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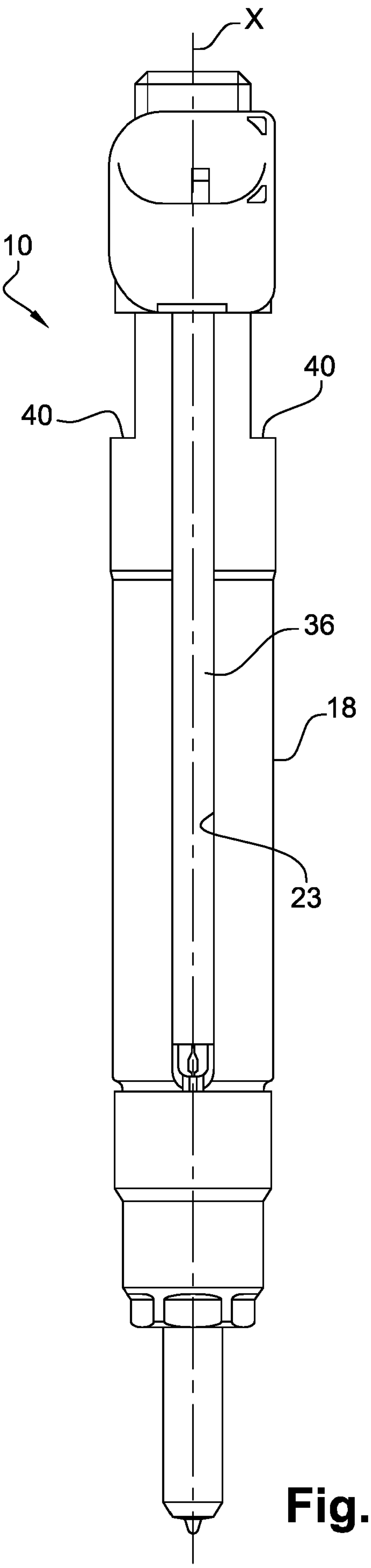
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Fig. 1

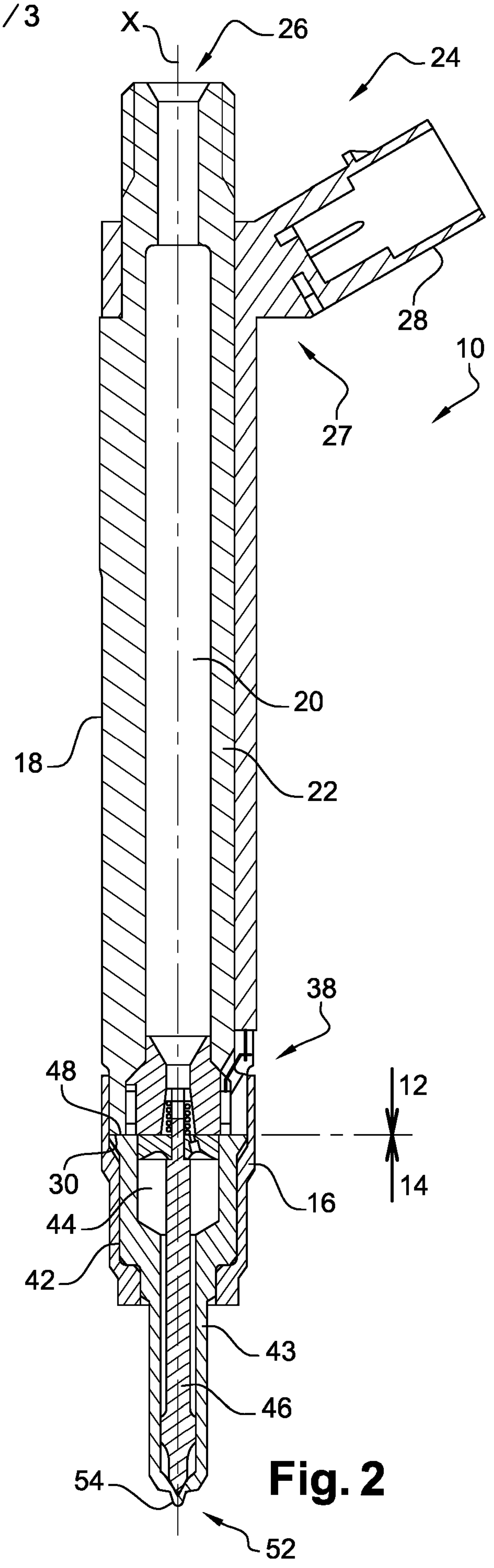
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Fig. 2

