed towards the center located fuel injectors (11b, 11c). The electrical power output of the three heating elements (12a, 12b, 301) is typically adapted to a total consumption of approximately 800 W at 10 V, but this value is not limitative. Fuel is supplied into the separate compartment (300) through the transfer bores (302) and the heated fuel is supplied to the center fuel injectors (11b, 11c) through the outlet bores (303). To avoid pumping effects, and thereby non homogeneous heat flux distribution, by the intermittent injector duty cycle order the diameter of the transfer bores (302) is typically limited to 50% of that of the outlet bores (303).

[0021] Figure 4d shows a layout in which the rail cavity, by any appropriate mechanical means (400), is divided into two separate left (401) and right (402) hand cavities. Each cavity, equipped with an individual inlet pipe (403) and (404), supplies hot fuel to respectively the left (11a, 11b) and right (11c, 11d) hand injectors. Heat flux distribution oscillations due to the intermittent injector duty cycle order are hereby significantly reduced.

[0022] Figure 4e shows a layout in which is combined only one cold fuel inlet pipe (503), communicating with an internal transfer bore (504), and a rail cavity separated by any appropriate mechanical means (500) in two left (501) and right (502) hand cavities. Each cavity supplies hot fuel to respectively the left (11a, 11b) and right (11c, 11d) hand injectors.

[0023] For convenience the figures 3 to 4e show the different constituent elements such as fuel inlet pipes (13, 201 and 202, 203) and the location of the separate heating compartment (300) in the same plane as the cut of the main fuel rail. However, this is not mandatory as long as the active heating elements all maintain an axial location parallel to or on the fuel rail main axis (14).

[0024] To optimally comply with under-bonnet packaging requirements both the inlet pipes and the separate third heating element compartment can be axially turned clock- or anticlockwise around the fuel rail main axis (14).

Example

[0025] Figure 5 shows a recording of the average temperature evolution of the liquid in the tubes connecting the fuel-rail to the fuel injectors at a cold start event at an ambient temperature of - 5° C.

[0026] The recording demonstrates that when all dimensional and orientation parameters are correctly adapted according to the invention the common temperature profile at the fuel injector inlets remains well below the flash-boiling threshold.

[0027] The tests made with the present invention demonstrate clearly that the suggested layout is a very efficient and low cost means to obtain a well controlled heating of the fuel on the upstream side of the fuel injectors without imposing major geometrical changes of existing fuel supply lines or the introduction of a secondary expensive fuel reservoir.

Claims

1. A fuel rail, which is mounted on an IC-engine with the purpose of improvement of the cold start and warm up phases by usage of low vaporizing fuels such as ethanol, in which is inserted one or more heating elements (12a, 12b) in such a way that the heating part (100) of each element is oriented along or parallel to the main symmetry axis of the principal cavity of the said fuel rail (10) and each heating element is composed of two parts, an inactive support part (101) and an active heating part (100) having lengths (La, X), which can be individually tuned to obtain a maximum homogeneity of the heat flux along the rail towards the fuel injectors (11a-11d).

2. The fuel rail as in claim 1, in which the electrical body and connector of each heating element can be oriented in-line with the part oriented along or parallel to the rail main symmetry axis or tilted at an arbitrary angle between 1 ° and 90° with respect to the axially oriented part.

3. The fuel rail as in claim 1 or 2, in which one or more cold fuel inlet pipe(s) (201, 202, 203, 403, 404, 503) is/are positioned and connected to the rail main cavity in such a way that the cold fuel arrives symmetrically with respect to the heating elements (12a, 12b).

4. The fuel rail as in any of claims 1 to 3, in which a center-positioned axial heating element (301) is inserted in a separated cavity being co-axial with the fuel rail main axis to supply with heated fuel the center-connected fuel injectors (11b, 11c).

5. The fuel rail as in claim 4, in which the center-positioned cavity communicates with the right and left hand cavities through two inlet bores (302) and with the center-positioned fuel injectors (11b, 11c) through a number of outlet bores (303) equal to the number of center-positioned injectors, and for which the diameter ratio between inlet and outlet bores (302, 303) is equal or less than 0.5.

