(12) UK Patent Application (19) GB (11) 2 321 278 (13) A

(43) Date of A Publication 22.07.1998

(21) Application No 9800771.9

(22) Date of Filing 14.01.1998

(30) Priority Data
(31) 1970288 (32) 16.01.1997 (33) DE

(71) Applicant(s)
Daimler-Benz AG
(Incorporated in the Federal Republic of Germany)
Epplestrasse 225, D-70546 Stuttgart,
Federal Republic of Germany

P & S Prototypen & Sondermaschinen
Entwicklungsgesellschaft mbH
(Incorporated in the Federal Republic of Germany)
Mannheimer Strasse 235, 55543 Bad Kreunznach,
Federal Republic of Germany

(72) Inventor(s)
Karl-Heinz Hoffmann
Gregor Renner

(51) INT CL^6
F02M 51/06 // F02M 61/06

(52) UK CL (Edition P)
F1B B2JCB B2J15B3 B2J15C B2P4

(56) Documents Cited
GB 2296940 A **GB 2193386 A** **US 5479902 A**

(58) Field of Search
UK CL (Edition P) **F1B B2JCB B2P4**
INT CL^6 **F02M 51/06**
Online: WPI

(72) cont
Friedrich Wirbeleit
Jens-Peter Wobbe

(74) Agent and/or Address for Service
Jensen & Son
70 Paul Street, LONDON, EC2A 4NA, United Kingdom

(54) Abstract Title
Protection of piezo stack of a fuel injection valve for an internal combustion engine

(57) A fuel injection valve has a piezo stack actuator (4, figure 1) located in a guide, a valve stem 8 connected to the piezo stack with closing spring 24, a valve housing 6 creating a annular gap 12 for high pressure fuel, a pressure equalising cylinder 11 with annular gap 18 creating a low pressure area behind it in which the piezo stack is placed and flow limiter 13 through which fuel is precisely metered to the combustion chamber. The fuel injector valve is located in an injector housing and fuel is supplied to the valve by an annular space between the injector housing and the guide for the piezo stack. Fuel pressure in gap 12 acting on the cylinder 11 and the flow limiter 13 may assist the closing of the valve due the ratio of surface areas on which the fluid acts.

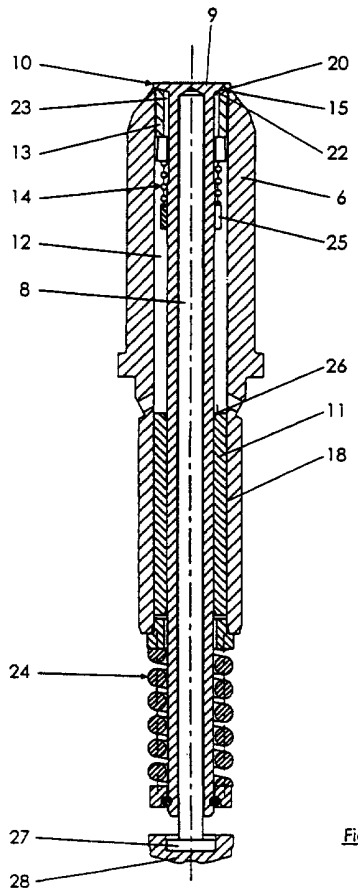


Fig. 2

GB 2 321 278 A

Westport Fuel Systems Canada Inc.
EX 2016
Robert Bosch LLC et al. v. Westport Fuel Systems Canada Inc.
IPR2023-00293
Page 1 of 16