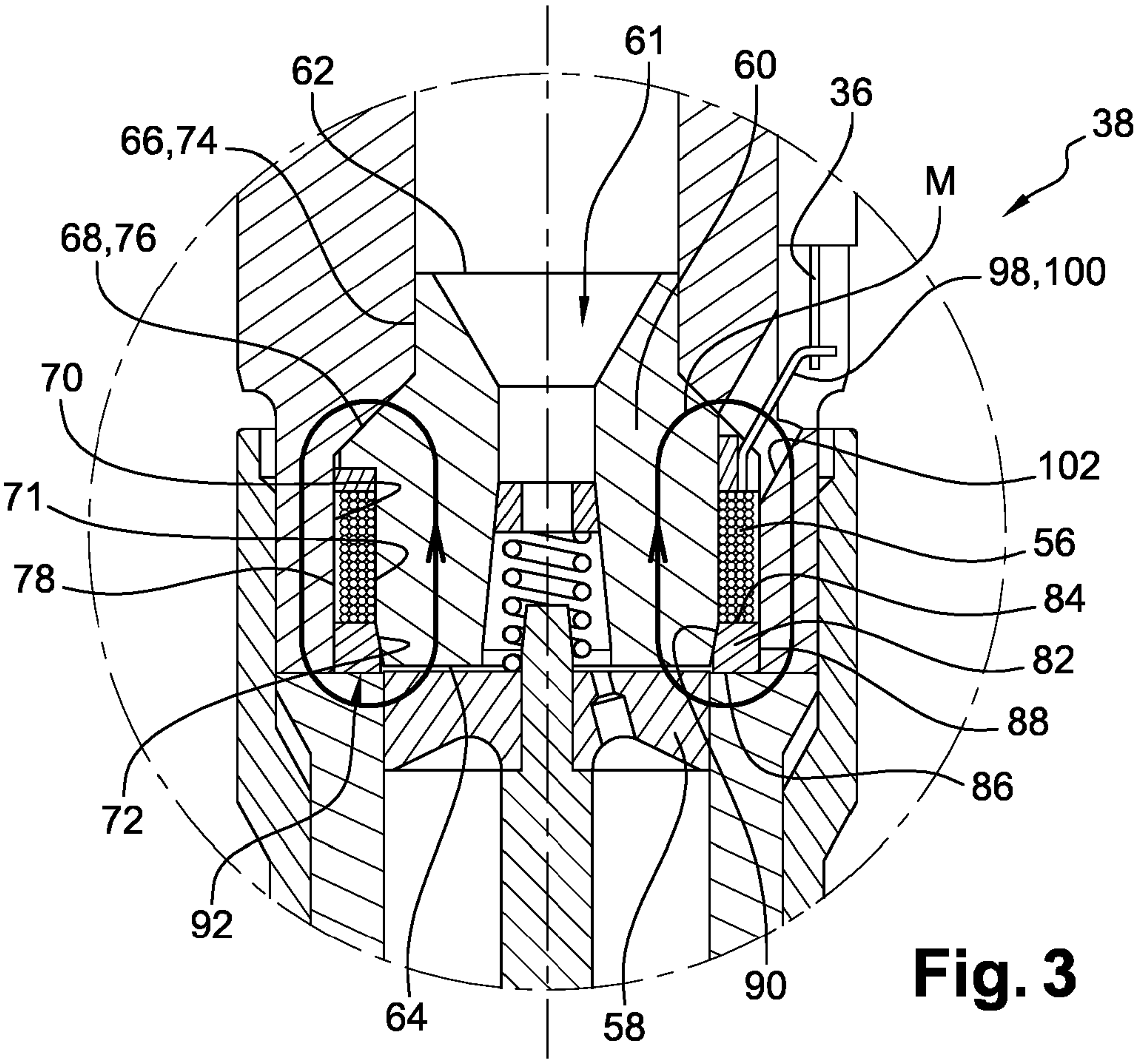
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Fig. 3

