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(54) FUEL INJECTOR HAVING A SELF-CONTAINED REPLACEABLE PILOT VALVE ASSEMBLY

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F02M 47/02 (2006.01)
F02M 51/06 (2006.01)

(52) **U.S. Cl.**

CPC ***F02M 63/0029*** (2013.01); ***F02M 47/027*** (2013.01); ***F02M 51/061*** (2013.01); ***F02M 61/168*** (2013.01); *F02M 2200/28* (2013.01); *F02M 2200/708* (2013.01); *F02M 2200/8076* (2013.01)

(58) **Field of Classification Search**

CPC F02M 63/0026; F02M 63/0029; F02M 63/0031; F02M 63/0033

See application file for complete search history.

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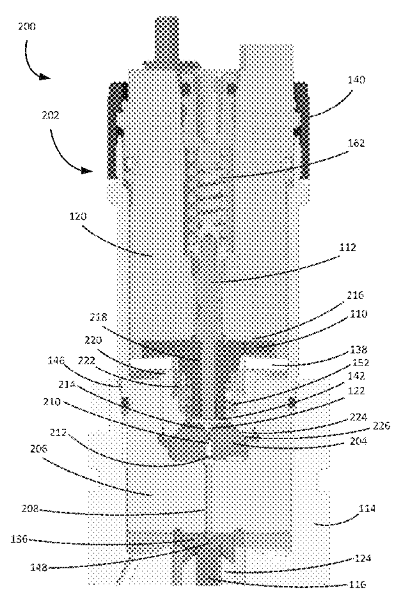
(57) **ABSTRACT**

A fuel injector device for injecting fuel into a combustion chamber of an internal combustion engine is provided. Included in the fuel injector is a body having a chamber and a pilot valve assembly including a seat retainer configured to be detachably insertable into the chamber of the body. A pilot valve seat is disposed in the seat retainer and substantially enclosed by the seat retainer. A stator assembly is disposed in the seat retainer and at least partially enclosed by the seat retainer. The pilot valve seat and the stator assembly in the pilot valve assembly are replaceable as a single unit of the pilot valve assembly for the fuel injector.