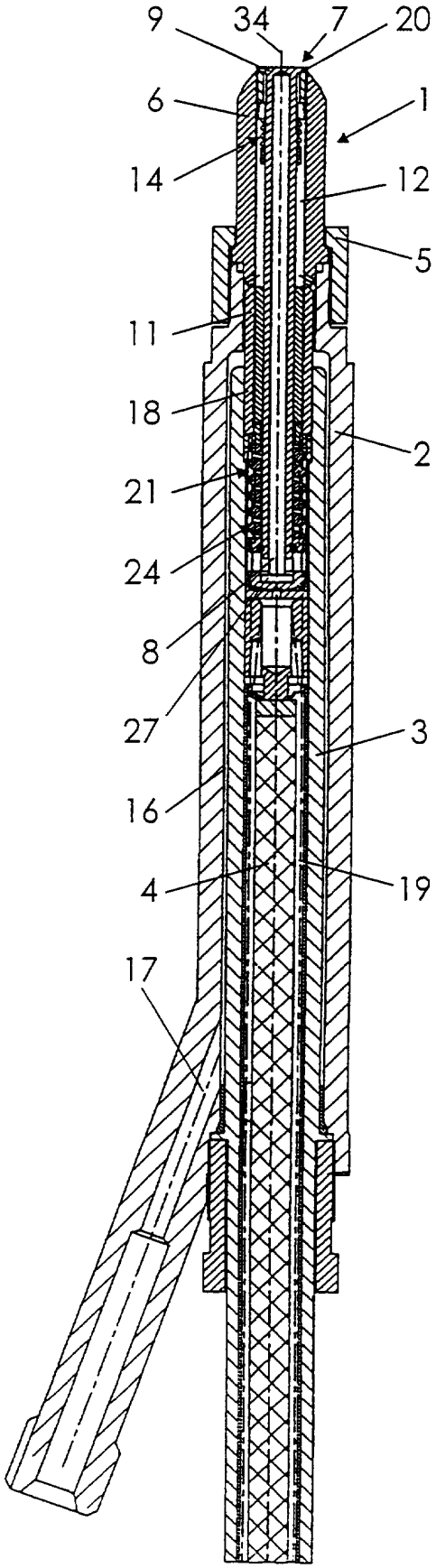


Fig. 1

Westport Fuel Systems Canada Inc.
EX 2016
Robert Bosch LLC et al. v. Westport Fuel