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(71) Applicant: **IOP MARINE A/S** [DK/DK]; Engager 7, 2605 Brøndby (DK).

(72) Inventor: **SOWINSKI, Grzegorz**; Lauritz Sørensens Vej 6 st. th., 2000 Frederiksberg (DK).

(74) Agent: **NORDIC PATENT SERVICE**; Bredgade 30, 1260 Copenhagen K (DK).

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(54) **Title:** METHOD FOR TESTING AN INJECTOR VALVE

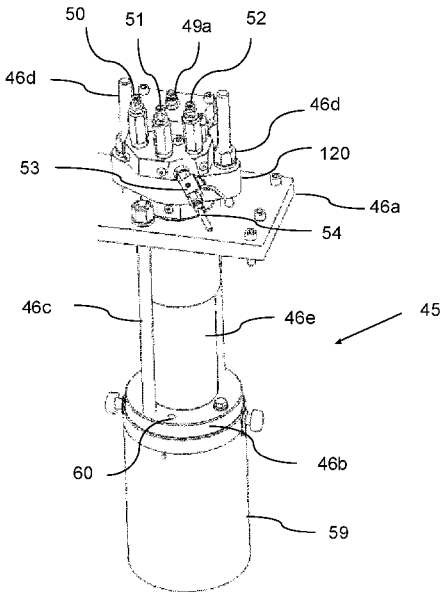


Fig. 21

(57) **Abstract:** A method of testing a non-return valve (77) of an injector valve (44) for a combustion engine. The valve (44) holds a sealing chamber (136) with a plunger piston (58) for forming a compression chamber (74), a one-way valve (70) for fuel oil inlet to the compression chamber (74, a non-return valve (77) in fluid connection with the compression chamber (74) for supply of fuel oil from the compression chamber (74) to the non-return valve (77), and a nozzle valve (61a). The nozzle valve (61a) holds a chamber (81), a connection seat (88), and a piston cut-off shaft (62) with a cut-off shaft tip (61c) protruding through an opening (61b) of the nozzle valve (61a). The method comprises applying a lifting pressure to the cut-off shaft tip (61c) to thereby maintain the cut-off shaft (62) in a lifted position from the connection seat (88) in which the nozzle valve (61a) is open, supplying plunger oil to the plunger piston (58) at a first test plunger oil pressure to close the compression chamber (74), supplying fuel oil at a first test fuel oil pressure to the one-way valve (70), said first test fuel oil pressure being lower than a predetermined fuel oil pressure required for opening the non-return valve (77), and checking whether any of the supplied fuel oil reaches out from the nozzle valve opening (61b). A method for testing whether the nozzle valve (61a) is tight is also provided.

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TITLE

METHOD FOR TESTING AN INJECTOR VALVE

TECHNICAL FIELD

The disclosure relates to a method for testing an injector valve for liquid gas, such as liquefied petroleum gas, LGP.

BACKGROUND

WO 2016/155746 discloses a method for testing an injector valve for liquid gas such as methanol. The injector valve may be used for a two-stroke combustion engine. The injector valve is supplied with sealing oil and control oil for controlling the supply of liquid gas. The disclosed injector valve holds a plunger piston chamber for forming a compression chamber, a suction valve with a suction piston and a nozzle valve with a nozzle piston, one or more nozzle openings, and a control oil channel, wherein the fuel fluid channels provide a fluid connection from the plunger piston chamber to the nozzle openings when the suction valve is open by a pressure on the suction piston provided by a fluid pressure in the plunger piston chamber and when the nozzle valve is open by a pressure on the nozzle piston provided by a control oil pressure supplied via the control oil channel. For the test disclosed in WO 2016/155746, the injector valve is placed in a holder and the top cover is removed and substituted with a connecting piece and the pressure of the control oil is increased until the opening pressure for the nozzle valve is reached and the injector valve sprays oil from the nozzle openings into a spray chamber. As a result, the opening pressure of the nozzle valve can be checked. However, there is no disclosure of a leakage test of the suction valve.

DK 202070137 A1 and WO 2021/043380 disclose a method for testing a valve body of an injector valve for liquid gas, and a method for testing the assembled injector valve. The injector valve may be used as a fuel booster injection valve for the liquefied petroleum gas, LGP, and may be designed for performing two functions: to pressurize or boost the LPG to the desired injection pressure, and to ensure the correct timing and duration of the LPG injection.

During normal operation, the injector valve is supplied with sealing oil, plunge oil, control oil, and liquid petroleum gas, LPG, as fuel. Sealing oil is to prevent internal leak of liquid gas from entering unintended areas of the injector valve. Plunge oil is to pressurize the fuel, LPG. Control oil is to control the timing of opening the injector valve for delivering compressed fuel gas to the combustion chamber. Liquid fuel is supplied to the injector valve constantly.

The valve body of the valve disclosed in DK 202070137 A1 and WO 2021/043390 holds a plunger piston chamber for forming a compression chamber, a suction valve with a suction piston, one or more fuel fluid channels, a nozzle valve with a nozzle piston, one or more nozzle openings, and a control oil channel, wherein the fuel fluid channels provide a fluid connection from the plunger piston chamber to the nozzle openings when the suction valve is open by a pressure on the suction piston provided by a fluid pressure in the plunger piston chamber and when the nozzle valve is open by a pressure on the nozzle piston provided by a control oil pressure supplied via the control oil channel. The test of the valve body includes a test for verifying that the suction valve is tight, and a test for testing that the nozzle valve is tight.

A new injector valve for LPG for a two-stroke combustion engine has been developed by MAN Energy Solutions. This injector valve is also supplied with sealing oil and control oil for controlling the supply of liquid gas. Leaks if any could be very dangerous.

Thus, there is also a need for an improved method for testing this new injector valve for leaks, and there is also a need for an improved working test of this injector valve.

SUMMARY

It is an object of the present disclosure to provide an improved method for testing an injector valve for valve leaks.

This object is achieved in accordance with a first aspect by providing a method of testing an injector valve (44) for a combustion engine, which injector valve (44) comprises:

a plunger piston sealing chamber (136) with a plunger piston (58) for forming a plunger compression chamber (74), said plunger piston (58) being provided with a plunger piston fuel oil opening (57b) at the bottom and said plunger piston (58) being controlled by supply of plunger oil at a plunger oil pressure via a cover plunger oil supply channel (63);

a suction one-way valve (70) for fuel oil inlet via a suction valve fuel inlet (72), a plunger chamber supply channel (73) for supply of fuel oil from the suction one-way valve (70) to the plunger compression chamber (74) or to the plunger piston fuel oil opening (57b);

a non-return valve (77) in fluid connection with the plunger compression chamber (74) or the plunger piston fuel oil opening (57b) via a non-return valve supply channel (75) for supply of fuel oil to the non-return valve (77);

a nozzle valve (61a) with a nozzle valve chamber (81), a nozzle valve piston cut-off shaft (62), a nozzle valve spring (96), a nozzle valve connection seat (88), and a nozzle valve opening (61b), said nozzle valve piston cut-off shaft (62) having a nozzle valve piston cut-off shaft tip (61c) protruding through the opening (61b) of the nozzle valve (61a); and

a number of nozzle valve chamber supply channels (78a, 78b, 79a, 79b, 80a,80b) providing a fluid connection from the non-return valve (77) to the nozzle valve chamber (81) for supply of fuel oil from the plunger compression chamber (74) or from the plunger piston fuel oil opening (57b) via the non-return valve (77) to the nozzle valve chamber (81); said method comprising:

(a) applying a predetermined lifting pressure to the nozzle valve piston cut-off shaft tip (61c) protruding through the opening (61b) of the nozzle valve (61a), said lifting pressure being higher than a spring force exerted by the nozzle valve spring (96) on the nozzle valve piston cut-off shaft (62) to thereby maintain the nozzle valve piston cut-off shaft (62) in a lifted position from the nozzle valve connection seat (88) in which the nozzle valve (61a) is open;

(b) supplying plunger oil to the plunger piston (58) via the cover plunger oil supply channel (63) at a first test plunger oil pressure, said first test plunger oil pressure being equal to or larger than a predetermined plunger oil pressure required for maintaining the plunger piston (58) at the bottom of the plunger piston sealing chamber (136) to thereby close the plunger compression chamber (74) while maintaining a fluid connection from the plunger chamber supply channel (73) via the plunger piston fuel oil opening (57b) to the non-return valve supply channel (75);

(c) supplying fuel oil at a first predetermined test fuel oil pressure to the suction valve fuel inlet (72), via the suction one-way valve (70) and the piston fuel oil opening (57b) to the non-return valve supply channel (75), said first predetermined test fuel oil pressure being lower than a predetermined fuel oil pressure required for opening the non-return valve (77); and

(d) checking whether any of the supplied fuel oil reaches out from the nozzle valve opening (61b).

If the non-return valve 77 is tight, no oil should be observed reaching out from the nozzle valve opening 61b.

In a possible implementation form of the first aspect, the injector valve (44) before being tested is in an assembled condition with an atomizer (43) provided at a bottom of the valve (44) with the nozzle valve piston cut-off shaft tip (61c) protruding into the atomizer (43) for output of fuel from the nozzle valve opening (61b) through the atomizer (43), and the atomizer (43) is removed when testing the injector valve (44).

In a possible implementation form of the first aspect, the injector valve under test (44) further comprises

a hydraulic piston chamber (155) holding a hydraulic piston (64) connected to the nozzle valve piston cut-off shaft (62), said hydraulic piston (64) being controlled by supply of control oil at a control oil pressure via control oil supply channels (141, 142) for opening and closing the nozzle valve (61a).

In a possible implementation form of the first aspect, the injector valve under test (44) further comprises

sealing oil channels (131, 132, 133, 134) in fluid connection with the plunger piston sealing chamber (136) for sealing the plunger piston (58), and in fluid connection with the hydraulic piston chamber (155) for sealing the hydraulic piston (64); and the method before the supply of plunger oil at step (b) comprises a sealing step by

supplying sealing oil at a first sealing oil pressure to the plunger piston sealing chamber (136) and the hydraulic piston chamber (155) via the sealing oil channels (131, 132, 133, 135), said first sealing oil pressure being higher than or equal to a predetermined sealing oil pressure required for sealing of the plunger piston (58) within the plunger piston

sealing chamber (23) and for sealing of the hydraulic piston (64) within the hydraulic piston chamber (155).

In a possible implementation form of the first aspect, the predetermined sealing oil pressure is in the range of 60-100 bar, such as in the range of 70-90 bar, such as around 80 bar.

In a possible implementation form of the first aspect, the valve (44) being tested is placed in a function test valve holder (45) holding a nozzle valve piston lifting unit (46b) with a lifting piston (67) and lifting oil channels (66), said nozzle valve piston lifting unit (46b) being positioned with the lifting piston (67) engaging the nozzle valve piston cut-off shaft tip (61b), and lifting oil is supplied at a predetermined pressure to the lifting piston (67) via the lifting oil channels (68) to thereby provide said predetermined lifting pressure for maintaining the nozzle valve piston cut-off shaft (62) in the lifted position.

In a possible implementation form of the first aspect, the nozzle valve piston lifting unit (46b) further has lifting unit fuel oil leakage channels (83, 84) and a lifting unit fuel oil outlet (85) in fluid connection with the nozzle valve opening (61b), whereby any fuel oil reaching out from the nozzle valve opening (61b) will reach out from the lifting unit fuel oil outlet (85).

In a possible implementation form of the first aspect, the lifting unit fuel oil outlet (85) faces an oil injector chamber (59) for collection of oil leaking or reaching out from the lifting unit fuel oil outlet (85).

In a possible implementation form of the first aspect, the first test plunger oil pressure is in the range of 280-320 bar, such as about 300 bar.

In a possible implementation form of the first aspect, the step of supplying plunger oil to the plunger piston (58) at step (b) comprises a first step of slowly increasing the pressure of supplied plunger oil to a first lower initial oil pressure and then proceed by increasing the oil pressure to the first test plunger oil pressure.

In a possible implementation form of the first aspect, the first lower initial oil pressure is in the range of 10 to 50 bar.

In a possible implementation form of the first aspect, the first predetermined test fuel oil pressure of step (c) is about 30 bar.

In a possible implementation form of the first aspect, the non-return valve (77) comprises a non-return valve housing (87a), a non-return valve spindle (86), a non-return valve connection seat (76) and a non-return valve spring (87b) for forcing the non-return valve spindle (86) against the non-return valve connection seat (76) to thereby close the non-return valve (77), and the predetermined fuel oil pressure required for opening the non-return valve (77) is determined by the spring force of the non-return valve spring (87b).

In a possible implementation form of the first aspect, the method further comprises:

(e) slowly increasing the pressure of the supply of fuel oil to the suction valve fuel inlet (72) until the non-return valve (77) opens.

In a possible implementation form of the first aspect, the non-return valve (77) opens when the pressure of the supplied fuel oil overcomes the spring force of the non-return valve spring (87b).

In a possible implementation form of the first aspect, the method further comprises:

(f) observing the pressure of supplied fuel oil when fuel oil droplets or a stream of fuel oil flow reach out from the nozzle valve opening (61b) to thereby determine an opening pressure for the non-return valve (77).

In a possible implementation form of the first aspect, the method further comprises:

(g) release the pressure of the supply of fuel oil to a pressure well below the determined opening pressure of the non-return valve (77), such as at least 10-20 bar or at least 30 bar below the determined opening pressure of the non-return valve (77).

In a possible implementation form of the first aspect, the method further comprises:

(h) increasing the pressure of the supply of fuel oil to the suction valve fuel inlet (72) until it reaches a pressure being in the range of 3-5 bar below the determined opening pressure of the non-return valve (77); and

(i) checking whether any of the supplied fuel oil reaches out from the nozzle valve opening (61b).

If the non-return valve is tight, no oil should be observed reaching out from the nozzle valve opening 61b.

In a possible implementation form of the first aspect, the fuel oil is supplied by a fuel oil pump (37) in fluid connection with the suction valve fuel inlet, and the fuel oil pressure is read from a fuel oil pressure gauge (36).

In a possible implementation form of the first aspect, the method further comprises:

(j) turn off the fuel oil pump (37) while and wait about 15 seconds for the fuel oil pressure gauge (36) to stabilize and observe the fuel oil pressure at the fuel oil pressure gauge (36);

(k) wait about 60 seconds and observe the fuel oil pressure at the fuel oil pressure gauge (36).

In a possible implementation form of the first aspect, the method further comprises:

releasing the predetermined lifting pressure from the nozzle valve piston cut-off shaft tip (61c) to thereby close the nozzle valve (61a) with the spring force of the nozzle valve spring (96) forcing the nozzle valve piston cut-off shaft (62) against the nozzle valve connection seat (88);

supplying fuel oil at a second predetermined test fuel oil pressure to the suction valve fuel inlet (72), via the suction one-way valve (70) and the piston fuel oil opening (57b) to the non-return valve supply channel (75), said second predetermined test fuel oil pressure being higher than a predetermined fuel oil pressure required for opening the non-return valve (77); and

checking whether any of the supplied fuel oil reaches out from the nozzle valve opening (61b).

If the nozzle valve 61a is tight, no oil should be observed reaching out from the nozzle valve opening 61b.

In a possible implementation form of the first aspect, the second predetermined test fuel oil pressure is about 5 bar higher than the predetermined fuel oil pressure required for opening the non-return valve (77).

According to a second aspect there is provided a method of testing an injector valve (44) for a combustion engine, which injector valve (44) comprises:

a plunger piston sealing chamber (136) with a plunger piston (58) for forming a plunger compression chamber (74), said plunger piston (58) being provided with a plunger piston fuel oil opening (57b) at the bottom and said plunger piston (58) being controlled by supply of plunger oil at a plunger oil pressure via a cover plunger oil supply channel (63);

a suction one-way valve (70) for fuel oil inlet via a suction valve fuel inlet (72), a plunger chamber supply channel (73) for supply of fuel oil from the suction one-way valve (70) to the plunger compression chamber (74) or to the plunger piston fuel oil opening (57b);

a non-return valve (77) in fluid connection with the plunger compression chamber (74) or the plunger piston fuel oil opening (57b) via a non-return valve supply channel (75) for supply of fuel oil to the non-return valve (77);

a nozzle valve (61a) with a nozzle valve chamber (81), a nozzle valve piston cut-off shaft (62), a nozzle valve spring (96), a nozzle valve connection seat (88), and a nozzle valve opening (61b), said nozzle valve piston cut-off shaft (62) having a nozzle valve piston cut-off shaft tip (61c) protruding through the opening (61b) of the nozzle valve (61a);

a number of nozzle valve chamber supply channels (78a, 78b, 79a, 79b, 80a,80b) providing a fluid connection from the non-return valve (77) to the nozzle valve chamber (81) for supply of fuel oil from the plunger compression chamber (74) or from the plunger piston fuel oil opening (57b) via the non-return valve (77) to the nozzle valve chamber (81); said method comprising:

supplying plunger oil to the plunger piston (58) via the cover plunger oil supply channel (63) at a test plunger oil pressure, said test plunger oil pressure being equal to or larger than a plunger oil pressure required for maintaining the plunger piston (58) at the bottom of the plunger piston sealing chamber (136) to thereby close the plunger compression chamber (74) while maintaining a fluid connection from the plunger chamber

supply channel (73) via the plunger piston fuel oil opening (57b) to the non-return valve supply channel (75);

supplying fuel oil at a second predetermined test fuel oil pressure to the suction valve fuel inlet (72), via the suction one-way valve (70) and the piston fuel oil opening (57b) to the non-return valve supply channel (75), said second predetermined test fuel oil pressure being higher than a predetermined fuel oil pressure required for opening the non-return valve (77); and

checking whether any of the supplied fuel oil reaches out from the nozzle valve opening (61b).

If the nozzle valve 61a is tight, no oil should be observed reaching out from the nozzle valve opening 61b.

In a possible implementation form of the second aspect, the second predetermined test fuel oil pressure is about 5 bar higher than the predetermined fuel oil pressure required for opening the non-return valve (77).

In a possible implementation form of the second aspect, the test plunger oil pressure is in the range of 280-320 bar, such as about 300 bar.

According to a third aspect there is provided a method of testing an injector valve (44) for a combustion engine, which injector valve (44) comprises:

a plunger piston sealing chamber (136) with a plunger piston (58) for forming a plunger compression chamber (74), said plunger piston (58) being controlled by supply of plunger oil at a plunger oil pressure via a cover plunger oil supply channel (63), and said plunger piston (58) holding first and second plunger leakage channels (89,90) providing a fluid connection from the bottom of the plunger piston (58) to an upper sidewall part of the plunger piston (58);

a suction one-way valve (70) for fuel oil inlet via a suction valve fuel inlet (72), a plunger chamber supply channel (73) for supply of fuel oil from the suction one-way valve (70) to the plunger compression chamber (74);

a non-return valve (77) in fluid connection with the plunger compression chamber (74) via a non-return valve supply channel (75) for supply of fuel oil from the plunger compression chamber (74) to the non-return valve (77);

a nozzle valve (61a) with a nozzle valve chamber (81), a nozzle valve piston cut-off shaft (62), a nozzle valve spring (96), a nozzle valve connection seat (88), and a nozzle valve opening (61b), said nozzle valve piston cut-off shaft (62) having a nozzle valve piston cut-off shaft tip (61c) protruding through the opening (61b) of the nozzle valve (61a); and

a number of nozzle valve chamber supply channels (78a, 78b, 79a, 79b, 80a,80b) providing a fluid connection from the non-return valve (77) to the nozzle valve chamber (81) for supply of fuel oil from the plunger compression chamber (74) or from the plunger piston fuel oil opening (57b) via the non-return valve (77) to the nozzle valve chamber (81); and

a third plunger compression leakage channel (91) providing a fluid connection from the plunger piston sealing chamber (136) to a fuel oil leakage outlet (92) positioned at an outer surface of the valve, wherein the third plunger compression leakage channel (91) has an inlet opening facing the plunger piston sealing chamber (136) at a position being faced by an outlet opening of the second plunger compression leakage channel (90) when the plunger piston (58) is in its most upper position within the plunger piston sealing chamber (136); said method comprising:

supplying fuel oil at a predetermined leakage test fuel oil pressure to the suction valve fuel inlet (72), via the suction one-way valve (70) and the piston fuel oil opening (57b) to the plunger compression chamber, said predetermined leakage test fuel oil pressure being lower than a predetermined fuel oil pressure required for opening the non-return valve (77) and higher than a fuel oil pressure required for lifting the plunger piston (58) to its most upper position when no plunger oil pressure is applied to the plunger piston (58); and

checking whether any of the supplied fuel oil reaches out from the fuel oil leakage outlet (92).

Fuel oil should be observed reaching out from the oil leakage outlet 92.

In a possible implementation form of the third aspect, the predetermined leakage test fuel oil pressure of step is in the range of 20 to 40 bar, such as in the range of 25 to 35 bar, such as about 30 bar.

In a possible implementation form of the third aspect, there is no supply of plunger oil at a plunger oil pressure to the plunger piston (58).

In a possible implementation form of the third aspect, the injector valve under test (44) further comprises

a hydraulic piston chamber (155) holding a hydraulic piston (64) connected to the nozzle valve piston cut-off shaft (62), said hydraulic piston (64) being controlled by supply of control oil at a control oil pressure via control oil supply channels (141, 142) for opening and closing the nozzle valve (61a).

In a possible implementation form of the third aspect, the injector valve under test (44) further comprises

sealing oil channels (131, 132, 133, 134) in fluid connection with the plunger piston sealing chamber (136) for sealing the plunger piston (58), and in fluid connection with the hydraulic piston chamber (155) for sealing the hydraulic piston (64); and the method before the supply of fuel oil comprises a sealing step by

supplying sealing oil at a first sealing oil pressure to the plunger piston sealing chamber (136) and the hydraulic piston chamber (155) via the sealing oil channels (131, 132, 133, 135), said first sealing oil pressure being higher than or equal to a predetermined sealing oil pressure required for sealing of the plunger piston (58) within the plunger piston sealing chamber (23) and for sealing of the hydraulic piston (64) within the hydraulic piston chamber (155).

In a possible implementation form of the third aspect, the predetermined sealing oil pressure is in the range of 60-100 bar, such as in the range of 70-90 bar, such as around 80 bar.

According to a fourth aspect there is provided a method of testing an injector valve (44) for a combustion engine, which injector valve (44) comprises:

a plunger piston sealing chamber (136) with a plunger piston (58) for forming a plunger compression chamber (74), said plunger piston (58) being controlled by supply of plunger oil at a plunger oil pressure via a cover plunger oil supply channel (63);

a suction one-way valve (70) for fuel oil inlet via a suction valve fuel inlet (72), a plunger chamber supply channel (73) for supply of fuel oil from the suction one-way valve (70) to the plunger compression chamber (74);

a non-return valve (77) in fluid connection with the plunger compression chamber (74) via a non-return valve supply channel (75) for supply of fuel oil from the plunger compression chamber (74) to the non-return valve (77);

a nozzle valve (61a) with a nozzle valve chamber (81), a nozzle valve piston cut-off shaft (62), a nozzle valve spring (96), a nozzle valve connection seat (88), and a nozzle valve opening (61b), said nozzle valve piston cut-off shaft (62) having a nozzle valve piston cut-off shaft tip (61c) protruding through the opening (61b) of the nozzle valve (61a); and

a number of nozzle valve chamber supply channels (78a, 78b, 79a, 79b, 80a,80b) providing a fluid connection from the non-return valve (77) to the nozzle valve chamber (81) for supply of fuel oil from the plunger compression chamber (74) or from the plunger piston fuel oil opening (57b) via the non-return valve (77) to the nozzle valve chamber (81); said method comprising:

(aa) supplying fuel oil at a predetermined nozzle valve test fuel oil pressure to the suction valve fuel inlet (72), via the suction one-way valve (70) to the plunger compression chamber (74), said predetermined nozzle valve test fuel oil pressure being lower than a fuel oil pressure required for opening the non-return valve (77);

(bb) supplying plunger oil to the plunger piston (58) via the cover plunger oil supply channel (63) at a first nozzle valve test plunger oil pressure, said first nozzle valve test plunger oil pressure being larger than or equal to a non-return valve plunger oil pressure required for opening the non-return valve (77) and smaller than or equal to a nozzle valve plunger oil pressure required for opening the nozzle valve (61a) by overcoming the force of the nozzle valve spring (96); and

(cc) checking whether any of the supplied fuel oil reaches out from the nozzle valve opening (61b).

The suction one-way valve 70 for fuel oil inlet is a one-way valve, whereby fuel oil being compressed can only escape via the non-return valve 77 into the nozzle valve chamber 81. Since the nozzle valve 61a should not be open, no fuel oil should reach out from the nozzle valve opening 61b.

In a possible implementation form of the fourth aspect, the predetermined nozzle valve test fuel oil pressure is equal to or larger than a predetermined fuel oil pressure required for lifting the plunger piston (58) to its most upper position when no plunger oil pressure is applied to the plunger piston (58).

In a possible implementation form of the fourth aspect, the predetermined nozzle valve test fuel oil pressure of step (aa) is in the range of 20 to 40 bar, such as in the range of 25 to 35 bar, such as about 30 bar.

In a possible implementation form of the fourth aspect, the first nozzle valve test plunger oil pressure is in the range of 140-160 bar, such as about 150 bar.

In a possible implementation form of the fourth aspect, the injector valve under test (44) further comprises

a hydraulic piston chamber (155) holding a hydraulic piston (64) connected to the nozzle valve piston cut-off shaft (62), said hydraulic piston (64) being controlled by supply of control oil at a control oil pressure via control oil supply channels (141, 142) for opening and closing the nozzle valve (61a).

In a possible implementation form of the fourth aspect, the injector valve under test (44) further comprises

sealing oil channels (131, 132, 133, 134) in fluid connection with the plunger piston sealing chamber (136) for sealing the plunger piston (58), and in fluid connection with the hydraulic piston chamber (155) for sealing the hydraulic piston (64); and the method before the supply of plunger oil at step (bb) or before the supply of fuel oil at step (aa) comprises a sealing step by

supplying sealing oil at a first sealing oil pressure to the plunger piston sealing chamber (136) and the hydraulic piston chamber (155) via the sealing oil channels (131, 132, 133, 135), said first sealing oil pressure being higher than or equal to a predetermined sealing oil pressure required for sealing of the plunger piston (58) within the plunger piston sealing chamber (23) and for sealing of the hydraulic piston (64) within the hydraulic piston chamber (155).

In a possible implementation form of the fourth aspect, the predetermined sealing oil pressure is in the range of 60-100 bar, such as in the range of 70-90 bar, such as around 80 bar.

In a possible implementation form of the fourth aspect, the non-return valve (77) comprises a non-return valve housing (87a), a non-return valve spindle (86), a non-return valve connection seat (76) and a non-return valve spring (87b) for forcing the non-return valve spindle (86) against the non-return valve connection seat (76) to thereby close the non-return valve (77), and the fuel oil pressure required for opening the non-return valve (77) is determined by the spring force of the non-return valve spring (87b).

