FIG. 2). The injector **10** may be a multi-syringe injector, wherein several syringes **12** may be oriented in a side-by-side or other relationship and include plungers **26** separately actuated by respective pistons **13** associated with the injector **10**. In embodiments with two syringes arranged in a side-by-side relationship and filled with two different medical fluids, the injector **10** may deliver fluid from one or both of the syringes **12**.

[00190] The injector **10** may be enclosed within a housing **14** formed from a suitable structural material, such as plastic or metal. The housing **14** may be of various shapes and sizes depending on the desired application. The injector **10** includes at least one syringe port **16** for connecting the at least one syringe **12** to a respective piston **13** (**FIG. 2**).

[00191] At least one fluid path set **17** may be fluidly connected with the at least one syringe **12** for delivering medical fluid **F** from the at least one syringe **12** to a catheter, needle, or other fluid delivery connection (not shown) inserted into a patient at a vascular access site. Fluid flow from the at least one syringe **12** may be regulated by a controller **200** (**FIG. 2**). The controller **200** may operate various pistons, piston mechanical components (such as components for engagement and disengagement of the piston with a plunger), valves, and/or flow regulating structures to regulate the delivery of the medical fluid, such as saline solution and contrast, to the patient based on user selected injection parameters. One aspect of a suitable front-loading fluid injector that may be modified for use with the above-described system including at least one syringe and at least one piston for engaging and releasable retaining a plunger of a syringe engaged with the fluid injector described herein with reference to **FIGS. 1-2** is disclosed in United States Patent No. 5,383,858, whereas another aspect of relevant multi-fluid delivery systems that may be modified for use with the present system are found in U.S. Patent No. 7,553,294; U.S. Patent No. 7,666,169; International Patent Application No. PCT/US2012/037491; and U.S. Application Publication No. 2014/0027009; the disclosures of each of which are incorporated herein by reference. Other embodiments may include new fluid injector systems designed to include various embodiments of the connection interface between the piston **13** of the injector **10** and the plunger **26** of the syringe **12** described herein.

[00192] Referring to **FIG. 3**, a representative embodiment of a dual syringe angiography injector system **100** (hereinafter referred to as "injector **100**") is illustrated. The injector **100** is configured for injection of two medical fluids through a first fluid path **17A** for a medical fluid, such as an imaging contrast media for an angiography injection procedure, and a second fluid path **17B** for a flushing fluid, such as saline or Ringer's lactate. The injector **100** may include an injector housing **14** having two syringe ports **16** configured to engage two syringes **12**.

[00193] The injector housing **14** may further include at least one user interface **11** through which an operator can view and control the status of an injection procedure. The user interface **11** may be in operative communication with a controller (similar to controller **200** described herein, **FIG. 2**) which sends and receives commands to and from user interface **11**.

[00194] The injector **100** may further include at least one upstream air detector **240** for detecting one or more air bubbles within an air detection tubing region **250** of the first fluid path **17A** and the second fluid path **17B**. The air detection tubing region **250**, for example, may be associated with a proximal portion of the first fluid path **17A** and the second fluid path **17B**. The at least one air detector **240** may include an ultrasonic sensor, and optical sensor, or the like, configured to detect the one or more air bubbles within the fluid path.

[00195] With continued reference to **FIG. 3**, the injector **100** may further include bulk fluid containers **19A** and **19B** for filling and refilling the respective syringes **12** with imaging contrast media and flushing fluid, respectively. The bulk fluid containers **19A** and **19B** may be in selective fluid communication with the syringes **12** via respective bulk fluid paths **21A** and **21B** and bulk fluid valves **23A** and **23B**.

[00196] Further details and examples of suitable non-limiting powered injector systems, including syringes, controllers, and air detectors, are described in U.S. Patent No. 5,383,858; U.S. Patent No. 7,553,294; U.S. Patent No. 7,666,169; U.S. Patent No. 8,945,051; U.S. Patent No. 10,022,493; and U.S. Patent No. 10,507,319, the disclosures of which are hereby incorporated by reference in their entireties. While the injector **100** is described herein in the context of a dual syringe angiography (CV) injector, it is to be understood that the injector **100** may be adapted for single- and multiple-syringe configurations of any injection procedure (e.g. CT, PET, MRI, ultrasound, etc.)