Systems Canada Inc.
IPR2023-00293
Page 2 of 16

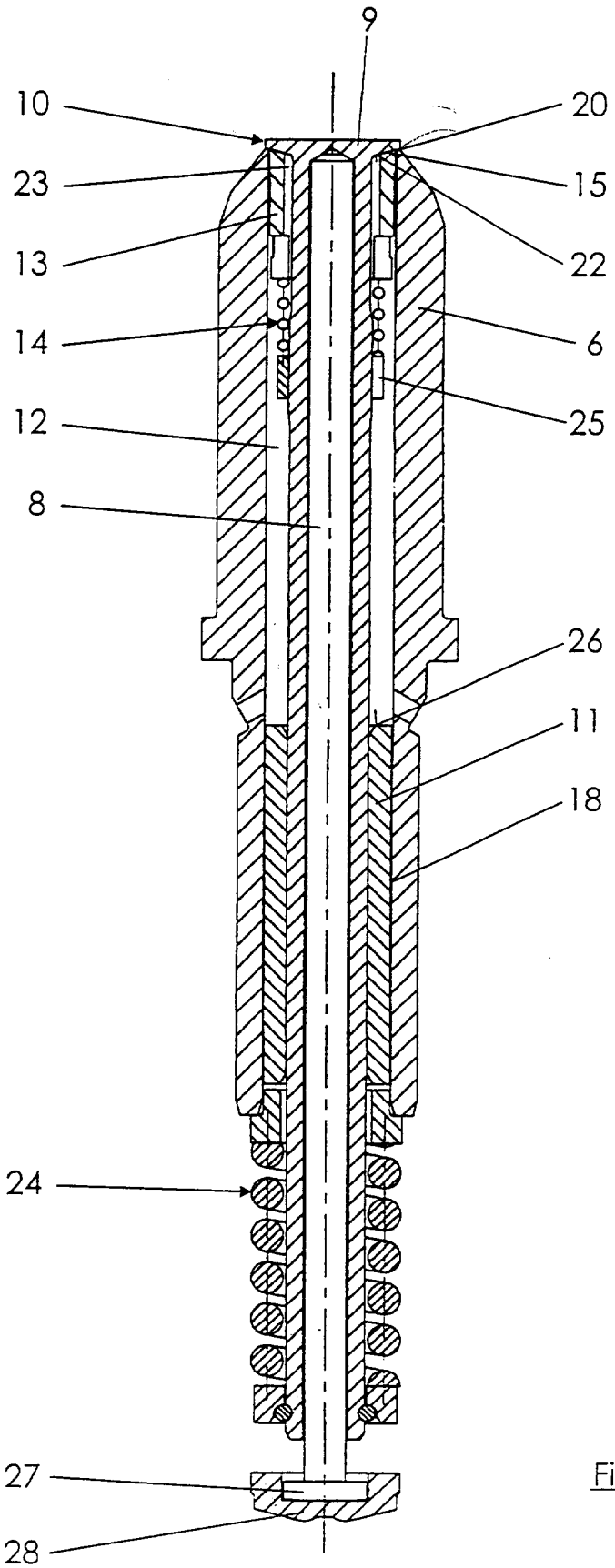
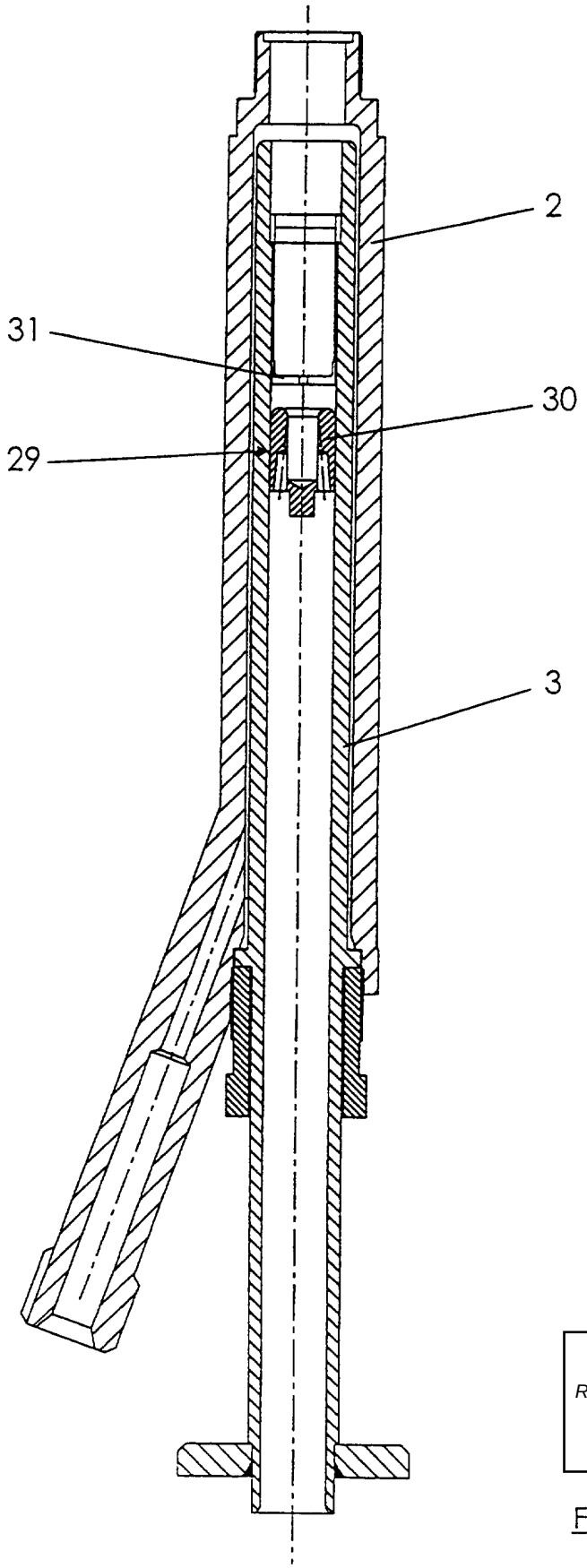