6. The fuel rail as in any of claims 1 to 3, in which the fuel rail main cavity having the active heating elements (12a, 12b) axially inserted at each extremity is separated in two non-communicating cavities (401, 402; 501, 502) dividing the main cavity in right and left hand parts each supplying an equal number of fuel injectors with heated fuel.

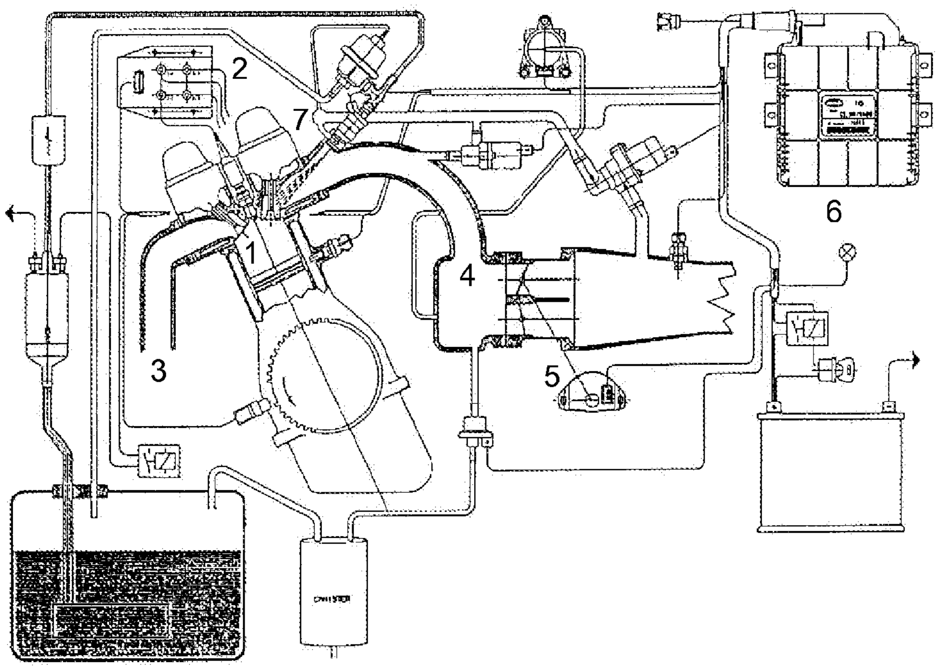

FIG. 1

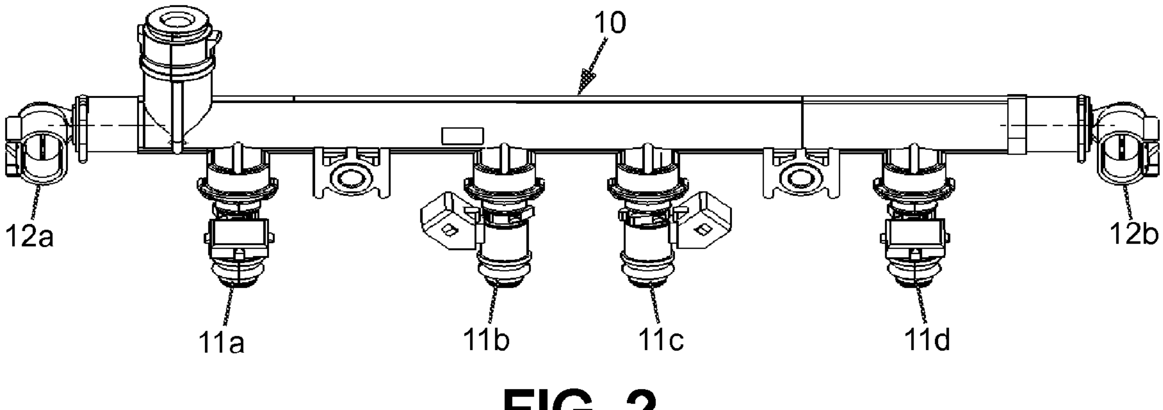

FIG. 2