In a possible implementation form of the fourth aspect, the method further comprises:

(dd) increase the supply of plunger oil to the plunger piston (58) in steps from the first nozzle valve test plunger oil pressure to a final nozzle valve test plunger oil pressure, said final nozzle valve test plunger oil pressure being larger than the nozzle valve plunger oil pressure required for opening the nozzle valve (61a) by overcoming the force of the nozzle valve spring (96); and

(ee) after each step of increase in the supply of plunger oil then checking whether any of the supplied fuel oil reaches out from the nozzle valve opening (61b).

In a possible implementation form of the fourth aspect, the final nozzle valve test plunger oil pressure is in the range of 175 to 200 bar, such as about 185 bar.

In a possible implementation form of the fourth aspect, the supply of plunger oil is increased in steps of 5 bar.

In a possible implementation form of the fourth aspect, the method further comprises:

(ff) observing the pressure of supplied fuel oil when fuel oil droplets or a stream of fuel oil flow reach out from the nozzle valve opening (61b) to thereby determine an opening pressure for the nozzle valve (61a).

In a possible implementation form of the fourth aspect, the method further comprises:

(gg) changing the supply of plunger oil to the plunger piston (58) from the final nozzle valve test plunger oil pressure to a closed nozzle valve test plunger oil pressure, said closed nozzle valve test plunger oil pressure having a value in the range of 5 -10 bar below the determined opening pressure for the nozzle valve (61a); and

(hh) checking whether any of the supplied fuel oil reaches out from the nozzle valve opening (61b).

If the nozzle valve 61a is tight, no fuel oil should be observed.

The foregoing and other objects are achieved by the features of the independent claims. Further implementation forms are apparent from the dependent claims, the description and the figures. These and other aspects of the invention will be apparent from the embodiments described below.

BRIEF DESCRIPTION OF THE DRAWINGS

In the following detailed portion of the present disclosure, the aspects, embodiments and implementations will be explained in more detail with reference to the example embodiments shown in the drawings, in which:

Fig. 1 is a diagram of a test system with lines for supply of control oil, sealing oil, constant oil, lifting oil, fuel oil and test gas for testing an injector valve being placed in a function test valve holder according to an example embodiment;

Fig. 2 is a perspective view of an assembled injector valve according to an example embodiment;

Fig. 3 is a longitudinal sectional view of the assembled injector valve of Fig. 2 according to an example embodiment;

Fig. 4 is a longitudinal sectional view of the assembled injector valve of Fig. 3 when turned a first angle according to an example embodiment;

Fig. 5 is a longitudinal sectional view of the assembled injector valve of Fig. 3 when turned a second angle according to an example embodiment;

Fig. 6 is an amplified longitudinal sectional view of the top cover of the assembled injector valve of Fig. 2 according to an example embodiment;

Fig. 7 is a longitudinal sectional view of the assembled injector valve of Fig. 3 when turned a third angle according to an example embodiment;

Fig. 8 is an amplified view of the top cover with inlet ports of the assembled injector valve of Fig. 2 according to an example embodiment;

Fig. 9 is an amplified longitudinal sectional view of a part of the sectional view of Fig. 3, which part illustrates the arrangement of a suction one-way valve for fuel inlet, a plunger piston compression chamber for fuel compression, and a non-return valve for delivery of compressed fuel according to an example embodiment;

Fig. 10 is an amplified longitudinal sectional view of a part of the amplified sectional view of Fig. 9, which part shows the non-return valve of Fig. 9 at a first angle according to an example embodiment;

Fig. 11 is an amplified longitudinal sectional view showing the non-return valve of Fig. 9 at a second angle for illustrating the arrangement of supply channels for supply of compressed fuel to a nozzle valve according to an example embodiment;

Fig. 12 is an amplified longitudinal sectional view showing the arrangement of further supply channels for supply of compressed fuel to the nozzle valve according to an example embodiment;

Fig. 13 is an amplified longitudinal sectional view of a part of the sectional view of Fig. 5, which part illustrates the arrangement of control oil supply and drain channels for actuation of a hydraulic piston according to an example embodiment;

Fig. 14 is an amplified longitudinal sectional view of a part of the sectional view of Fig. 7, which part illustrates the arrangement of oil leakage channels for control and sealing oil leakage form the hydraulic piston according to an example embodiment;

Fig. 15 is an amplified longitudinal sectional view of a part of the assembled injector valve of Fig. 2, which part illustrates the arrangement of oil leakage channels for fuel oil leakage from the hydraulic piston according to an example embodiment;

Fig. 16 is an amplified longitudinal sectional view of a part of the assembled injector valve of Fig. 2, which part illustrates the arrangement of oil leakage channels for collecting oil leakage from an intermediate valve part and from an atomizer part according to an example embodiment;

Fig. 17 is an amplified longitudinal sectional view of a part of the sectional view of Fig. 16, which part illustrates the arrangement of oil leakage chambers for collecting leakage oil at an upper and a lower surface of the intermediate valve part according to an example embodiment;

Fig. 18 is a cross-sectional view of an upper surface part of the intermediate valve part of Fig. 17, illustrating the arrangement of different oil channels with oil sealings according to an example embodiment;

Fig. 19 is a cross-sectional view of an upper surface part of a spindle guide housing facing a lower surface of the intermediate valve part of Fig. 17, illustrating the arrangement of different oil channels with oil sealings according to an example embodiment;

Fig. 20 is a perspective view of the injector valve of Fig. 2 with an atomizer unit nut and a corresponding atomizer being removed according to an example embodiment;

Fig. 21 illustrates the injector valve of Fig. 20 when placed in a function test valve holder with a spray chamber and a nozzle valve piston lifting unit according to an example embodiment;

Fig. 22 shows the function test valve holder of Fig. 21 from another angle illustrating the arrangement of a fuel oil inlet connection piece and a lifting oil connection piece according to an example embodiment;

Fig. 23 is an amplified longitudinal sectional view illustrating the arrangement of the injector valve of Fig. 20 relative to the nozzle valve piston lifting unit of the function test valve holder according to an example embodiment;

Fig. 24 is an amplified longitudinal sectional view illustrating the arrangement of the injector valve of Fig. 20 relative to the fuel oil inlet connection piece of Fig. 22 according to an example embodiment;

Fig. 25 is an amplified longitudinal sectional view illustrating the arrangement of the injector valve of Fig. 20 relative to a fuel oil leakage outlet provided in a test sleeve of the function test valve holder of Fig. 21 according to an example embodiment;

Fig. 26 is a longitudinal sectional view illustrating the arrangement of the injector valve of Fig. 20 relative to the function test valve holder of Fig. 21 with a fuel oil drain sleeve for drain of oil from the fuel oil leakage outlet to the spray chamber according to an example embodiment;

Fig. 27 illustrates the assembled injector valve of Fig. 2 when placed in a detection test valve holder according to an example embodiment;

Fig. 28 is a longitudinal sectional view illustrating the arrangement of the injector valve of Fig. 2 relative to the detection test valve holder of Fig. 27, which detection test valve holder holds a test air inlet port and a number of test air outlet ports according to an example embodiment; and

Fig. 29 is a schematic diagram illustrating a test setup holding the detection test valve holder and injector valve of Fig. 28 with the test air outlet ports connection to a detection test liquid chamber according to an example embodiment.

LIST OF REFERENCE NUMBERS FOR THE DRAWINGS

Test system	1
Gas inlet	1a
Air inlet	1b
Gas outlet	1c
Control oil outlet	1d
Sealing oil outlet	1e

Fuel oil outlet	1f
Plunger oil outlet	1g
Lifting oil outlet	1h
Constant oil outlet	1i
Control/Sealing oil valve	2
Control oil directional valve	3
Control oil pressure relief valve	4
Hydraulic accumulator	5
Control/Sealing oil pressure gauge	6
Control/Sealing oil air driven pump	7
Control/Sealing oil pressure control valves	8
Control/sealing oil air pump safety valve	9
Plunger oil directional valve	10
Plunger oil pressure relief valve	11
Plunger oil pressure control valve	12
Plunger oil pressure gauge	13
Plunger oil pressure safety valve	14
Plunger oil air driven pump	15
Oil tank	16
Oil tank filler cap	17
Oil tank stop valve	18
Oil filter	19
Nitrogen booster	20
Booster oil pressure relief valve	21
Nitrogen inlet non-return valve	22
Nitrogen gas pressure control valve	23
Gas stop valve	24
Nitrogen gas pressure gauge	25
Constant oil valve	26
Lifting oil pressure relief valve	27
Lifting oil pressure control valves	28
Lifting oil air pump safety valve	29
Lifting oil pressure gauge	30

Lifting oil air driven pump	31
Fuel oil pressure relief valve	32
Fuel oil pressure control valves	33
Fuel oil air pump safety valve	34
Fuel oil pressure safety valve	35
Fuel oil pressure gauge	36
Fuel oil air driven pump	37
Fuel booster injector valve (FBIV)	44
Atomizer	43
Top cover	120
Plunger oil inlet port	49b
Control oil inlet port	130
Sealing oil inlet port	128
Constant oil inlet port	129
Barrel flange	121
Barrel body	122
Intermediate part	123
Spindle guide housing	124
Hydraulic piston bushing	125
Spindle guide union nut	127
Atomizer union nut	126
Spindle guide housing seal	201
Cover plunger oil channel	63
Cover fluid channels	56a, 56b, 56c
Air bleeding outlet	55
Plunger oil chamber	57a
Plunger piston	58
Plunger piston fuel oil opening	57b
Plunger piston head chamber	156
Plunger compression chamber	74
Plunger piston head seal	187
Plunger piston chamber seal	188

Plunger piston head chamber leakage channels	148, 149
Oil leakage outlets	157, 158
Plunger compression chamber leakage channels	89, 90, 91
Fuel oil leakage outlet	92
Plunger piston sealing bore	135
Plunger piston sealing chamber	136
Sealing oil channels	131, 132, 133, 134
Suction one-way valve	70
Suction valve fuel inlet	72
Plunger chamber supply channel	73
Non-return valve	77
Non-return valve supply channel	75
Non-return valve connection seat	76
Non-return valve spindle	86
Non-return valve housing	87a
Non-return valve spring	87b
Non-return valve upper chamber	186
Non-return valve seal	185
Non-return valve leakage channels	144, 146
Non-return valve leakage chambers	145, 147
Nozzle valve chamber supply channels	78a, 78b, 79a, 79b, 80a, 80b
Control oil supply channels	140, 141
Control oil drain channels	142, 143a
(Drain channels 142 and 143a connect to constant oil port 129)	
Control oil drain restriction	143b
Hydraulic piston	64
Hydraulic piston seal	189
Hydraulic piston actuation chamber	65
Hydraulic piston actuation chamber seal	184
Hydraulic piston chamber	155
Hydraulic piston bushing seals	190, 191, 192, 193
Hydraulic piston sealing bore	137
Hydraulic piston sealing channel	138

Hydraulic piston sealing chamber	139
Hydraulic piston bushing leakage channel	154
Hydraulic piston bushing leakage chamber	153
Control and sealing oil leakage channels	150, 151, 152
Nozzle valve	61a
Nozzle valve opening	61b
Nozzle valve piston cut-off shaft	62
Nozzle valve piston cut-off shaft tip	61c
Nozzle valve piston guide	95
Nozzle valve connection seat	88
Nozzle valve chamber	81
Nozzle valve spring	96
Nozzle valve lower chamber	82
Nozzle valve piston leakage chamber	159
Nozzle valve bushing leakage chamber	161
Fuel oil leakage channels	160, 162, 163, 164
Atomizer fuel oil leakage chamber	194
Atomizer fuel oil leakage channel	168
Intermediate leakage oil collecting channel	169
Intermediate leakage oil outlet channel	197
Intermediate outer leakage oil chamber	198
Upper oil leakage channel	167
Upper oil leakage outlets	165, 166
Intermediate upper leakage oil chamber	170
Spindle guide upper leakage oil chamber	171
Intermediate upper sealing rings	172, 173,174, 175, 176, 177, 178
Spindle guide upper sealing rings	179, 180, 181, 182, 183
Spindle guide union nut inner sealing ring	199
Spindle guide union nut outer sealing ring	200
Barrel body outer sealing rings	205, 206, 207, 208, 209

Plunger oil connecting piece	49a
Control oil connecting piece	50
Sealing oil connecting piece	51

Constant oil connecting piece	52
Air bleed stop valve	53
Air bleed drain hose	54
Function test valve holder	45
Function test top plate	46a
Nozzle valve piston lifting unit	46b
Valve holder nuts	46c
Function test valve connecting nuts	46d
Function test sleeve	46e
Oil injection chamber	59
Drain hose hole	60
Fuel oil inlet connecting piece	47
Lifting oil connecting piece	48b
Lifting oil channels	66
Lifting piston	67
Piston push up distance	68
Lifting unit fuel oil leakage channels	83, 84
Lifting unit fuel oil outlet	85
Fuel inlet channel	71
Function test sleeve fuel oil leakage outlet	93
Fuel oil drain sleeve	94
Detection test valve holder	97a
Detection test sleeve	97b
Detection test top plate	97c
Detection test bottom plate	97d
Plunge oil plug	115
DTS air inlet port	107
DTS air inlet channel	195
DTS air inlet chamber	196
DTS lower air outlet chamber	203
DTS lower air outlet port	110

DTS bottom air outlet chamber	204
DTS bottom air outlet port	114
DTS barrel body air outlet chamber I	210
DTS barrel body air outlet port I	111
DTS barrel body air outlet chamber II	211
DTS barrel body air outlet port II	113
DTS barrel body air outlet chamber III	212
DTS barrel body air outlet port III	112
Detection test liquid drain valve	108
Detection test hoses	98, 99, 100, 101, 102, 103, 104, 105
Non-return valves	109a, 109b, 109c, 109d, 109e, 109f, 109g, 109h
Detection test liquid chamber	106

DETAILED DESCRIPTION

An injector valve according to a preferred embodiment is designed by MAN Energy Solutions for a two-stroke combustion engine. The engine is a duel fuel engine, which can run on standard heavy fuel oil or on a liquefied petroleum gas, LGP, such as a mixture of propane and butane.

The injector valve may be used as a fuel booster injection valve for the liquefied petroleum gas, LGP, and may be designed for performing two functions: to pressurize or boost the LPG to the desired injection pressure, and to ensure the correct timing and duration of the LPG injection.

During normal operation, the injector valve is supplied with sealing oil, plunge oil, control oil, constant oil, and liquid petroleum gas, LPG, as fuel. Sealing oil is to prevent internal leak of liquid gas from entering unintended areas of the injector valve. Plunge oil is to pressurize the fuel, LPG. Control oil is to control the timing of opening the injector valve for delivering compressed fuel gas to the combustion chamber. Liquid fuel is supplied to the injector valve constantly. As long as the control oil is supplied, the injector valve will be closed, and when the supply of control oil is stopped, the valve will open when the pressure provided by the plunge oil to the fuel overcomes the opening pressure of the valve. The supplied constant oil runs opposite to the direction of supplied control oil, and

when control oil is supplied, a pressure is built up in the valve for closing the valve, and when the supply of control oil stops, there is no counter pressure to the supplied constant oil and the valve opens.

An embodiment of the fully assembled injector valve 44 is described in the following with reference to Figs. 2 to 19.

The injector valve holds a top cover 120, a barrel body 122 with a barrel flange 121, a spindle guide housing 124, an intermediate part 123 between the barrel body 122 and the spindle guide housing 124, a spindle guide union nut 127 for connecting the barrel body 122 with the intermediate part 123 and the spindle guide housing 124, and atomizer union nut 126 holding an atomizer 43 for output of the compressed fuel gas. See Figs. 2 and 3.

The top cover 120 holds a plunger oil inlet port 49b, a control oil inlet port 130, a sealing oil inlet port 128, a constant oil inlet port 129, which during normal operation functions as a control oil drainage port, but which during test can be used for supply of oil at a constant pressure, and an air bleeding outlet 55. The top cover 120 further holds cover plunger oil channel 63 in direct fluid connection with the plunger oil inlet port 49b, and cover fluid channels 56a, 56b, 56c, in fluid connection with the air bleeding outlet 55. See Figs. 3, 4, 5, 6 and 8.

The barrel body 122 holds a plunger piston 58, see Figs. 3 and 4, inserted into a plunger piston sealing chamber 136 and a plunger piston head chamber 156. The plunger piston 58 has an upper piston head moving within the plunger piston head chamber 156, while the bottom of plunger piston 58 faces a plunger compression chamber 74. In the bottom of plunger piston 58 there is provided a plunger piston fuel oil opening 57b. The length of the plunger piston head chamber 156 determines the maximum movement of the plunger piston 58 and thereby the minimum size of the compression chamber 74. The pressure of any fuel within the compression chamber 74 will be determined by the pressure provided to the top of the plunger piston 58. A plunger head seal 187 is provided in the head of the plunger piston 58 for sealing the connection between the head of the plunger piston 58 and the plunger head chamber 156, and a piston chamber seal 188 is provided in the barrel body 122 for sealing the connection between plunger piston 58 and the compression chamber 74. A bottom part of the plunger piston 58 holds two plunger compression

chamber leakage channels 89 and 90, which can be in fluid connection with a third plunger compression chamber leakage channels 91 and a fuel oil leakage outlet 92, both arranged in the barrel body 122. When the plunger piston 58 is in the upper position, leakage channels 89 and 90 are in fluid connection with leakage channel 91 and thereby the fuel oil leakage outlet 92. When plunger oil is supplied to the plunger oil channel 63 via the plunger oil inlet port 49b, the plunger piston 58 is pressed downwards and a plunger oil chamber 57a is formed between the head of the plunger piston 58 and the bottom of the top cover 120, see Fig. 6.

The barrel body 122 also holds plunger piston head chamber leakage channels 148, 149 for drainage of leaked plunger oil from the plunger piston head chamber 156 into corresponding oil leakage outlets 158, 158, see Fig. 7. The sealing oil inlet port 128 is in fluid connection with sealing oil channels 131, 132, 133 and 134, which are provided in the barrel body 122, the intermediate part 123, and the spindle guide housing 124. The sealing oil channels are fluidly connected to a plunger piston sealing bore 135 for supply of sealing oil to the plunger piston sealing chamber 136.

A suction one-way valve 70 with a suction valve inlet port 72, see Figs. 4 and 9, is provided in the barrel body 122 for supply of fuel to the plunger compression chamber 74 via a plunger chamber supply channel 73. Compressed fuel is led from the plunger piston compression chamber 74 into a non-return valve 77 via a non-return valve supply channel 75. When the plunger piston 58 is at the bottom of the plunger piston compression chamber 74, the fuel is supplied from the plunger chamber supply channel 73 via the plunger piston fuel oil opening 57b into the non-return valve supply channel 75.

The non-return valve 77, see Figs. 10 and 11, is formed by a non-return valve housing 87a holding a non-return valve spindle 86, which is pressed through a non-return valve connection seat 76 by a non-return valve spring 87b. When the pressure from supplied fuel is larger than the pressure from the spring 87b, the non-return valve 77 opens and fuel is supplied from nozzle-valve chamber supply channels 78a, 78b in the barrel body 122, via nozzle-valve chamber supply channels 79a, 79b in the intermediate part 123, through nozzle-valve chamber supply channels 80a, 80b in the spindle guide housing 124 into a nozzle valve chamber 81 formed in the spindle guide housing, see Figs. 11 and 15.

A non-return valve upper chamber 186 is formed around the upper part of the non-return valve housing 87a and a non-return valve seal 185 is provided as a seal between the non-return valve housing 87a and the barrel body 122. A first non-return valve leakage chamber 145 is provided for collection of fuel leaking through the seal 185, which first leakage chamber 145 is in fluid connection with a first non-return valve leakage channel 144, which ends in the fuel oil leakage outlet 92. A second non-return valve leakage chamber 147 inside the non-return valve housing 87a is via a second non-return valve leakage channel in fluid connection with the first non-return valve leakage chamber 145, see Fig. 3 and 10.

The spindle guide housing 124 holds a hydraulic piston 64 within a hydraulic piston bushing 125, see Fig. 15. The hydraulic piston 64 connects to a nozzle valve piston guide 95 further connected to a nozzle valve piston cut-off shaft 62 forming part of a nozzle valve 61a. The nozzle valve 61a holds a nozzle valve spring 96 within the nozzle valve chamber 81 for pressing the nozzle valve piston cut-off shaft 62 against a nozzle valve connection seat 88, with a nozzle valve lower chamber 82 being formed above the connection seat 88. The nozzle valve piston cut-off shaft 62 holds a nozzle valve piston cut-off shaft tip 61c protruding through a nozzle valve opening 61b.When there is no pressure on the hydraulic piston 64, and when the pressure from fuel supplied via channels 80a and 80b is larger than the pressure from the spring 96, the nozzle valve 61a opens and fuel flows is sprayed out via the nozzle valve opening 61b and the atomizer 43.

The pressure on the hydraulic piston 64 is determined by the pressure of supplied control oil. The control oil is supplied from the control oil inlet port 130 via a first control oil supply channel 140 in the barrel body and a second control oil supply channel 141 in the intermediate part 123 to a hydraulic piston actuation chamber 65 formed on top of the hydraulic piston 64. When the supply of control oil is stopped, the control oil is drained from the piston actuation chamber 65 to the constant oil inlet port 129 via a control oil drain restriction 143b and a first control oil drain channel 143a in the intermediate part 123, and further via a second control oil drain channel in the barrel body 122, see Figs. 5 and 15.

Sealing oil is supplied to the hydraulic piston bushing 125 from the sealing oil inlet port 128 via the sealing oil channel 134 into a hydraulic piston sealing bore 137, which is fluidly connected to a hydraulic piston sealing channel 138 and a hydraulic piston sealing

chamber 139 facing the hydraulic piston 64 for sealing the piston 64 within the bushing 125, see Figs. 4 and 14. The upper part of the hydraulic piston 64 holds a hydraulic piston head moving within a hydraulic piston chamber 155, and the hydraulic piston head holds a hydraulic piston seal 189 for sealing the hydraulic piston head within the hydraulic piston chamber 155. The lower surface part of the intermediate part 123 holds a hydraulic piston actuation chamber seal 184 for sealing the hydraulic piston actuation chamber 65, see Fig. 14.

A number of seals, sealing chambers and sealing channels are provided in connection with the hydraulic piston bushing 125 as illustrated in Figs. 14 and 15 and discussed in the following. Control oil may leak through the hydraulic piston seal 189 into the hydraulic piston chamber 155 from where it may flow to a hydraulic piston bushing leakage chamber 153 via a hydraulic piston bushing leakage channel 154. From the leakage chamber 153 the leaked control oil may flow to the oil leakage outlet 158 via first, second and third control and sealing oil leakage channels 152, 151 and 150. The hydraulic piston bushing 125 holds a first upper hydraulic piston bushing seal 190 for sealing of control oil, which may flow from the actuation chamber 65 via the seal 189 and into the hydraulic piston bushing leakage chamber 153. The hydraulic piston bushing 125 also holds a second hydraulic piston bushing seal 191 for sealing of sealing oil, which may flow from the sealing bore 137 to the leakage chamber 153, and a third hydraulic piston bushing seal 192 for sealing of sealing oil, which may flow from the sealing bore 137 into a nozzle valve bushing leakage chamber 161, which is fluidly connected to a first fuel oil leakage channel 162 in the spindle guide housing 124, a second fuel oil leakage channel 163 in the intermediate part 123, and a third fuel oil leakage channel 164 in the barrel body 122. Around the connection between the hydraulic piston 64 and the nozzle valve piston guide 95, a nozzle valve leakage chamber 159 is provided, which is connected to the leakage chamber 161 via a fourth fuel oil leakage channel 160, whereby supplied fuel leaking from the nozzle valve chamber 81 along the nozzle valve piston guide 95 can flow from the leakage chamber 161 to the first fuel oil leakage channel 164.

Figs. 16 and 17 show the arrangement of further leakage chambers and channels. Fuel oil supplied from the nozzle valve chamber 81, via the nozzle valve lower chamber 88 and passing the nozzle valve piston cut-off shaft 62 may leak into an atomizer fuel oil leakage chamber 194 between the atomizer 43 and atomizer union nut 126. From leakage

chamber 194 the leaked fuel oil may pass an atomizer fuel oil leakage channel 168 and a spindle guide upper leakage oil chamber 171 in the spindle guide housing 124, an intermediate upper leakage oil chamber 170 and an intermediate leakage oil collecting channel 169 in the intermediate part 123, an into an upper oil leakage channel 167 in the barrel body 122, and out via a upper oil leakage outlets 165 and 166, which are fluidly connected to the upper oil leakage channel 167. An intermediate outer leakage chamber 198 is provided between the intermediate part 123 and the spindle guide union nut 127, and an intermediate leakage oil outlet channel 197 connects the channel 169 to the leakage chamber 198.

The intermediate part 123 has a number of supply and leakage channels passing through between the barrel body 122 and the spindle guide housing 124, which demands a corresponding number of seals. This is illustrated in Figs. 18 and 19, where Fig. 18 is a cross-sectional view of an upper surface part of the intermediate valve part 123, and Fig. 19 is a cross-sectional view of an upper surface part of the spindle guide housing 124 facing a lower surface of the intermediate valve part 123.

In Fig. 18, a first intermediate upper sealing ring 172 seals the second control oil supply channel 141, a second intermediate upper sealing ring 173 seals the first control oil drain channel 143a, a third intermediate upper sealing ring 174 seals the sealing oil channel 133, a fourth intermediate upper sealing ring 175 seals the second control and sealing oil leakage channel 151, a fifth intermediate upper sealing ring 176 seals the second fuel oil leakage channel 163, a sixth intermediate upper sealing ring 177 seals the nozzle valve supply channel 79a, and a seventh intermediate upper sealing ring 178 seals the nozzle valve supply channel 79b. The intermediate upper leakage oil chamber 170 is provided between the sealing rings 172, 173, 174, 175, 176, 177 and 178 for collection of leaked oil and, with the leakage oil chamber 170 being connected to the intermediate leakage oil collecting channel 169.

In Fig. 19 a first spindle guide upper sealing ring 179 seals the nozzle valve supply channel 79b, a second spindle guide upper sealing ring 180 seals the nozzle valve supply channel 79a, a third spindle guide upper sealing ring 181 seals the second fuel oil leakage channel 163, a fourth spindle guide upper sealing ring 182 seals the second control and sealing oil leakage channel 151, and a fifth spindle guide upper sealing ring 183 seals the sealing oil

channel 133. The spindle guide upper leakage oil chamber 171 is provided between the sealing rings 179, 180, 181, 182 and 183 for collection of leaked oil and, with the leakage oil chamber 171 being connected to the intermediate leakage oil collecting channel 168. The upper surface part of the spindle guide housing 124 also has a centre opening for connection to the hydraulic piston bushing 125 holding the hydraulic piston 64.

A spindle guide union nut inner sealing ring 199 is provided as a seal between the spindle guide union nut 127 and the spindle guide housing 124, and a spindle guide housing seal 201 is provided as a seal between the atomizer union nut 126 and the spindle guide housing 124, see Fig. 16. Furthermore, a spindle guide union nut outer sealing ring 200 is provided at the outside of the spindle guide union nut 127, which is also illustrated in Fig. 16.