15 Claims, 4 Drawing Sheets



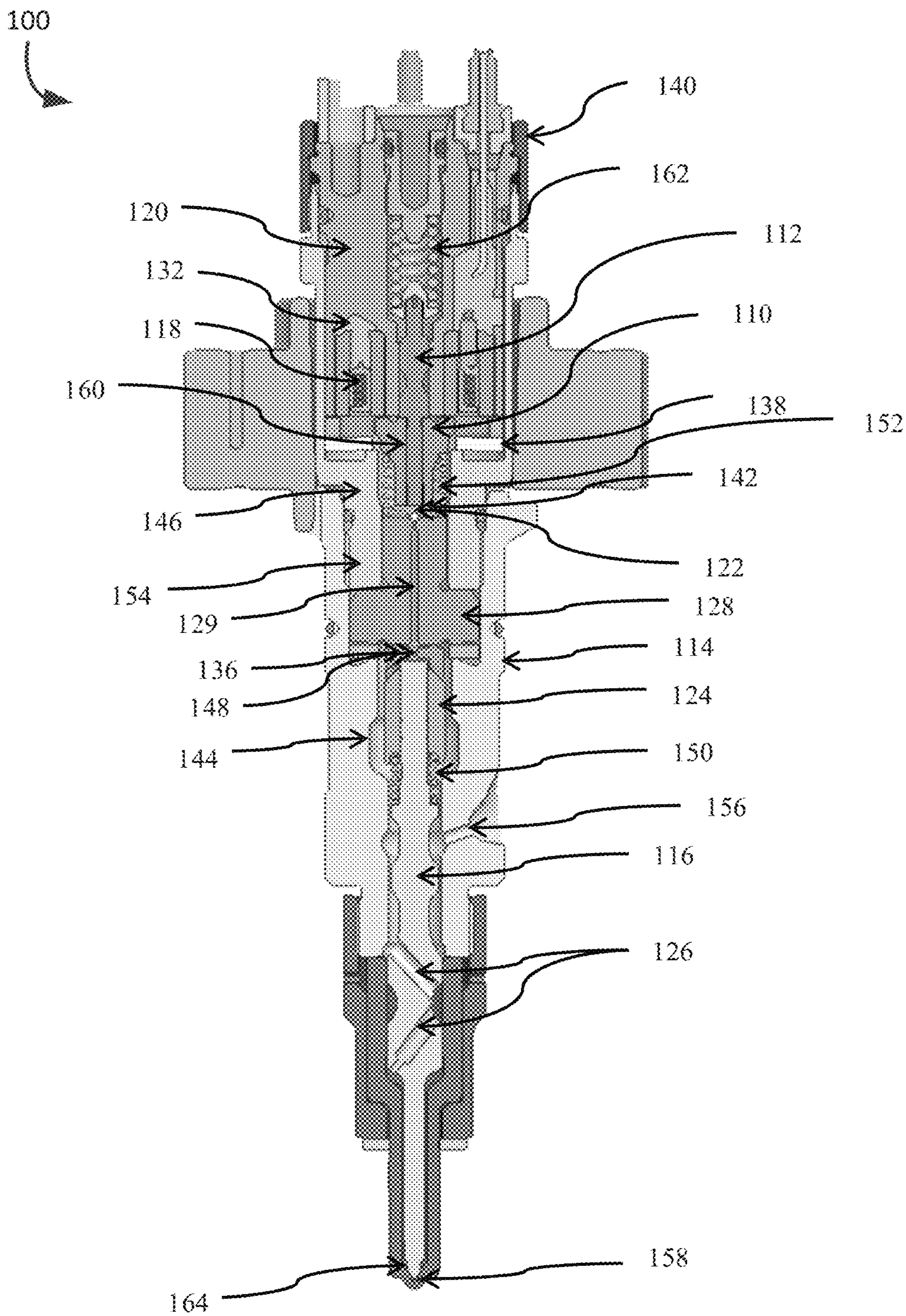
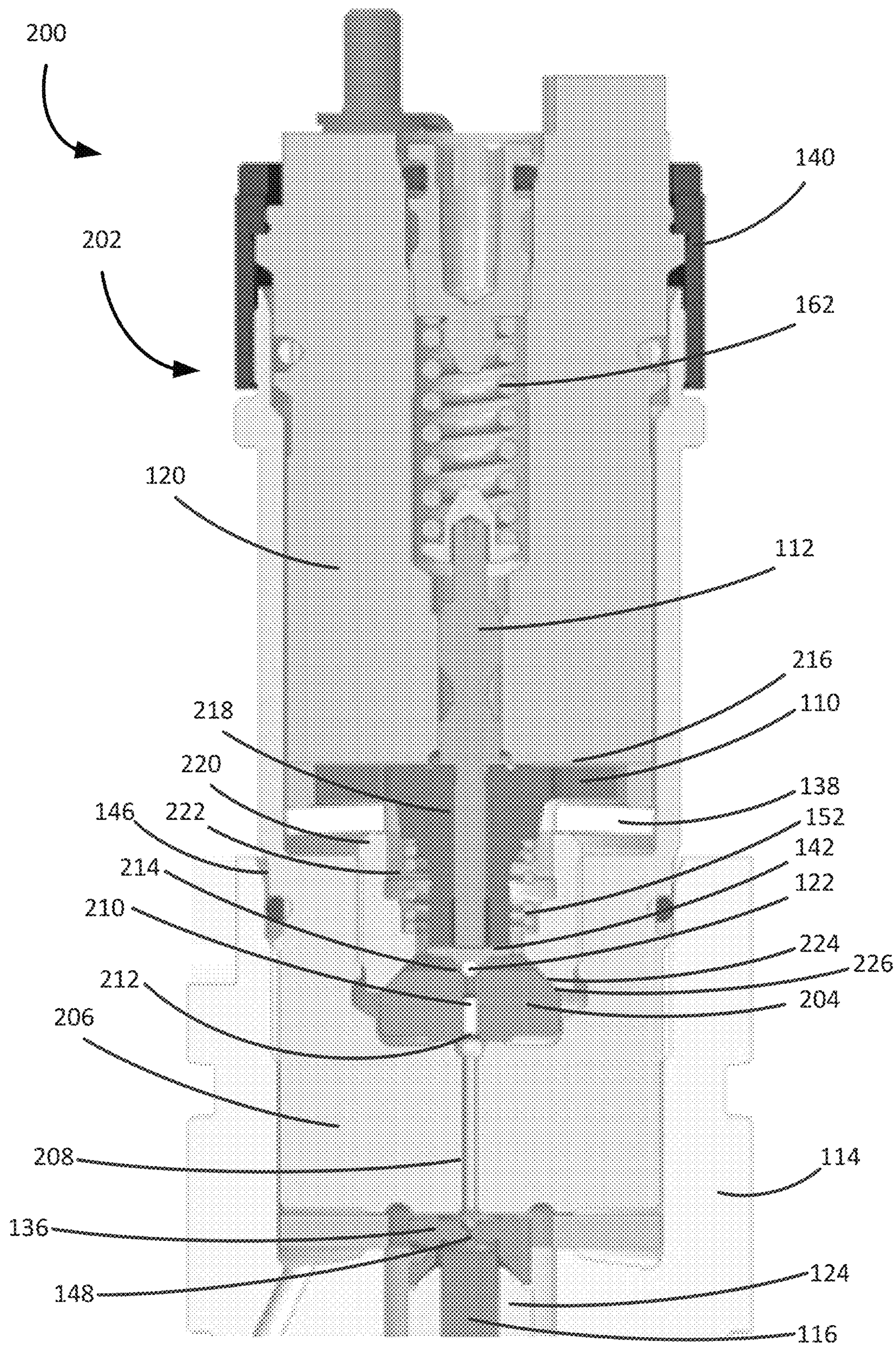


FIG. 1
Prior Art


200
202
140
162
120
112
216
110
218
220
138
146
222
152
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214
122
210
224
226
204
212
206
114
208
136
124
148
116