Fig. 2

Westport Fuel Systems Canada Inc.
EX 2016
Robert Bosch LLC et al. v. Westport Fuel Systems Canada Inc.
IPR2023-00293
Page 3 of 16



Westport Fuel Systems Canada Inc.
EX 2016
Robert Bosch LLC et al. v. Westport Fuel Systems Canada Inc.
IPR2023-00293
Page 4 of 16

Fig. 3

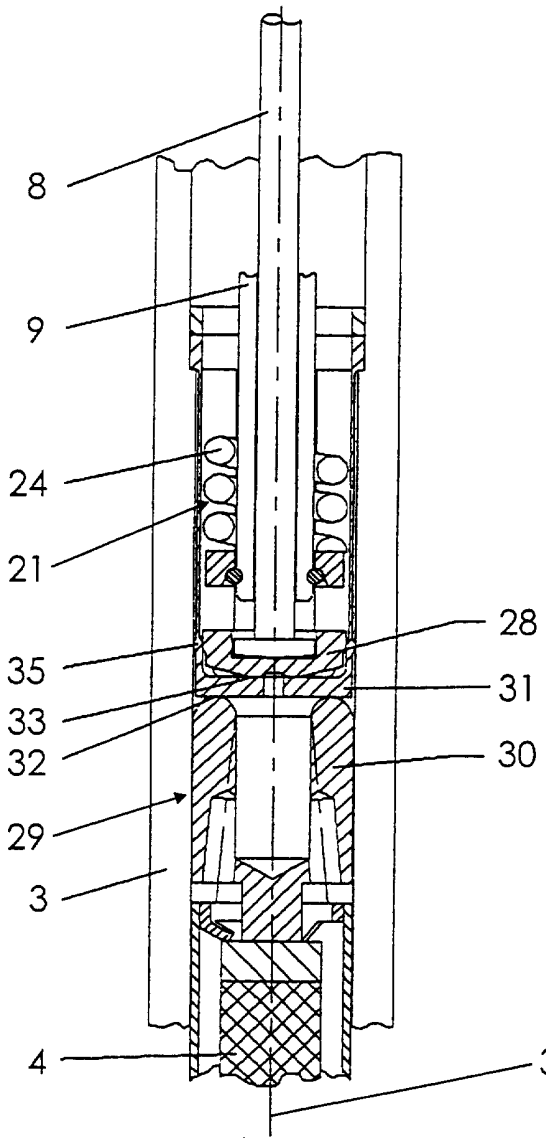


Fig. 4

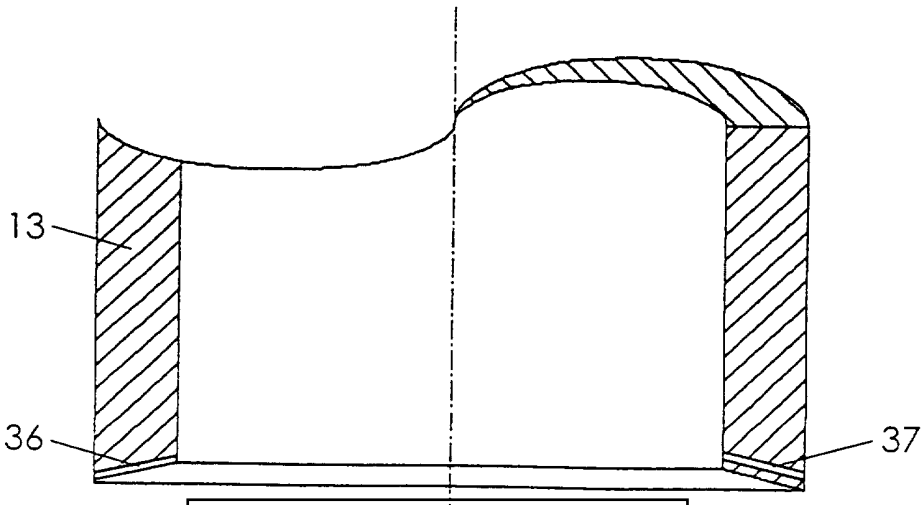


Fig. 5

Westport Fuel Systems Canada Inc.
EX 2016
Robert Bosch LLC et al. v. Westport Fuel Systems Canada Inc.
IPR2023-00293
Page 5 of 16

Valve for the metered delivery of fluids

The present invention relates to a valve for the metered delivery of fluids, particularly but not exclusively, an injection valve for fuel injection systems.

DE 195 00 706 A1 discloses a fuel injection valve for internal combustion engines, which valve has a hydraulic travel amplifier for converting an adjustment travel of a piezoelectric actuator. In this valve, fluid-feeding and fluid-discharging ducts are separate from one another, the fluid being directed into an annular space through a duct arranged in the valve housing.

However, a disadvantage with this is that the duct subjects the fuel injection valve to torsional stress while fuel is being fed into the annular space.

EP 0 218 895 B1 discloses a metering valve for metering fluids or gases. In this previously known metering valve, a piezoelectric actuator and its piezo stack, whose length is variable under the effect of a control voltage, is connected at one of its ends to the valve needle and at its other end to a damping piston which bounds a fluid-filled damping space and which is guided in an axially displaceable fashion in the axial direction of the piezo stack, and is configured in such a way that, when there is a change in length of the piezo stack brought about by the control voltage, said damping piston is fixed relative to the housing. As a result of a contraction of the piezo stack, the valve needle is lifted off the valve seat.

In this solution, the fuel which is to be injected into the combustion space is fed to the valve at the side of the valve facing away from the combustion space of the internal combustion engine, and flows from there through a duct into an annular gap which is formed between the lower part of the valve and the piezo stack arranged therein. From there, the fuel is directed into a further annular space, which is bounded by the wall of the valve housing and by the valve needle. Then, the fuel flows into an annular space which is located in the valve outlet opening which is closed off by the valve needle.

A disadvantage with the present solution is that the fuel which is fed into the valve under pressure is applied directly to the piezo stack. The pressures of approximately 1000 bar acting on the piezo ceramics shorten the piezo stack in such a way that precise functioning of the valve is no longer ensured owing to losses of the

Westport Fuel Systems Canada Inc.
EX 2016
Robert Bosch LLC et al. v. Westport Fuel Systems Canada Inc.
IPR2023-00293
Page 6 of 16

actuation travel of the valve needle.