In order to perform a function test of the injection valve 44 of Fig. 2, the atomizer union nut 126 and the atomizer 43 are removed from the injection valve as illustrated in Fig. 20. This leaves the spindle guide housing 124 uncovered with the tip of the nozzle valve piston cut-off shaft 62 protruding at the end of the spindle guide housing 124. The spindle guide union nut 127 is maintained. The function test includes a test of the non-return valve 77, which requires that the nozzle valve piston cut-off shaft 62 is lifted from the nozzle valve connection seat 88 to keep the nozzle valve open.

When performing the function test, the injection valve 44 of Fig. 20 is installed in a function test valve holder 45, see Figs. 21 to 26, and supplied with oil and gas for testing delivered by the test system 1 of Fig. 1.

The function test valve holder 45 holds a function test top plate 46a, a nozzle valve piston lifting unit 46b, valve holder nuts 46c for connecting the function test top plate 46a with the lifting unit 46b, a function test sleeve 46e, and an oil injection chamber 59 beneath the lifting unit 46b. A drain hose hole 60 goes through the lifting unit 46b into the drain hose chamber 59. Function test valve connecting nuts 46d holds the injection valve 44 of Fig. 20 in position during the function test. The function test sleeve 46e is dimensioned to fit to the barrel body 122 of the injector valve 44 and holds a fuel inlet channel 71 facing the suction valve inlet port 72 of the barrel body 122, and a fuel oil connecting piece 47 is connected to the fuel inlet channel 71 for inlet of fuel oil. A function test sleeve fuel oil

leakage outlet 93 is provided in the function test sleeve 46a and faces the fuel oil leakage outlet 92 of the barrel body 122. A fuel oil drain sleeve 94 can be connected to the fuel oil leakage outlet 93 and passed through the drain hose hole 60 into the drain hose chamber 59.

In order to connect to the supply lines of the test system 1 of Fig. 1, a plunger oil connecting piece 49a is connected to the plunger oil inlet port 49b, a control oil connecting piece 50 is connected to the control oil inlet port 130, a sealing oil connecting piece 51 is connected to the sealing oil inlet port 128, and a constant oil connecting piece 52 is connected to the constant oil inlet port 129. The air bleeding outlet 55 is provided with an air bleed stop valve 53, which connects to an air bleed drain hose 54. During a preliminary deaeration process, the air bleed stop valve 53 is open and the air bleed drain hose 54 is led through the drain hose hole 60 into the oil injector chamber 59.

The nozzle valve piston lifting unit 46b holds has a lifting oil channel 66 connected to a lifting oil connecting piece 48 for input of lifting oil from the test system 1. A centre part of the lifting unit 46b is dimensioned to fit closely to the protruding tip of the nozzle valve piston cut-off shaft 62 when inserted into the function test valve holder 45, and a lifting piston 67 is arranged in the lifting unit 46b for lifting the the nozzle valve piston cut-off shaft 62 when lifting oil is supplied to the lifting oil channel 66. The length of the lifting of the nozzle valve piston cut-off shaft 62 is here denoted piston push up distance 68. Fuel oil may leak along the lifted nozzle valve piston cut-off shaft 62 into lifting unit fuel oil leakage channels 83, 84 and out into the oil injection chamber 59 via a lifting unit fuel oil outlet 85.

The fully assembled injection valve 44 of Fig. 2 is exposed to a leakage detection test and placed in a detection valve holder 97a when performing the leakage detection test and supplied with air at 7 bar for detection of any leakages. In order to fluidly separate different outer parts of the valve 44 during the leakage detection test, first, second, third, fourth and fifth barrel body outer sealing rings 205, 206, 207, 208 and 209 are provided at the outer part of the barrel body 122 as illustrated in fig. 28.

The detection valve holder 97a, see Figs. 27, 28 and 29, holds a detection test sleeve 97b, a detection test top plate 97c, and a detection test bottom plate 97d. The detection test bottom plate 97d has a center opening dimensioned to fit the atomizer 43 of the

assembled injector valve 44, whereby the atomizer protrudes the bottom plate 97d into a detection test sleeve, DTS, bottom air outlet chamber 204, having a detection test sleeve, DTS, bottom air outlet port 114 and a detection test liquid drain valve 108.

When fully assembled injector valve 44 is positioned in the detection valve holder 97a, with the injector valve 44 holding the plunger oil connecting piece 49a, the control oil connecting piece 50, the sealing oil connecting piece 51, and the constant oil connecting piece 52. The air bleeding outlet 55 is provided with the air bleed stop valve 53, which is closed during the leakage detection test and a plunge oil plug 115 is inserted into the plunger oil connecting piece 49a.

The detection test sleeve 97b is dimensioned to fit to the barrel body outer sealing rings 205, 206, 207, 208, 209 thereby forming a number of air inlet and outlet chambers. The detection test sleeve 97b further holds a number of corresponding air inlet and outlet ports, which is illustrated in Fig. 28. The detection test sleeve 97b hence holds a detection test sleeve, DTS, air inlet port 107 and a detection test sleeve, DTS, air inlet channel 195 leading into a detection test sleeve, DTS, air inlet chamber 196 being sealed by sealing rings 200 and 209; a detection test sleeve, DTS, lower air outlet port 110 facing a detection test sleeve, DTS, lower air outlet chamber 203 being sealed by sealing ring 200; a detection test sleeve, DTS, barrel body air outlet port I 111 facing a detection test sleeve, DTS, barrel body outlet chamber I 210 being sealed by sealing rings 209 and 208; a detection test sleeve, DTS, barrel body air outlet port II 113 facing a detection test sleeve, DTS, barrel body outlet chamber II 211 being sealed by sealing rings 206 and 205; a detection test sleeve, DTS, barrel body air outlet port III 112 facing the fuel oil leakage outlet 92 of the barrel body 122 being sealed by sealing rings 208 and 207; and a detection test sleeve, DTS, barrel body outlet chamber III 212 being sealed by sealing rings 207 and 206.

A detection test liquid chamber 106 is provided holding a liquid and detection test hoses, which are connected to the air outlet ports and connecting pieces, are ending in the liquid chamber 106 to thereby detect any air leakage by bubbles in the liquid chamber 106. The detection test hoses are connected as follows: detection test hose 98 is connected to the control oil connecting piece 50, detection test hose 99 is connected to the sealing oil connecting piece 51, detection test hose 100 is connected to the constant oil connecting

piece 52, detection test hose 101 is connected to DTS barrel body air outlet port II 113, detection test hose 102 is connected to DTS barrel body air outlet port III 112, detection test hose 103 is connected to DTS barrel body air outlet port I 111, detection test hose 104 is connected to DTS lower air outlet port 110, and detection test hose 105 is connected to DTS bottom air outlet port 114. Each of the detection test hoses holds a non-return valve 109.

Fig. 1 is a diagram of showing the test system 1 used for performing the function test of the injection valve 44 of Fig. 20.

The test system 1 comprises a gas inlet 1a, an air inlet 1b, a gas outlet 1c, a control oil outlet 1d, a sealing oil outlet 1e, a fuel oil outlet 1f, a plunger oil outlet 1g, a lifting oil outlet 1h and a constant oil outlet 1i. Air is provided via the air inlet 1b at a pressure in the range of 7 – 10 bar in , which pressurized air is used as input to pressure control valves, a plunger oil pressure control valve 12, lifting oil pressure control valve 28, control/sealing oil pressure control valve 8, and fuel oil pressure control valve 33. A gas inlet 1a is provided for inlet of a test gas in the form of Nitrogen at a pressure in the range of 80-300 bar. The pressurized Nitrogen is supplied to a Nitrogen booster 20 via a Nitrogen inlet non-return valve 22, and from the Nitrogen booster 20 the Nitrogen is supplied to a gas stop valve 24, with a Nitrogen gas pressure control valve 23 provided for controlling the pressure of the gas being output from the gas stop valve 24 to gas outlet 1c.

In order to deliver a test fluid in the form of a hydraulic oil, which may be a mineral hydraulic oil with a viscosity of 10 centistokes (cSt), an oil tank 16 is provided for holding the hydraulic oil. The oil tank 16 is provided with an oil tank filler cap 17, an oil tank stop valve 18, and an oil filter 19. An outlet of the oil tank 16 is via the stop valve 18 and oil filter 19 connected to four air driven pumps, a plunger oil air driven pump 15 being controlled by the plunger oil pressure control valve 12, a control/sealing oil air driven pump 7 being controlled by the control/sealing oil pressure control valve 8 and the control/sealing oil air pump safety valve 9, a lifting oil air driven pump 31 being controlled by the lifting oil pressure control valve 28 and the lifting oil air pump safety valve 29, and a fuel oil air driven pump 37 being controlled by the fuel oil pressure control valve 33 and the fuel oil air pump safety valve 34. The oil pressure from the plunger oil air drive pump 15 can be read from plunger oil pressure gauge 13, the oil pressure from the control/sealing oil air

driven pump 7 can be read from a control/sealing oil pressure gauge 6, and the oil pressure from the fuel oil air driven pump 37 can be read from a fuel oil pressure gauge 36.

A hydraulic accumulator 5 is provided, which accumulator 5 may be charged by fuel oil up to a pressure of 250 bar. However, in the present test system 1 the maximum fuel oil pressure is 50 bar. The hydraulic accumulator 5 is a membrane type of accumulator. It has a chamber which is divided by a rubber membrane. On one side of the membrane is Nitrogen at a pressure of 20-25 bar, on the other side of the membrane is hydraulic oil supplied from the fuel oil air driven pump 37. While the pressure of hydraulic oil is 0 bar, then the whole volume of accumulator is filled with Nitrogen. While applying hydraulic oil at a pressure above 2-25 bar, then the Nitrogen will start compress, as the hydraulic oil will start filling the volume of hydraulic accumulator. The purpose of the accumulator 5 in the test system 1 is to accumulate hydraulic oil inside with a pressure of 20-25 bar and to reduce oil pressure fluctuation coming from the fuel oil air driven pump 37.

A plunger oil directional valve 10 is provided for opening and closing of plunger oil supply, which can be supplied from the plunger oil air driven pump 15 or from the Nitrogen booster 20 to the plunger oil outlet 1g. The oil pressure from the plunger oil air driven pump 15 can be read from a plunger oil pressure gauge 13, while the oil pressure from the plunger oil air driven pump 15 can be released by a plunger oil pressure relief valve 11, in which case released hydraulic oil will flow back to the oil tank 16. A plunger oil pressure safety valve 14 is provided. The plunger oil pressure safety valve 14 is adjusted to a maximum working pressure of 320 bar at the output side of the plunger oil air driven pump 15. If the plunger oil pressure exceeds the 320 bar, the plunger oil safety valve 14 will open and hydraulic oil will flow back to the oil tank 16.

The plunger oil directional valve 10 is also connected to the Nitrogen booster 20 via a booster oil pressure relief valve 21. The Nitrogen booster 20 holds an inlet chamber with Nitrogen and an outlet chamber with hydraulic oil, which may be boosted in pressure by increasing the pressure of Nitrogen in the inlet chamber. When both the plunger oil pressure relief valve 11 and the plunger oil directional valve 10 are closed, the oil pressure of the outlet chamber in Nitrogen booster 20 can determined by the pressure of supplied Nitrogen and by the oil pressure produced the plunger oil air driven pump 15, and when

opening the plunger oil directional valve 10, the oil pressure is supplied to the plunger oil outlet 1g.

Fuel oil is provided from the fuel oil air driven pump 37 to the fuel oil outlet 1f, and the oil pressure from the fuel oil air driven pump 37 can be read from the fuel oil pressure gauge 36, while the oil pressure from the fuel oil air driven pump 37 can be released by a fuel oil pressure relief valve 32, in which case released hydraulic oil will flow back to the oil tank 16. A fuel oil pressure safety valve 35 is provided for protection of the fuel oil pressure gauge 36. The fuel oil pressure safety valve 35 is adjusted to a maximum working pressure of 60 bar at the output side of the fuel oil air driven pump 37. If the fuel oil pressure exceeds the 60 bar, the fuel oil safety valve 35 will open and hydraulic oil will flow back to the oil tank 16.

A control/sealing oil directional valve 2 is provided for opening and closing of oil supply from the control/sealing oil air driven pump 7 to the sealing oil outlet 1e or to a control oil directional valve 3, which controls opening an closing of oil supply to the control oil outlet 1d. The oil pressure from the control/sealing oil air driven pump 7 can be read from the control/sealing oil pressure gauge 6, while the oil pressure from the control/sealing oil air driven pump 7 can be released by a control oil pressure relief valve 4, in which case released hydraulic oil will flow back to the oil tank 16.

Lifting oil is provided from the lifting oil air driven pump 31 to the lifting oil outlet 1h, and the oil pressure from the lifting oil air driven pump 31 can be read from the lifting oil pressure gauge 30, while the oil pressure from the lifting oil air driven pump 30 can be released by a lifting oil pressure relief valve 27, in which case released hydraulic oil will flow back to the oil tank 16.

A constant oil valve 26 is provided for opening and closing of oil supply to the constant oil outlet 1i, which is supplied with oil directly from the oil tank 16 via the oil tank stop valve 18 and oil filter 19. There is no air driven pump for generating an oil pressure in the oil supply line between the oil thank 16 and the constant oil outlet 1i.

Function test of injector valve

The function test includes a test of the non-return valve 77, which requires that the nozzle valve piston cut-off shaft 62 is constantly held in a lifted position from the nozzle valve connection seat 88 to keep the nozzle valve open. The test of the non-return valve 77 is followed by several tests, for which the nozzle valve piston cut-off shaft 62 is in the normal operating mode. These tests include a test of the tightness of the nozzle valve piston cut-off shaft 62 against the nozzle valve connection seat 88, a test of a fuel injection sequence, and an indirectly test of the suction one-way valve 70.

In order to perform a function test of the injection valve 44 of Fig. 2, the atomizer union nut 126 and the atomizer 43 are removed from the injection valve as illustrated in Fig. 20. This leaves the spindle guide housing 124 uncovered with the tip of the nozzle valve piston cut-off shaft 62 protruding at the end of the spindle guide housing 124. The spindle guide union nut 127 is maintained. When performing the function test, the injection valve 44 of Fig. 20 is installed in the function test valve holder 45, see Fig. 21.

The plunger oil connecting piece 49a is connected to the plunger oil inlet port 49b, the control oil connecting piece 50 is connected to the control oil inlet port 130, the sealing oil connecting piece 51 is connected to the sealing oil inlet port 128, the constant oil connecting piece 52 is connected to the constant oil inlet port 129, and the air bleed stop valve 53 is connected to the air bleeding outlet 55. The top cover 120 of the valve 44 is secured to the function test valve holder 45 by two function test valve connecting nuts 46d.

Before start of the test procedures, the test system 1 need to be configured to the initial settings as follows:

Air inlet 1b is connected to an external source of compressed air min 7 bar max 10bar, and gas inlet 1a is connected to an external source of nitrogen min 80bar.

The hydraulic accumulator 5 is filled with nitrogen up to 20-25 bar.

The fuel oil pressure safety valve 35 is adjusted to pressure 60bar (the purpose of safety valve 35 is to protect fuel oil pressure gauge 36 with range 0-60bar). Safety valve 14 is adjusted to 320bar. All pressure relief valves 4, 11, 27, 32 are set open.

The pressure control valves 33, 8, 28 and 12 are set in closed position to obtain an outlet pressure of the valves of 0 bar.

The air pump safety valves are adjusted to max pressure:

- Fuel oil air pump safety valve 34 is adjusted to a pressure allowing the fuel oil air driven pump 37 to deliver an oil pressure of max 50 bar.
- Control/sealing oil air pump safety valve 9 is adjusted to a pressure allowing the control/sealing oil air driven pump 7 to deliver an oil pressure of max 300 bar.
- Lifting oil air pump safety valve 29 is adjusted to a pressure allowing the lifting oil air driven pump 31 to deliver an oil pressure of max 300 bar.

The oil tank stop valve 18 is set open.

The gas stop valve 24 is set closed

The oil tank 16 is filled with clean hydraulic oil with 7-10 cSt viscosity.

Flexible hoses are connected to the oil outlets 1f,1d,1e,1i,1h,1g., with the other ends of hoses being provided with quick couplings which are normally closed. When the quick couplings are connected to corresponding connecting pieces on the injector valve and the test valve holder, the quick couplings opens.The gas outlet port 1c is equipped with a quick coupling which is normally closed

The oil outlets of the test system 1 are fluidly connected via the hoses and quick couplings to the oil connecting pieces by connecting the control oil outlet 1d to the control oil connecting piece 50, connecting the sealing oil outlet 1e to the sealing oil connecting piece 51, connecting the plunger oil outlet 1g to the plunger oil connecting piece 49a, connecting the constant oil outlet 1i to the constant oil connecting piece 52, connecting the fuel oil outlet 1f to the fuel oil inlet connecting piece 47, which is connected to the function test sleeve 46e, and connecting the lifting oil outlet 1h to the lifting oil connecting piece 48b, which is connected to the nozzle valve piston lifting unit 48a.

<u>Deaeration</u>

Before testing the non-return valve 77, a deaeration of the valve 44 is performed:

1. Connect the air bleed drain hose 54 to the air bleed stop valve 53 and lead the air bleed drain hose 54 to the oil injection chamber 59 through the drain hose hole 60.
2. Set the control/sealing oil valve 2 of the test system 1 to sealing position.
3. Close control oil pressure relief valve 4.

4. Increase sealing oil pressure up to 80 bar by use of control/sealing oil pressure control valve 8 and control/sealing oil pressure gauge 6 to lubricate or seal the plunger piston 58 and hydraulic piston 64.
5. Open the air bleed stop valve 53.
6. Close booster oil pressure relief valve 21.
7. Close plunger oil pressure relief valve 11.
8. Set plunger oil directional valve 10 to open position.
9. Increase plunger oil pressure up to 10-50 bar by use of plunger oil pressure control valve 12 and plunger oil pressure gauge 13.

Plunger oil will now flow through the plunger oil connection piece 49a through the cover plunger oil channel 63 to the plunger oil chamber 57a until all air has been bled from the plunger oil chamber 57a through the cover fluid channels 56c, 56b, 56a, the air bleed stop valve 53 and through the air bleed drain hose 54 into oil the injection chamber 59.

10. Check if any air bubbles are received in the injection chamber 59 via the air bleed drain hose 54.
11. When air bubbles are no longer received in the injection chamber 59 via the air bleed drain hose 54 then close air bleed stop valve 53.

12. Set the control/sealing oil valve 2 of the test system 1 to control position.
13. Set control oil directional valve 3 to open position.
14. Open constant oil valve 26.
15. Close control oil pressure relief valve 4.
16. Increase control oil pressure up to 10-50 bar by use of control/sealing oil pressure control valve 8 and control/sealing oil pressure gauge 6.
17. Apply the control oil to the control oil connecting piece 50 for 20 seconds.

By applying the control oil for 20 seconds at a pressure in the range of 10-50 bar, air will bleed from the hydraulic piston actuation chamber 65, which is formed above the hydraulic piston 64, through the control oil drain restriction 143b and the drain channels 143a, 142 through the constant oil port 129 and constant oil connecting piece and through the constant oil valve 26 into the oil tank 16.

Test of non-return valve 77

For this test the nozzle valve piston cut-off shaft 62 has to be hold in a lifted position from the nozzle valve connection seat 88 to keep the nozzle valve open.

1. Increase lifting oil pressure up to 300 bar by use of lifting oil pressure control valve 28 and lifting oil pressure gauge 30. The lifting oil pressure relief valve 27 shall be closed.
2. Supply lifting oil at the pressure of 300 bar to the lifting oil connecting piece 48b.

The lifting oil will now flow through the lifting oil channels 66 to the lifting piston 67, whereby the lifting piston 67 will be lifted to push up the nozzle valve piston cut-off shaft 62 a distance 68, which is about 2 mm, to keep the nozzle valve piston cut-off shaft 62 in the open position. The nozzle valve piston cut-off shaft 62 is connected to the hydraulic piston 64, which is pushed up the same distance.

3. Set the control/sealing oil valve 2 of the test system 1 to sealing position.
4. Close control oil pressure relief valve 4.
5. Increase sealing oil pressure up to 80 bar by use of control/sealing oil pressure control valves 8 and control/sealing oil pressure gauge 6 to lubricate or seal the plunger piston 58 and hydraulic piston 64.
6. Close booster oil pressure relief valve 21.
7. Close plunger oil pressure relief valve 11.
8. Set plunger oil directional valve 10 to open position.
9. Increase slowly plunger oil pressure up to 10-50 bar and then to 300 bar by use of plunger oil pressure control valve 12 and plunger oil pressure gauge 13.

This will slowly move the plunger piston 58 downwards until it is at the bottom of the plunger compression chamber 74.

10. Close the fuel oil pressure relief valve 32.
11. Increase fuel oil pressure up to 30 bar by use of fuel oil pressure control valves 33 and fuel oil pressure gauge 36, whereby the hydraulic accumulator 5 will be filled up.
12. Supply the fuel oil at the oil pressure of 30 bar to the fuel oil inlet connecting piece 47.

The fuel oil will now flow through fuel inlet channel 71 and into the suction one-way valve 70 through the suction valve inlet port 72, and from the suction one-way valve 70 via the

plunger chamber supply channel 73 via the plunger piston fuel oil opening 57b and via the non-return valve supply channel 75 into the non-return valve 77.

If the non-return valve 77 is not tight, there will be a leakage at the non-return valve connection seat 76 and the fuel oil will flow through the nozzle valve chamber supply channels 78a, 78b, 79a, 79b, 80a, 80b to the nozzle valve chamber 81. From nozzle valve chamber 81 the fuel oil will then pass to the nozzle valve lower chamber 82, passing the lifted nozzle valve piston cut-off shaft 62 and into lifting unit fuel oil leakage channels 83, 84 and out into the oil injection chamber 59 via lifting unit fuel oil outlet 85.

13. Check if any oil drops or flow into the injection chamber 59 via the lifting unit fuel oil outlet 85.
14. Slowly increase the fuel oil pressure above 30 bar by use of fuel oil pressure control valve 33 and fuel oil pressure gauge 36 until the non-return valve 77 opens by observing droplets of oil or a running stream of oil from the lifting unit fuel oil outlet 85 into the oil injection chamber 59.

The non-return valve 77 holds the non-return valve spindle 86, which is pressed through the non-return valve connection seat 76 by the non-return valve spring 87b, and the non-return valve 77 opens when the fuel oil pressure operating on the non-return valve spindle 86 is larger than the pressure from the spring 87b.

15. Write down the observed opening pressure of the non-return valve 77.
16. Release the fuel oil pressure by opening the fuel oil pressure relief valve 32 and the fuel oil pressure control valve 33.

This will allow the non-return valve spindle 86 to properly close the non-return valve connection seat 76 to make a tight connection between the valve spindle 86 and the valve connection seat 76.

17. Increase the fuel oil pressure slowly by use of fuel oil pressure control valve 33 and fuel oil pressure gauge 36 to a pressure equal to the observed opening pressure of the non-return valve subtracted by 3-5 bar.
18. Let the fuel oil air driven pump fill up the hydraulic accumulator 5.
19. Check if any oil drops or flow into the injection chamber 59 via the lifting unit fuel oil outlet 85.

If any oil comes out the non-return valve is not tight. A few oil droplets are allowed, as it can be oil, which has not drained yet.

20. Turn off the fuel oil air driven pump 37 by use of fuel oil pressure control valve 33.

21. Wait 15 seconds to let the fuel oil pressure gauge 36 stabilize and write down the pressure.
22. Now using a stopwatch, wait 60 seconds and observe how much the pressure has fallen.

The non-return valve 77 has passed the test, if the pressure has not decreased more than 2 bar.

Test of the tightness of the nozzle valve piston cut-off shaft 62 against the nozzle valve connection seat 88

In this test the nozzle valve piston cut-off shaft 62 is in its normal operation mode without being constantly held in a lifted position from the nozzle valve connection seat 88.

1. Open the lifting oil pressure relief valve 27 and the lifting oil pressure control valve 28 to release the lifting oil pressure.

By releasing the lifting oil pressure, the nozzle valve piston cut-off shaft 62 is released and will engage the nozzle valve connection seat 88 to hold a tight connection.

2. Apply fuel oil at a pressure of 5 bar higher than the observed opening pressure for the non-return valve 77.

Since the non-return valve 77 is open the fuel oil will fill up the nozzle valve chamber 81.

3. Check if any oil drops or flow into the injection chamber 59 via the lifting unit fuel oil outlet 85.

If the connection between the nozzle valve piston cut-off shaft 82 and the nozzle valve connection seat 88 is tight, no oil should be observed coming out from the lifting unit fuel oil outlet 85.

4. Open the fuel oil pressure relief valve 32 and the fuel oil pressure control valve 33 to release the fuel oil pressure.
5. Open the control oil pressure relief valve 4 and the control/sealing oil pressure control valve 8 to release the sealing oil pressure.
6. Close constant oil valve 26.
7. Open the plunger oil pressure relief valve 11 and the plunger oil pressure control valve 12 to release the plunger oil pressure.
8. Open booster oil pressure relief valve 21
9. Apply 80-100 bar of Nitrogen to the Nitrogen booster 21 via the gas inlet port 1a.

10. Close plunger oil directional valve 10 and plunger oil pressure relief valve 11.
11. Build up pressure in the Nitrogen booster 21 to 150 bar by use of plunger oil pressure control valve 12 and plunger oil pressure gauge 13.
12. Increase sealing oil pressure up to 80 bar by use of control/sealing oil pressure control valve 8 and control/sealing oil pressure gauge 6 to lubricate or seal the plunger piston 58 and hydraulic piston 64.
13. Increase fuel oil pressure up to 30 bar by use of fuel oil pressure control valves 33 and fuel oil pressure gauge 36. The fuel oil pressure relief valve 32 has to be closed when increasing fuel oil pressure.

Since there is no pressure on top of the plunger piston 58, the fuel oil pressure through the suction on-way valve 70 will lift the plunger 58. When the plunger piston 58 is lifted to the top, the plunger compression chamber leakage channel 90 meets the plunger compression chamber leakage channel 91, and fuel oil starts to leak from plunger compression chamber 74 through the plunger compression chamber leakage channels 89, 90 and 91 to fuel oil leakage outlet chamber 92. From the fuel oil leakage outlet chamber 92 the fuel oil flows to the function test sleeve fuel oil leakage outlet 93 and continuous to flow through the fuel oil drain sleeve 94 to the oil injection chamber 59.

The pressure for the nozzle valve piston cut-off shaft 62 is determined by the pressure working in the area between the nozzle valve connection seat 88 and the diameter of the nozzle valve piston guide 95. The opening pressure for the nozzle valve piston cut-off shaft 62, which is the pressure required to overcome the force from the nozzle valve spring 96, should be in the range of 388 – 447 bar. The hydraulic gearing of the piston plunger 58 is 2.47. Therefore, the corresponding pressure to open the nozzle valve piston cut-off shaft 62 from the pressure supplied to the plunger oil chamber 57a on top of the plunger piston 58 is between 157 – 181 bar.