FIG. 2

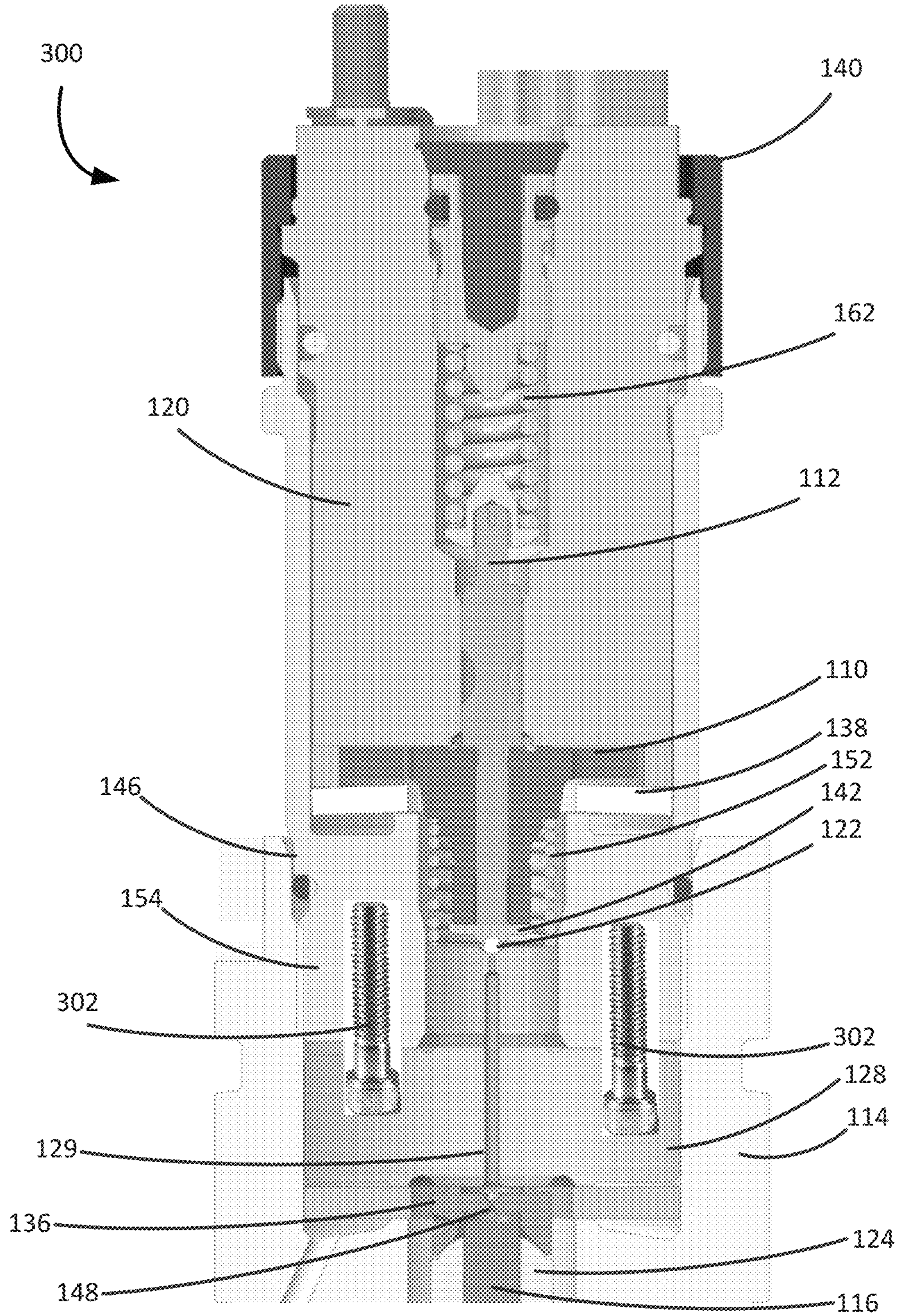
300
140
162
120
112
110
138
146
152
142
122
154
302
302
128
114
129
136
124
148
116

FIG. 3

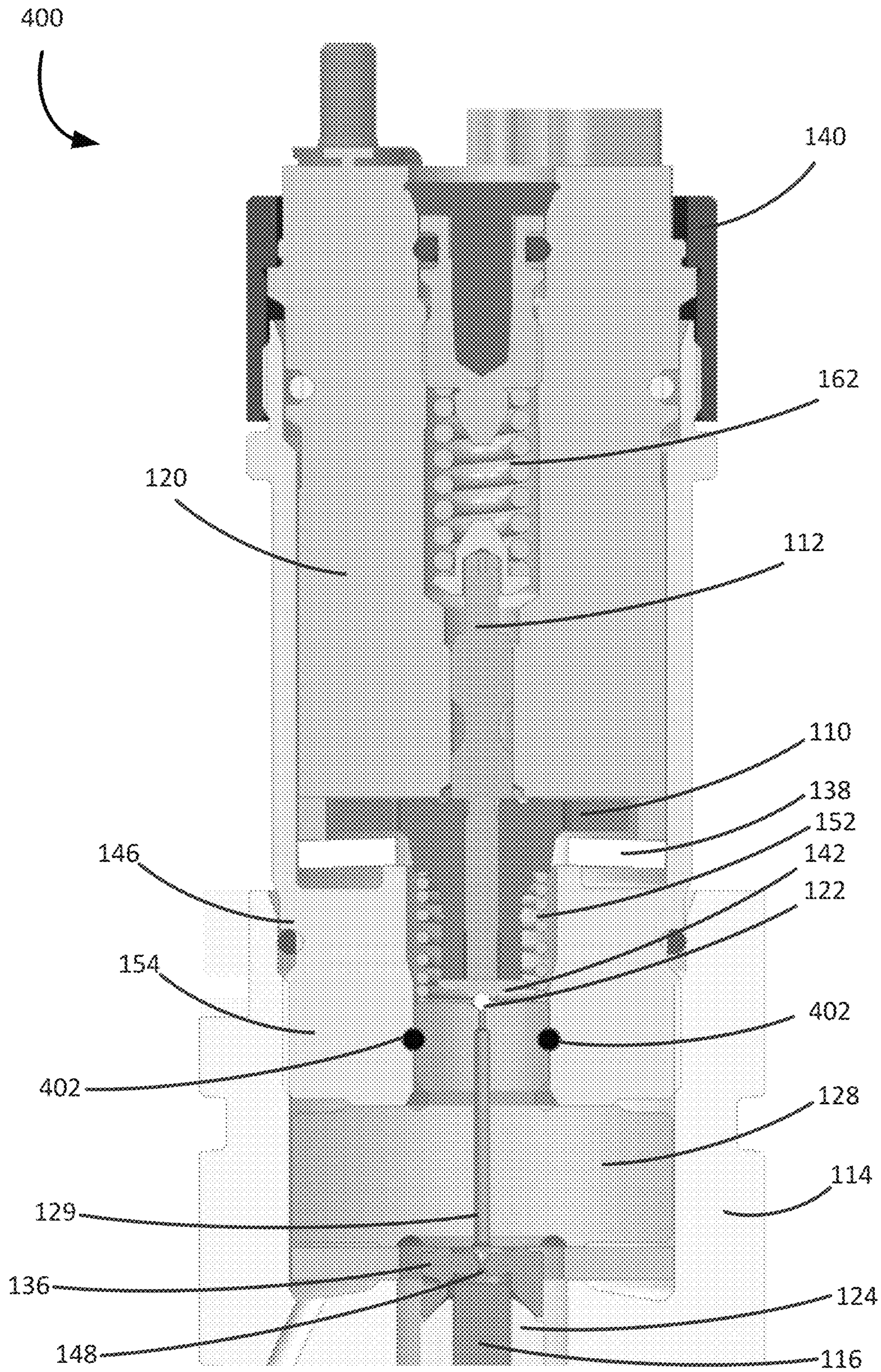
400
140
162
120
112
110
138
152
146
142
122
154
402
402
128
114
129
136
124
148
116

FIG. 4

FUEL INJECTOR HAVING A SELF-CONTAINED REPLACEABLE PILOT VALVE ASSEMBLY

FIELD OF THE DISCLOSURE

The present disclosure generally relates to common-rail fuel injector devices for injecting fuel into a combustion chamber of an internal combustion engine, and more particularly to a fuel injector having a self-contained replaceable pilot valve assembly.