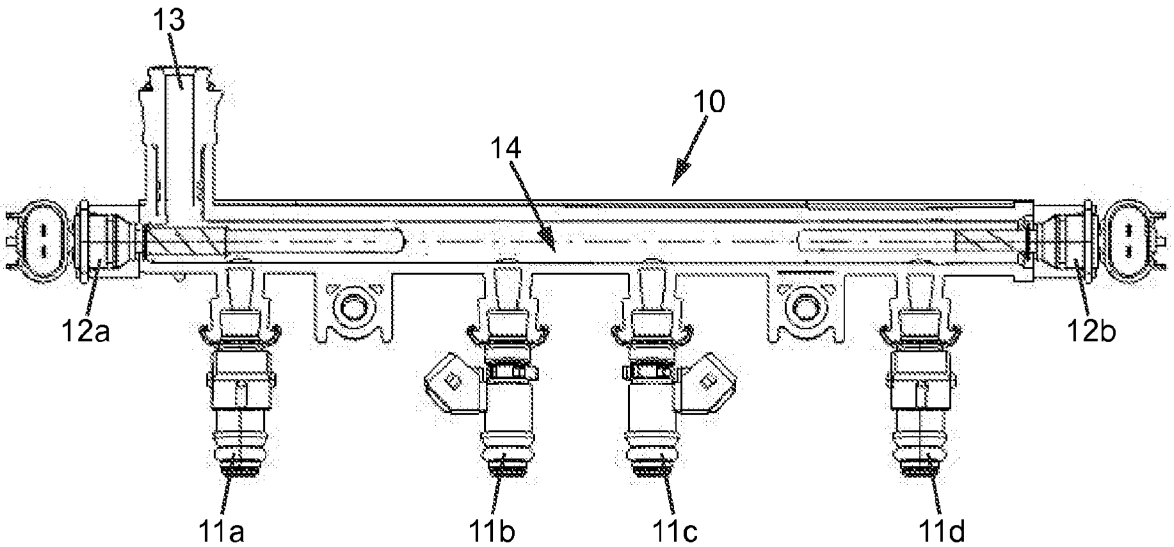

FIG. 3a

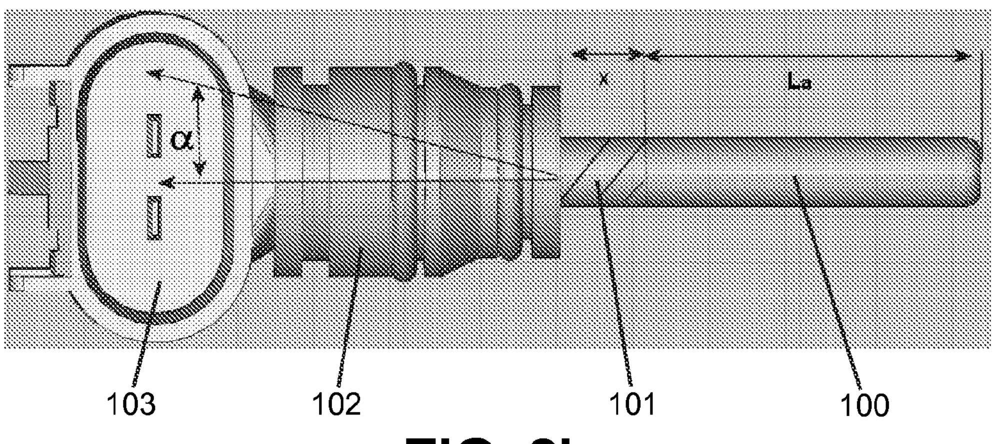

FIG. 3b

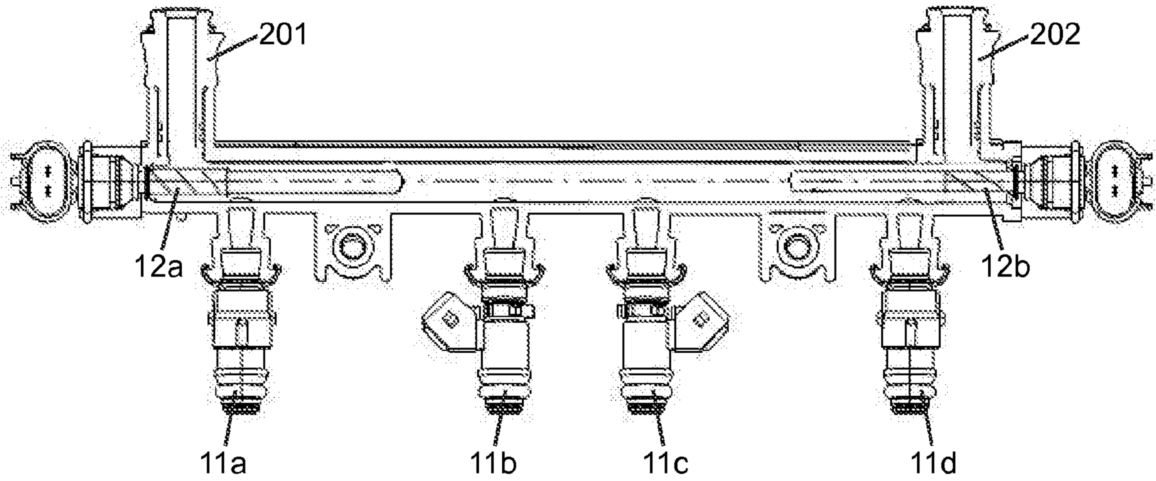
201
202
12a
12b
11a
11b
11c
11d

FIG. 4a

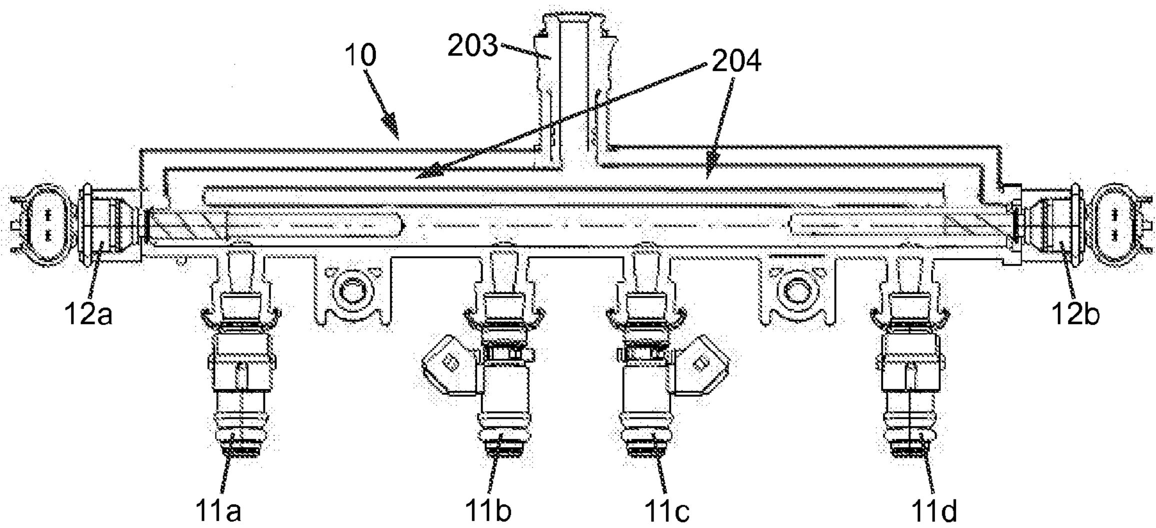