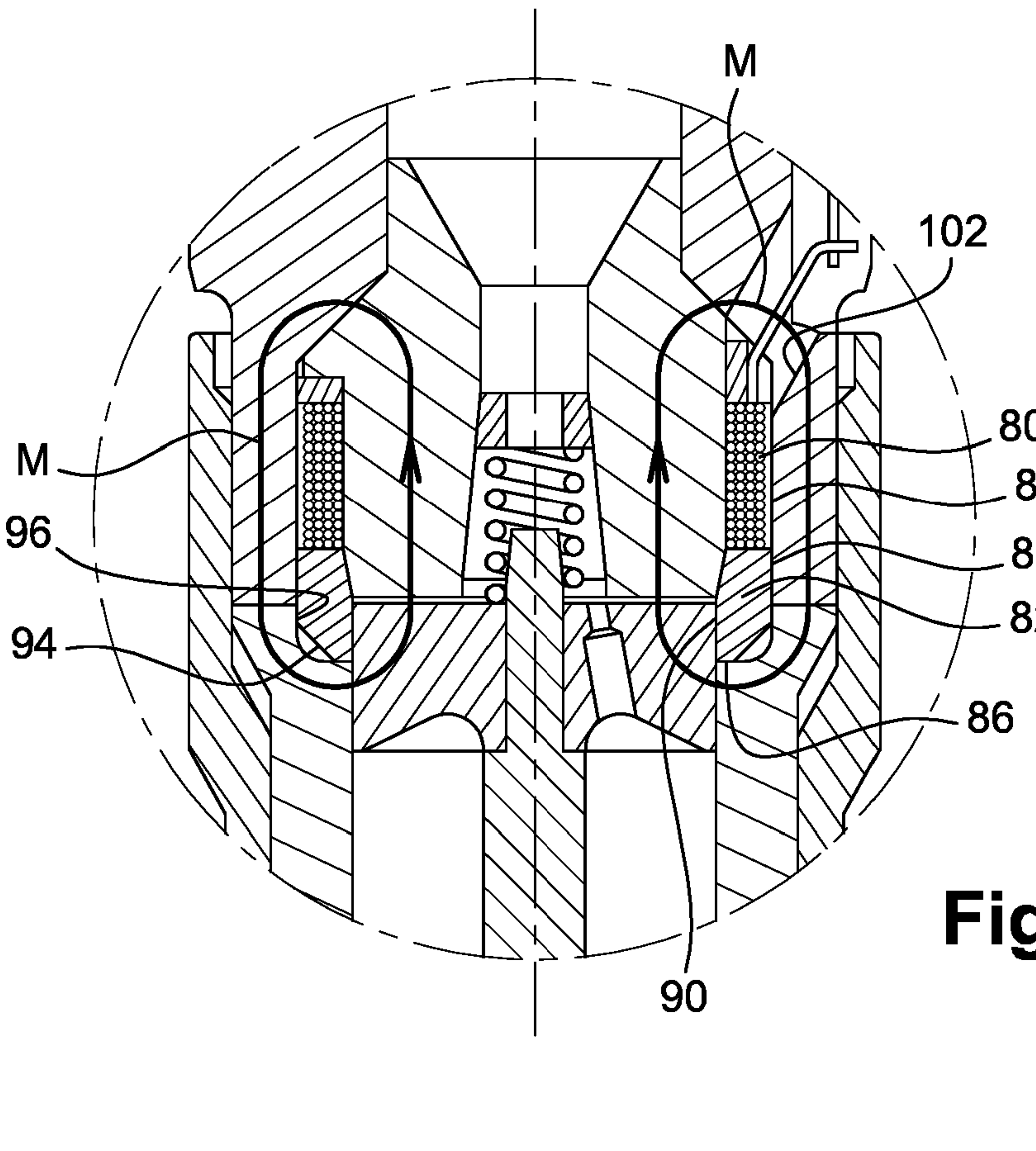
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Fig. 4