BACKGROUND OF THE DISCLOSURE

An introduction of fuel into cylinders of an internal combustion engine is most commonly achieved using fuel injectors. A commonly used injector is a closed-nozzle injector which includes a nozzle assembly having a spring-biased needle valve element positioned adjacent the injector nozzle for allowing fuel to be injected into the cylinder of an internal combustion engine. The needle valve element also functions to provide a deliberate, abrupt end to fuel injection. The needle valve is positioned in the injector body and although biased downward by a spring force, a hydraulic force acting on the needle valve primarily holds the needle valve in the closed position. When an actuated force exceeds the biasing hydraulic force or causes a change in the magnitude of the hydraulic force, the needle valve element moves to allow fuel to pass through the injector nozzle, thus marking the beginning of the fuel injection event.

Manufacturers have implemented extra high pressure injection systems, also known as XPI, where the pressures can reach 2600 bar. Such high injection pressures cause wear and tear conditions in the injectors. During operation, the fuel injectors may need maintenance and/or replacement work depending on a degree of the wear and tear conditions of components of the injectors. Conventional injectors are typically serviceable only with special tools at designated service locations, and are difficult to replace, thereby increasing maintenance costs and time. Thus, vehicles having the injectors must be brought into the designated service locations and wait for the maintenance crew. Further, as injection pressures increase, greater forces must be applied to the injector components to achieve the required sealing at component interfaces/joints. Conventional injectors often include internal component configurations which are well suited to achieving desired high pressure performance characteristics but do so at high design and manufacturing costs. Accordingly, there is a need for an enhanced fuel injector that addresses one or more of the drawbacks of conventional injectors.

SUMMARY OF THE DISCLOSURE

In one embodiment of the present disclosure, a fuel injector includes a body having a chamber and a pilot valve assembly including a seat retainer configured to be detachably insertable into the chamber of the body. A pilot valve seat is disposed in the seat retainer and substantially enclosed by the seat retainer. A stator assembly is disposed in the seat retainer and at least partially enclosed by the seat retainer. The pilot valve seat and the stator assembly in the pilot valve assembly are replaceable as a single unit of the pilot valve assembly for the fuel injector.

In one aspect of the embodiment, no portion of the pilot valve seat is exposed outside of the seat retainer. In another aspect of the embodiment, the seat retainer and the stator assembly are integrated as a unitary unit. In one embodiment, a lower portion of the seat retainer includes a retainer central passage extending longitudinally from a lower end of the seat retainer toward an upper end of the seat retainer. The pilot valve seat includes a valve seat central passage extending longitudinally from a lower end of the pilot valve seat toward an upper end of the pilot valve seat. The valve seat central passage is fluidly coupled to the retainer central passage of the seat retainer. In another embodiment, an inner cavity within the chamber of the body is configured for receiving, at least partially, a lower end of the seat retainer.

In yet another aspect of the embodiment, the pilot valve assembly includes an armature assembly disposed in the seat retainer and a guide support disposed in the seat retainer between the armature assembly and the pilot valve seat. In one example, the stator assembly includes a solenoid disposed directly above the armature assembly, and the solenoid has an active state in which the armature assembly is in an upward position and an inactive state in which the armature assembly is in a downward position. In another example, the armature assembly is positioned within the chamber and includes a plunger central bore configured for receiving a plunger. In yet another example, the guide support has an inner bore configured to receive an armature spring and a lower end of the armature assembly. In one embodiment, a lower end of the guide support includes a radially inclined inner surface having a wider opening relative to a longitudinal axis of the guide support toward an edge of the lower end. In another embodiment, the radially inclined inner surface of the guide support is configured to matingly receive an upper portion of the pilot valve seat.

In another embodiment of the present disclosure, a fuel injector includes a body having an upper chamber and a lower chamber, and an armature assembly disposed in the upper chamber. A seat retainer having an inner chamber is configured to receive the armature assembly. A pilot valve seat is inserted into the inner chamber of the seat retainer. In one example, the pilot valve seat is attached to the seat retainer using at least one coupling mechanism to permit replacement of the pilot valve seat and the seat retainer as a single unit for the fuel injector.

In one aspect of the embodiment, the at least one coupling mechanism is a threaded fastener. In another aspect of the embodiment, the at least one coupling mechanism is a snap ring.

While multiple embodiments are disclosed, still other embodiments of the present disclosure will become apparent to those skilled in the art from the following detailed description, which shows and describes illustrative embodiments of the present disclosure. Accordingly, the drawings and detailed description are to be regarded as illustrative in nature and not restrictive.

BRIEF DESCRIPTION OF THE DRAWINGS

The above-mentioned and other features of this disclosure and the manner of obtaining them will become more apparent and the disclosure itself will be better understood by reference to the following description of embodiments of the present disclosure taken in conjunction with the accompanying drawings, wherein:

FIG. **1** is a cross-sectional view of a prior art mid-range XPI fuel injector;

FIG. **2** is a partial cross-sectional view of an exemplary embodiment of a common rail fuel injector featuring a self-contained replaceable pilot valve assembly in accordance with embodiments of the present disclosure;

FIG. **3** is a partial cross-sectional view of another embodiment of a common rail fuel injector featuring a first connecting mechanism in accordance with embodiments of the present disclosure; and

FIG. **4** is a partial cross-sectional view of yet another embodiment of a common rail fuel injector featuring a second connecting mechanism in accordance with embodiments of the present disclosure.