[00197] The injector **100** may include a piston, similar to the piston **13** described herein in **FIG. 2**, respectively associated with each of the syringes **12**. Each piston is configured to drive a respective plunger within a barrel of the respective syringe **12**. Due to the high pressures associated with CV angiography, the syringe **12** may be inserted into a pressure jacket **15** to control radial expansion of the syringe**.** The controller is operatively associated with the pistons to reciprocatively move the plungers within the syringes **12** and thereby execute an injection procedure.

[00198] The controller may be programmed or configured to execute a filling operation during which the piston associated with each syringe **12** is withdrawn toward a proximal end of the syringe **12** to draw injection fluid (e.g. imaging contrast media and flushing fluid) into the syringe **12** from the bulk fluid containers **19A**, **19B**. During such filling operation, the

controller may be programmed or configured to selectively actuate the bulk fluid valves **23A** and **23B** to establish fluid communication between the respective syringes **12** and the bulk fluid containers **19A**, **19B** via the bulk fluid paths **21A** and **21B** to control filling of the syringes **12** with the appropriate injection fluid. Upon completion of the filing operation, and optionally a priming operation to remove any air from the syringes **12** (for example by priming any such air back into the bulk fluid containers **19A**, **19B** or through a priming tube), the controller may be programmed or configured to selectively actuate the bulk fluid valves **21A** and **21B** to block fluid communication between the respective syringes **12** and the bulk fluid container **19A**, **19B** via the bulk fluid paths **17A** and **17B**.

[00199] After the filling operation and priming operation, the controller may be programmed or configured to execute a delivery operation during which the piston associated with one or both of the syringes **12** is moved toward a distal end of the syringe **12** to inject injection fluid into the first fluid path **17A** and the second fluid path **17B**. The controller may be programmed or configured to selectively actuate the fluid valves **23A** and **23B** to establish fluid communication between the syringes **12** and the patient, via the fluid paths **17A**, 17**B**. According to various embodiments, the first fluid path **17A** and the second fluid path **17B** may merge at a fluid mixing connector that provides turbulent mixing of the first fluid and the second fluid, such as a fluid mixing connector described in International PCT Application Nos. PCT/US2021/019507 and PCT/US2014/026324, the disclosures of which are incorporated herein by reference.

[00200] Referring now to **FIG. 4**, a schematic diagram of example components of an embodiment of controller **200** for implementing and performing the systems and methods described herein is shown according to embodiments of the present disclosure. In some embodiments, the controller **200** may include additional components, fewer components, different components, or differently arranged components than those shown in **FIG. 4**. The controller **200** may include a bus **202**, at least one processor **204**, memory **206**, a storage component **208**, an input component **210** (such as a GUI, keyboard, or other user interface **11**, shown in **FIG. 3**), an output component **212** (such as a GUI or other user interface **11**), and a communication interface **214** (such as a GUI or other user interface **11**). The bus **202** may include a component that permits communication among the components of the controller **200**. In some non-limiting embodiments, the at least one processor **204** may be implemented in hardware, firmware, or a combination of hardware and software. For example, the at least one processor **204** may include a processor (e.g., a central processing unit (CPU), a graphics processing unit (GPU), an accelerated processing unit (APU), etc.), a microprocessor, a digital

signal processor (DSP), and/or any processing component (e.g., a field-programmable gate array (FPGA), an application-specific integrated circuit (ASIC), etc.) that can be programmed to perform a function. Memory **206** may include random access memory (RAM), read only memory (ROM), and/or another type of dynamic or static storage device (e.g., flash memory, magnetic memory, optical memory, etc.) that stores information and/or instructions for use by the at least one processor **204**.

[00201] The storage component **208** may store information and/or software related to the operation and use of the controller **200**. For example, the storage component **208** may include a hard disk and/or another type of computer-readable medium. The input component **210** may include a component that permits the controller **200** to receive information, such as via user input (e.g., the GUI, a touch screen display, a keyboard, a keypad, a mouse, a button, a switch, a microphone, etc.). Additionally, or alternatively, the input component **210** may include a sensor for sensing information (e.g., a global positioning system (GPS) component, an accelerometer, a gyroscope, an actuator, etc.). The output component **212** may include a component that provides output information from the controller **200** (e.g., the GUI, a display, a speaker, one or more light-emitting diodes (LEDs), etc.). The communication interface **214** may include a transceiver-like component (e.g., a transceiver, a separate receiver and transmitter, etc.) that enables the controller **200** to communicate with other devices, such as via a wired connection, a wireless connection, or a combination of wired and wireless connections. The communication interface **214** may permit the controller **200** to receive information from another device and/or provide information to another device. The input component **210**, output component **212**, and/or the communication interface **214** may correspond to, or be components of, the user interface **11** (see **FIG. 3**).