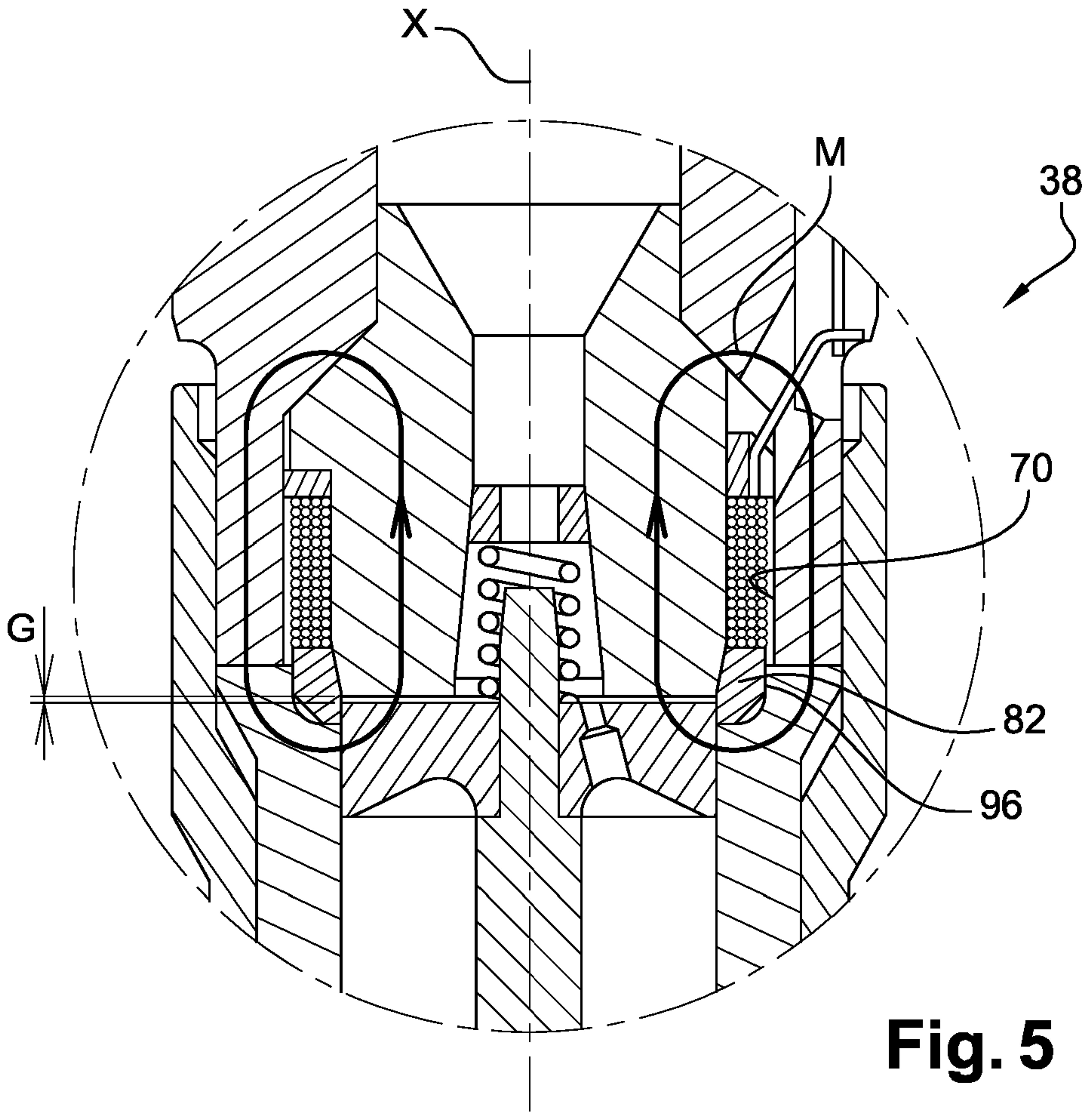

Fig. 5

FUEL INJECTOR

TECHNICAL FIELD

The present invention relates to a direct acting solenoid diesel fuel injector.