While the present disclosure is amenable to various modifications and alternative forms, specific embodiments have been shown by way of example in the drawings and are described in detail below. The intention, however, is not to limit the present disclosure to the particular embodiments described. On the contrary, the present disclosure is intended to cover all modifications, equivalents, and alternatives falling within the scope of the present disclosure as defined by the appended claims.

DETAILED DESCRIPTION OF EMBODIMENTS

In the following detailed description, reference is made to the accompanying drawings which form a part hereof, and in which is shown by way of illustration specific embodiments in which the present disclosure is practiced. These embodiments are described in sufficient detail to enable those skilled in the art to practice the present disclosure, and it is to be understood that other embodiments can be utilized and that structural changes can be made without departing from the scope of the present disclosure. Therefore, the following detailed description is not to be taken in a limiting sense, and the scope of the present disclosure is defined by the appended claims and their equivalents.

FIG. **1** shows a cross-sectional view of a prior art mid-range XPI fuel injector **100**. Fuel injector **100** generally includes an armature assembly **110**, a plunger **112**, an injector body **114**, and a needle valve **116**. Injector body **114** includes upper chamber **146** and lower chamber **144** for receiving a plurality of components therein. The disclosed embodiment provides an inner cavity within lower chamber **144** for receiving needle valve **116**, a needle sleeve **124**, a needle spring **150**, a needle seal **136**, a pilot valve seat **128**, and a check ball **122**. The disclosed embodiment further provides an inner cavity within upper chamber **146** for receiving armature assembly **110**, plunger **112**, an armature spring **152**, a spring disk **138**, and a stator assembly **120**. Upper chamber **146** is a low pressure environment of fuel injector **100** relative to the high pressure environment below check ball **122**.

Stator assembly **120** is fixed within the upper chamber **146** and retained in place by retainer **140**. In the disclosed embodiment, the bottom surface of stator assembly **120** is a precision calibrated distance away from armature assembly **110**. The other end of armature assembly **110** is supported via abutting engagement with check ball retainer **142**.

The middle section of plunger **112** includes an angled shoulder disposed on the upper surface of armature assembly **110** thereby creating a reciprocal connection such that when armature assembly **110** moves in the upward direction plunger **112** moves therewith. Armature spring **152** is biased against the flanged elements of armature assembly **110** and biases armature assembly **110** and plunger **112** in an upward direction. Armature assembly **110** is positioned within an inner cavity of upper chamber **146** and further includes central bore **160** for receiving the shaft of plunger **112** there through. The outer diameter of the shaft of plunger **112** is sized and configured to provide a close or match fit in relation to the inner diameter of central bore **160** while still permitting sliding movement of plunger **112**. This close/match fit inhibits fuel leakage between the outer diameter of the shaft of plunger **112** and the inner diameter of central bore **160** while permitting relative sliding movement.

Injector body **114** also includes lower chamber **144** which further includes an inner cavity that houses needle valve **116**, needle sleeve **124**, needle spring **150**, needle seal **136**, pilot valve seat **128**, and check ball **122**. Needle spring **150** biases needle valve **116** in a downward direction and applies a closing spring force to needle valve **116** thereby preventing fuel from exiting through injector orifice **158** when solenoid **132** is inactive. Needle seal **136** includes control orifices **148** integrated within the seal. Needle seal **136** is disposed above needle valve **116** and includes end points that terminate adjacent needle sleeve **124**. The surface of the lower end of pilot valve seat **128** abuts the top surface of needle seal **136**, while the surface of the upper end of pilot valve seat **128** is disposed immediately below armature spring **152**. Pilot valve seat **128** further includes valve seat central passage **129**. Valve seat central passage **129** extends longitudinally from the lower end of pilot valve seat **128** toward the upper end. Pilot valve seat **128** is held in place against the upwardly acting fuel pressure by a threaded seat retainer **154**.

Lower chamber **144** further includes fuel entry orifice **156** which is configured to supply fuel to the inner cavity of lower chamber **144**. The inner cavity as well as cross drilled fluid channels **126** in needle valve **116** facilitates fuel flow throughout lower chamber **144**. The fuel supply pressure may be within a pressure range of approximately 500-2600 bar. Control orifices **148** function to route fuel flow up valve seat central passage **129**. When coils **118** are de-energized and solenoid **132** is in an inactive state, check ball **122** is in sealing engagement with pilot valve seat **128**. Check ball **122** also functions as a moveable valve member and thus moves out of sealing engagement with pilot valve seat **128**. When check ball **122** is in sealing engagement with pilot valve seat **128**, fuel from lower chamber **144** is blocked from entering upper chamber **146**. When fuel is supplied to lower chamber **144** and check ball **122** is in sealing engagement with pilot valve seat **128** the inner cavity of lower chamber **144** becomes a highly pressurized volume. When check ball **122** functions as a moveable valve member and moves out of sealing engagement with pilot valve seat **128**, high pressure fuel flows up valve seat central passage **129** through pilot valve seat **128** and into the inner cavity of upper chamber **146**.

Injector **100** utilizes needle valve **116** in a normally closed position. When needle valve **116** is in its normally closed position, coils **118** are de-energized and solenoid **132** is in an inactive state. Additionally, plunger return spring **162** exerts a spring force downwardly such that plunger **112** and armature assembly **110** exert a downward force on check ball retainer **142** which thus secures and retains check ball **122** into sealing engagement with pilot valve seat **128**. Pressurized fuel is continuously supplied to the inner cavity of lower chamber **144**.

When coils **118** are de-energized fuel from lower chamber **144** is blocked from entering upper chamber **146** thus the inner cavity of lower chamber **144** becomes highly pressurized. Due to the fuel supply pressure acting downwardly on needle valve **116**, a large downward hydraulic force pushes needle valve **116** in the downward direction. Needle spring **150** also is positioned in the inner cavity of lower chamber **144** and is compressed about the upper end of needle valve **116** such that when solenoid **132** is inactive, high pressure fuel as well as a downward spring force on needle valve **116** both act to secure needle valve **116** against needle valve seat **164**. Securing needle valve **116** against needle valve seat **164** prevents high pressure fuel from exiting injector **100** via injector orifice **158**.