14. Set the plunger oil directional valve 10 to open position to apply the plunger oil pressure accumulated in the Nitrogen booster 20 to the top of the plunger piston 58.
15. Check if any oil drop or flow into the oil injection chamber 59 via the lifting unit fuel oil outlet 85.

No oil should have been injected from the lifting unit port 85 into the oil injection chamber 59. Oil leakage between the plunger piston 58 and the pump barrel body 122 holding the plunger compression chamber 74 can be observed leaking into the oil injection chamber

59 through the plunger compression chamber leakage channels 91, the fuel oil leakage outlet chamber 92, the function test sleeve fuel oil leakage outlet 93, and the fuel oil drain sleeve 94.

16. Close the plunger oil directional valve 10.
17. Build up pressure in the Nitrogen booster 21 to 155 bar by use of plunger oil pressure control valve 12 and plunger oil pressure gauge 13.
18. Set the plunger oil directional valve 10 to open position to apply the plunger oil pressure accumulated in the Nitrogen booster 20 to the top of the plunger piston 58.
19. Check if any oil drop or flow into the oil injection chamber 59 via the lifting unit fuel oil outlet 85.
20. Close the plunger oil directional valve 10.

Repeat test steps 17 to 20, while incrementally raising the plunger oil pressure by 5 bar: 160 – 165 – 170 – 175 – 180 – 185 bar. Observe at what plunger oil pressure the nozzle valve piston cut-off shaft 62 lifts and oil flows through the nozzle valve connection seat 88, into lifting unit fuel oil leakage channels 83 and 84 and out from lifting unit fuel oil outlet 85.

Write down the plunger oil pressure when the nozzle valve cut-off shaft 62 lifts from the connection seat 88 and oil flow from fuel oil outlet 85, convert the oil plunger pressure to the pressure inside the nozzle valve chamber 81 by multiplying the plunger oil pressure with the gearing ratio of 2.47. Write down this pressure.

Recheck the tightness of the cut-off shaft 62 against tightness the connection seat 88 by repeating steps 17 to 20 while supplying a plunger oil pressure to the top of the plunger piston 58 that is the opening pressure subtracted by 5-10 bar. Observe that no oil flows through the lifting unit fuel oil outlet 85. The acceptance criteria for this test is that the opening pressure is in the interval 155-185 bar.

<u>Fuel injection sequence test</u>

1. Open the fuel oil pressure relief valve 32 and the fuel oil pressure control valve 33 to release the fuel oil pressure.

2. Open the control oil pressure relief valve 4 and the control/sealing oil pressure control valve 8 to release the sealing oil pressure.
3. Close plunger oil directional valve 10.
4. Close constant oil valve 26.
5. Set the control/sealing oil valve 2 to control position and set control oil directional valve 3 to open position
6. Close control oil pressure relief valve 4 and increase control oil pressure up to 300 bar by use of control/sealing oil pressure control valve 8 and control/sealing oil pressure gauge 6.

By supplying a control oil pressure of 300 bar on top of the hydraulic piston 64, this will keep the nozzle valve piston cut-off shaft 62 from opening.

7. Close plunger oil pressure relief valve 11. Build up pressure in the Nitrogen booster 21 to 300 bar by use of plunger oil pressure control valve 12 and plunger oil pressure gauge 13.
8. Close fuel oil pressure relief valve 32 and increase fuel oil pressure up to 30 bar by use of fuel oil pressure control valves 33 and fuel oil pressure gauge 36.

Since there is no pressure on top of the plunger piston 58, the fuel oil being inlet to the plunger compression chamber 74 through the suction one-way valve 70 will lift the plunger piston 58.

9. Open the plunger oil directional valve 10 to apply the boosted plunger oil pressure to the top of the plunger piston 58.
10. Check if any oil drop or flow into the oil injection chamber 59 via the lifting unit fuel oil outlet 85.

No oil should have been injected from the fuel oil outlet 85, because the control oil holds the hydraulic piston 64 down keeping the cut-off shaft 62 down as well.

11. Close plunger oil directional valve 10.
12. Build up pressure in the Nitrogen booster 21 to 300 bar by use of plunger oil pressure control valve 12 and plunger oil pressure gauge 13.
13. Check that the control/sealing oil valve 2 is set to control position and that the control oil directional valve is set 3 to open position.
14. Check that the control oil pressure is up to 300 bar.
15. Open the plunger oil directional valve 10 to apply the boosted plunger oil pressure to the top of the plunger piston 58.
16. Wait 1-2 seconds.

17. Close control oil directional valve 3.

The control oil directional valve 3 is a 3-way valve with two positions. When in closed position there is no fluid connection from the control/sealing oil valve 2 to control oil outlet 1d, but there is a fluid connection from the control oil outlet 1d to the oil tank 16. So, when the valve 3 is closed the pressure of control oil at port 1d is released, and when the valve 2 is in open position the oil flows from via valve 2 through valve 3 and there is a control oil pressure at control oil outlet 1d.

The fuel oil pressure in the nozzle valve chamber 81 can now lift the nozzle valve piston cut-off shaft 62.

18. Check if any oil drop or flow into the oil injection chamber 59 via the lifting unit fuel oil outlet 85.

An injection of oil into the oil injection chamber 59 should now has taken place.

19. Open control oil directional valve 3.

20. Increase control oil pressure up to 300 bar by use of control/sealing oil pressure control valve 8 and control/sealing oil pressure gauge 6.

21. Check if any oil drop or flow into the oil injection chamber 59 via the lifting unit fuel oil outlet 85.

No oil should have been injected from the fuel oil outlet 85, because the control oil holds the hydraulic piston 64 down keeping the cut-off shaft 62 down as well.

Repeat steps 1 to 21 a couple of times.

<u>Test of suction one-way valve 70</u>

The suction one-way valve 70 is tested indirectly.

1. Increase lifting oil pressure up to 300 bar by use of lifting oil pressure control valve 28 and lifting oil pressure gauge 30 with the lifting oil pressure relief valve 27 being closed, thereby supplying lifting oil at the pressure of 300 bar to the lifting oil connecting piece 48b.

The lifting oil will now flow through the lifting oil channels 66 to the lifting piston 67, whereby the lifting piston 67 will be lifted to push up the nozzle valve piston cut-off shaft 62 a distance 68, which is about 2 mm, to keep the nozzle valve piston cut-off shaft 62 in the

open position. The nozzle valve piston cut-off shaft 62 is connected to the hydraulic piston 64, which is pushed up the same distance.

2. Increase slowly plunger oil pressure up to 10-50 bar and then to 300 bar by use of plunger oil pressure control valve 12 and plunger oil pressure gauge 13 with the plunger oil relief valve 11 and the booster oil relief valve 21 being closed and the plunger oil directional valve 10 being open. The plunger oil pressure relief valve 11 shall be closed when increasing the plunger oil pressure.

This will slowly move the plunger piston 58 downwards until it is at the bottom of the plunger compression chamber 74.

3. Increase slowly the fuel oil pressure above the observed open pressure of the non-return valve 77 by use of fuel oil pressure control valve 33 and the fuel oil pressure gauge 36 with the fuel oil pressure relief valve 32 being closed.
4. Check if any oil drop or flow into the oil injection chamber 59 via the lifting unit fuel oil outlet 85.

If the non-return valve 77 cannot be opened, then no oil is coming out from fuel outlet 85, which is a sign of that either the non- return valve spindle 86 or the spindle of the suction one-way valve 70 are stuck.

If during the test of the tightness of the nozzle valve piston cut-off shaft 62 against the nozzle valve connection seat 88 or during the fuel injection sequence test the needle of the fuel oil pressure gauge 36 rises up to 60 bar, then it is a sign that the valve seat of the suction one-way valve 70 is leaking.

Leakage detection test

The fully assembled injection valve 44 of Fig. 2 is exposed to a leakage detection test and placed in the detection valve holder 97a when performing the leakage detection test and supplied with air at 7 bar for detection of any leakages.

1. Remove the injection valve 44 from the function test valve holder 45 and mount the atomizer union nut 126 and the atomizer 43 to obtain the fully assembled injection valve 44 of Fig. 2. Tighten the atomizer union nut 126 with recommended torque.

The valve 44 to be tested now also holds the control oil connecting piece 50, the sealing oil connecting piece 51, the plunger oil connecting piece 49a, the constant oil connecting piece 52, and air bleed stop valve 53.

2. Insert the assembled injector valve 44 in the detection test valve holder 97a and secure the valve 44 by tightening the connecting nuts 46d, see Fig. 27.

3. Connect the detection test hoses 98, 99, 100, 101, 102, 103, 104, 105 and the non- return valves 109a -109h follows, see Fig. 29:

- Connect hose 98 with valve 109a, and valve 109a to control oil connecting piece 50.
- Connect hose 99 with valve 109b, and valve 109b to sealing oil connecting piece 51.
- Connect hose 100 with valve 109c, and valve 109c to constant oil connecting piece 52.
- Connect hose 101 with valve 109d, and valve 109d to DTS air outlet port II 113.
- Connect hose 102 with valve 109e, and valve 109e to DTS air outlet port III 112.
- Connect hose 103 with valve 109f, and valve 109f to DTS air outlet port I 111.
- Connect hose 104 with valve 109g, and valve 109g to DTS lower air outlet port 110.
- Connect hose 105 with valve 109h, and valve 109h to DTS bottom air outlet port 114.

4. Plug the hole in plunger oil connecting piece 49b with plunger oil plug 115 and close the air bleed stop valve 53.

5. Insert all flexible hoses 98, 99, 100, 101, 102, 103, 104, 105 into the detection test chamber 106 holding liquid.

The valve 108, see Figs. 28 and 29, is a detection test liquid drain valve to drain liquid from the bottom of the detection test valve holder 97a when needed.

7. Supply air at 7 bar into DTS air inlet port 107 and thereby into the detection sleeve 97a, see Fig. 28.

The compressed air will flow from air inlet port 107 through air inlet channel 195 to air inlet chamber 196, see Fig. 28.

From chamber 196 the air can flow to upper oil leakage outlet 166, through upper oil leakage channel 167 and intermediate leakage oil collecting channel 169 and intermediate leakage oil outlet 197 to intermediate outer leakage oil chamber 198, see Figs. 16 and 17. If any air leakage through sealing ring 199, see Fig. 16, the air will flow from DTS lower air outlet chamber 203 to DTS lower air outlet port 110, and then through valve 109 and hose 104 into the test liquid chamber 106. A leakage through the sealing ring 199 will be visible as bubbles in liquid chamber 106.

If any leakage between the atomizer union nut 126 and the atomizer 43, the air will flow from air inlet chamber 196 through intermediate leakage oil outlet channel 197 and atomizer fuel oil leakage channel 168 to atomizer fuel oil leakage chamber 194 and then pass on to bottom air outlet chamber 204, see Figs 16 and 28. From chamber 204, the air passes through bottom air outlet port 114, valve 109h and hose 105 into the test liquid chamber 106. A leakage between union nut 126 and atomizer 43 will be visible as bubbles in liquid chamber 106.

If any leakage through barrel body outer sealing ring 209, the air will flow from air inlet chamber 196 to barrel body air outlet chamber I 210 to barrel body air outlet port I 111, and from port 111 through valve 109g and hose 104 into the test liquid chamber 106. A leakage will be visible as bubbles in liquid chamber 106.

From air inlet chamber 196 the air will flow to upper oil leakage outlet 166, through upper oil leakage channel 167 into intermediate upper leakage oil chamber 170. See Figs. 16 and 17. If any leakage through fourth intermediate upper sealing ring 175, see Fig. 18, the air will flow from chamber 170 to second control and sealing oil leakage channel 151 and pass on to first control and sealing oil leakage channel 150 to oil leakage outlet 158, see Fig. 7, and from outlet 158 to chamber 211 into barrel body air outlet port II 113, see Fig. 28. From port 113 through valve 109d and hose 10 into the test liquid chamber 106. A leakage through sealing ring 175 will be visible as bubbles in liquid chamber 106.

The compressed air will flow from air inlet chamber 196 to upper oil leakage outlet 166, through upper oil leakage channel 167 into upper oil leakage outlet 165 and into barrel body air outlet chamber III 212, see Figs. 16 and 28. If any leakage through second barrel body outer sealing ring 206, the air will flow from chamber III 212 to chamber II 211 and into air outlet port II 113. From port 113 through valve 109d and hose 10 into the test liquid chamber 106. A leakage through sealing ring 206 will be visible as bubbles in liquid chamber 106.

From air inlet chamber 196 the air will flow to upper oil leakage outlet 166, through upper oil leakage channel 167 into intermediate upper leakage oil chamber 170. See Figs. 16 and 17. If any leakage through fifth intermediate upper sealing ring 176, see Fig. 18, the

air will flow from chamber 170 to the second fuel oil leakage channel 163 through third fuel oil leakage channel 164 into fuel leakage outlet 92, see Figs. 15 and 28. From leakage outlet 92 the air can flow to barrel body outlet port III 112 and through valve 109e and hose 102 into the test liquid chamber 106. A leakage through fifth intermediate upper sealing ring 176 will be visible as bubbles in liquid chamber 106.

The compressed air will flow from air inlet chamber 196 to upper oil leakage outlet 166, through upper oil leakage channel 167 into upper oil leakage outlet 165 and into barrel body air outlet chamber III 212, see Figs. 16 and 28. If any leakage through third barrel body outer sealing ring 207, the air will flow from chamber 212 to into fuel leakage outlet 92. From leakage outlet 92 the air can flow to barrel body outlet port III 112 and through valve 109e and hose 102 into the test liquid chamber 106. A leakage through third barrel body outer sealing ring 207 will be visible as bubbles in liquid chamber 106.

From air inlet chamber 196 the air will flow to upper oil leakage outlet 166, through upper oil leakage channel 167 into intermediate upper leakage oil chamber 170. See Figs. 16 and 17. If any leakage through third intermediate upper sealing ring 174, see Fig. 18, the air will flow from chamber 170 to sealing oil channel 133 and from channel 133 through sealing oil channels 132 and 131 to the sealing oil inlet port 128 and sealing oil connecting piece 51, see Fig. 4. From connecting piece 51 through valve 109b and hose 99 into the test liquid chamber 106. A leakage through third intermediate upper sealing ring 174 will be visible as bubbles in liquid chamber 106.

From air inlet chamber 196 the air will flow to upper oil leakage outlet 166, through upper oil leakage channel 167 into intermediate upper leakage oil chamber 170. See Figs. 16 and 17. If any leakage through second intermediate upper sealing ring 173, see Fig. 18, the air will flow from chamber 170 to control oil drain channel 142 to constant oil inlet port 129 and constant oil connecting piece 52, see Fig. 5. From connecting piece 52 through valve 109c and hose 100 into the test liquid chamber 106. A leakage through second intermediate upper sealing ring 173 will be visible as bubbles in liquid chamber 106.

From air inlet chamber 196 the air will flow to upper oil leakage outlet 166, through upper oil leakage channel 167 into intermediate upper leakage oil chamber 170. See Figs. 16

and 17. If any leakage through first intermediate upper sealing ring 172, see Fig. 18, the air will flow from chamber 170 to control oil supply channel 140 to control oil inlet port 130 and control oil connecting piece 50, see Fig. 5. From connecting piece 50 through valve 109a and hose 98 into the test liquid chamber 106. A leakage through first intermediate upper sealing ring 172 will be visible as bubbles in liquid chamber 106.

8. Observe the test liquid chamber 106 for 2 minutes. If bubbles come out from one of the detection test hoses 98-105, it is a sign, that there is a leakage inside the injector valve 44.
This test is accepted if no more than 2 bubbles / 60 seconds is observed from each of hoses 98-105.

The invention has been described in conjunction with various embodiments herein. However, other variations to the disclosed embodiments can be understood and effected by those skilled in the art in practicing the claimed invention, from a study of the drawings, the disclosure, and the appended claims. In the claims, the word “comprising” does not exclude other elements or steps, and the indefinite article “a” or “an” does not exclude a plurality.

CLAIMS

1. A method of testing an injector valve (44) for a combustion engine, which injector valve (44) comprises:

a plunger piston sealing chamber (136) with a plunger piston (58) for forming a plunger compression chamber (74), said plunger piston (58) being provided with a plunger piston fuel oil opening (57b) at the bottom and said plunger piston (58) being controlled by supply of plunger oil at a plunger oil pressure via a cover plunger oil supply channel (63); characterized in that the injector valve further comprises

a suction one-way valve (70) for fuel oil inlet via a suction valve fuel inlet (72), a plunger chamber supply channel (73) for supply of fuel oil from the suction one-way valve (70) to the plunger compression chamber (74) or to the plunger piston fuel oil opening (57b);

a non-return valve (77) in fluid connection with the plunger compression chamber (74) or the plunger piston fuel oil opening (57b) via a non-return valve supply channel (75) for supply of fuel oil to the non-return valve (77);

a nozzle valve (61a) with a nozzle valve chamber (81), a nozzle valve piston cut-off shaft (62), a nozzle valve spring (96), a nozzle valve connection seat (88), and a nozzle valve opening (61b), said nozzle valve piston cut-off shaft (62) having a nozzle valve piston cut-off shaft tip (61c) protruding through the opening (61b) of the nozzle valve (61a); and

a number of nozzle valve chamber supply channels (78a, 78b, 79a, 79b, 80a,80b) providing a fluid connection from the non-return valve (77) to the nozzle valve chamber (81) for supply of fuel oil from the plunger compression chamber (74) or from the plunger piston fuel oil opening (57b) via the non-return valve (77) to the nozzle valve chamber (81); and characterized in that said method comprises:

(a) applying a predetermined lifting pressure to the nozzle valve piston cut-off shaft tip (61c) protruding through the opening (61b) of the nozzle valve (61a), said lifting pressure being higher than a spring force exerted by the nozzle valve spring (96) on the nozzle valve piston cut-off shaft (62) to thereby maintain the nozzle valve piston cut-off shaft (62) in a lifted position from the nozzle valve connection seat (88) in which the nozzle valve (61a) is open;

(b) supplying plunger oil to the plunger piston (58) via the cover plunger oil supply channel (63) at a first test plunger oil pressure, said first test plunger oil pressure being

equal to or larger than a predetermined plunger oil pressure required for maintaining the plunger piston (58) at the bottom of the plunger piston sealing chamber (136) to thereby close the plunger compression chamber (74) while maintaining a fluid connection from the plunger chamber supply channel (73) via the plunger piston fuel oil opening (57b) to the non-return valve supply channel (75);

(c) supplying fuel oil at a first predetermined test fuel oil pressure to the suction valve fuel inlet (72), via the suction one-way valve (70) and the piston fuel oil opening (57b) to the non-return valve supply channel (75), said first predetermined test fuel oil pressure being lower than a predetermined fuel oil pressure required for opening the non-return valve (77); and

(d) checking whether any of the supplied fuel oil reaches out from the nozzle valve opening (61b).

2. A method according to claim 1, wherein the injector valve under test (44) further comprises

a hydraulic piston chamber (155) holding a hydraulic piston (64) connected to the nozzle valve piston cut-off shaft (62), said hydraulic piston (64) being controlled by supply of control oil at a control oil pressure via control oil supply channels (141, 142) for opening and closing the nozzle valve (61a); and

sealing oil channels (131, 132, 133, 134) in fluid connection with the plunger piston sealing chamber (136) for sealing the plunger piston (58), and in fluid connection with the hydraulic piston chamber (155) for sealing the hydraulic piston (64); and wherein the method before the supply of plunger oil at step (b) comprises a sealing step by

supplying sealing oil at a first sealing oil pressure to the plunger piston sealing chamber (136) and the hydraulic piston chamber (155) via the sealing oil channels (131, 132, 133, 135), said first sealing oil pressure being higher than or equal to a predetermined sealing oil pressure required for sealing of the plunger piston (58) within the plunger piston sealing chamber (23) and for sealing of the hydraulic piston (64) within the hydraulic piston chamber (155).

3. A method according to claim 2, wherein the predetermined sealing oil pressure is in the range of 60-100 bar, such as in the range of 70-90 bar, such as around 80 bar.

4. A method according to any one of the claims 1 to 3, wherein the valve (44) being tested is placed in a function test valve holder (45) holding a nozzle valve piston lifting unit (46b) with a lifting piston (67) and lifting oil channels (66), said nozzle valve piston lifting unit (46b) being positioned with the lifting piston (67) engaging the nozzle valve piston cut-off shaft tip (61b), and wherein lifting oil is supplied at a predetermined pressure to the lifting piston (67) via the lifting oil channels (68) to thereby provide said predetermined lifting pressure for maintaining the nozzle valve piston cut-off shaft (62) in the lifted position; and

wherein the nozzle valve piston lifting unit (46b) further has lifting unit fuel oil leakage channels (83, 84) and a lifting unit fuel oil outlet (85) in fluid connection with the nozzle valve opening (61b), whereby any fuel oil reaching out from the nozzle valve opening (61b) will reach out from the lifting unit fuel oil outlet (85).

5. A method according to any one of the claims 1 to 4, wherein the first test plunger oil pressure is in the range of 280-320 bar, such as about 300 bar.

6. A method according to any one of the claims 1 to 5, wherein the step of supplying plunger oil to the plunger piston (58) at step (b) comprises a first step of slowly increasing the pressure of supplied plunger oil to a first lower initial oil pressure and then proceed by increasing the oil pressure to the first test plunger oil pressure, and wherein the first lower initial oil pressure is in the range of 10 to 50 bar.

7. A method according to any one of the claims 1 to 6, wherein the first predetermined test fuel oil pressure of step (c) is about 30 bar.

8. A method according to any one of the claims 1 to 6, wherein the method further comprises:

(e) slowly increasing the pressure of the supply of fuel oil to the suction valve fuel inlet (72) until the non-return valve (77) opens; and

(f) observing the pressure of supplied fuel oil when fuel oil droplets or a stream of fuel oil flow reach out from the nozzle valve opening (61b) to thereby determine an opening pressure for the non-return valve (77).

9. A method according to claim 8, wherein the method further comprises:

(g) release the pressure of the supply of fuel oil to a pressure well below the determined opening pressure of the non-return valve (77), such as at least 10-20 bar or at least 30 bar below the determined opening pressure of the non-return valve (77);

(h) increasing the pressure of the supply of fuel oil to the suction valve fuel inlet (72) until it reaches a pressure being in the range of 3-5 bar below the determined opening pressure of the non-return valve (77); and

(i) checking whether any of the supplied fuel oil reaches out from the nozzle valve opening (61b).

10. A method according to any one of the claims 1 to 9, said method further comprising:

releasing the predetermined lifting pressure from the nozzle valve piston cut-off shaft tip (61c) to thereby close the nozzle valve (61a) with the spring force of the nozzle valve spring (96) forcing the nozzle valve piston cut-off shaft (62) against the nozzle valve connection seat (88);

supplying fuel oil at a second predetermined test fuel oil pressure to the suction valve fuel inlet (72), via the suction one-way valve (70) and the piston fuel oil opening (57b) to the non-return valve supply channel (75), said second predetermined test fuel oil pressure being higher than a predetermined fuel oil pressure required for opening the non-return valve (77); and

checking whether any of the supplied fuel oil reaches out from the nozzle valve opening (61b).

11. A method of testing an injector valve (44) for a combustion engine, which injector valve (44) comprises:

a plunger piston sealing chamber (136) with a plunger piston (58) for forming a plunger compression chamber (74), said plunger piston (58) being provided with a plunger piston fuel oil opening (57b) at the bottom and said plunger piston (58) being controlled by supply of plunger oil at a plunger oil pressure via a cover plunger oil supply channel (63); characterized in that the injector valve further comprises

a suction one-way valve (70) for fuel oil inlet via a suction valve fuel inlet (72), a plunger chamber supply channel (73) for supply of fuel oil from the suction one-way valve (70) to the plunger compression chamber (74) or to the plunger piston fuel oil opening (57b);

a non-return valve (77) in fluid connection with the plunger compression chamber (74) or the plunger piston fuel oil opening (57b) via a non-return valve supply channel (75) for supply of fuel oil to the non-return valve (77);

a nozzle valve (61a) with a nozzle valve chamber (81), a nozzle valve piston cut-off shaft (62), a nozzle valve spring (96), a nozzle valve connection seat (88), and a nozzle valve opening (61b), said nozzle valve piston cut-off shaft (62) having a nozzle valve piston cut-off shaft tip (61c) protruding through the opening (61b) of the nozzle valve (61a);

a number of nozzle valve chamber supply channels (78a, 78b, 79a, 79b, 80a,80b) providing a fluid connection from the non-return valve (77) to the nozzle valve chamber (81) for supply of fuel oil from the plunger compression chamber (74) or from the plunger piston fuel oil opening (57b) via the non-return valve (77) to the nozzle valve chamber (81); and characterized in that said method comprises:

supplying plunger oil to the plunger piston (58) via the cover plunger oil supply channel (63) at a test plunger oil pressure, said test plunger oil pressure being equal to or larger than a plunger oil pressure required for maintaining the plunger piston (58) at the bottom of the plunger piston sealing chamber (136) to thereby close the plunger compression chamber (74) while maintaining a fluid connection from the plunger chamber supply channel (73) via the plunger piston fuel oil opening (57b) to the non-return valve supply channel (75);

supplying fuel oil at a second predetermined test fuel oil pressure to the suction valve fuel inlet (72), via the suction one-way valve (70) and the piston fuel oil opening (57b) to the non-return valve supply channel (75), said second predetermined test fuel oil pressure being higher than a predetermined fuel oil pressure required for opening the non-return valve (77); and

checking whether any of the supplied fuel oil reaches out from the nozzle valve opening (61b).

12. A method according to claim 11, wherein the second predetermined test fuel oil pressure is about 5 bar higher than the predetermined fuel oil pressure required for opening the non-return valve (77), and

wherein the test plunger oil pressure is in the range of 280-320 bar, such as about 300 bar.

13. A method of testing an injector valve (44) for a combustion engine, which injector valve (44) comprises:

a plunger piston sealing chamber (136) with a plunger piston (58) for forming a plunger compression chamber (74), said plunger piston (58) being controlled by supply of plunger oil at a plunger oil pressure via a cover plunger oil supply channel (63), and said plunger piston (58) holding first and second plunger leakage channels (89,90) providing a fluid connection from the bottom of the plunger piston (58) to an upper sidewall part of the plunger piston (58); characterized in that the injector valve further comprises

a suction one-way valve (70) for fuel oil inlet via a suction valve fuel inlet (72), a plunger chamber supply channel (73) for supply of fuel oil from the suction one-way valve (70) to the plunger compression chamber (74);

a non-return valve (77) in fluid connection with the plunger compression chamber (74) via a non-return valve supply channel (75) for supply of fuel oil from the plunger compression chamber (74) to the non-return valve (77);

a nozzle valve (61a) with a nozzle valve chamber (81), a nozzle valve piston cut-off shaft (62), a nozzle valve spring (96), a nozzle valve connection seat (88), and a nozzle valve opening (61b), said nozzle valve piston cut-off shaft (62) having a nozzle valve piston cut-off shaft tip (61c) protruding through the opening (61b) of the nozzle valve (61a); and

a number of nozzle valve chamber supply channels (78a, 78b, 79a, 79b, 80a,80b) providing a fluid connection from the non-return valve (77) to the nozzle valve chamber (81) for supply of fuel oil from the plunger compression chamber (74) or from the plunger piston fuel oil opening (57b) via the non-return valve (77) to the nozzle valve chamber (81); and

a third plunger compression leakage channel (91) providing a fluid connection from the plunger piston sealing chamber (136) to a fuel oil leakage outlet (92) positioned at an outer surface of the valve, wherein the third plunger compression leakage channel (91) has an inlet opening facing the plunger piston sealing chamber (136) at a position being faced by an outlet opening of the second plunger compression leakage channel (90) when the plunger piston (58) is in its most upper position within the plunger piston sealing chamber (136); and characterized in that said method comprises:

supplying fuel oil at a predetermined leakage test fuel oil pressure to the suction valve fuel inlet (72), via the suction one-way valve (70) and the piston fuel oil opening

(57b) to the plunger compression chamber, said predetermined leakage test fuel oil pressure being lower than a predetermined fuel oil pressure required for opening the non-return valve (77) and higher than a fuel oil pressure required for lifting the plunger piston (58) to its most upper position when no plunger oil pressure is applied to the plunger piston (58); and

checking whether any of the supplied fuel oil reaches out from the fuel oil leakage outlet (92).