BACKGROUND OF THE INVENTION

For applications such as a direct acting solenoid common rail injector it is desirable to have a solenoid with its pole face in a high pressure environment to transmit forces to components such as a nozzle needle which are within the high fuel pressure fluid that can be 3000 bar and above. It is desirable for the solenoid coil however to be in a low pressure environment as sealing electrical connections at high pressure is difficult and expensive. Also high pressure fluids such as fuels can be aggressive to polymers and can react with the copper used for coil wire. Prior art such as DE102012224247, DE102013218881, DE102013221484, DE102013221536, and DE102013224863 use an axially compressed high pressure sealing component which must have sufficient radial thickness to withstand the pressure difference from inside to outside. The solenoid armature needs to fit through the bore of this sealing component and the coil must be wound around the outside of it. This means that the inner diameter of the coil is significantly larger than the solenoid pole face. Not only does this waste space in the limited diameter available in a typical fuel injector, limiting the force that can be achieved from the solenoid, but the coil wire is longer than necessary which means its resistance and therefore coil heating are higher than desirable (hence the need for special measures such a flat wire and high temperature insulation in DE102013226572). Applications GB 2564869 and GB2567191 show but don’t describe a solenoid construction since their inventions are directed towards how the force required to operate the nozzle is reduced.

SUMMARY OF THE INVENTION

Accordingly, it is an object of the present invention to resolve the above mentioned problems in providing a fuel injector adapted to be part of a direct fuel injection equipment of an internal combustion engine. Said injector is adapted to be part of a direct diesel fuel injection equipment of an internal combustion engine and, it is extending along a longitudinal axis. It comprises an actuation assembly firmly tightened to a nozzle assembly by a capnut abutting, at an end, on a shoulder of the body of the nozzle assembly and, being screwed, at the other end, onto the body of the actuator assembly. Said actuator and nozzle bodies defining an inner space divided in an upper chamber in the actuator body and a lower chamber in the nozzle body wherein, in use, high pressure fuel enters said upper chamber via an inlet arranged in the wall of the actuator body and exits via spray holes arranged in the wall of the nozzle body.

Said injector is provided with an electromagnetic actuator assembly wherein, a solenoid wound around a pole piece fixed to the actuator body cooperates with a magnetic armature fixed to a nozzle needle guided in the nozzle body. The solenoid generates, when electrically energised, a magnetic field attracting said armature with sufficient force to move said needle from a closed position to an open position.

The pole piece is axially inserted in the upper chamber and is press-fitted with interference against a cylindrical inner face of the wall of the actuator body.

The inner face of the wall of the actuator body further defines a thrust face adapted to be in complementary contact with a face of the pole piece.

Also, said thrust face is tapered and widens out from said cylindrical inner face.

Also, an end portion of the inner face of the wall of the actuator body is cylindrical and extends out from the thrust face.

Also, the solenoid is wound in an annular recess defined between said end portion of the inner face of the wall of the actuator body and a cylindrical outer face of the pole piece.

The fuel injector is further provided with a non-magnetic metallic annular seal arranged axially between the solenoid and the upper face of the nozzle body and radially compressed against the outer face of the pole piece.

Also, the seal has a polygonal cross-section with an annular flat upper face adjacent to solenoid opposed to an annular flat lower face against the upper face of the nozzle body, an inner face at least partially compressed against the pole piece and, a cylindrical outer face.

Also, the portion of the pole piece outer face against which is pressed the seal inner face is tapered.

Also, the portion of the seal inner face radially pressed against the pole piece tapered face is complementary tapered.

The seal outer face is press fitted with interference against said end portion of the inner face of the wall of the actuator body.

An annular clearance is defined between the seal outer face and said end portion of the inner face of the wall of the actuator body.

Also, an annular groove is arranged in the lower face of the seal, said groove limiting the contact area between the seal and the nozzle body.

Also, the seal is inserted, at least partially, in an annular recess defined in the upper face of the nozzle body.

Also, the portion of the seal inserted in said recess surrounds the magnetic armature defining therebetween a functional annular gap.

Also, the seal is press-fitted with interference in said recess, at least a part of its outer face being compressed against the peripheral face of said recess.

Also, the seal outer face being press fitted with interference against the actuator body wall and against the nozzle body recess assures a coaxial centring of said bodies.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention is now described by way of example with reference to the accompanying drawings in which:

Figures 1 and 2 are axial views of a fuel injector as per the invention.

Figures 3, 4 and 5 are three embodiments of the actuator assembly of the injector of figures 1 and 2.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

In reference to the figures 1 and 2 is generally described a diesel fuel injector 10 of a direct injection equipment of an internal combustion engine. Said injector 10 has an elongated shape extending along a longitudinal axis X and it is designed to be inserted and clamped in a well provided in the engine block. The injector 10 comprises an actuation assembly 12, show on the upper part of the figures, and a nozzle assembly 14, said assemblies being fixed together by an injector capnut 16.