For a fuel injection, injector **100** requires an intermediate pressure or force loss, such as depressurizing the pressurized control volume by creating a low pressure drain flow from the control volume. The beginning of an injection event is initiated by energizing coils **118** with an electric current. As coils **118** of solenoid **132** are energized the solenoid acts as a type of electromagnet which then causes armature assembly **110** to rapidly move upwardly in magnetic attraction with solenoid **132**. Because plunger **112** is disposed atop armature assembly **110**, the strength of the solenoid's magnetic force acting on armature assembly **110** further causes plunger **112** to move upwardly against the downward biasing force of plunger return spring **162**. When coils **118** are energized solenoid **132** is in an active state thereby causing armature assembly **110** and plunger **112** to move to an upward position, permitting movement of check ball **122** out of sealing engagement with pilot valve seat **128**. During an injection event, check ball **122** functions as a moveable valve member, and when it moves out of sealing engagement with pilot valve seat **128**, high pressure fuel residing in valve seat central passage **129** flows through pilot valve seat **128** into the inner cavity of upper chamber **146**.

The flow of high pressure fuel from the inner cavity of lower chamber **144** to the inner cavity of upper chamber **146** creates a pressure differential. The pressure difference between the high fuel supply pressure in lower chamber **144** and the low pressure in upper chamber **146** results in significant hydraulic force acting in a direction to lift needle valve **116** and allow an injection event. Needle valve **116** is therefore lifted off needle valve seat **164** allowing fuel to be injected into the engine combustion chamber via injector orifice **158** which may contain various spray outlet arrangements.

The fuel injection event is ended by de-energizing coils **118**, which results in solenoid **132** being inactive and thus causing the downward force of plunger return spring **162** to force plunger **112** to exert a downward force on armature assembly **110**. The downward force exerted on armature assembly **110** via plunger return spring **162** forces check ball **122** back into sealing engagement with pilot valve seat **128**. When check ball **122** is in sealing engagement with pilot valve seat **128**, high pressure fuel from lower chamber **144** is once again blocked from entering the inner cavity of upper chamber **146**. As fuel is continuously supplied to lower chamber **144** and with check ball **122** in sealing engagement with pilot valve seat **128**, the inner cavity of lower chamber **144** again becomes highly pressurized. The seal created by check ball **122** as well as the high pressure fuel supplied to the inner cavity of lower chamber **144** both combine to produce a highly pressurized control volume in lower chamber **144**. Due to the fuel supply pressure acting downwardly on needle valve **116**, a large downward hydraulic force pushes needle valve **116** back to the downward direction. Needle spring **150** further applies a downward biasing spring force in order to expedite seating needle valve **116** against needle valve seat **164**, thus preventing high pressure fuel from exiting injector **100** and ending the injection event.

FIG. **2** shows an exemplary embodiment of the present disclosure designed to overcome one or more shortcomings of conventional injectors and/or offer features noted herein below. Like reference numerals represent like elements shown in FIG. **1**. Fuel injector **200** includes a self-contained replaceable pilot valve assembly **202** being detachably insertable into upper chamber **146** of injector body **114**. Advantageously, self-contained replaceable pilot valve assembly **202** is readily exchangeable from fuel injector **200** to another injector as desired. In this configuration, stator assembly **120** and a pilot valve seat **204** are constructed and arranged to be replaceable as a single unit in self-contained replaceable pilot valve assembly **202**. As such, self-contained replaceable pilot valve assembly **202** is exchangeable while operating in the field without having to be replaced in the designated service locations by the maintenance crew. Another advantage is that self-contained replaceable pilot valve assembly **202** can also be installed in a conventional injector, such as fuel injector **100**. In other words, originals parts of the conventional injector can be removed and exchanged with self-contained replaceable pilot valve assembly **202** out in the field.

More specifically, pilot valve seat **204** of fuel injector **200** is smaller than pilot valve seat **128** of fuel injector **100**, and is disposed within a seat retainer **206** of self-contained replaceable pilot valve assembly **202**. Seat retainer **206** can be threadably attached to injector body **114**, but can also be attached by, for example, glue, friction fit, snap fit, or other similar rigid coupling mechanism. In this example, pilot valve seat **204** is substantially enclosed by seat retainer **206** such that no portion of pilot valve seat **204** is exposed outside of seat retainer **206**. In another example, pilot valve seat **204** is fully enclosed by seat retainer **206**. For example, seat retainer **206** and stator assembly **120** are fully integrated as a unitary unit. In contrast, as shown in FIG. **1**, a lower portion of pilot valve seat **128** of fuel injector **100** is exposed out of threaded retainer **154**. This particular configuration of pilot valve seat **204** and seat retainer **206** allows for easy replacement of damaged or worn-out self-contained replaceable pilot valve assembly **202**. A lower portion of seat retainer **206** includes a retainer central passage **208** extending longitudinally from a lower end of seat retainer **206** toward an upper end of seat retainer **206**. When assembled, a valve seat central passage **210** of pilot valve seat **204** is fluidly coupled to retainer central passage **208** of seat retainer **206** such that fuel can flow up from control orifices **148** of needle seal **136** to an inner chamber of seat retainer **206** via retainer central passage **208** and valve seat central passage **210**.

Self-contained replaceable pilot valve assembly **202** generally includes pilot valve seat **204**, seat retainer **206**, armature assembly **110**, plunger **112**, stator assembly **120**, and a guide support **220**. Other components, such as check ball **122**, check ball retainer **142**, armature spring **152**, spring disk **138**, and the like, as shown in FIG. **2**, are also included in self-contained replaceable pilot valve assembly **202**. Pilot valve seat **204** further includes an inlet end **212**, an outlet end **214**, and valve seat central passage **210**. As discussed above, injector body **114** includes upper chamber **146** and lower chamber **144** for receiving a plurality of components therein, such as self-contained replaceable pilot valve assembly **202**. The disclosed embodiment provides an inner cavity within upper chamber **146** for receiving stator assembly **120**, solenoid **132**, coil **118**, armature spring **152**, and plunger return spring **162**. In this example, an inner cavity within upper chamber **146** is configured for receiving, at least partially, the lower end of seat retainer **206**. As with fuel injector **100**, upper chamber **146** is a low pressure environment of fuel injector **200** relative to the high pressure environment below pilot valve seat **204** and the lower end of seat retainer **206**.