14. A method according to claim 13, wherein the predetermined leakage test fuel oil pressure is in the range of 20 to 40 bar, such as in the range of 25 to 35 bar, such as about 30 bar, and

wherein there is no supply of plunger oil at a plunger oil pressure to the plunger piston (58).

15. A method according to any claim 13 or 14, wherein the injector valve under test (44) further comprises

a hydraulic piston chamber (155) holding a hydraulic piston (64) connected to the nozzle valve piston cut-off shaft (62), said hydraulic piston (64) being controlled by supply of control oil at a control oil pressure via control oil supply channels (141, 142) for opening and closing the nozzle valve (61a); and

sealing oil channels (131, 132, 133, 134) in fluid connection with the plunger piston sealing chamber (136) for sealing the plunger piston (58), and in fluid connection with the hydraulic piston chamber (155) for sealing the hydraulic piston (64); and wherein the method before the supply of fuel oil comprises a sealing step by

supplying sealing oil at a first sealing oil pressure to the plunger piston sealing chamber (136) and the hydraulic piston chamber (155) via the sealing oil channels (131, 132, 133, 135), said first sealing oil pressure being higher than or equal to a predetermined sealing oil pressure required for sealing of the plunger piston (58) within the plunger piston sealing chamber (23) and for sealing of the hydraulic piston (64) within the hydraulic piston chamber (155).

16. A method of testing an injector valve (44) for a combustion engine, which injector valve (44) comprises:

a plunger piston sealing chamber (136) with a plunger piston (58) for forming a plunger compression chamber (74), said plunger piston (58) being controlled by supply of plunger oil at a plunger oil pressure via a cover plunger oil supply channel (63); characterized in that the injector valve further comprises

a suction one-way valve (70) for fuel oil inlet via a suction valve fuel inlet (72), a plunger chamber supply channel (73) for supply of fuel oil from the suction one-way valve (70) to the plunger compression chamber (74);

a non-return valve (77) in fluid connection with the plunger compression chamber (74) via a non-return valve supply channel (75) for supply of fuel oil from the plunger compression chamber (74) to the non-return valve (77);

a nozzle valve (61a) with a nozzle valve chamber (81), a nozzle valve piston cut-off shaft (62), a nozzle valve spring (96), a nozzle valve connection seat (88), and a nozzle valve opening (61b), said nozzle valve piston cut-off shaft (62) having a nozzle valve piston cut-off shaft tip (61c) protruding through the opening (61b) of the nozzle valve (61a); and

a number of nozzle valve chamber supply channels (78a, 78b, 79a, 79b, 80a,80b) providing a fluid connection from the non-return valve (77) to the nozzle valve chamber (81) for supply of fuel oil from the plunger compression chamber (74) or from the plunger piston fuel oil opening (57b) via the non-return valve (77) to the nozzle valve chamber (81); and characterized in that said method comprises:

(aa) supplying fuel oil at a predetermined nozzle valve test fuel oil pressure to the suction valve fuel inlet (72), via the suction one-way valve (70) to the plunger compression chamber (74), said predetermined nozzle valve test fuel oil pressure being lower than a fuel oil pressure required for opening the non-return valve (77);

(bb) supplying plunger oil to the plunger piston (58) via the cover plunger oil supply channel (63) at a first nozzle valve test plunger oil pressure, said first nozzle valve test plunger oil pressure being larger than or equal to a non-return valve plunger oil pressure required for opening the non-return valve (77) and smaller than or equal to a nozzle valve plunger oil pressure required for opening the nozzle valve (61a) by overcoming the force of the nozzle valve spring (96); and

(cc) checking whether any of the supplied fuel oil reaches out from the nozzle valve opening (61b).

17. A method according to claim 16, wherein the predetermined nozzle valve test fuel oil pressure is equal to or larger than a predetermined fuel oil pressure required for lifting the plunger piston (58) to its most upper position when no plunger oil pressure is applied to the plunger piston (58).

18. A method according to claim 16 or 17, wherein the predetermined nozzle valve test fuel oil pressure of step (aa) is in the range of 20 to 40 bar, such as in the range of 25 to 35 bar, such as about 30 bar, and wherein the first nozzle valve test plunger oil pressure is in the range of 140 to 160 bar, such as about 150 bar.

19. A method according to any one of the claims 16 to 18, wherein the injector valve under test (44) further comprises

a hydraulic piston chamber (155) holding a hydraulic piston (64) connected to the nozzle valve piston cut-off shaft (62), said hydraulic piston (64) being controlled by supply of control oil at a control oil pressure via control oil supply channels (141, 142) for opening and closing the nozzle valve (61a); and

sealing oil channels (131, 132, 133, 134) in fluid connection with the plunger piston sealing chamber (136) for sealing the plunger piston (58), and in fluid connection with the hydraulic piston chamber (155) for sealing the hydraulic piston (64); and wherein the method before the supply of plunger oil at step (bb) or before the supply of fuel oil at step (aa) comprises a sealing step by

supplying sealing oil at a first sealing oil pressure to the plunger piston sealing chamber (136) and the hydraulic piston chamber (155) via the sealing oil channels (131, 132, 133, 135), said first sealing oil pressure being higher than or equal to a predetermined sealing oil pressure required for sealing of the plunger piston (58) within the plunger piston sealing chamber (23) and for sealing of the hydraulic piston (64) within the hydraulic piston chamber (155).

20. A method according to any one of the claims 16 to 19, wherein the method further comprises:

(dd) increase the supply of plunger oil to the plunger piston (58) in steps from the first nozzle valve test plunger oil pressure to a final nozzle valve test plunger oil pressure, said final nozzle valve test plunger oil pressure being larger than the nozzle valve

plunger oil pressure required for opening the nozzle valve (61a) by overcoming the force of the nozzle valve spring (96); and

(ee) after each step of increase in the supply of plunger oil then checking whether any of the supplied fuel oil reaches out from the nozzle valve opening (61b).

21. A method according to claim 20, wherein the final nozzle valve test plunger oil pressure is in the range of 175 to 200 bar, such as about 185 bar, and wherein the supply of plunger oil is increased in steps of 5 bar.

22. A method according to any claim 20 or 21, wherein the method further comprises:

(ff) observing the pressure of supplied fuel oil when fuel oil droplets or a stream of fuel oil flow reach out from the nozzle valve opening (61b) to thereby determine an opening pressure for the nozzle valve (61a);

(gg) changing the supply of plunger oil to the plunger piston (58) from the final nozzle valve test plunger oil pressure to a closed nozzle valve test plunger oil pressure, said closed nozzle valve test plunger oil pressure having a value in the range of 5 -10 bar below the determined opening pressure for the nozzle valve (61a); and

(hh) checking whether any of the supplied fuel oil reaches out from the nozzle valve opening (61b).

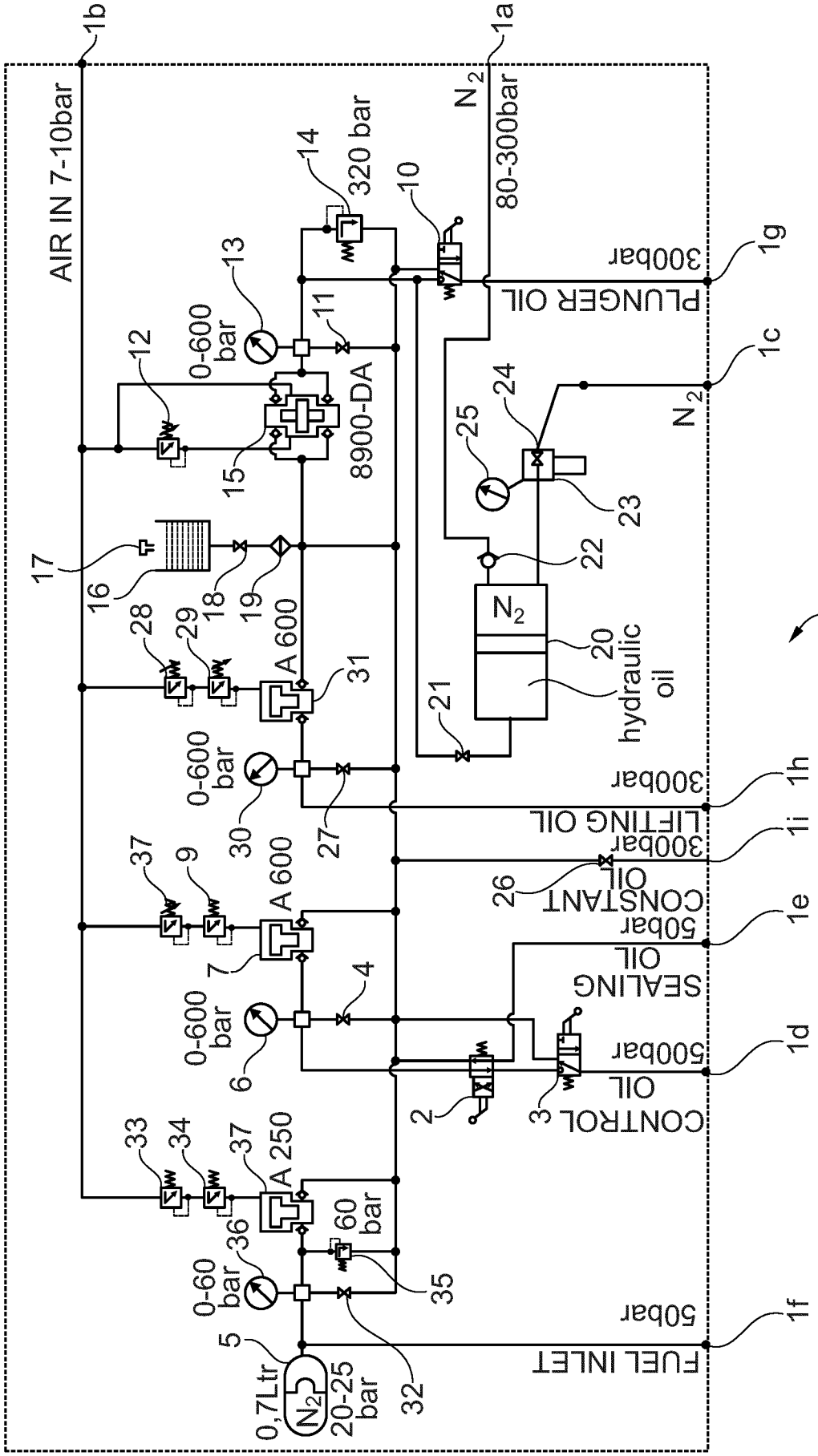

1b
AIR IN 7-10bar
1a
N_2
80-300bar
14
320 bar
10
13
0-600 bar
11
12
8900-DA
15
1g
300bar
PLUNGER OIL
1c
N_2
24
25
23
22
N_2
20
hydraulic oil
21
17
16
18
19
A 600
28
29
31
0-600 bar
30
27
1h
300bar
LIFTING OIL
1i
300bar
26
CONSTANT OIL
37
9
A 600
7
4
0-600 bar
6
1e
50bar
SEALING OIL
1d
500bar
CONTROL OIL
2
3
33
34
37
A 250
60 bar
36
0-60 bar
35
1f
50bar
FUEL INLET
5
0,7Ltr
N_2
20-25 bar
32
1

Fig. 1

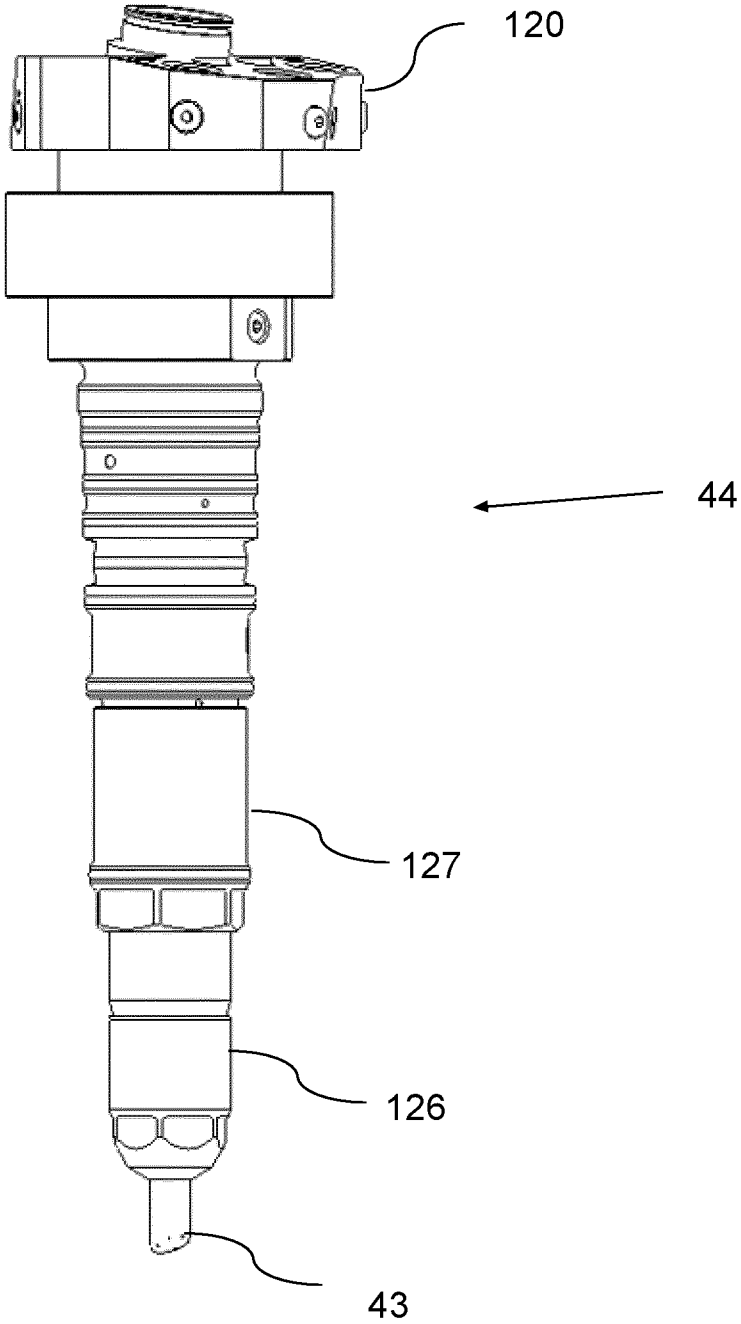


Fig. 2

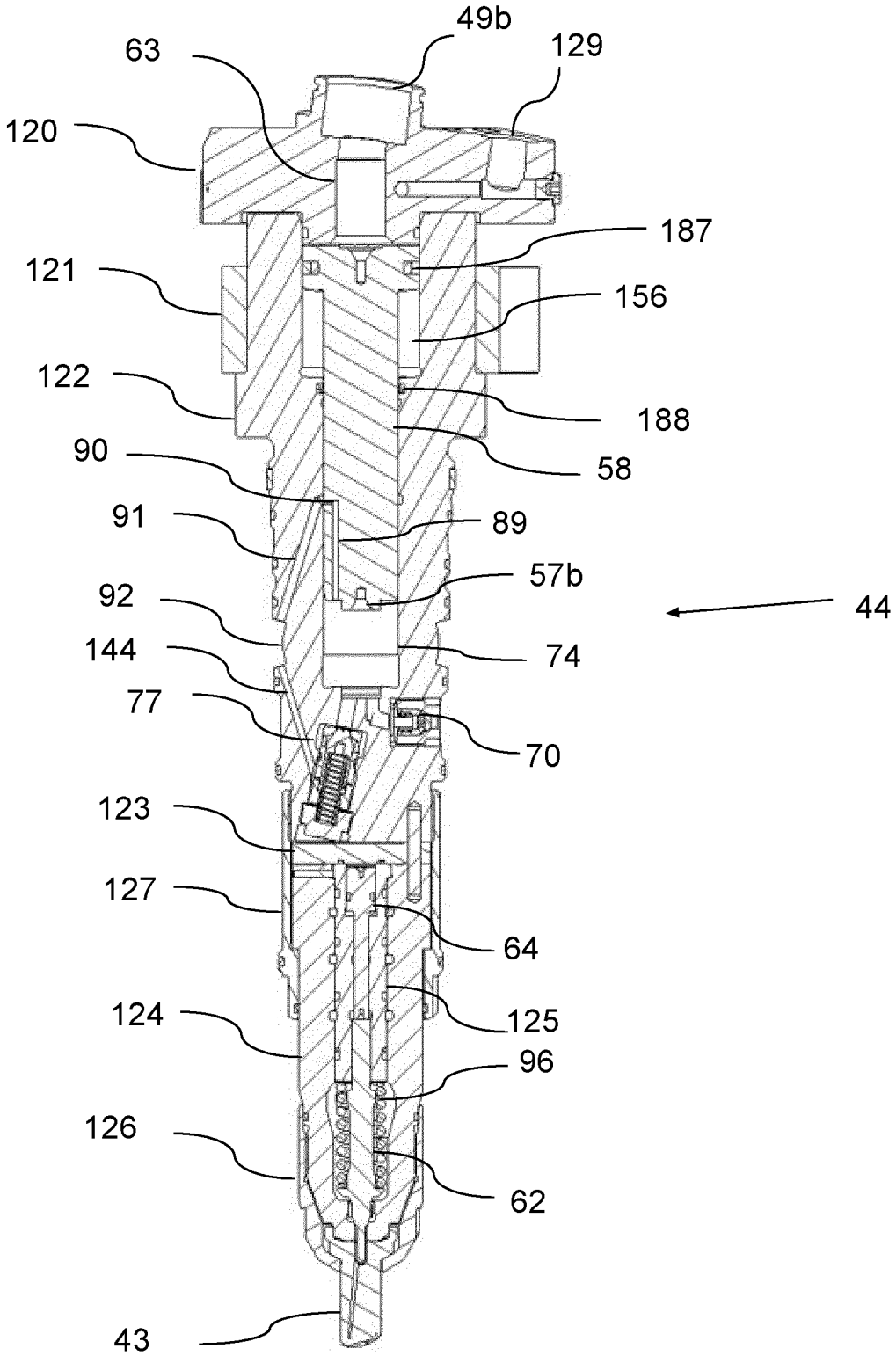

49b
63
129
120
187
121
156
122
188
90
58
91
89
57b
92
44
144
74
77
70
123
127
64
124
125
96
126
62
43