[00202] The, the controller **200** may perform the method described herein based on the at least one processor **204** executing software instructions stored by a computer-readable medium, such as the memory **206** and/or the storage component **208**. A computer-readable medium may include any non-transitory memory device. A memory device includes memory space located inside of a single physical storage device or memory space spread across multiple physical storage devices. Software instructions may be read into the memory **206** and/or the storage component **208** from another computer-readable medium or from another device via communication interface **214**. When executed, software instructions stored in the memory **206** and/or storage component **208** may cause processor **204** to perform one or more processes described herein. Additionally, or alternatively, hardwired circuitry may be used in place of or in combination with software instructions to perform one or more processes described herein.

[00203] Having described the general structure and function of the injector **10**, **100**, a non-limiting embodiment of a syringe **300** configured for use with the injector **10** of **FIGS. 1-2** or the injector **100** of **FIG. 3** will now be discussed in greater detail with reference to **FIG. 5A-5B**. The syringe **300** generally has a cylindrical syringe barrel **318** formed from glass, metal, or a suitable medical-grade plastic. The barrel **318** has a proximal end **320** and a distal end **324**, with a sidewall **319** (shown in **FIG. 5B**) extending therebetween along a length of a syringe longitudinal axis **315** extending through a center of the barrel **318**. The barrel **318** may be made from a transparent or translucent material. A nozzle **322** extends from the distal end **324** of the barrel **318**. As shown in **FIG. 5B**, the barrel **318** has an outer surface **321** and an inner surface **323** that defines an interior volume **325** for receiving the fluid therein. The proximal end **320** of the barrel **318** may be sealed with the plunger **326** that is slidable through the barrel **318**. The plunger **326** forms a liquid-tight seal against the inner surface **323** of sidewall **319** of the barrel **318** as the plunger **326** is advanced through the barrel **318**. Plunger **326** is configured to releasably engage a piston of fluid injector **10, 100**, according to various engagement mechanism as described herein.

[00204] A drip flange **335** may extend radially outward from the outer surface **321** of the syringe barrel **318** and prevent fluid that drips from the nozzle **322** from entering the syringe port on the injector. In some embodiments, the drip flange **335** defines a stop surface that delimits the insertion section **330** of the syringe **300**.

[00205] With reference to **FIG. 5A**, in some embodiments, the proximal end **320** of the syringe **300** is sized and adapted for being removably inserted in the syringe port of the injector **10, 100** (shown in **FIGS. 1** and **3**) or inserted into a pressure jacket (not shown) engaged to a fluid injector. The proximal end **320** of the syringe **300** may define an insertion section **330** that is removably insertable into the syringe port of the injector **10** shown in **FIG. 1** or the injector **100** shown in **FIG. 3**, while the remaining portion of the syringe **300** remains outside of the syringe port. In other embodiments, the syringe **300** may be inserted into a bore of a pressure jacket and releasably retained in the pressure jacket by one or more retention features, for example as described in PCT International Application No. PCT/US2020/049885, the disclosure of which is incorporated herein by this reference. In certain embodiments, the proximal end **320** of the syringe **300** includes one or more syringe retaining members **331** adapted to form a locking engagement with a corresponding locking mechanism in the syringe port of the injector **10**, **100** for releasably retaining the syringe **300** in the syringe port. Suitable non-limiting configurations for retaining members for releasably locking the syringe **300** with the injector **10**, **100** are described in U.S. Patent Nos. 9,173,995, and 9,199,033, the disclosures

of which are incorporated herein by reference in their entirety. The syringe **300**, is omitted from many of the figures of the corresponding plunger engagement mechanisms of the present disclosure for clarity.