10
203
204
12a
12b
11a
11b
11c
11d

FIG. 4b

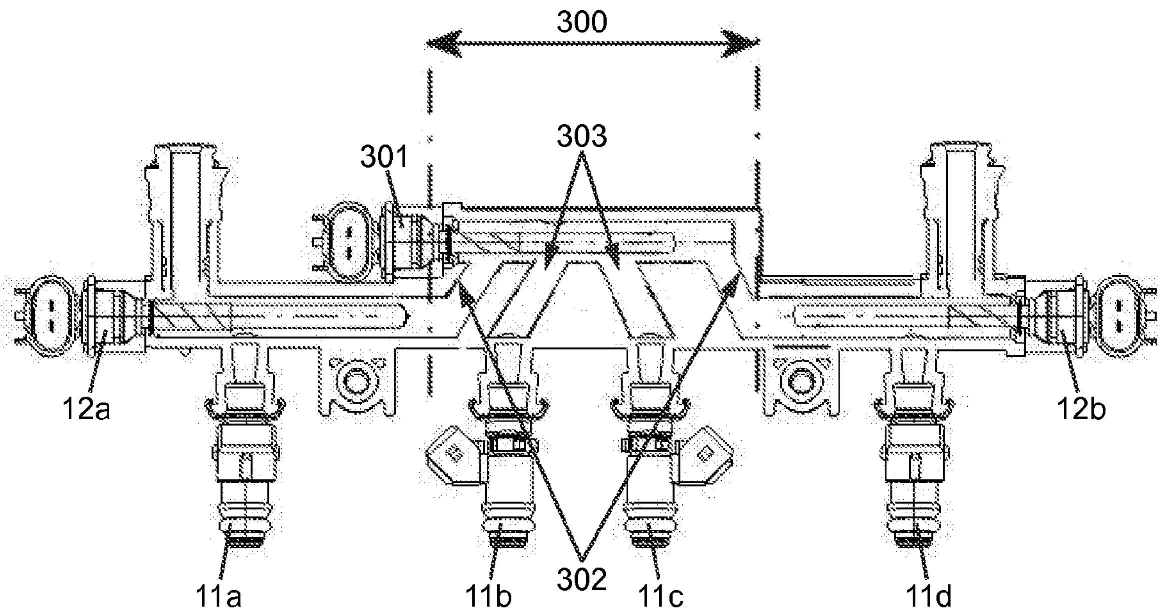
300
303
301
12a
12b
11a
11b
302
11c
11d

FIG. 4c

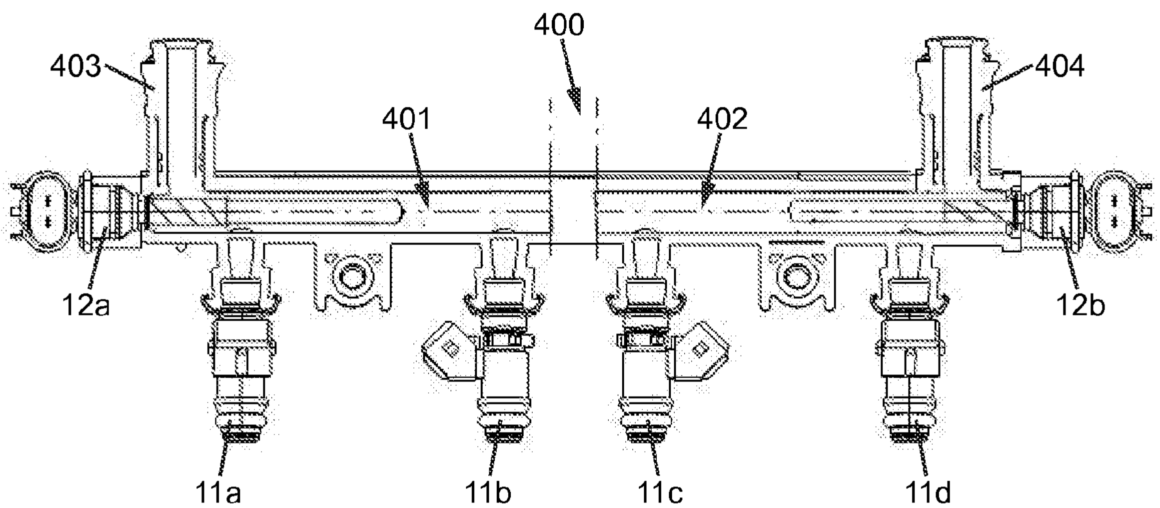
400
403
404
401
402
12a
12b
11a
11b
11c
11d