Fig. 3

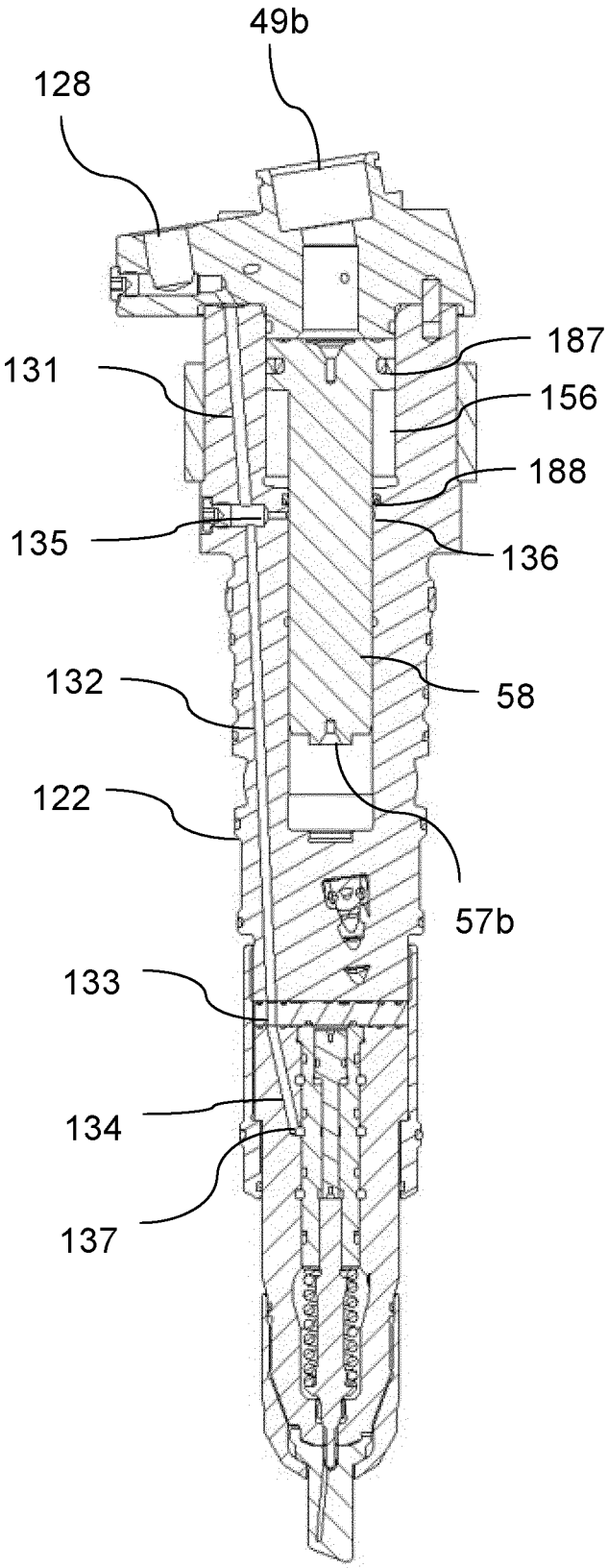

49b
128
187
131
156
188
135
136
132
58
122
57b
133
134
137

Fig. 4

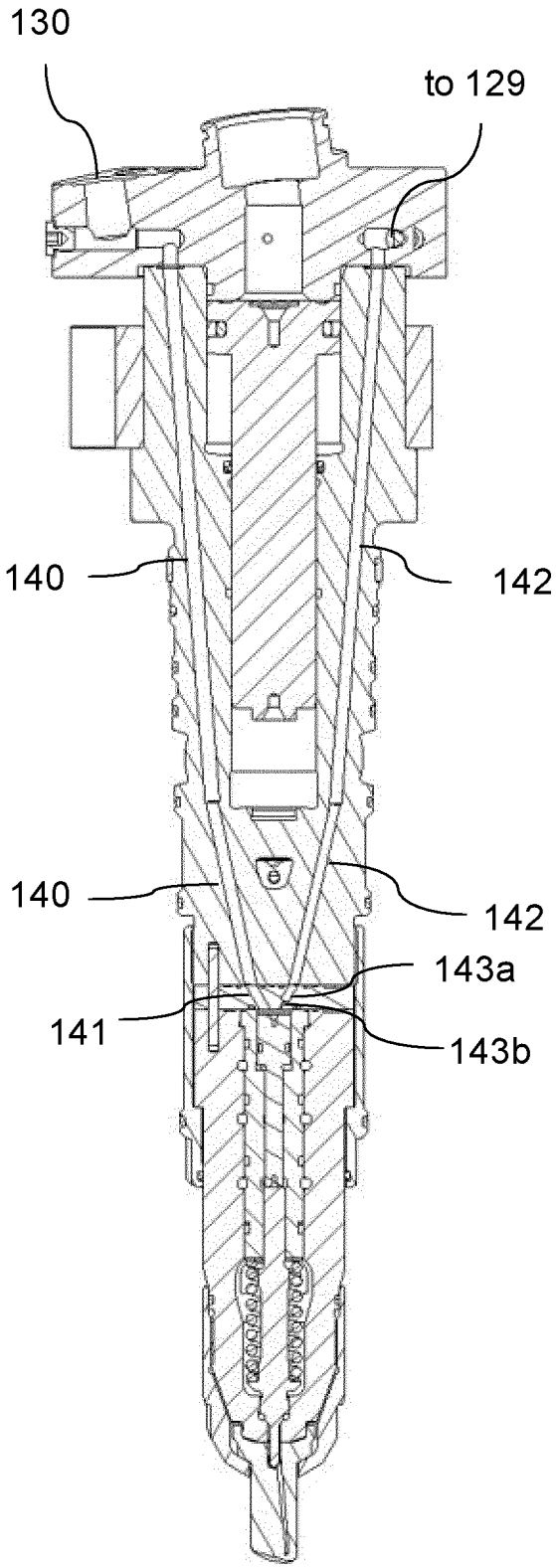

130
to 129
140
142
140
142
143a
141
143b

Fig. 5

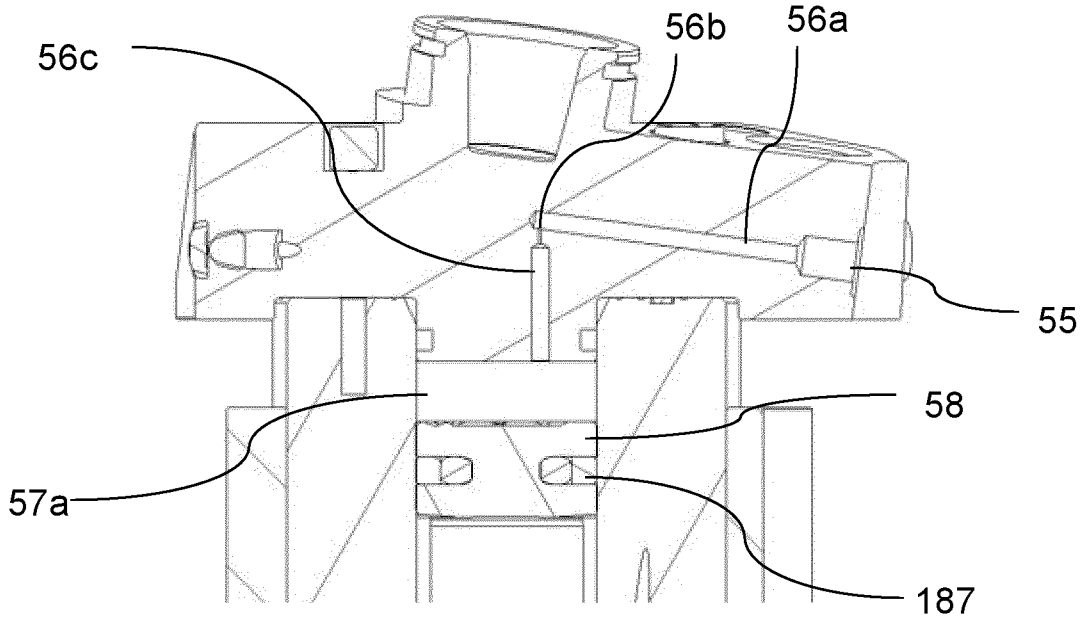


Fig. 6

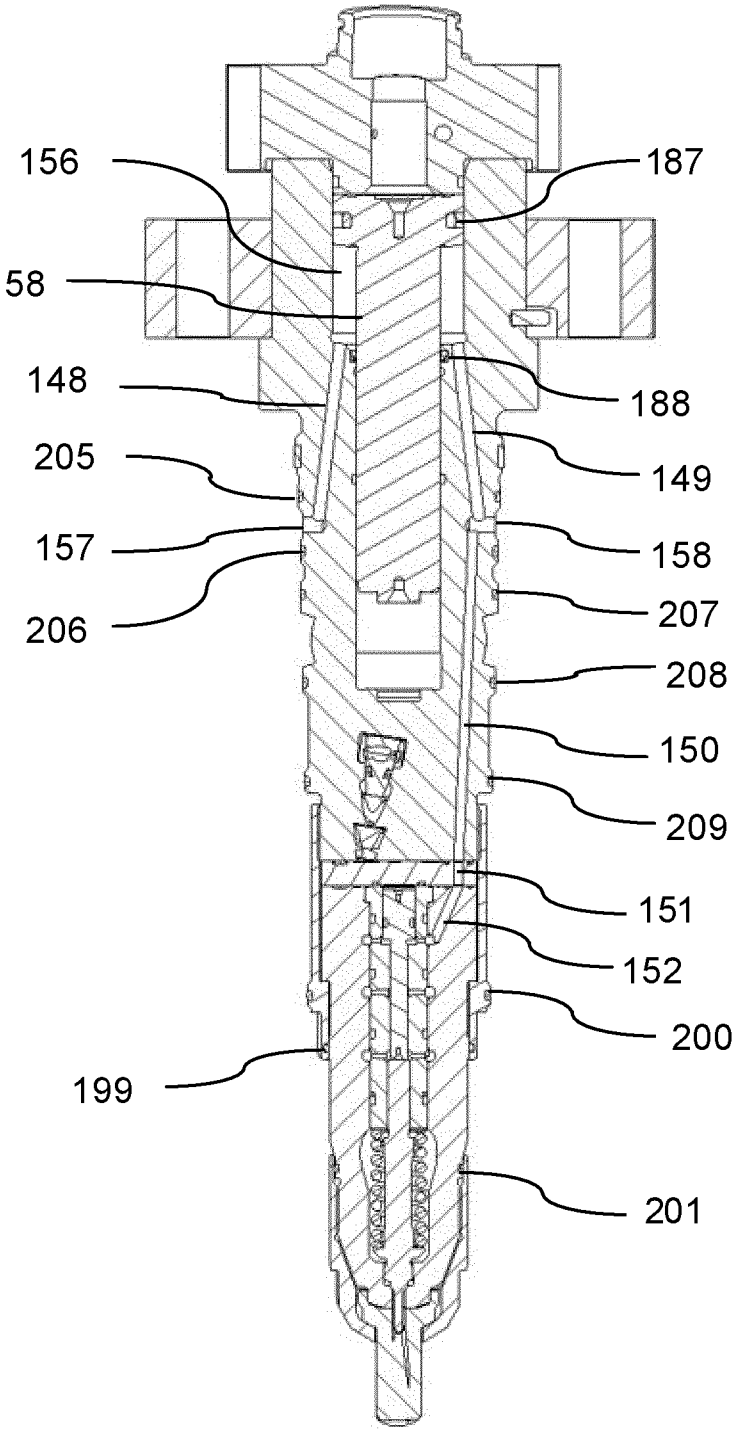

156
187
58
148
188
205
149
157
158
206
207
208
150
209
151
152
200
199
201

Fig. 7

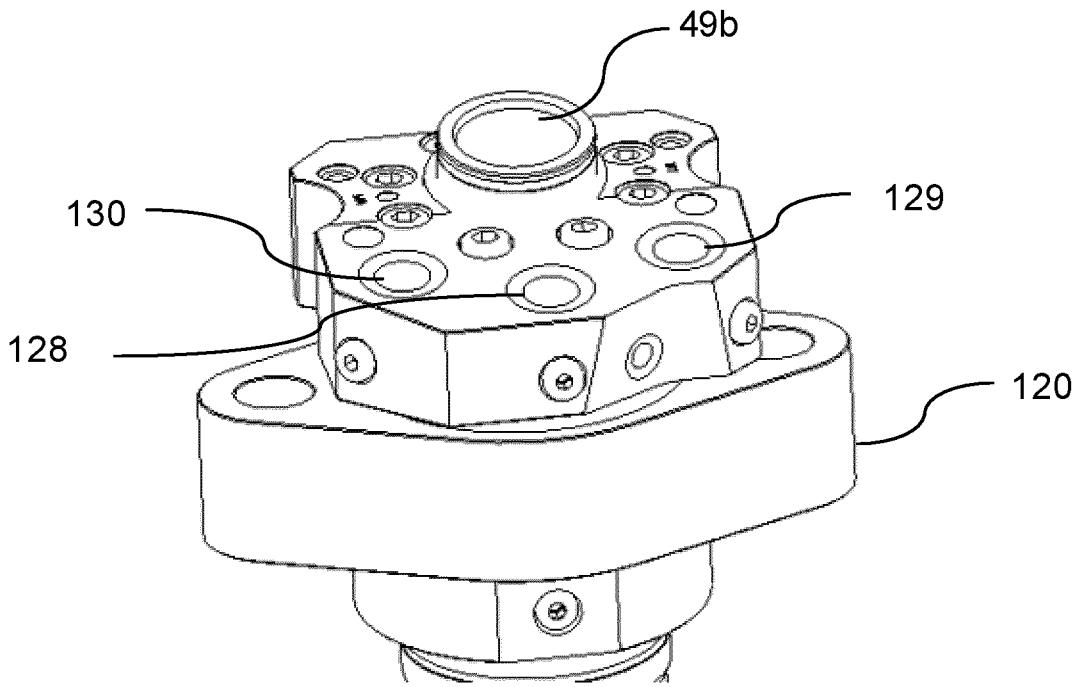


Fig. 8

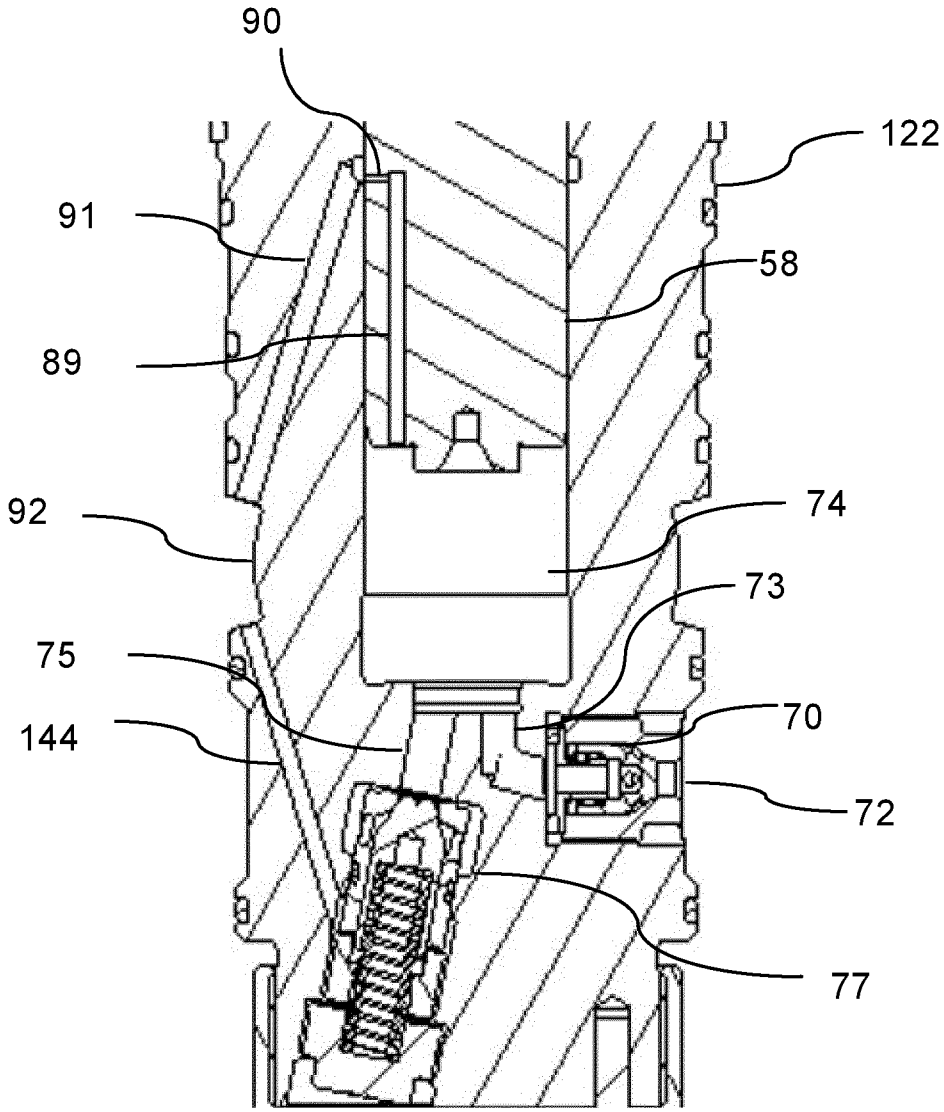


Fig. 9

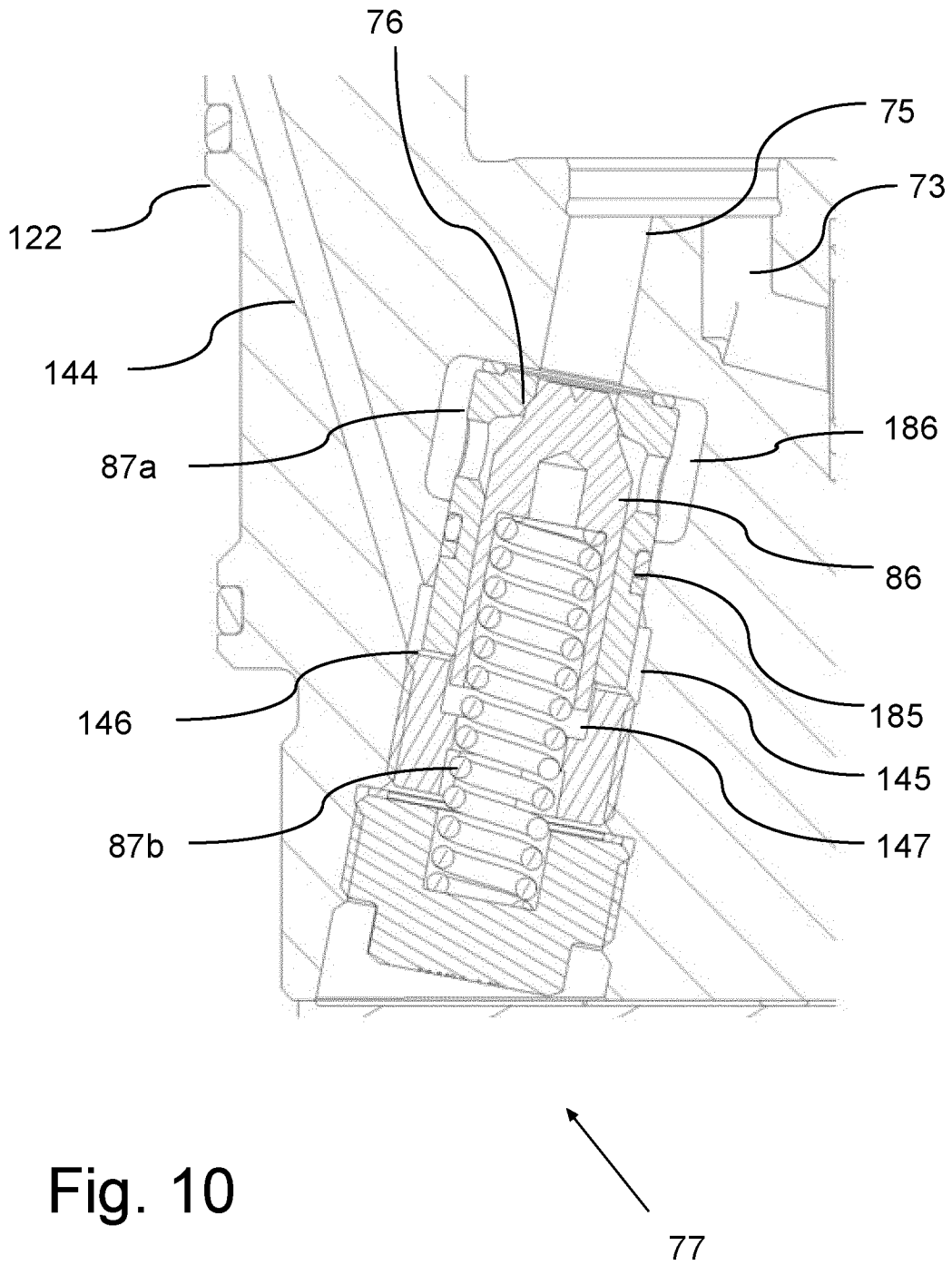


Fig. 10

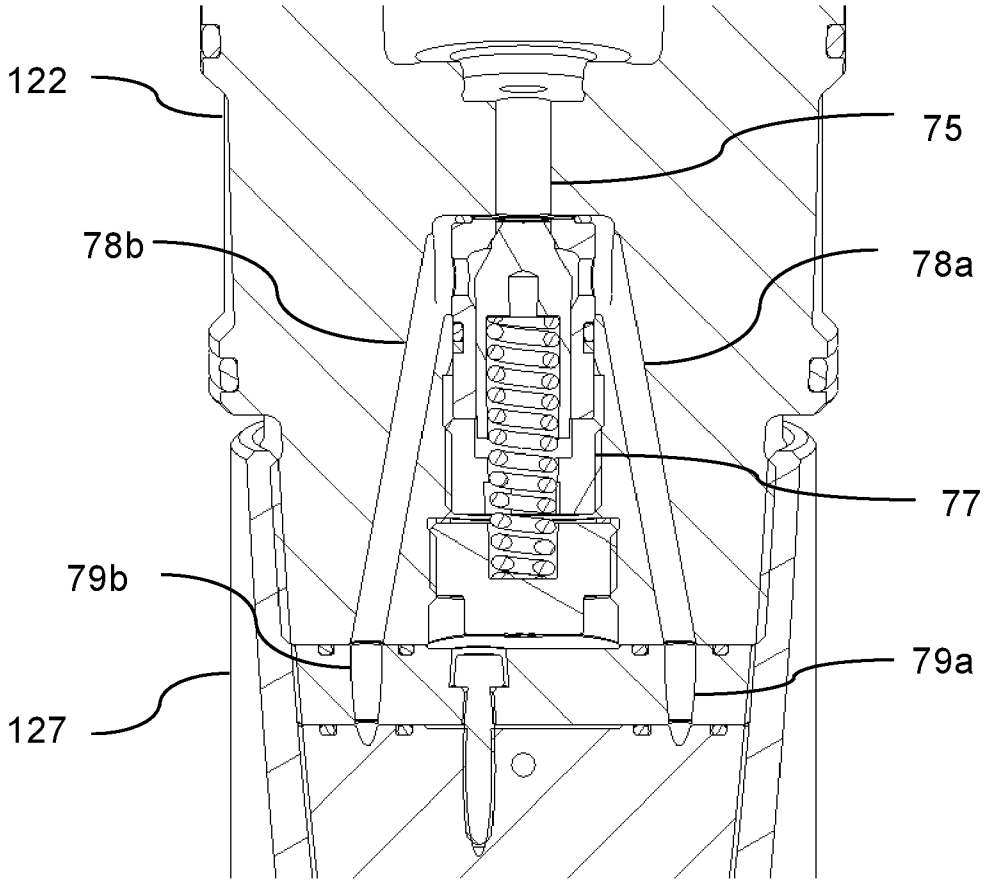


Fig. 11

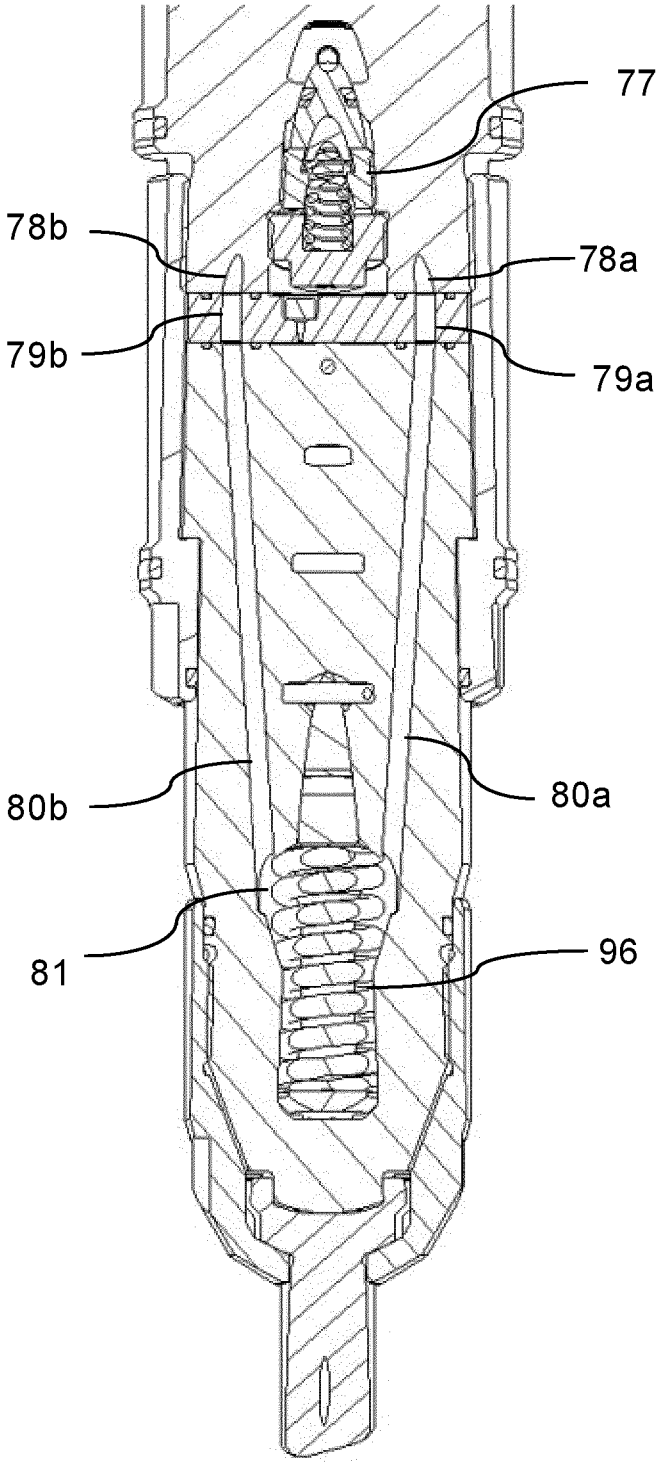


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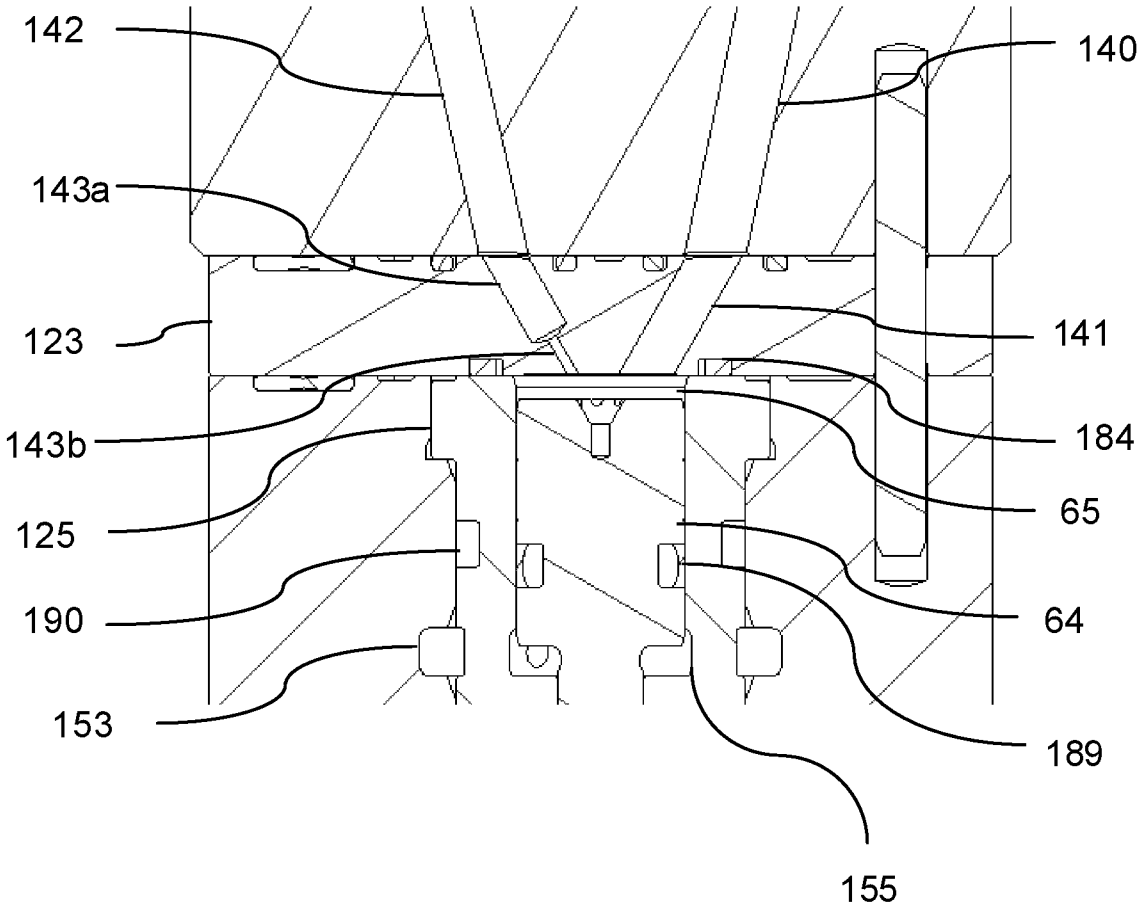