[00206] With reference to **FIGS. 6-8C**, the plunger **326** is shown in accordance with one embodiment of the present disclosure. The plunger **326** includes a plunger body **332** defining a plunger longitudinal axis **334** and having a proximal end **336**, a distal end **338**, and a circumferential sidewall **339** connecting the proximal end **336** and the distal end **338**. The sidewall **339** may have a uniform or non-uniform thickness between the proximal end **336** and the distal end **338**. At least a portion of the sidewall **339** may be conical. The plunger body **332** may be formed from glass, metal, or a suitable medical-grade plastic.

[00207] The plunger body **332** has an interior cavity **340** (**FIG. 7**) with a conical-shaped portion **342** at the distal end **338** of the plunger body **332** and a cylindrical-shaped portion **344** at the proximal end **336** of the plunger body **332**. The conical-shaped portion **342** may be monolithically formed with the cylindrical-shaped portion **344**. In some embodiments, the conical-shaped portion **342** may be affixed or otherwise secured to the cylindrical-shaped portion **344** of the plunger body **332** using, for example, a frictional fit and/or an adhesive, welding, or by molding. The conical-shaped portion **342** may have a truncated end **346** having a molded boss **348** configured for engagement with a sensing member, as described herein. In some embodiments, the distal end **338** of the plunger body **332** may be open or enclosed. In some embodiments, the cylindrical-shaped portion **344** may have a ledge **345** that protrudes in a radially-outward direction relative to the longitudinal axis **334**. In this manner, ledge **345** partitions the cylindrical-shaped portion **344** into a first portion **347a** having a first inner diameter and a second portion **347b** having a second inner diameter that is larger than the first inner diameter.

[00208] With reference to **FIG. 7**, the plunger **326** may have one or more release tabs **380** protruding from an inner surface **352** of the interior cavity **340** of the plunger body **332**. In some embodiments, the one or more release tabs **380** may protrude radially inward from the inner surface **352** of at least a portion of the cylindrical-shaped portion **344** of the plunger body **332**, such as the first portion **347a**. The one or more release tabs **380** may be configured for interacting with at least a portion of the plunger engagement mechanism on the piston to release the plunger **326** from the piston upon rotation of the plunger **326** about its longitudinal axis **334**, such as by rotation of the syringe **300**. In some embodiments, a plurality of release tabs **380** may be separated radially relative to the plunger longitudinal axis **334** along a circumference of the inner surface **352** of the interior cavity **340**. In such embodiments, the

release tabs **380** are separated from each other by portions of the inner surface **352** of the interior cavity **340**. In embodiments where more than two release tabs **380** are provided, the release tabs **380** may be evenly spaced apart from each other. In some embodiments, the release tabs **380** may have unequal angular extension and/or unequal angular spacing between the retaining ribs **350** about the inner surface **352** of the interior cavity **340**. A proximal end **382** of each release tab **380** may have a pointed or angled guide surface **384** that is configured for orienting the plunger **326** relative to at least a portion of the plunger engagement mechanism, as according to certain embodiments described herein.

[00209] With reference to **FIG. 6**, the plunger **326** may have a plunger cover **357** with a resilient seal **358** that covers at least a portion of an outer surface **360** of the plunger body **332**. The seal **358** may be a flexible seal that engages an inner surface **323** of the syringe barrel **318** (shown in **FIG. 5B**) such that the seal **358** seals the interior volume **325** of the syringe barrel **318** in a liquid-tight manner. The seal **358** may be provided separately from the plunger body **332**, or it may be integrally formed with the plunger body **332**, such as by co-molding. In some embodiments, the outer surface **360** of the plunger body **332** may have a circumferential groove **362**. At least a portion of seal **358** may be retained within the circumferential groove **362**. The exterior surface **364** of the seal **358** may have one or more lips, projections, or other sealing elements **366** that slidingly engage an inner surface of the syringe barrel **318**. In some embodiments, at least the sealing elements **366** of the seal **358** may be made from an elastomeric material that resiliently engages the inner surface **323** of the syringe barrel **18**. The at least one extension **356** on the plunger body **332** may prevent the seal **358** from coming out of axial alignment with syringe **300** as plunger **326** is moved through the syringe barrel **318**.