The actuation assembly 12 comprises a tubular actuator body 18 defining an inner chamber 20, also identified as upper chamber 20, surrounded by a peripheral wall 22 extending about said longitudinal axis X from an upper end 24, where are provided a fuel inlet 26 and an electric connector 28, to a lower end defining a transverse lower face 30 wherein opens said upper chamber 20, said lower face 30 being limited to the annular area surrounding said opening. The peripheral wall 22 is further provided with a longitudinal groove 23 arranged on its outer face and extending between the upper and the lower ends. Over the upper end 24 of the body is engaged a plastic moulded electric connection assembly 27 defining an opening for said body engagement, and comprising an electrical connector 28 from where extends a lengthy arm wherein are overmoulded electrical terminals 36 overmoulded, said wires being arranged in said longitudinal groove 23..

The actuator body 18 is further provided with flats 40 arranged in the upper part in the vicinity to the inlet 26 and of the connector 28 so that when arranged on the engine the fuel inlet 26, the connector 28 and said flats 40 protrude outside the well enabling clamping of the injector to the engine block.

On the lower part of the injector, the nozzle assembly 14 has a body 42 with a large upper portion joining via an intermediate shoulder, a narrow lower portion, said body 42 defining a peripheral wall 43 surrounding a lower chamber 44 in which is axially X guided a needle valve member 46. The body 42 longitudinally extends from an annular upper face 48 surrounding the opening of the lower chamber to a tip end 52 provided with spray holes 54.

As shown, the lower face 30 of the actuator body is pressed in surface contact against the upper face 48 of the nozzle body, the capnut 16 abutting at an end against said intermediate shoulder of the nozzle body and being firmly tightened at the other end, onto the actuator body 18.

The actuator assembly 38 is an electromagnetic assembly comprising an annular solenoid 56 fixed to the actuator body and cooperating with a disc-like magnetic armature 58 fixed to the valve member 46. The solenoid 56 is wound around a core member 60, or magnetic pole piece 60 that is arranged in the lower end of the upper chamber 20, said pole piece 60 being substantially cylindrical and axially extending from an upper face 62, facing said upper chamber 20 to an opposed transverse under face 64 facing the lower chamber 44 in the nozzle body. Between said opposed faces 62, 64 the pole piece 60 has a peripheral face complementary inserted in the lower end of the actuator body, the under face 64 being in approximately flush surface continuity with the lower face 30 of the actuator body.

As better shown on figures 3, 4 and 5, the pole piece 60 is provided with an axial through hole 61 opening in said opposed upper and under faces 62, 64, said hole 61 defining a fluid communication between the upper and lower chambers. The pole piece 60 outer face comprises coaxial faces defining a thin cylinder 66 on the upper part close to the upper face 62, an intermediate conical thrust face 68 enlarging said thin cylinder to join a larger cylinder 70 on the lower part close to the lower face 64 and, a final small conical face 72 narrowing the large cylinder 70 when joining the under face 64. As shown on the figures, the larger cylindrical 70 face has a smaller diameter than the larger end of the conical face 68, defining an annular space 71 in which is wound the solenoid.

The inner face of the peripheral wall 22 of the actuator body has in the lower end of the upper chamber 20 a profile complementary to the pole piece 60 with a thin cylinder 74 and, a female conical face 76 enlarging to a larger cylinder 78.

The pole piece 60 is press fitted in the actuator body with interference between the male and the female thin cylinders 66, 74, the intermediate conical faces 68, 76 lying against one another. The large cylindrical faces 70, 78 are concentric and, the annular space 71 in which is arranged the solenoid 56 defines therebetween an annular void 80 that, in use remains at low pressure.

To ensure sealing of said void 80 for avoiding fuel to wet the solenoid 56, the actuator assembly further comprises an annular non-magnetic seal 82, afterward described, arranged right below the solenoid 56.

In use, when the solenoid 56 is not energised, the needle valve member, downwardly pushed by a spring compressed between the magnetic armature 58 and an annular seat press fitted in the axial through hole 61 of the pole piece, seats in a closed position of the spray holes 54 preventing injection event and, in said position a small air gap G is defined between the armature 58 and the pole piece 60.