Furthermore, in the prior art, the injection of the fuel into the combustion space is not precisely defined since, after the valve needle has lifted off out of the valve seat, the fuel is injected into the combustion space through the ensuing gap in a radially uncontrollable fashion.

For this reason, the present invention seeks to implement the introduction of fluid into the combustion space in a defined fashion and of ensuring the method of operating of the piezo stack according to the invention even when the pressures at which the fuel is introduced into the valve are very high.

According to the present invention there is provide a valve for the precisely metered delivery of fluids, having an injector housing in which a piezo stack is arranged, and a valve housing which is connected to the injector housing and in which a valve closure device, which has a plunger, is displaceably arranged,

a) a control voltage being applicable to the piezo stack in such a way that it experiences lengthening and the valve closure device which bears against the piezo stack is displaced with respect to the valve housing by a distance which corresponds to the lengthening of the piezo stack,

b) a gap for the ejection of fluid from the interior of the valve housing is provided in a valve opening by lengthening the piezo stack between the valve closure device and a valve seat,

c) a resetting device is provided, by means of which the valve-closure device can be reset against the valve seat,

d) an annular gap which can be filled with fluid is formed in the valve housing,

e) in the region of the annular gap facing the injector housing, a separating device is provided which separates fluid-feeding and fluid-discharging ducts from one another,

f) the valve-closure device has a sealing element in the region of the valve opening,

g) the annular gap has a constriction of its cross-section in the region of the sealing element,

wherein

h) the plunger is surrounded by a valve stem and the annular gap is formed

Westport Fuel Systems Canada Inc.
EX 2016
Robert Bosch LLC et al. v. Westport Fuel Systems Canada Inc.
IPR2023-00293
Page 7 of 16

between the valve stem and the valve housing,

i) the separating device comprises a pressure-equalization cylinder, which is arranged so as to be displaceable with respect to the valve housing and is permanently connected to the valve stem,

j) the piezo stack is surrounded by a piezo guide,

k) an annular space, into which a fluid-feeding line leads, is formed between the piezo guide and the injector housing,

l) the constriction forms a flow-limiter, which bears against the sealing element of the valve stem and has, in its outer jacket, openings through which the fluid is directed out of the annular gap and into the combustion space.

A valve-closure device, which has a plunger which can be actuated by a piezo stack, is arranged in the valve housing. The valve plunger is surrounded by a valve stem, advantageously permitting the longitudinal compensation of the valve to be brought about by temperature, while avoiding stress gradients.

Furthermore, a piezo guide, which contains the piezo stack and, in combination with the separating device, spatially separates the fluid-feeding and the fluid-discharging ducts, is arranged in an injector housing.

A significant advantage which is achieved as a result of this is that the fuel which is fed to the valve under high pressure is not applied to the piezo stack. In this way, satisfactory functioning of the inverse, piezoelectric effect of the piezo stack is ensured.

The fluid is directed into the region of the valve facing the combustion space by means of the annular space which is bounded by the piezo guide and the injector housing in the radial direction. This advantageously brings about uniform stressing of the valve.

A flow-limiter is arranged on the sealing element of the valve stem, in the annular space which is bounded by the separating device and the sealing element of the valve stem, in such a way that when the valve is open the fluid is ejected through the flow-limiter into the combustion space. When the fluid is ejected through the flow-limiter, a precisely defined ejection jet of the fluid is advantageously obtained, thus contributing to a particularly favourable distribution of the fluid in the combustion space of an internal combustion engine.

Westport Fuel Systems Canada Inc.
EX 2016
Robert Bosch LLC et al. v. Westport Fuel Systems Canada Inc.
IPR2023-00293
Page 8 of 16

Advantageous developments and refinements of the invention will now be described by way of example with reference to embodiments described in principle below with reference to the drawings, in which

Fig. 1 shows an overall view of a valve for the metered delivery of fluids;

Fig. 2 shows a view of a valve housing having a valve-closure device with a resetting device;

Fig. 3 shows a view of an injector housing having a transmission mechanism which has a lever and a clamping sleeve;

Fig. 4 shows an enlarged view of the transmission mechanism in accordance with Fig. 3; and

Fig. 5 shows a view of a detail of the refinement of a flow-limiter.