[00210] With reference to **FIG. 7**, the plunger **326** may have at least one resiliently deflectable retaining member **368** (hereinafter "retaining member **368**") protruding proximally from the plunger body **332**. In some embodiments, the at least one retaining member **368** may protrude proximally from an inner surface **352** of the interior cavity **340** of the plunger body **332**. The at least one retaining member **368** has a first distal end **370** connected to the plunger body **332** and a second proximal end **372** radially deflectable relative to the first end **370** in a direction toward and/or away from the longitudinal axis **334**. As described herein, the second end **372** may be radially deflectable relative to the first end **370** when the at least one retaining member **368** engages at least a portion of a plunger engagement mechanism on a piston of the injector **10**, **100** (**FIGS. 1** and **3**). That is, as the portion of the plunger engagement mechanism is moved in a distal direction and contacts the retaining member **368,** the retaining member **368** is radially deflected by the portion of the plunger engagement mechanism. In an analogous

manner, during a disengagement operation of the piston from the plunger, as the portion of the plunger engagement mechanism is moved in a proximal direction and contacts the retaining member **368,** the retaining member **368** is radially deflected by the portion of the plunger engagement mechanism. The first end **370** and the second end **372** may be spaced apart in a direction that extends substantially along a direction of the plunger longitudinal axis **334** of the plunger **326**. The at least one retaining member **368** may be linearly or curvilinearly contiguous between the first end **370** and the second end **372**. In some embodiments, one or more retaining members **368** may extend in a direction parallel to a direction of the plunger longitudinal axis **334**. In other embodiments, one or more retaining members **368** may extend in a direction that is angled relative to the direction of the plunger longitudinal axis **334**. For example, one or more retaining members **368** may be angled toward or away from the plunger longitudinal axis **334** in a direction extending from the proximal end **336** to the distal end **338** of the plunger body **332**.

[00211] In some embodiments, a plurality of retaining members **368** are spaced apart radially from the plunger longitudinal axis **334** along a circumference of the inner surface **352** of the interior cavity **340**. In such embodiments, the retaining members **368** are separated from each other by portions of the inner surface **352** of the interior cavity **340**. In embodiments where more than two retaining members **368** are provided, the retaining members **368** may be evenly spaced apart from each other. In one exemplary and non-limiting aspect with six retaining members **368** having equal angular separation therebetween, such as shown in **FIGS. 7-8C**, for example, each retaining member **368** is separated by 60 degrees from the retaining members **368** adjacent on either side. In some embodiments, the retaining members **368** may have unequal angular extension and/or unequal angular spacing between the retaining members **68** about the inner surface **352** of the interior cavity **340**. The radial spacing of the at least one retaining member **368** relative to the plunger longitudinal axis **334** is selected to correspond to an outer circumference of the piston, as described herein.

[00212] The second end **372** of the retaining member **368** has at least one catch **374**. The at least one catch **374** protrudes radially from the retaining member **368**. The at least one catch **374** is configured to interact with the portion of the plunger engagement mechanism to deflect the second end **372** as the portion of the plunger engagement mechanism passes by the at least one catch **372.** In some embodiments, the at least one catch **374** may protrude radially inward toward the plunger longitudinal axis **334** of the plunger body **332**. In this manner, the at least one retaining member **368** is configured for deflecting in a radially outward direction due to contact between the catch **374** and at least a portion of the plunger engagement mechanism on

the piston, as described herein. In some embodiments, the at least one catch **374** may protrude radially outward away the plunger longitudinal axis **334** of the plunger body **332**. In this manner, the at least one retaining member **368** is configured for deflecting in a radially inward direction due to contact between the catch **374** and at least a portion of the plunger engagement mechanism on the piston, as described herein. The at least one retaining member **368** is configured to return toward its undeflected state by moving in a radially inward direction.

[00213] The at least one catch **374** may be formed integrally with the second end **372** of the at least one retaining member **368** or it may be affixed or otherwise secured to the second end **372** of the at least one retaining member **368** using, for example, a frictional fit and/or an adhesive, welding, or by co-molding. In other embodiments, the at least one catch **374** may be formed on the second end **372** of the at least one retaining member **368** by etching, laser cutting, or machining. As described herein, the at least one catch **374** is shaped to be received within a catch receiving space or groove of a plunger engagement mechanism provided on the piston of the injector **10, 100** to lock the at least one retaining member **368** relative to the piston when the plunger engagement mechanism is in a locked state or position by an embodiment of the mechanisms described herein. As shown in **FIGS. 7-8C**, the catch **374** may have a distal surface **377** with a rounded edge. In some embodiments, the catch **374** may have a proximal surface **379** with a rounded edge. The shape of the distal surface **377** and the proximal surface **379** may be such that the catch **374** cannot, by itself, form a locking engagement with a corresponding locking feature on the plunger engagement mechanism on the piston. Instead, catch **374** must act with actuation of the plunger engagement mechanism to form a locking engagement with the piston.