FIG. 4d

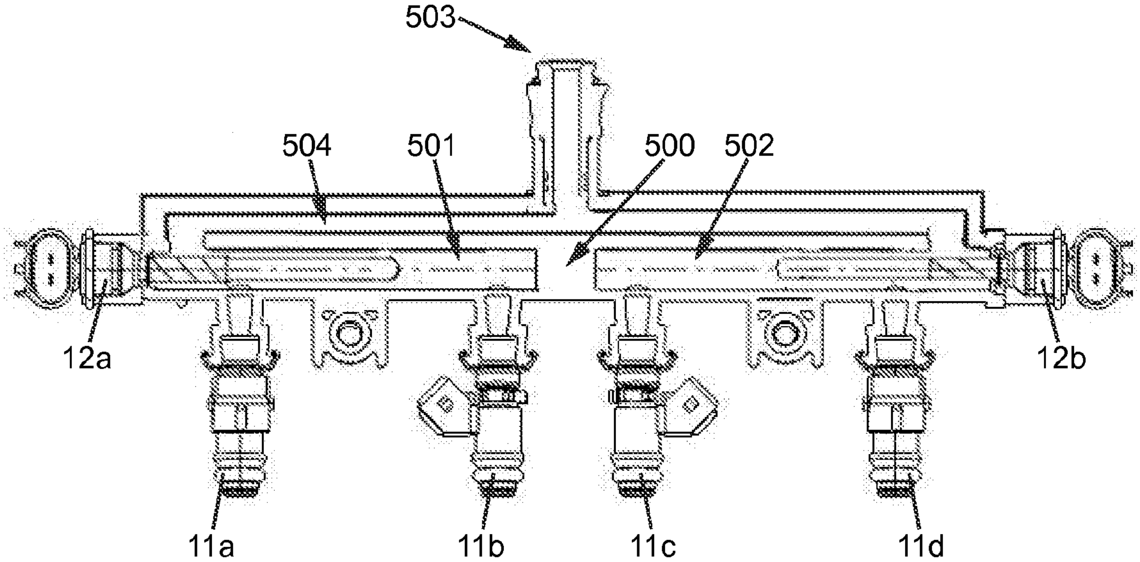
503
504
501
500
502
12a
12b
11a
11b
11c
11d

FIG. 4e

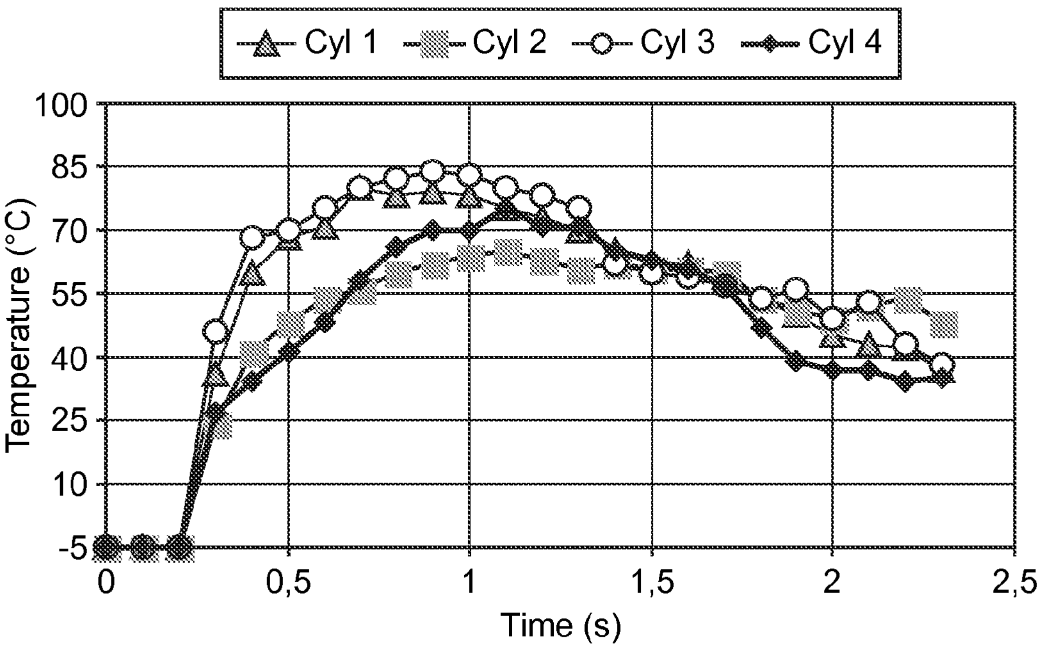
Cyl 1
Cyl 2
Cyl 3
Cyl 4
100
85
70
55
40
25
10
-5
Temperature (°C)
0
0,5
1
1,5
2
2,5
Time (s)

FIG. 5

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EUROPEAN SEARCH REPORT

Application Number
EP 09 17 4659

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A,P	EP 2 071 159 A1 (MAGNETI MARELLI SIST S AUTOMOT [BR]) 17 June 2009 (2009-06-17) * figure 3 * -----	1	TECHNICAL FIELDS SEARCHED (IPC) F02M

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	18 March 2010	Etschmann, Georg

3

CATEGORY OF CITED DOCUMENTS

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