Fig. 1 shows a valve 1 for the precisely metered delivery of the fluids, in particular an injection valve for fuel injection systems of an internal combustion engine. The valve 1 is composed of an injector housing 2, a piezo guide 3, in which a piezo stack 4 is arranged, and a valve housing 6 which is connected to the injector housing 2 by means of a union nut 5. Furthermore, a valve-closure device 7 is displaceably arranged in the valve housing 6.

The valve-closure device 7 is composed of a plunger 8 and a valve stem 9. The plunger 8 is fitted here into the valve stem 9 which is of sleeve-like and cylindrical design. In addition, a sealing element, which is designed as a step 10, is provided on the valve stem 9 at its end facing the combustion space.

The valve housing 6, the step 10 and a separating device, which is permanently connected to the valve stem 9 and is formed as a pressure-equalization cylinder 11, form an annular gap 12 which is filled with fluid during operation. When the valve 1 is open, a precisely meterable quantity of fluid is injected from this annular gap 12 through a flow-limiter 13 into a combustion space which is not illustrated in the drawing. The flow-limiter 13 is pressed, by means of a spring device 14, against a cross-sectional face 15 of the step 10 of the valve stem 9, in such a way that, when the fluid emerges from the valve 1, it initially flows through the flow-limiter 13. The spring device 14 has a cylindrical stop 25 which is permanently connected to the valve stem 9.

An annular space 16, into which a line 17, which feeds fluid to the valve

Westport Fuel Systems Canada Inc.
EX 2016
Robert Bosch LLC et al. v. Westport Fuel Systems Canada Inc.
IPR2023-00293
Page 9 of 16

1, leads is formed between the piezo guide 3 and the injector housing 2. From said annular space 16, the fluid flows into the annular space 12. The piezo guide 3 and the pressure-equalization cylinder 11 advantageously shield the piezo stack 4 from the fluid-feeding process. The piezo stack 4 lies completely in the low-pressure region of the fluid-discharging ducts and its method of operation is not adversely affected by the fluid fed in at very high pressure.

In order to feed back the fluid into the interior of the valve 1, a thin gap 18, through which the fluid can flow out of the annular space 12 in the direction of the piezo stack 4, is provided between the pressure-equalization cylinder 11 and the valve housing 6. From said gap 18, the fluid flows into an annular space 19, which is bounded by the piezo guide 3 and the piezo stack 4. In the annular space 19, the piezo stack 4 is completely surrounded by the fluid. As a result, uniform ambient conditions arise, and the piezo stack 4 is cooled by the fluid which is flowing off. This measure prevents large temperature gradients, and thus temperature differences in the valve 1, which could be brought about by the method of operation as a result of stresses in the individual components of the valve 1 with respect to one another and, inter alia, by undesired and/or automatic opening of the valve 1. The fluid leaves the annular space 19 at the end of the piezo stack 4 facing away from the combustion space, and then leaves the valve 1.

If a control voltage is applied to the piezo stack 4, the latter experiences lengthening and displaces the valve-closure device 7 with respect to the valve housing 6 by a distance which corresponds to the lengthening of the piezo stack 4. The displacement of the valve-closure device 7 generates a gap between the step 10 and a valve seat 20, through which gap fluid can be ejected from the interior of the valve housing 6. After the injection process has ended, the control voltage is switched off and the piezo stack 4 shortens to its original length. In this context, the valve-closure device 7 is returned to the valve seat 20 by a resetting device 21, and thus closes the valve 1.

Fig. 2 shows the valve housing 6 with the valve-closure device 7 and with the resetting device 21. As can be seen in said figure, the step 10 of the valve stem 9 is designed as a closing cone 22, the closing cone 22 tapering in the direction of the annular gap 12. The conical shaping of the step 10 has the advantage that the

Westport Fuel Systems Canada Inc.
EX 2016
Robert Bosch LLC et al. v. Westport Fuel Systems Canada Inc.
IPR2023-00293
Page 10 of 16

fluid from an annular space 23 experiences a better flow-guidance through the flow-limiter 13 and is introduced into the combustion space in a plurality of directed jets. The annular space 23 is bounded by the valve stem 9 and the flow-limiter 13.

The resetting device 21, which is implemented by means of a spring device 24, draws back the valve stem 9 against the valve seat 20 after the injection process has ended. A further refinement which returns the valve stem 9 to the valve seat 20 can be implemented by means of the surface area ratio between the cross-sectional face 15 of the step 10 of the valve stem 9 and the end side 26, facing the combustion space, of the pressure-equalization cylinder 11. If the fluid applies pressure to the two faces 15 and 26, the surface area ratio must be configured in such a way that, without the spring force of the spring device 24, a resultant resetting force is present at the valve-closure device 7, which force returns the latter to the valve seat 20 in the unlengthened state of the piezo stack 4, and thus closes the valve 1.