[00214] With reference to **FIGS. 8A-8C**, a plunger **326** is shown in accordance with various embodiments of the present disclosure. The components of the plunger **326** shown in **FIGS. 8A-8C** are substantially similar or identical to the components of the plunger **326** described herein with reference to **FIGS. 6-7**. Accordingly, reference numerals in **FIGS. 8A-8C** are used to illustrate identical components of the corresponding reference numerals in **FIGS. 6-7**, and only the relative differences between the embodiments of plunger **326** are discussed herein.

[00215] With reference to **FIGS. 8A-8C**, the plunger **326** may have one or more release tabs **380** protruding from the inner surface **352** of at least a portion of the cylindrical-shaped portion **344** of the plunger body **332**, such as the second portion **347b**. The one or more release tabs **380** may protrude axially from the ledge **345** and radially inward from the inner surface **352** of the second portion **347b** of the cylindrical-shaped portion **344** and may protrude radially inward from the inner surface **352** of the second portion **347b** along the entire width of the ledge **345**

(**FIG. 8A**) or along a portion of the width of the ledge **345** (**FIG. 8B** and **8C**). As described herein, the one or more release tabs **380** are configured for interacting with at least a portion of the plunger engagement mechanism on the piston to effect a release of the plunger **326** from the piston upon rotation of the plunger **326** about its longitudinal axis **334**, such as due to rotation of the syringe **300**.

[00216] The embodiment of plunger **326** in **FIG. 8C** has at least one retaining member **368** with a catch **374** that protrudes radially outward in a direction away from the plunger longitudinal axis **334**. In this manner, the at least one retaining member **368** shown in **FIG. 8C** is configured for deflecting in a radially inward direction due to contact between the catch **374** and at least a portion of the plunger engagement mechanism on the piston, as described herein. The at least one retaining member **368** shown in **FIG. 8C** is configured to return toward its undeflected state by moving in a radially outward direction.

[00217] Referring to **FIG. 9**, an embodiment of piston **400** is shown separate from an injector. In other embodiments, the piston **400** may be configured for use with a fluid injector such as described herein, or any fluid injector configured for medical use. The piston **400** is configured reciprocal movement within the housing of the injector via a drive mechanism. The drive mechanism may include, for example, an electric motor **402** (shown in **FIG. 2**), hydraulic system, a pneumatic system, or any combination thereof. The controller **200** (**FIG. 2**) may be configured for controlling operation of the drive mechanism and, in turn, controlling reciprocal movement of the piston **400**. In certain embodiments, the controller **200** may be configured to control engagement and/or disengagement of piston **400** with a plunger.

[00218] With continued reference to **FIG. 9**, the piston **400** has a body **404** and a piston head **406** at a distal end of the body **404**. The piston head **406** is configured for removably connecting to a plunger of a syringe, such as the plunger **326** shown in **FIG. 8C**. The piston head **406** extends radially outwardly beyond the radial edge of the body **404**. The piston **400** is constructed from a relatively rigid material, such as metal, plastic, or a combination thereof, that resists deformation. The piston head **406** has a substantially cylindrical structure with a distal end that is configured to be received inside at least a portion of the interior cavity **340** (**FIG. 8C**) of the plunger **326**. In some embodiments, at least a portion of the piston head **406** may be made from a transparent or translucent material that is configured to permit a passage of electromagnetic radiation emitted by one or more electromagnetic radiation sources in the piston **400** for illuminating at least a portion of plunger **326** and/or syringe **300**.