Fig. 13

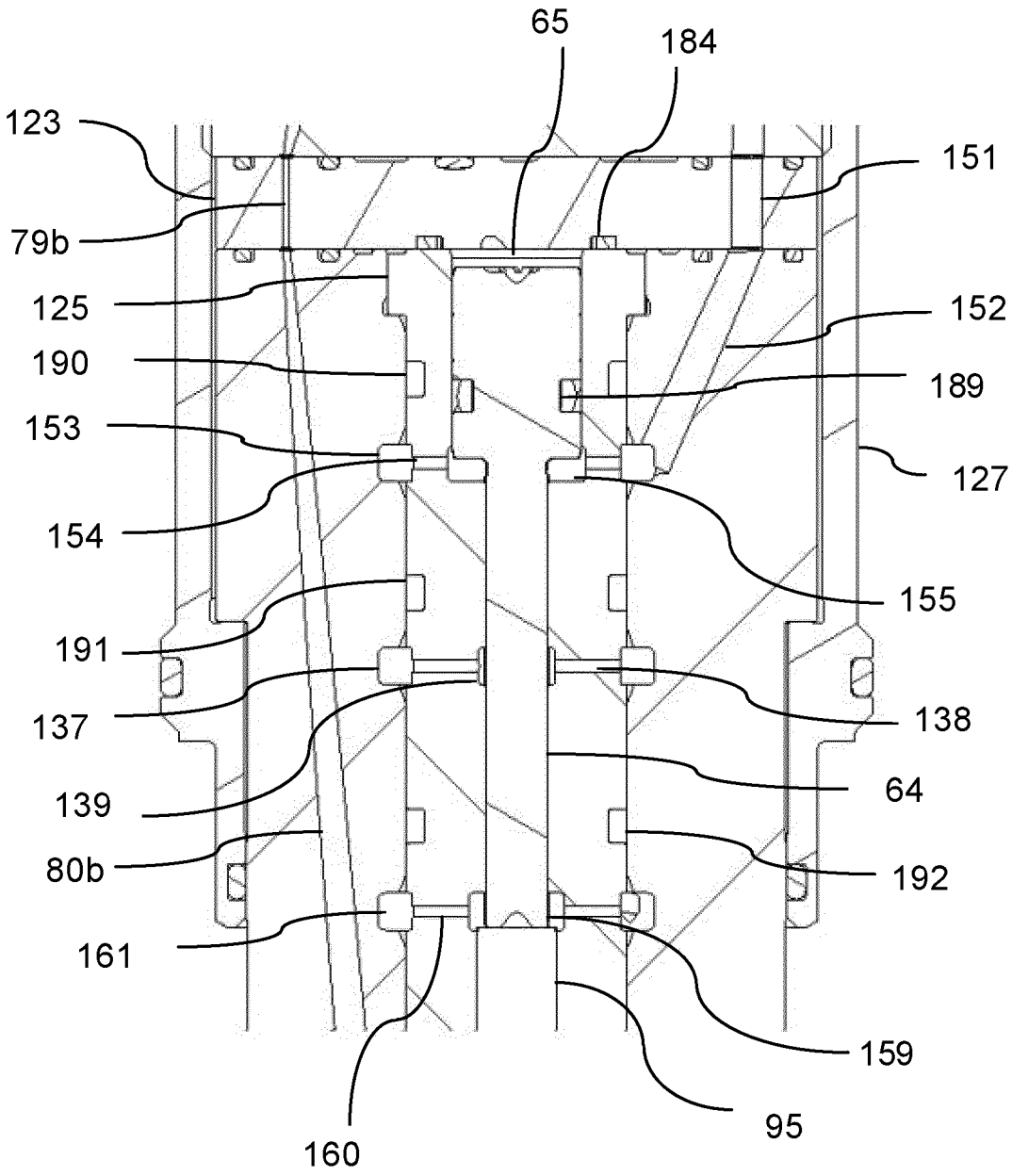

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Fig. 14

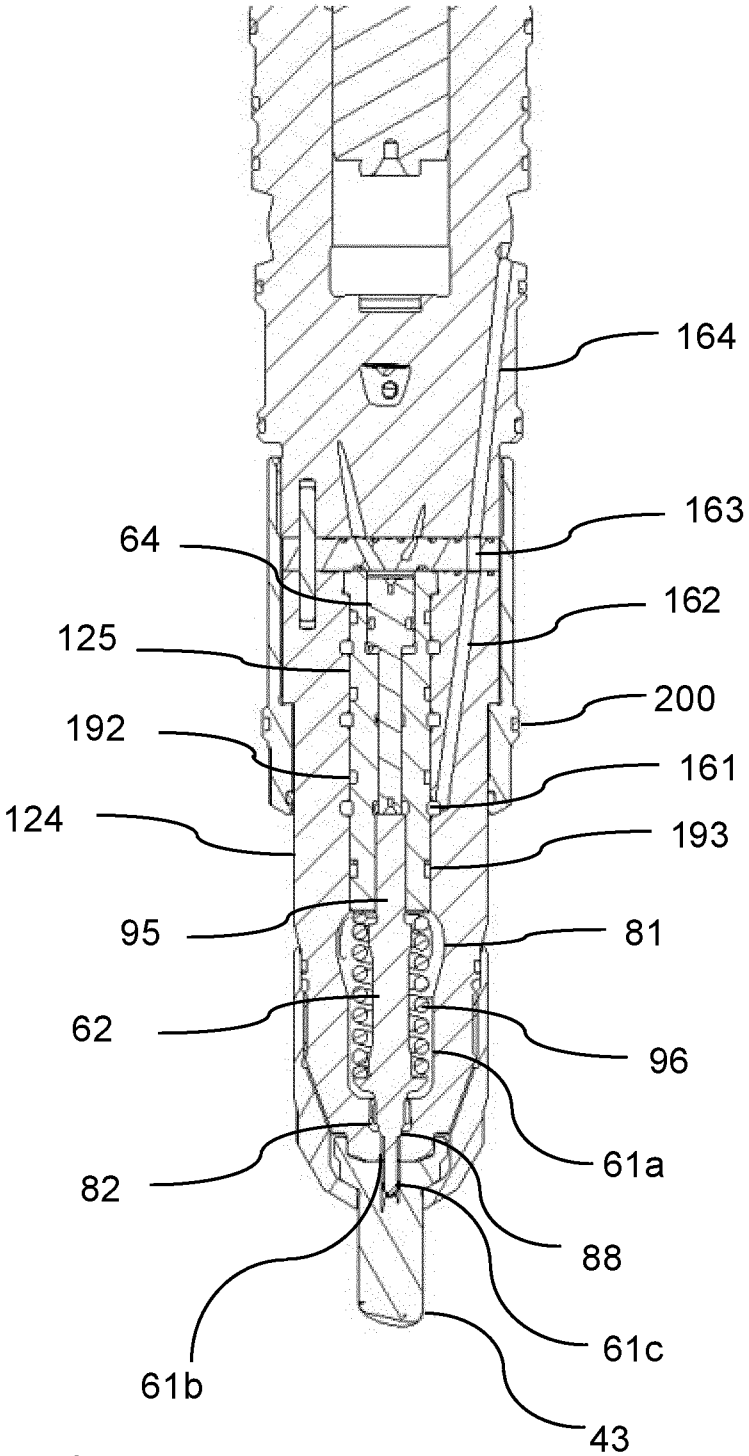

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Fig. 15

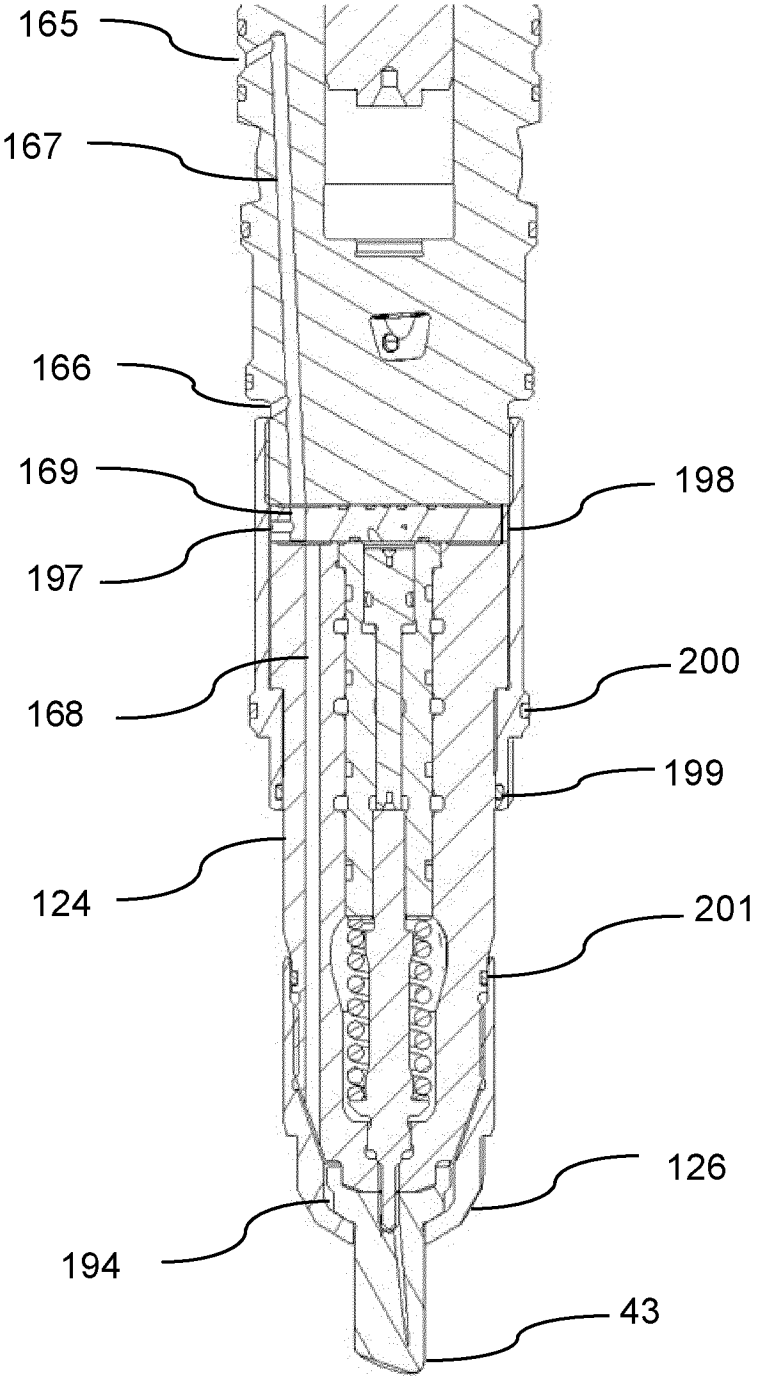


Fig. 16

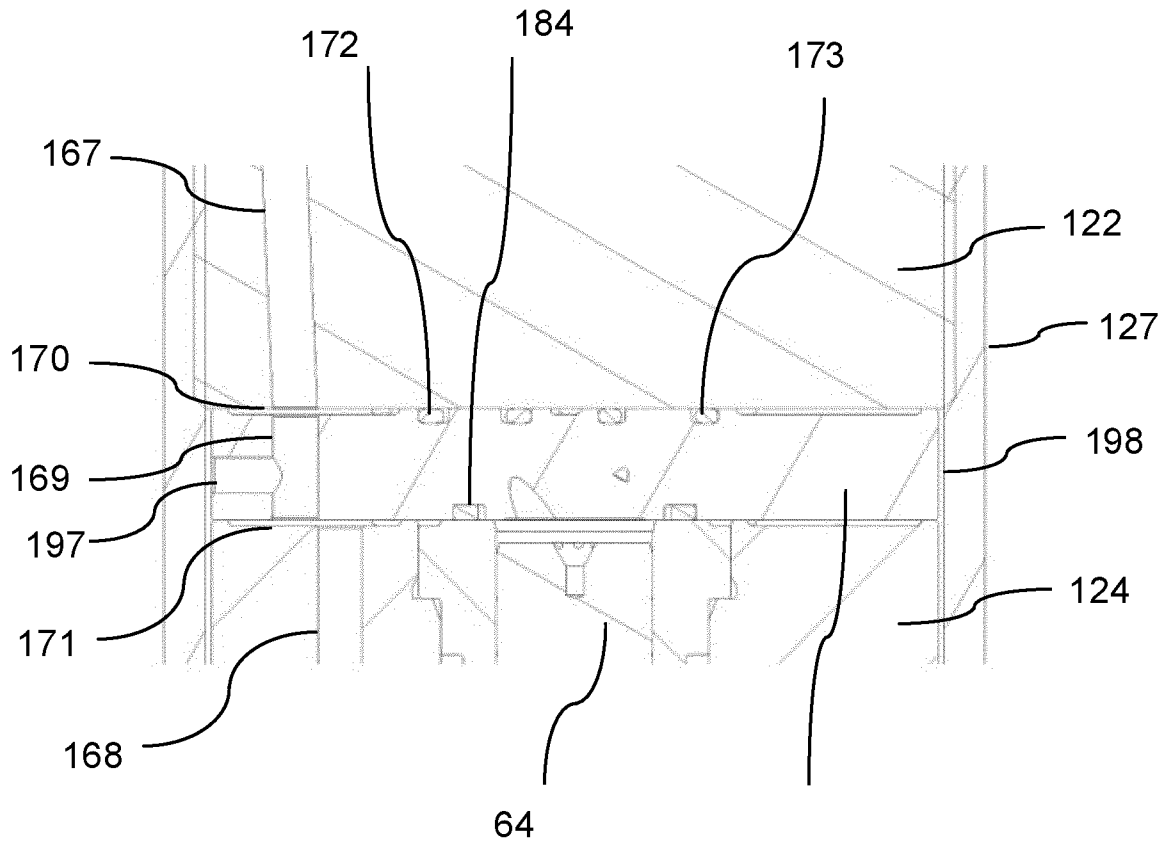


Fig. 17

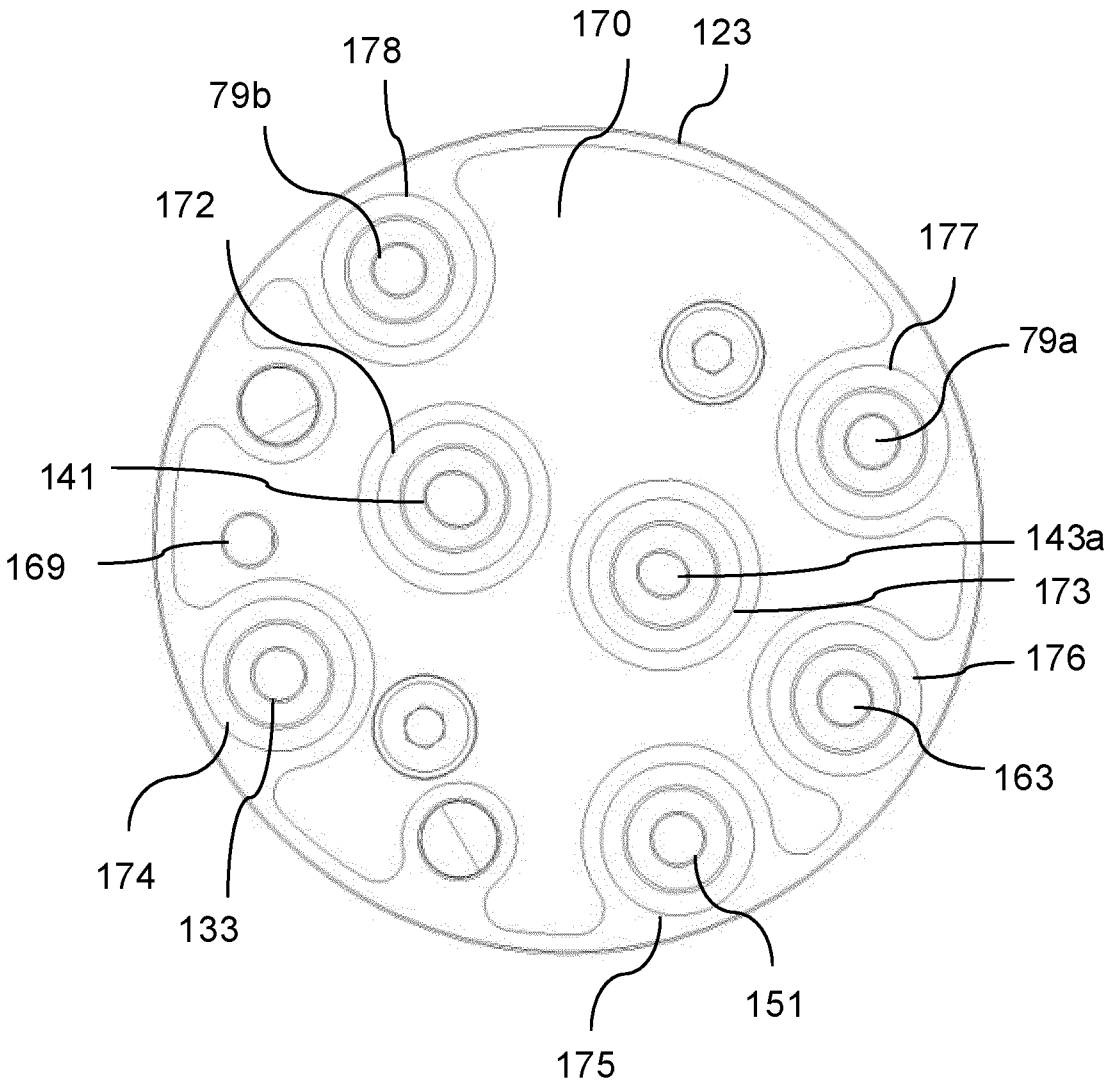

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Fig. 18

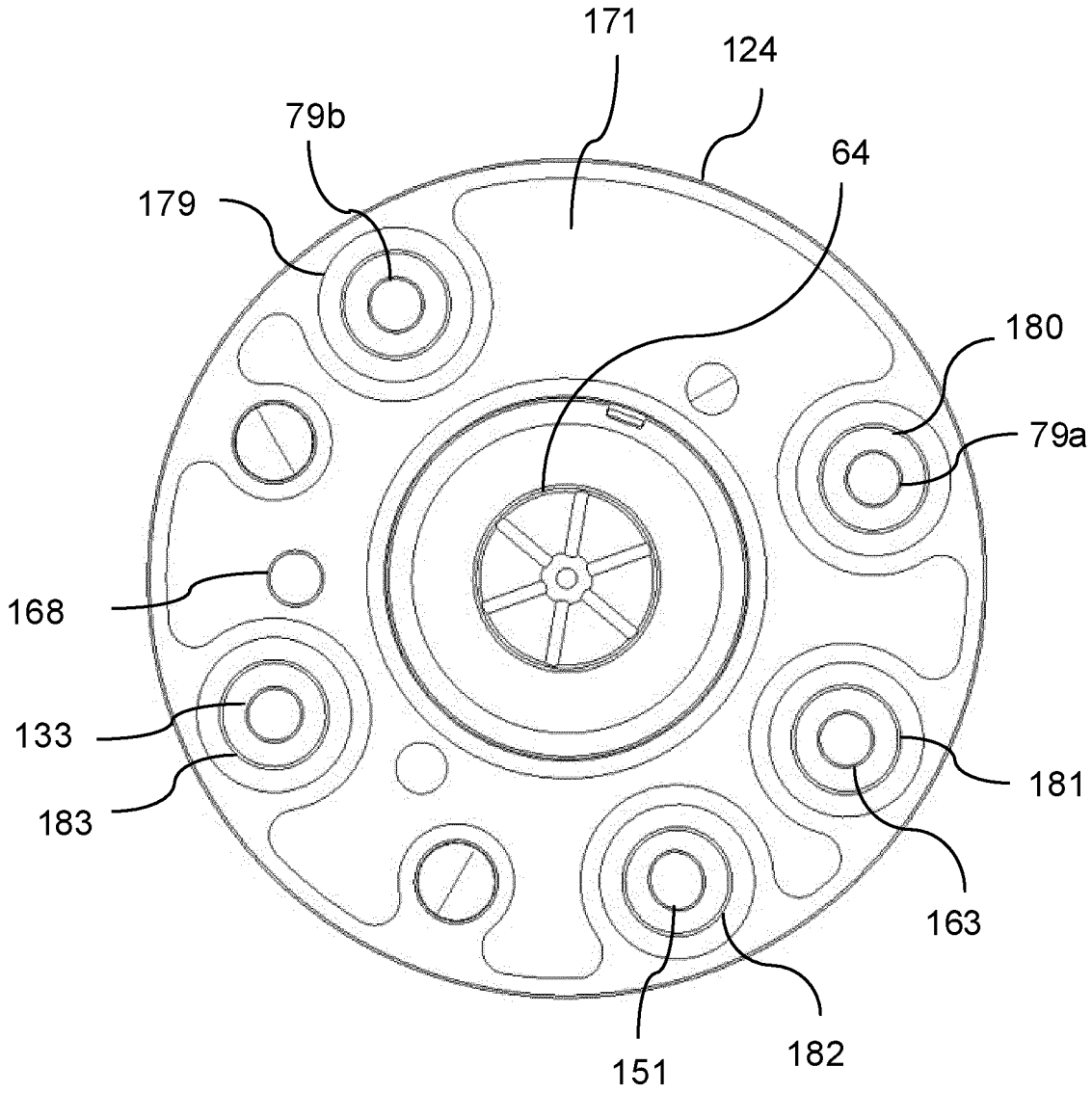


Fig. 19

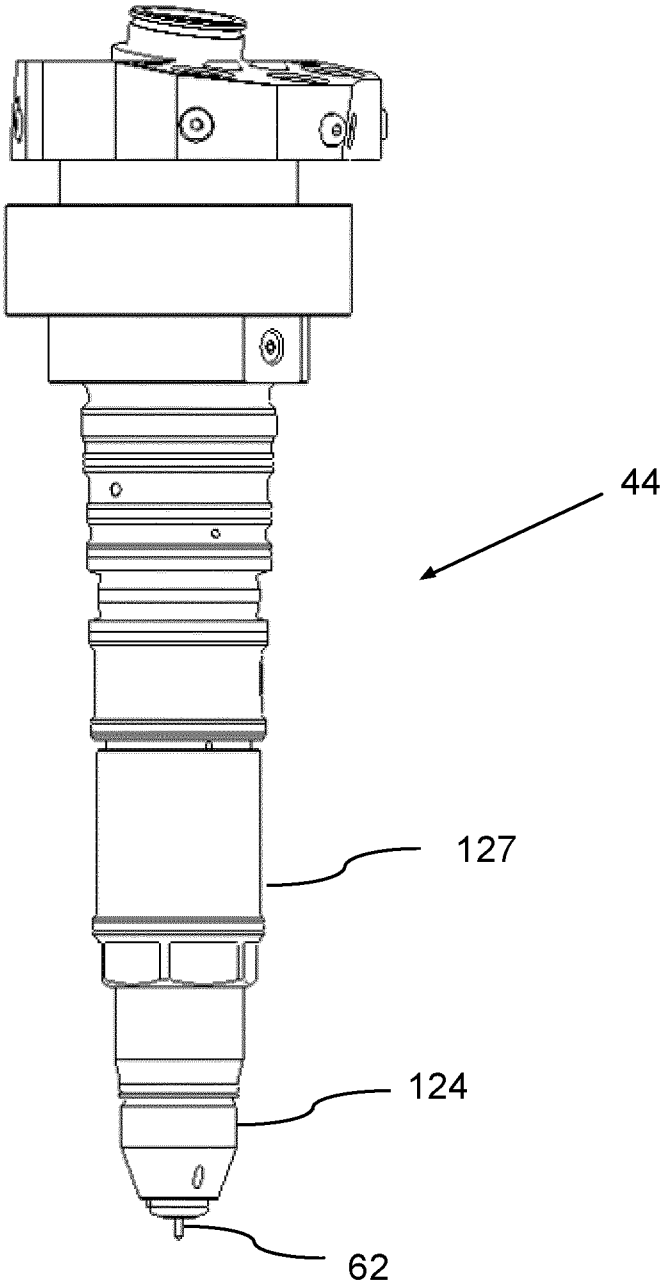


Fig. 20

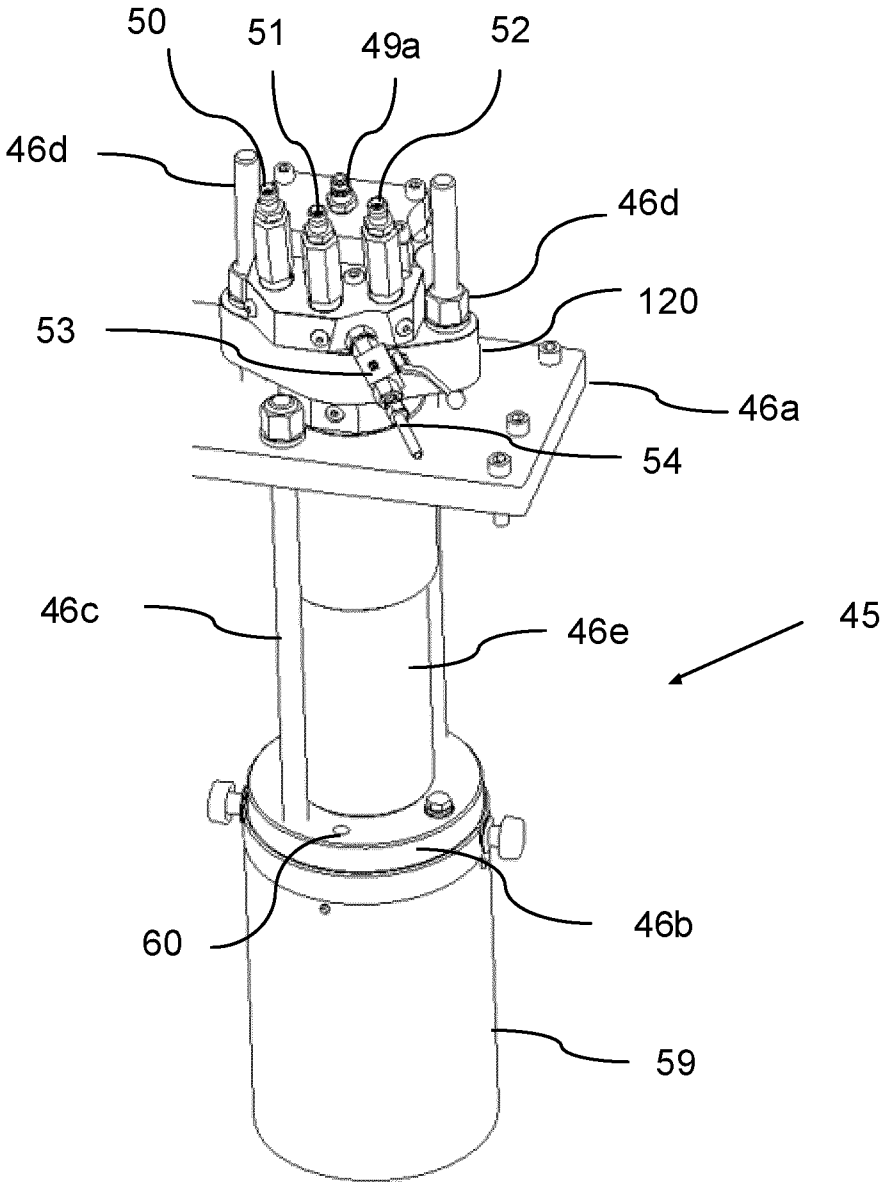


Fig. 21

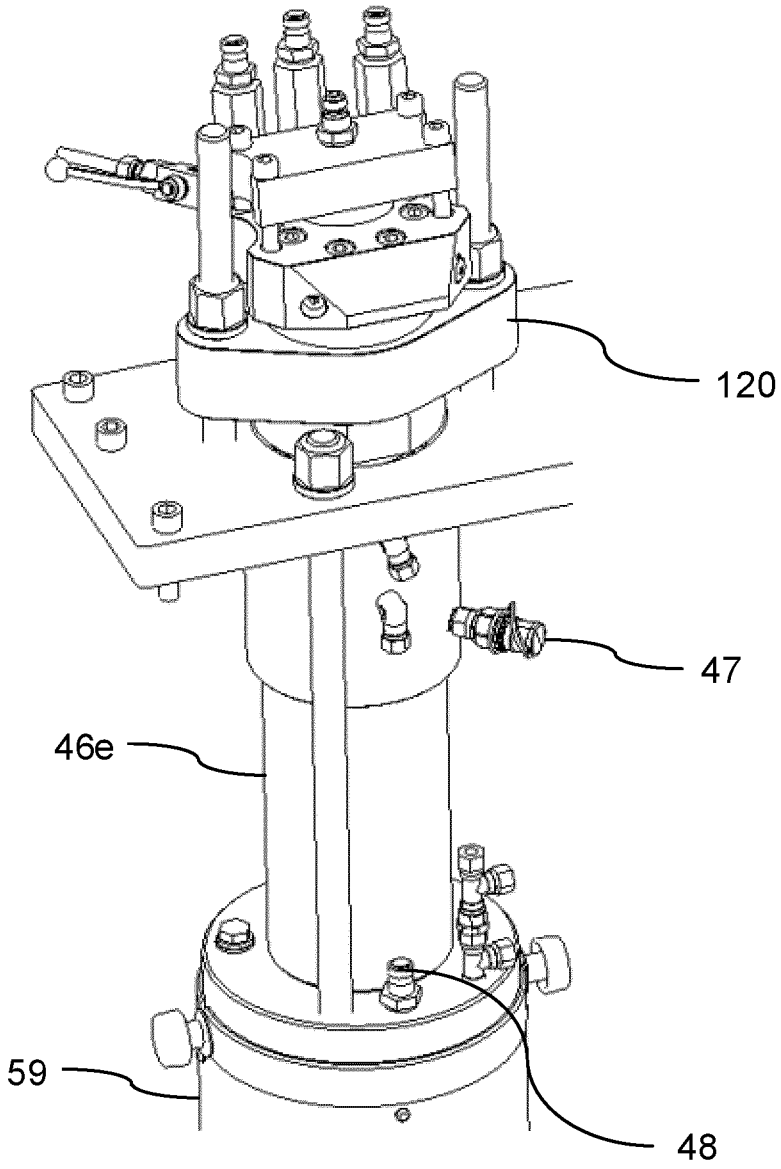


Fig. 22

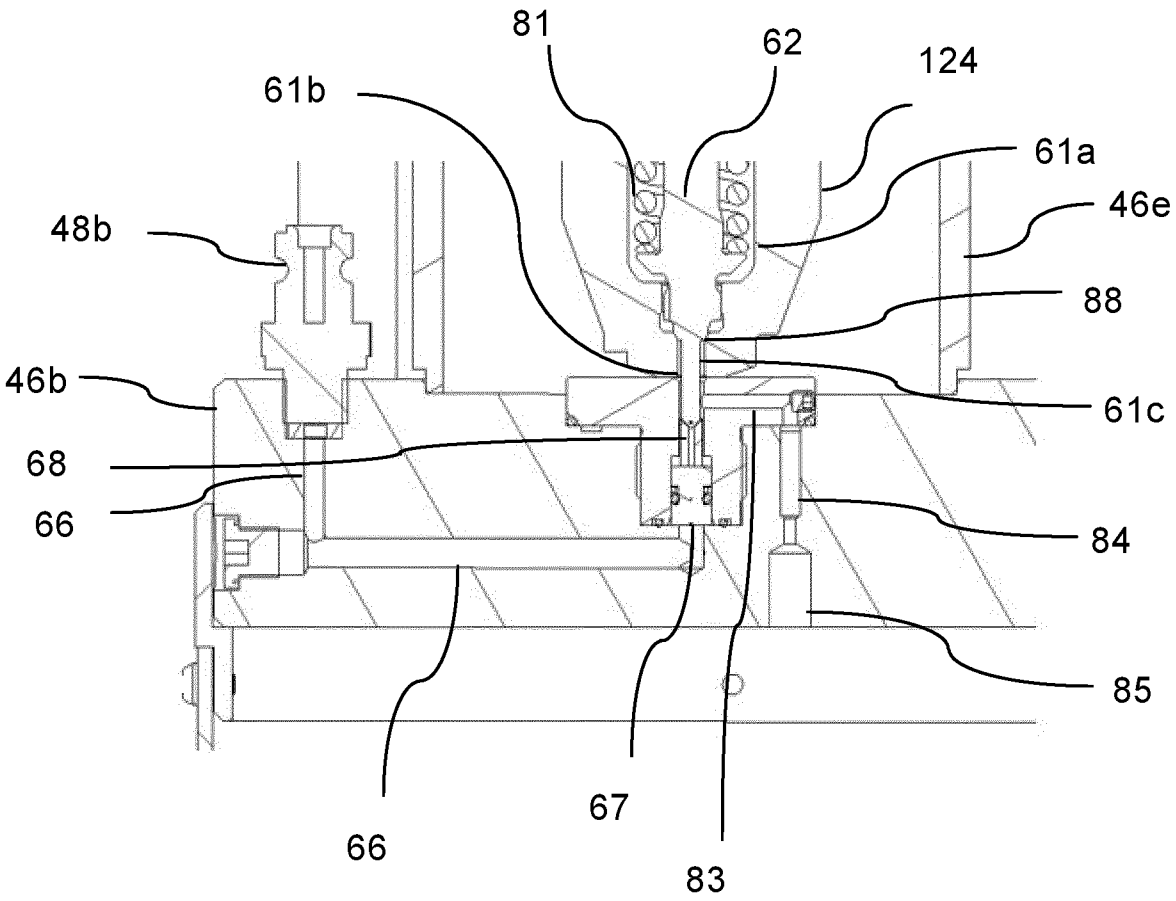


Fig. 23

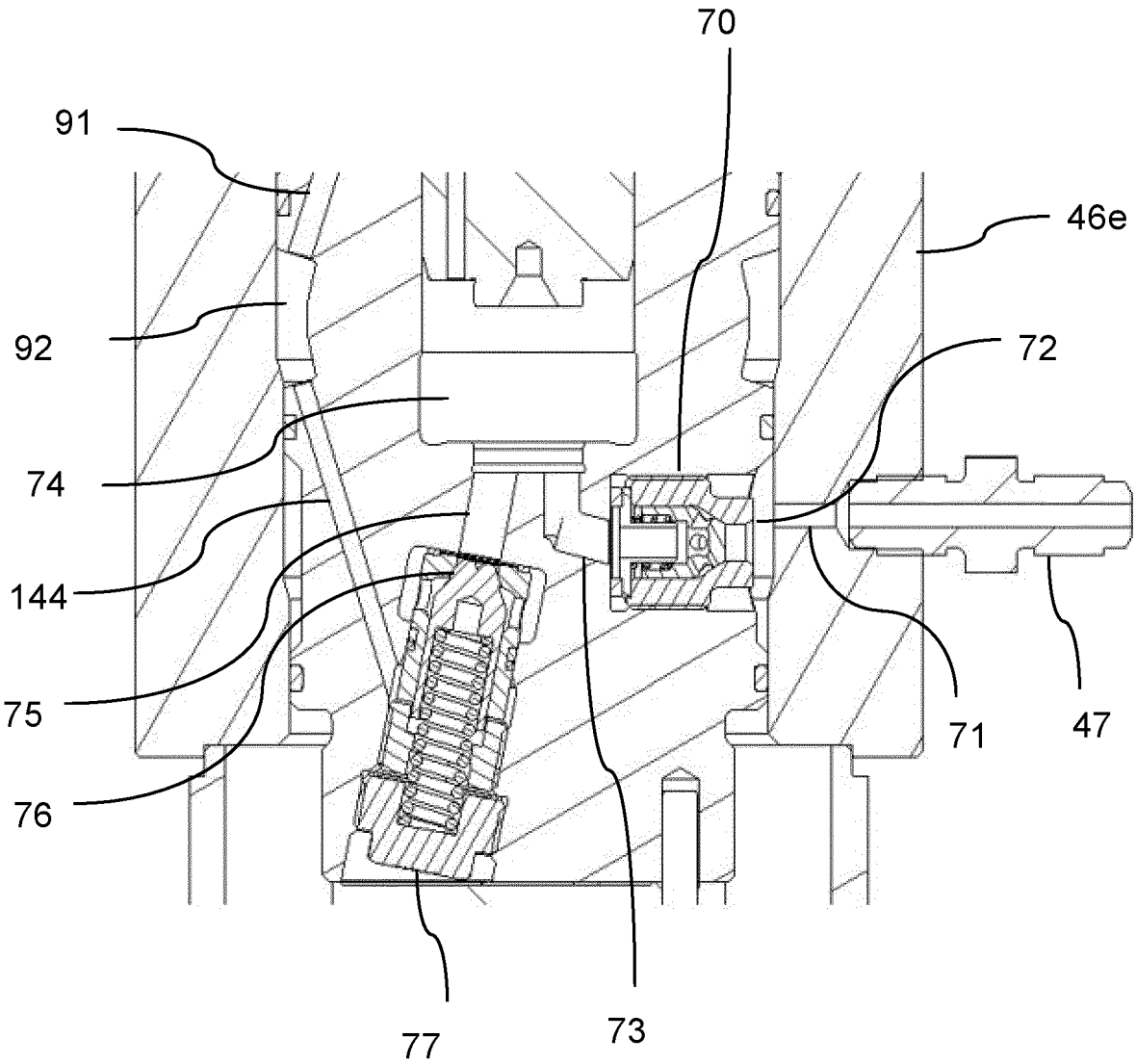


Fig. 24

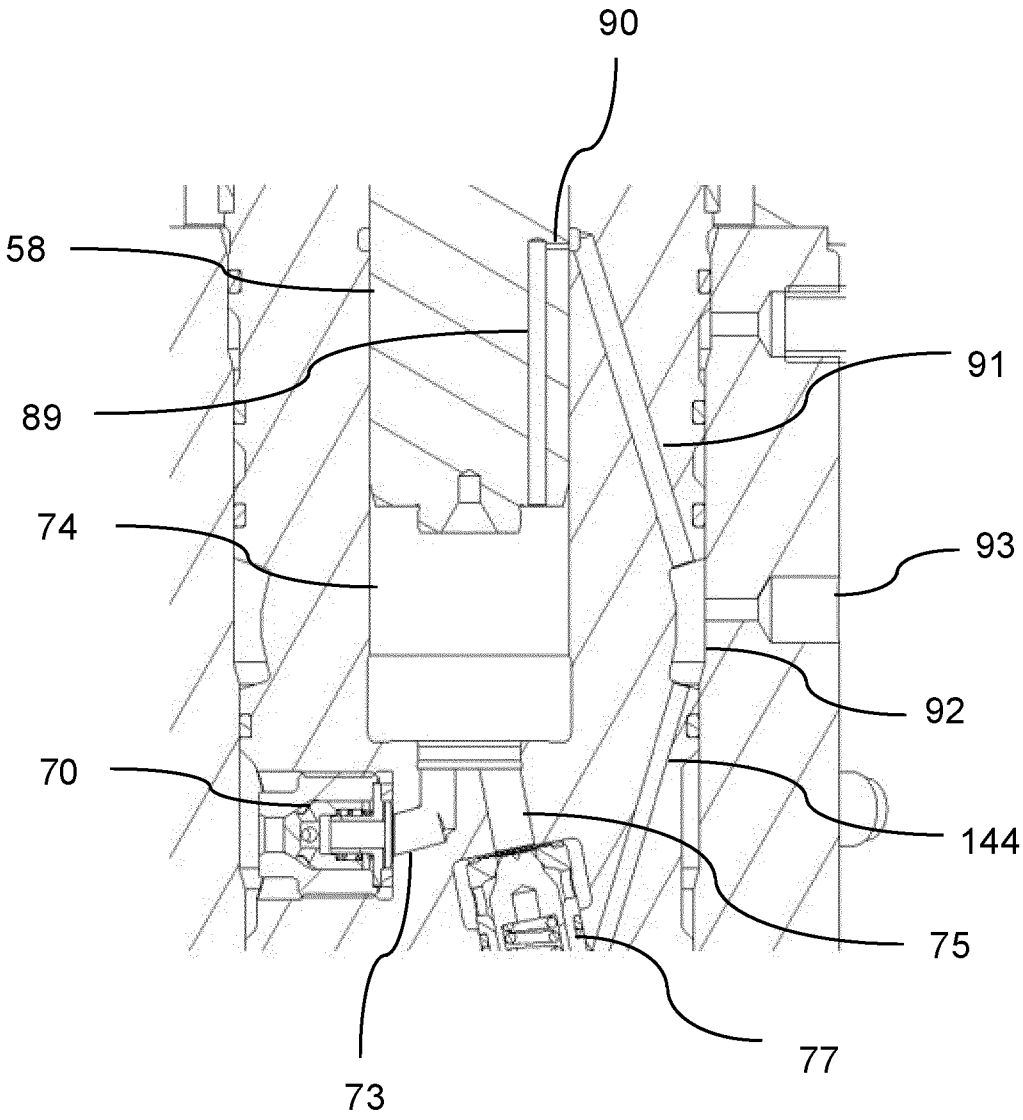


Fig. 25

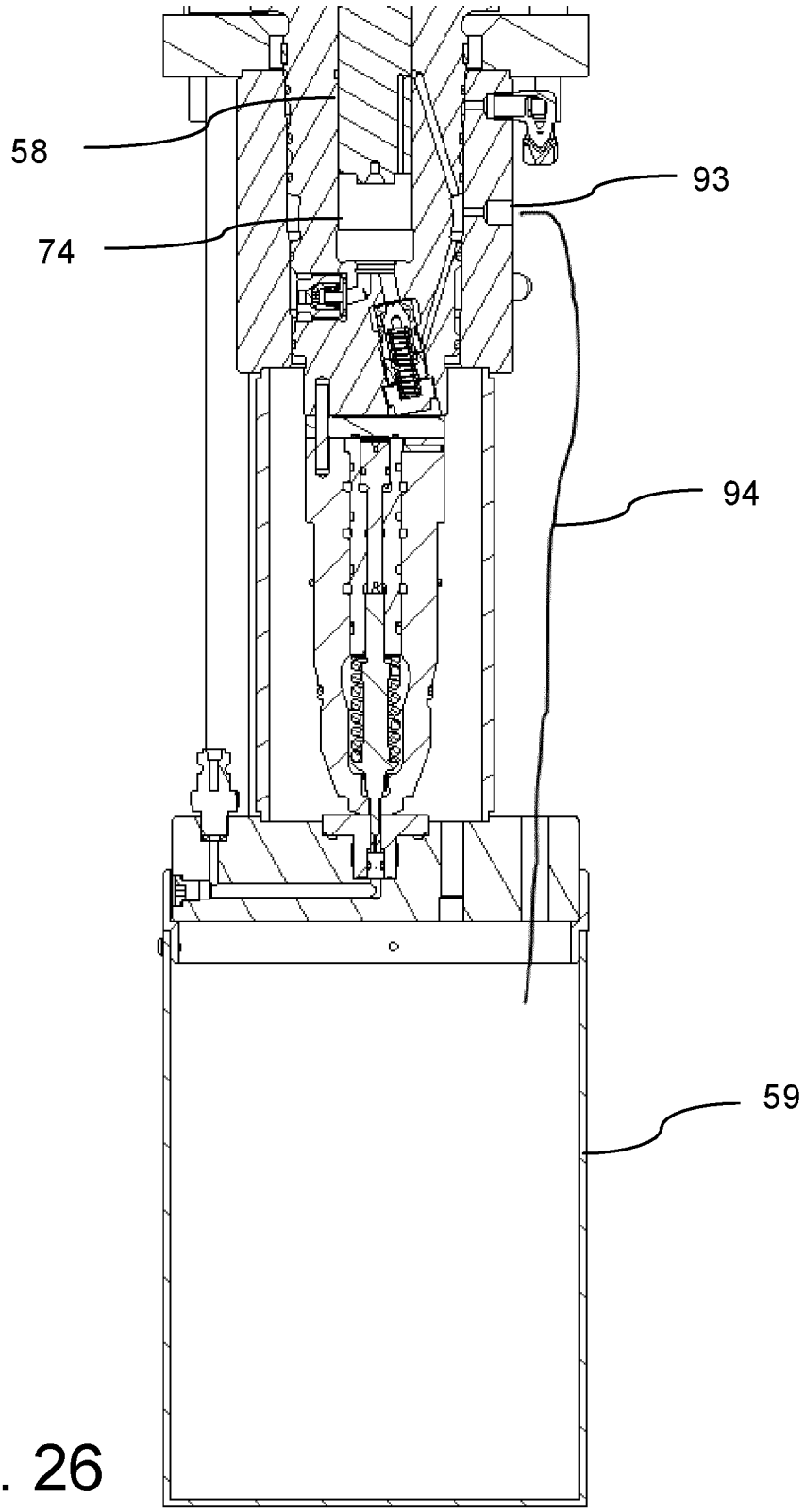


Fig. 26

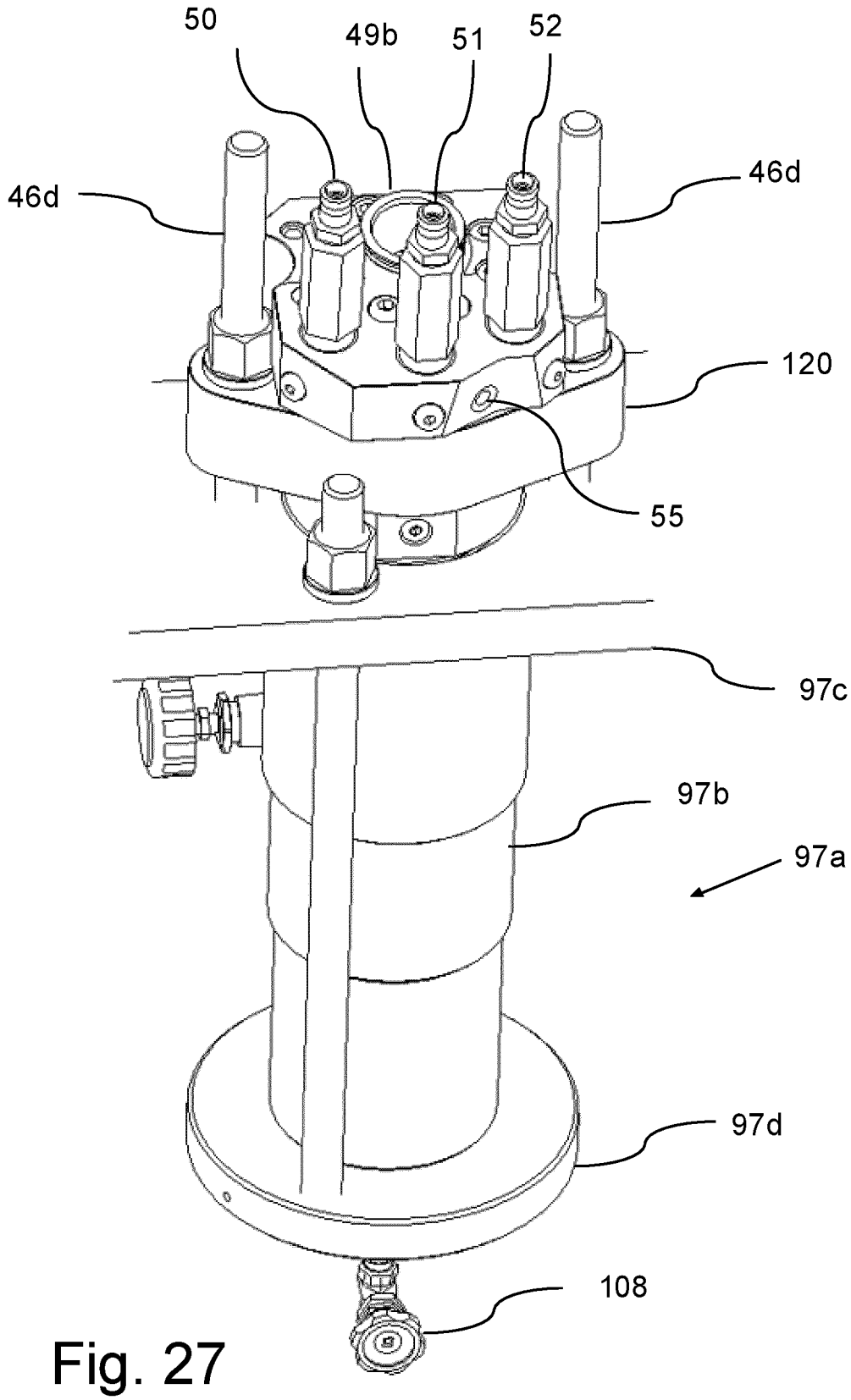


Fig. 27

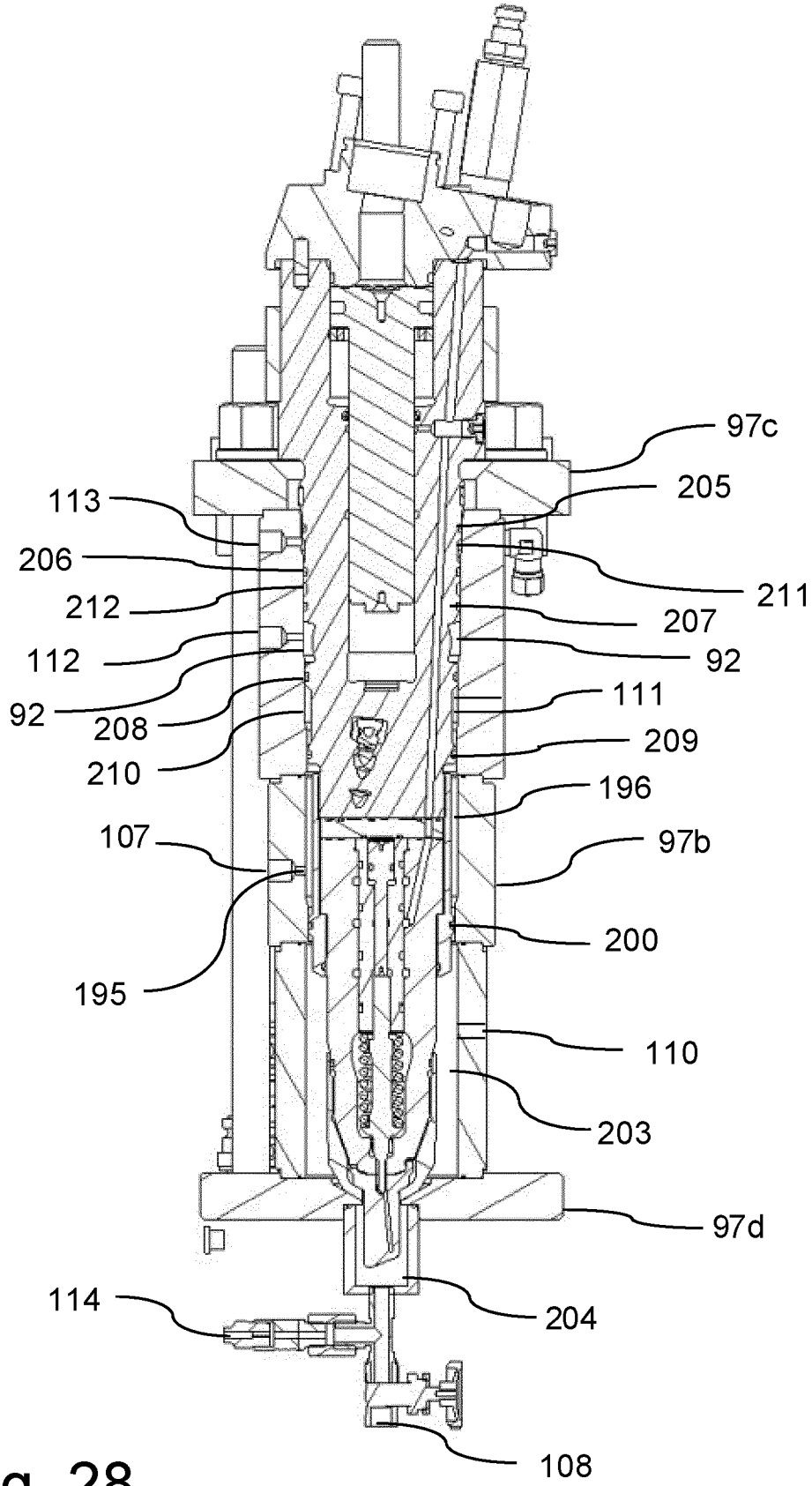

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Fig. 28

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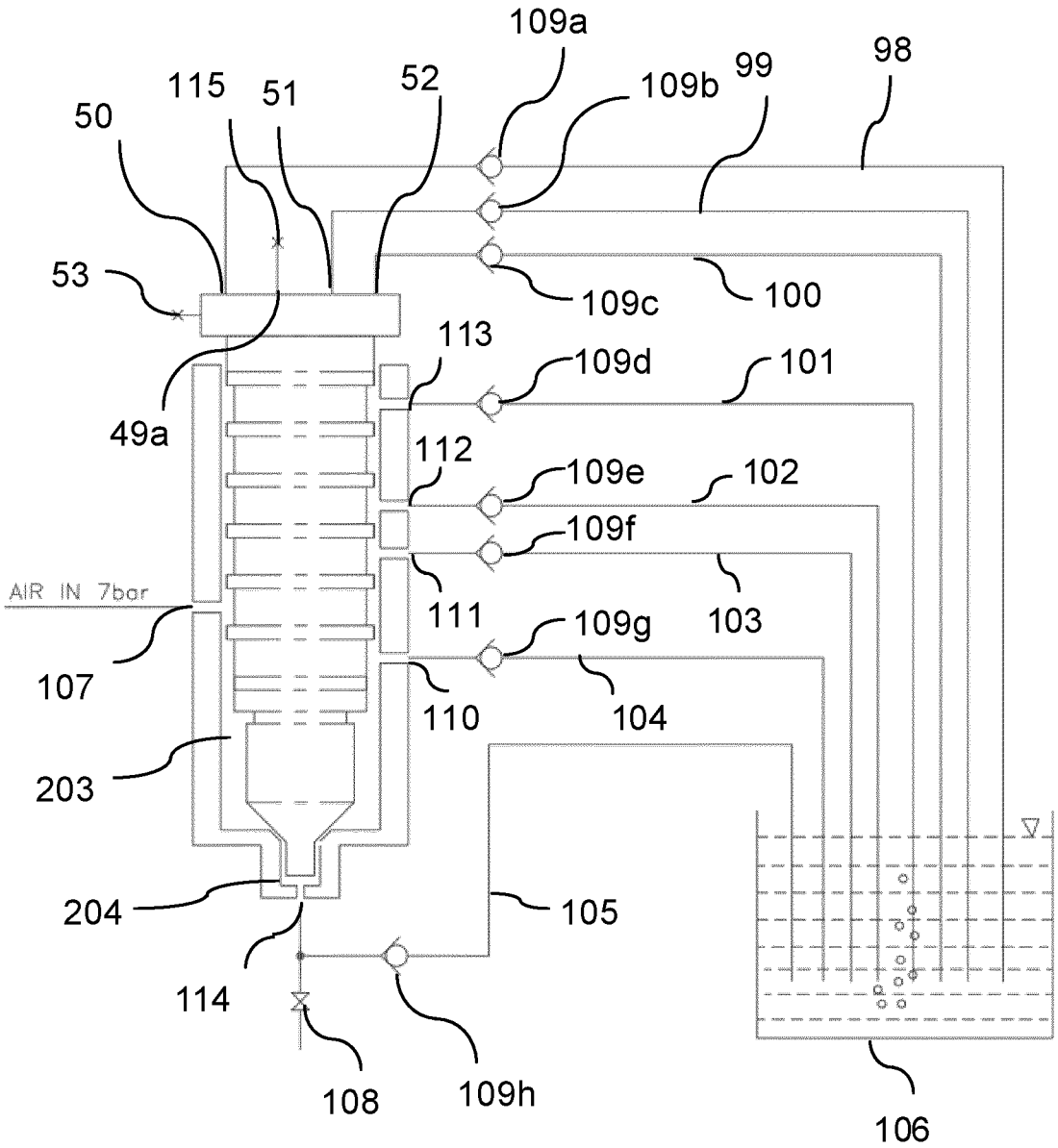

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Fig. 29

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2022/081327

A. CLASSIFICATION OF SUBJECT MATTER
INV. F02M65/00
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F02M

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2021/043380 A1 (IOP MARINE AS [DK]) 11 March 2021 (2021-03-11) page 2 - page 5; figures 1-21	1-10
A	WO 2016/155746 A1 (IOP MARINE AS [DK]) 6 October 2016 (2016-10-06) figures 1-24	1

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance;; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance;; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
16 February 2023	24/04/2023

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Morales Gonzalez, M

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/EP2022/081327

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims;; it is covered by claims Nos.:

1-10