In one embodiment, a bottom surface of stator assembly **120** has a precision calibrated distance from one end of armature assembly **110**. The distance between stator assembly **120** and armature assembly **110** is indicated by a stroke gap **216**. An exemplary distance of stroke gap **216** is approximately 47 microns. After extended use of fuel injector **200**, the distance of stroke gap **216** can change over time (e.g., become larger or smaller) causing an inaccurate operation of the fuel injection event. Recalibrating stroke gap **216** in the field can be difficult without proper tools. However, it is advantageous that an old self-contained replaceable pilot valve assembly **202** can readily be replaced with a new self-contained replaceable pilot valve assembly **202** for either fuel injector **200** or fuel injector **100**.

Stator assembly **120** further includes solenoid **132** disposed directly above armature assembly **110**, wherein solenoid **132** has an active state in which armature assembly **110** moves to an upward position and an inactive state in which armature assembly **110** moves to a downward position. Armature assembly **110** is positioned within the inner cavity of upper chamber **146** and further includes a plunger central bore **218** for receiving plunger **112** there through.

Plunger **112** includes a shaft portion disposed within plunger central bore **218** of armature assembly **110** for creating a reciprocal connection such that when armature assembly **110** moves in the upward direction, plunger **112** moves therewith. An outer diameter of the shaft of plunger **112** is sized and configured to provide a close or match fit in relation to an inner diameter of plunger central bore **218** while still permitting sliding movement of plunger **112**. This close/match fit inhibits fuel leakage between the outer diameter of the shaft of plunger **112** and the inner diameter of plunger central bore **218** while permitting relative sliding movement. Armature assembly **110** further includes flanged elements disposed directly below solenoid **132** and coils **118**. Armature spring **152** is biased against the flanged elements of armature assembly **110** and biases armature assembly **110** and plunger **112** in an upwardly direction.

Guide support **220** is disposed below the flanged elements of armature assembly **100** between spring disk **138** and pilot valve seat **204**, and has an inner bore **222** configured to receive armature spring **152** and a lower end of armature assembly **110**. In one embodiment, a lower end of guide support **220** includes a radially inclined inner surface **224** having a wider opening relative to a longitudinal axis of guide support **220** toward an edge of the lower end. Radially inclined inner surface **224** is configured to matingly receive an upper portion of pilot valve seat **204** having a corresponding sloped or angled outer surface **226** such that pilot valve seat **204** is securely held by guide support **220** during operation.

As similarly with fuel injector **100**, when coils **118** are de-energized and solenoid **132** is in an inactive state, check ball **122** is in sealing engagement with pilot valve seat **204**. Check ball **122** also functions as a moveable valve member and thus moves out of sealing engagement with pilot valve seat **204**. When check ball **122** is in sealing engagement with pilot valve seat **204**, fuel from lower chamber **144** is blocked from entering upper chamber **146**. When fuel is supplied to lower chamber **144** and check ball **122** is in sealing engagement with pilot valve seat **204**, the inner cavity of lower chamber **144** becomes a highly pressurized volume. When check ball **122** functions as a moveable valve member and moves out of sealing engagement with pilot valve seat **204**, high pressure fuel flows up retainer central passage **208** and valve seat central passage **210** and into the inner chamber of seat retainer **206**.

When coils **118** are energized solenoid **132** is in an active state thereby causing armature assembly **110** and plunger **112** to move to an upward position, permitting movement of check ball **122** out of sealing engagement with pilot valve seat **204**. During an injection event, check ball **122** functions as a moveable valve member, and when it moves out of sealing engagement with pilot valve seat **204**, high pressure fuel residing in retainer central passage **208** and valve seat central passage **210** flows through seat retainer **206** and pilot valve seat **204** into the inner chamber of seat retainer **206**.

FIG. **3** is a cross-sectional view of fuel injector **300** which includes a plurality of fasteners **302** according to the present disclosure. Fuel injector **300** is a variant of fuel injector **200** and generally includes elements of fuel injector **100**. Like reference numerals represent like elements shown in FIG. **1**. One aspect of fuel injector **300** is that a first coupling mechanism, such as fasteners **302**, are used to fixedly and removably attach threaded retainer **154** to pilot valve seat **128**. In this example, fasteners **302** are threaded bolts, but any other suitable fastener types known in the art can be used to suit different applications. In this configuration, components associated with threaded retainer **154** and pilot valve seat **128** are replaceable as a single unit.

FIG. **4** is a cross-sectional view of fuel injector **400** which includes at least one snap ring **402** according to the present disclosure. Fuel injector **400** is another variant of fuel injector **200** and generally includes elements of fuel injector **100**. Like reference numerals represent like elements shown in FIG. **1**. One aspect of fuel injector **400** is that a second coupling mechanism, such as a snap ring **402**, is used to fixedly and removably attach threaded retainer **154** to pilot valve seat **128**. In this example, snap ring **402** is disposed between an inner surface of threaded retainer **154** and an outer surface of pilot valve seat **128** for facilitating secure attachment between threaded retainer **154** and pilot valve seat **128**. Again, in this configuration, components associated with threaded retainer **154** and pilot valve seat **128** are replaceable as a single unit.

It is to be understood that the above description is intended to be illustrative, and not restrictive. Many other embodiments will be apparent to those of skill in the art upon reading and understanding the above description. For example, it is contemplated that features described in association with one embodiment are optionally employed in addition or as an alternative to features described in associate with another embodiment. The scope of the present disclosure should, therefore, be determined with reference to the appended claims, along with the full scope of equivalents to which such claims are entitled.