When the solenoid is energised, a magnetic field M is generated and loops around the solenoid circulating within a magnetic circuit comprising the pole piece 60, the actuator body 18, the nozzle body 42 and the armature 58, said field M upwardly attracting the armature 58 closing said air gap G and moving the needle valve member 46 in an open position for enabling fuel injection through the spray holes 54.

In a first embodiment presented on figure 3, said annular seal 82 has polygonal cross section with an upper annular face 84 adjacent to the solenoid, an opposed lower face 86 in surface contact with the nozzle body upper face 48, a cylindrical outer face 88 lying against the large cylindrical face 78 of the actuator body and a conical inner face 90 lying against said final conical face 72 of the pole piece.

During assembly of the injector when tightening the capnut 16, the actuator body 18 downwardly pushes the pole piece 60 through their intermediate conical thrust faces 68, 76 and, the pole piece 60 outwardly pushes the seal 82 because of radial forces generated between the final conical face 72 and the seal inner face 90, said forces radially compressing the seal 90 between the pole piece 60 and the actuator body 18.

The seal 82 is also axially compressed and its lower face 86 is in sealing surface contact against the upper face 48 of the nozzle body. To further improve the sealing property said lower face 86 is provided with an annular groove 92 reducing the area of the lower face 86 and enabling to concentrate the sealing force on said reduced area.

Thanks to said arrangement, the void 80 is sealed and the low pressure zone wherein the solenoid is, is perfectly separated from the high pressure zone comprising the upper chamber 20 the lower chamber 44 and the through hole 61. Also, the high performance magnetic materials used for the pole piece typically have low mechanical properties and, the radial compression at both ends of the pole piece, on the thin cylindrical face 66 and on the final conical face 72, enhance the mechanical resistance and behavior of the pole piece. Furthermore the efficiency of the magnetic field M is improved since the seal 82 is made of non-magnetic material, the magnetic field M being forced to go from the actuator body 18 to the nozzle body 42, around the seal 82 then to the armature 58 avoiding magnetic leaks directly from the actuator body to the pole piece.

In a second embodiment presented on figure 4 the nozzle body upper face 48 is provided with an annular recess 94 surrounding the opening of the lower chamber and, the seal 82 extends in said recess surrounding an upper part of the armature. Thanks to said downward extension of the seal, magnetic leaks are minimized by forcing the magnetic field M to a downward path below the pole piece. Also, magnetic side loading may be minimised in using the seal 82 to ensure concentric alignment of the actuator body 18 and the nozzle body 42, the outer face 88 of the seal being in contact with the larger cylindrical face 78 of the actuator body and also with the outer face 96 of the recess. In said arrangement, the seal is radially compressed between the pole piece and said larger cylindrical face 78 of the actuator body.

In an alternative embodiment presented on figure 5, the seal 82 extends in the recess 94 of the nozzle body and, it is not in contact against the face of the actuator body. In this arrangement, the seal is radially compressed between the pole piece and outer face 96 of said recess.

LIST OF REFERENCES

X	longitudinal axis
M	magnetic field
G	air gap
10	fuel injector
12	actuation assembly
14	nozzle assembly
16	capnut
18	actuator body
20	inner chamber - upper chamber
22	peripheral wall of the actuator body
23	longitudinal groove
24	upper end
26	inlet

27	electric connection assembly
28	electric connector
30	lower face
36	electrical terminals
38	actuator assembly
40	flats
42	nozzle body
43	peripheral wall of the nozzle body
44	lower chamber
46	needle valve member
48	upper face
52	tip end of the injector
54	spray holes
56	solenoid
58	magnetic armature
60	magnetic pole piece
61	through hole
62	upper face
64	under face
66	thin cylinder of the pole piece
68	intermediate conical face of the pole piece
70	large cylinder of the pole piece
71	annular space
72	final conical face of the pole piece
74	thin cylinder of the actuator body inner face
76	intermediate conical face of the actuator body inner face
78	large cylinder of the actuator body inner face
80	void
82	seal
84	upper face of the seal
86	lower face of the seal
88	outer face of the seal
90	inner face of the seal
92	annular groove
94	recess
96	outer face of the recess