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-10

method of testing an injector valve for a combustion engine comprising a plunger piston, a suction one way valve and a non return valve, said method comprises applying a predetermined lifting pressure to the nozzle valve piston cut off shaft tip, supplying plunger oil to the plunger piston and supplying fuel oil at a first determined test fuel oil pressure to the suction valve fuel inlet.

---

2. claims: 11, 12

method of testing an injector valve for a combustion engine comprising a plunger piston, a suction one way valve, a non return valve, said method comprises applying a predetermined lifting pressure to the nozzle valve piston cut off shaft tip, supplying plunger oil to the plunger piston and supplying fuel oil at a second determined test fuel oil pressure to the suction valve fuel inlet.

---

3. claims: 13-15

method for testing an injector valve for a combustion engine comprising a plunger piston, a suction one way valve, a non return valve and first and second plunger leakage channels, said method comprises: supplying fuel oil at a determined leakage test fuel oil pressure to the suction valve fuel inlet.

---

4. claims: 16-22

method of testing an injector valve for a combustion engine comprising a plunger piston, a suction one way valve and a non return valve, said method comprises applying a predetermined lifting pressure to the nozzle valve piston cut off shaft tip, supplying plunger oil to the plunger piston and supplying fuel oil at a predetermined nozzle valve test fuel oil pressure to the suction valve fuel inlet and supplying plunger oil to the plunger piston via the cover plunger oil supply channel.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2022/081327

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2021043380 A1	11-03-2021	CN 114341474 A	12-04-2022
		DK 180473 B1	07-05-2021
		EP 4025775 A1	13-07-2022
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		KR 20220156980 A	28-11-2022
		WO 2016155746 A1	06-10-2016