A collar 27 is provided at that end of the plunger 8 which faces away from the combustion space. A conical section-like attachment 28 is arranged on the collar 27 in such a way that the plunger 8 can be guided coaxially with the piezo guide 3. This prevents the plunger 8 tilting during the transmission of the deflection by a transmission mechanism 29. The attachment 28 centres the plunger 8 in the piezo guide 3.

In Figs. 3 and 4 it is clear that deflection of the piezo stack 4 is passed on via the attachment 28 to the plunger 8, and thus to the valve shaft 9, by means of the transmission mechanism 29. Here, the transmission mechanism 29 has the function of amplifying the lengthening of the piezo stack 4, which is approximately 1.2 o/oo with respect to its entire length. During the injection process, the piezo stack 4 presses onto a clamping sleeve 30 bearing against it, and thus presses said clamping sleeve 30 in turn on to a lever 31. The clamping sleeve 30 is shaped in such a way that a pressure point 32 between the clamping sleeve 30 and the lever 31 lies near to the internal surface of the piezo guide 3. A pressure point 33 is arranged between the lever 31 and the attachment 28 near to a line of symmetry 34. The lever 31 is composed of four radially arranged parts which are of equal size and which tilt about a pivot 35 in the direction of the valve-closure device 7 when pressure is applied by the clamping sleeve 30. The pivot 35 bears against the inside of the piezo guide 3. The amplification

Westport Fuel Systems Canada Inc.
EX 2016
Robert Bosch LLC et al. v. Westport Fuel Systems Canada Inc.
IPR2023-00293
Page 11 of 16

of the lengthening of the piezo stack 4 is achieved by means of the different position of the two pressure points 32 and 33 between the clamping sleeve 30 and the lever 31 as well as between the lever 31 and the attachment 28. The tilting of the lever 31 permits a much greater deflection of the valve-closure device 7 than would be possible to implement with direct transmission of the lengthening of the piezo stack 4.

Fig. 5 shows a view of a detail of the refinement of the flow-limiter 13. In the present exemplary embodiment, two times four drill holes 36 and 37 are provided on that side of the flow-limiter 13 which faces the combustion space. The drill holes 36 and 37 are arranged on two conical faces which are located one behind the other and whose directrices are located on the outer surface of the flow-limiter 13 and whose cone tips are located on the line of symmetry 34 in the interior of the valve housing 6. Here, the drill holes 36 and the drill holes 37 are each offset by 90° with respect to one another, the drill holes 36 being arranged offset by 45° with respect to the drill holes 37. They are formed obliquely in the cylindrical flow-limiter 13 in such a way that they run parallel to the closing cone 22. If the valve stem 9 is lifted out of the valve seat 20, the fluid which is under pressure in the annular space 23 is directed into a combustion space through the drill holes 36 and 37 of the flow-limiter 13. As a result, a precise jet of the fluid is defined and the fluid, for example a fuel, can be introduced precisely into a combustion space.

Instead of the drill holes 36 and 37, it is possible, in an embodiment of the flow-limiter 13 (not illustrated) which deviates from the embodiment illustrated in Fig. 5, also to provide a plurality of slits or the like in one or more planes, arranged offset with respect to one another, for the precise ejection of fluid.

Furthermore, it is self-evident that in a form of the flow-limiter 13 (not illustrated in more detail) which deviates from the embodiment according to Fig. 5, it is possible to provide, instead of the two times four drill holes 36 and 37, a different number of drill holes or through-openings in the arrangement described above or in an arrangement which differs therefrom.

Westport Fuel Systems Canada Inc.
EX 2016
Robert Bosch LLC et al. v. Westport Fuel Systems Canada Inc.
IPR2023-00293
Page 12 of 16