What is claimed is:

1. A fuel injector, comprising:

an injector body having a chamber in contact with fuel inside the chamber, the injector body including an integrated needle sleeve for receiving a needle valve;

a pilot valve assembly including a seat retainer configured to be detachably insertable into the chamber of the injector body and an armature assembly and a guide support disposed in the seat retainer, the seat retainer extending outside of the chamber of the injector body when inserted into the chamber of the injector body;

a pilot valve seat disposed in the seat retainer and substantially enclosed by the seat retainer, the seat retainer substantially enclosing the pilot valve seat by enclosing a lower portion of the pilot valve seat to be fully within the seat retainer; and

a stator assembly disposed in the seat retainer, the stator assembly being in contact with a portion of the seat retainer and at least partially enclosed by the portion of the seat retainer in contact with the stator assembly;

wherein:

a lower end of the guide support includes a radially inclined inner surface in contact with an upper portion of the pilot valve seat having a corresponding radially inclined outer surface, the radially inclined inner surface having a wider opening relative to a longitudinal axis of the guide support, toward an edge of the lower end;

each of the seat retainer, the pilot valve seat, the stator assembly, and the armature assembly includes a central axis aligned to each other; and

the stator assembly, the pilot valve seat, and the armature assembly are replaceable as a single unit for the fuel injector.

2. The fuel injector of claim **1**, wherein no portion of the pilot valve seat is exposed outside of the seat retainer.

3. The fuel injector of claim **1**, wherein the seat retainer and the stator assembly are integrated as a unitary unit.

4. The fuel injector of claim **1**, wherein a lower portion of the seat retainer includes a retainer central passage extending longitudinally from a lower end of the seat retainer toward an upper end of the seat retainer.

5. The fuel injector of claim **4**, wherein the pilot valve seat includes a valve seat central passage extending longitudinally from a lower end of the pilot valve seat toward an upper end of the pilot valve seat.

6. The fuel injector of claim **5**, wherein the valve seat central passage is fluidly coupled to the retainer central passage of the seat retainer.

7. The fuel injector of claim **1**, wherein the chamber of the injector body is configured for receiving, at least partially, a lower end of the seat retainer.

8. The fuel injector of claim **1**, wherein the guide support is disposed between the armature assembly and the pilot valve seat.

9. The fuel injector of claim **8**, wherein the stator assembly includes a solenoid disposed directly above the armature assembly, and the solenoid has an active state in which the armature assembly is in an upward position and an inactive state in which the armature assembly is in a downward position.

10. The fuel injector of claim **8**, wherein the armature assembly is positioned within the chamber and includes a plunger central bore configured for receiving a plunger.

11. The fuel injector of claim **8**, wherein the guide support, has an inner bore configured to receive an armature spring and a lower end of the armature assembly.

12. A pilot valve assembly used in a fuel injector, the pilot valve assembly comprising:

a seat retainer having an inner chamber configured to be detachably insertable into a chamber of an injector body of the fuel injector, a lower portion of the seat retainer including a retainer central passage and the seat retainer extending outside of the chamber of the injector body when inserted into the chamber of the injector body;

a stator assembly disposed in the inner chamber of the seat retainer, the stator assembly being in contact with a portion of the seat retainer and at least partially enclosed by the portion of the seat retainer in contact with the stator assembly;

a pilot valve seat disposed in the inner chamber of the seat retainer and substantially enclosed by the seat retainer, the seat retainer substantially enclosing the pilot valve seat by enclosing a lower portion of the pilot valve seat to be fully within the seat retainer such that the pilot valve seat does not extend into the retainer central passage;

an armature assembly disposed between the stator assembly and the pilot valve seat configured to facilitate reciprocal movement within the inner chamber of the seat retainer,

a guide support disposed in the inner chamber of the seat retainer between the armature assembly and the pilot valve seat, a lower end of the guide support including a radially inclined inner surface having a wider opening relative to a longitudinal axis of the guide support toward an edge of the lower end, the radially inclined inner surface being in contact with an upper portion of the pilot valve seat having a corresponding radially inclined outer surface;

wherein:

each of the seat retainer, the pilot valve seat, the stator assembly, and the armature assembly includes a central axis aligned to each other; and

the stator assembly, the pilot valve seat, and the armature assembly disposed, at least partially, in the inner chamber of the seat retainer are replaceable as a single unit for the fuel injector.

13. The pilot valve assembly of claim **12**, wherein the retainer central passage extends longitudinally from a lower end of the seat retainer toward an upper end of the seat retainer.

14. The pilot valve assembly of claim **13**, wherein the pilot valve seat includes a valve seat central passage extending longitudinally from a lower end of the pilot valve seat toward an upper end of the pilot valve seat such that the valve seat central passage is fluidly coupled to the retainer central passage of the seat retainer.

15. A fuel injector, comprising:

an injector body having a chamber in contact with fuel inside the chamber, the injector body including an integrated needle sleeve for receiving a needle valve;

a pilot valve assembly including a seat retainer configured to be detachably insertable into the chamber of the injector body and an armature assembly and a guide support disposed in the seat retainer, the seat retainer extending outside of the chamber of the injector body when inserted into the chamber of the injector body;

a pilot valve seat disposed in the seat retainer and substantially enclosed by the seat retainer, the seat retainer substantially enclosing the pilot valve seat by enclosing a lower portion of the pilot valve seat to be fully within the seat retainer;

a plunger positioned above the pilot valve seat and extending through the armature assembly; and

a stator assembly disposed in the seat retainer, the stator assembly being in contact with a portion of the seat retainer and at least partially enclosed by the portion of the seat retainer in contact with the stator assembly;

wherein:

a lower end of the guide support includes a radially inclined inner surface in contact with an upper portion of the pilot valve seat having a corresponding radially inclined outer surface, the radially inclined inner surface having a wider opening relative to a longitudinal axis of the guide support toward an edge of the lower end;

each of the seat retainer, the pilot valve seat, the stator assembly, and the armature assembly includes a central axis aligned to each other; and the stator assembly, the pilot valve seat, and the armature assembly are replaceable as a single unit for the fuel injector.

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