CLAIMS:

1. Fuel injector (10) adapted to be part of a direct diesel fuel injection equipment of an internal combustion engine, said injector extending along a longitudinal axis (X) and comprising an actuation (12) assembly firmly tightened to a nozzle assembly (14) by a capnut (16) abutting, at an end, on a shoulder of the body (42) of the nozzle assembly and, being screwed, at the other end, onto the body (18) of the actuator assembly, said actuator and nozzle bodies (18, 42) defining an inner space divided in an upper chamber (20) in the actuator body and a lower chamber (44) in the nozzle body wherein, in use, high pressure fuel enters said upper chamber (20) via an inlet (26) arranged in the wall of the actuator body and exits via spray holes (54) arranged in the wall of the nozzle body,

said injector being provided with an electromagnetic actuator assembly (38) wherein, a solenoid (56) wound around a pole piece (60) fixed to the actuator body cooperates with a magnetic armature (58) fixed to a nozzle needle (46) guided in the nozzle body, said solenoid (56) generating, when electrically energised, a magnetic field (M) attracting said armature (58) with sufficient force to move said needle (46) from a closed position to an open position, and wherein

the pole piece (60) is axially inserted in the upper chamber (20) and is press-fitted with interference against a cylindrical inner face (74) of the wall of the actuator body and,

wherein, the inner face of the wall of the actuator body further defines a thrust face (76) adapted to be in complementary contact with a face of the pole (68) piece and,

wherein said thrust face (76) is tapered and widens out from said cylindrical inner face (74).

2. Fuel injector (10) as claimed in claim 1 wherein an end portion (78) of the inner face of the wall of the actuator body is cylindrical and extends out from the thrust face (76).

3. Fuel injector (10) as claimed in claim 2 wherein the solenoid (56) is wound in an annular recess (71) defined between said end portion of the inner face of the wall of the actuator body and a cylindrical outer face of the pole piece.

4. Fuel injector (10) as claimed in any one of the preceding claims further provided with a non-magnetic metallic annular seal (82) arranged axially between the solenoid (56) and the upper face (48) of the nozzle body and radially compressed against the outer face of the pole piece.

5. Fuel injector (10) as claimed in claim 4 wherein the seal (82) has a polygonal cross-section with an annular flat upper face (84) adjacent to solenoid opposed to an annular flat lower face (86) against the upper face (48) of the nozzle body, an inner face (90) at least partially compressed against the pole piece and, a cylindrical outer face (88).

6. Fuel injector (10) as claimed in claim 5 wherein the portion of the pole piece (72) outer face against which is pressed the seal inner face is tapered.

7. Fuel injector (10) as claimed in claim 6 wherein the portion of the seal inner face (90) radially pressed against the pole piece tapered face (72) is complementary tapered.

8. Fuel injector (10) as claimed in any one of the claims 5 to 7 taken in combination with any one of the claims 2 or 3 wherein, the seal outer face (88) is press fitted with interference against said end portion of the inner face of the wall of the actuator body.

9. Fuel injector (10) as claimed in any one of the claims 5 to 7 taken in combination with any one of the claims 2 or 3 wherein, an annular clearance is defined between the seal outer face (88) and said end portion of the inner face of the wall of the actuator body.

10. Fuel injector (10) as claimed in any one of the claims 5 to 9 wherein an annular groove (92) is arranged in the lower face (86) of the seal, said groove limiting the contact area between the seal (82) and the nozzle body (42).

11. Fuel injector (10) as claimed in any one of the claims 5 to 10 wherein the seal (82) is inserted, at least partially, in an annular recess (94) defined in the upper face of the nozzle body.

12. Fuel injector (10) as claimed in claim 11 wherein the portion of the seal (82) inserted in said recess (94) surrounds the magnetic armature (58) defining therebetween a functional annular gap.

13. Fuel injector (10) as claimed in claim in any one of the claims 11 or 12 wherein the seal (82) is press-fitted with interference in said recess (94), at least a part of its outer face being compressed against the peripheral face (96) of said recess.

14. Fuel injector (10) as claimed in the combination of claims 8 and 13, the seal outer face (88) being press fitted with interference against the actuator body (18) wall and against the nozzle body (42) recess assures a coaxial centring of said bodies.