Claims

1. A valve for the precisely metered delivery of fluids, having an injector housing in which a piezo stack is arranged, and a valve housing which is connected to the injector housing and in which a valve closure device, which has a plunger, is displaceably arranged,

a) a control voltage being applicable to the piezo stack in such a way that it experiences lengthening and the valve closure device which bears against the piezo stack is displaced with respect to the valve housing by a distance which corresponds to the lengthening of the piezo stack,

b) a gap for the ejection of fluid from the interior of the valve housing is provided in a valve opening by lengthening the piezo stack between the valve closure device and a valve seat,

c) a resetting device is provided, by means of which the valve-closure device can be reset against the valve seat,

d) an annular gap which can be filled with fluid is formed in the valve housing,

e) in the region of the annular gap facing the injector housing, a separating device is provided which separates fluid-feeding and fluid-discharging ducts from one another,

f) the valve-closure device has a sealing element in the region of the valve opening,

g) the annular gap has a constriction of its cross-section in the region of the sealing element,

wherein

h) the plunger is surrounded by a valve stem and the annular gap is formed between the valve stem and the valve housing,

i) the separating device comprises a pressure-equalization cylinder, which is arranged so as to be displaceable with respect to the valve housing and is permanently connected to the valve stem,

j) the piezo stack is surrounded by a piezo guide,

k) an annular space, into which a fluid-feeding line leads, is formed between the piezo guide and the injector housing,

Westport Fuel Systems Canada Inc.
EX 2016
Robert Bosch LLC et al. v. Westport Fuel Systems Canada Inc.
IPR2023-00293
Page 13 of 16

l) the constriction forms a flow-limiter, which bears against the sealing element of the valve stem and has, in its outer jacket, openings through which the fluid is directed out of the annular gap and into the combustion space.

2. A valve according to Claim 1, wherein the sealing element is formed as a step.

3. A valve according to Claim 1 or 2, wherein the flow-limiter is pressed against the cross-sectional face of the step of the valve stem in the annular gap by means of a spring device.

4. A valve according to any one of Claims 1 to 3, wherein the step of the valve stem comprises a closing cone, the closing cone tapering in the direction of the annular gap.

5. A valve according to any one of Claims 1 to 4, wherein, in order to centre the plunger, a collar is provided in the piezo guide on the side of the plunger facing away from the combustion space, against which collar an at least approximately conical-section-like step is arranged in such a way that the plunger is guidable coaxially with the piezo guide.

6. A valve according to Claim 5, wherein, in order to amplify the deflection of the valve closure device when the piezo stack lengthens, a transmission mechanism is provided between the piezo stack and the step.

7. A valve according to Claim 6, wherein the transmission mechanism has a clamping sleeve, which bears against the piezo stack, and a lever, which is arranged between the step and the clamping sleeve, and by means of which the lengthening of the piezo stack is transmittable in amplified fashion to the plunger.

8. A valve according to any one of Claims 1 to 7, wherein, in order to discharge fluid from the interior of the valve housing in a valve-closing position, fluid-

Westport Fuel Systems Canada Inc.
EX 2016
Robert Bosch LLC et al. v. Westport Fuel Systems Canada Inc.
IPR2023-00293
Page 14 of 16

discharging ducts are provided which are separated from the fluid-feeding means by the pressure-equalising cylinder and the piezo guide.

9. A valve according to any one of Claims 1 to 8, wherein the resetting device comprises a spring device which is arranged between the valve stem and the valve housing in such a way that, in the non-lengthened state of the piezo stack, the valve stem bears against the valve seat of the valve housing.

10. A valve according to any one of Claims 1 to 8, wherein the resetting device is constructed, by means of the surface area ratio between that end side, of a cross-sectional face of the step of the valve stem and an end side, facing the combustion space, of the pressure-equalization chamber in such a way that when pressure is applied to the cross-sectional face and to the end side by the fluid, the valve stem bears against the valve seat of the valve housing in the non-lengthened state of the piezo stack.

11. A valve according to any one of Claims 1 to 10, wherein the openings are formed as drill holes which are arranged on the side of the flow-limiter which faces the combustion space.

12. A valve for the precisely metered delivery of fluids, according to any one of the preceding claims, adapted for supplying fuel to a cylinder of an internal combustion engine.

13. A valve for the precisely metered delivery of fluids, substantially as described herein with reference to, and as illustrated in, the accompanying drawings.

Westport Fuel Systems Canada Inc.
EX 2016
Robert Bosch LLC et al. v. Westport Fuel Systems Canada Inc.
IPR2023-00293
Page 15 of 16

The Patent Office

11

Application No: GB 9800771.9
Claims searched: 1-13

Examiner: David Glover
Date of search: 23 March 1998

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.P): F1B (B2JCB, B2P4)

Int Cl (Ed.6): F02M 51/06

Other: Online: WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
A	GB 2296940 A	(Robert Bosch GmbH)	
A	GB 2193386 A	(Toyota)	
A	US 5479902	(Daimler-Benz AG)	

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

Westport Fuel Systems Canada Inc.
EX 2016
Robert Bosch LLC et al. v. Westport Fuel Systems Canada Inc.
IPR2023-00293
Page 16 of 16