[00219] In some embodiments, a sensing member, such as a spring-loaded pin (see, e.g., pin **767**, **FIGS. 21A-21B**) connected to a sensor, may be provided. The sensing member may

extend along a longitudinal axis of the piston **400** and may protrude through at least a portion of the piston head **406**. The sensing member may be operative for sensing contact with a surface, such as a surface **348** of the plunger **326**, and control a movement of the piston **400** based on the sensed condition. For example, an initial contact between the sensing member and surface **348** of the plunger **326** may cause the pin to be retracted in a proximal direction such that it makes contact with the sensor. The sensor may be connected to the drive mechanism of the piston **400** such that, upon activation of the sensor by the pin, the sensor controls the movement of the drive mechanism. For example, the drive mechanism may be stopped or slowed from a first rate to a second, slower rate.

[00220] In some embodiments, the piston head **406** has a plunger engagement mechanism **412** configured for releasably engaging the plunger **326** to facilitate reciprocally driving the plunger **326** within the barrel of the syringe **300** (**FIG. 5A-5B**). With continued reference to **FIG. 9**, the plunger engagement mechanism **412** has a plunger engagement sleeve **414** having a central opening **416** and a plunger engagement post **418** that is reciprocally movable within the central opening **416** of the plunger engagement sleeve **414** along a direction of a longitudinal piston axis **420**. The plunger engagement post **418** is reciprocally driven by an actuator **422**. The plunger engagement mechanism **412** is operable between an engaged position or state, and a disengaged position or state. In the engaged position or state, the plunger engagement post **418** may be positioned within the plunger engagement sleeve **414** to capture at least one retaining member **368** associated with the plunger **326** in a receiving space **415** between the plunger engagement sleeve **414** and the plunger engagement post **418**. Conversely, in the disengaged position or state, the plunger engagement post **418** may be positioned relative to the plunger engagement sleeve **414** to permit removal of the at least one retaining member **368** associated with the plunger **400** from the receiving space **415** between the plunger engagement sleeve **414** and the plunger engagement post **418**. **FIG. 9** shows portions of the plunger engagement mechanism **412** in the engaged position or state and the disengaged position or state. Specifically, the plunger engagement post **418** in **FIG. 9** is shown both in its engaged position or state (right side of cross-section) and in its disengaged position or state (left side of cross-section). During movement of the plunger engagement mechanism **412** from the engaged position or state to the disengaged position or state, the plunger engagement sleeve **414** and/or the plunger engagement post **418** may be linearly and/or rotatably movable relative to the piston **400**.

[00221] With reference to **FIGS. 10A-10B**, the plunger engagement sleeve **414** has a hollow body **424**, wherein at least a portion of an outer surface of the hollow body **424** defines at least

a portion of the piston head **406** (shown in **FIG. 9**). A distal portion or end **426** of the plunger engagement sleeve **414** is shaped to be received within the interior cavity **340** of the plunger **326**, while at least a portion of the plunger **326**, such as the at least one retaining member **368**, is configured to be received within the central opening **416** (see, e.g., **FIG. 9**). The central opening **416** extends through the hollow body **424** of the plunger engagement sleeve **414**.

[00222] With reference to **FIG. 10B**, a portion of an inner surface **428** of the central opening **416** at the distal end of the opening **416** may have a ramp **430** such that an inner diameter of the opening **416** narrows in a direction from the distal end **426** of the hollow body **424** toward a proximal portion or end **432**. The ramp **430** may be configured for engaging with catch **374** and deflecting the at least one retaining member **426** associated with the plunger **326** in a radially inward direction during connection of the plunger **326** to the distal portion or end **426** of the plunger engagement sleeve **414**. The ramp **430** may terminate at a locking rib **434**. The at least one catch **374** may flex over and rest against a proximal surface of the locking rib **434** in a manner where at least one catch **374** may readily flex over and move past locking rib **434** if the piston is moved in the proximal direction, unless the plunger engagement mechanism **412** is moved to the locked engagement configuration. That is, the at least one retaining member **426** and corresponding catch **374** may readily flex and move into and out of the central opening **416** of plunger engagement sleeve **414** if the piston is in the disengaged configuration. In some embodiments, the locking rib **434** extends continuously or discontinuously around the inner surface **428** of the hollow body **424** of the plunger engagement sleeve **414** and defines a surface that engages the at least one catch **374** on the at least one retaining member **368** on the plunger **326** to prevent removal of the plunger **326** from the piston **400** when the plunger **326** is in locked engagement with the plunger engagement mechanism **412**, as described herein. The inner surface **426** of the central opening **416** may be substantially cylindrical proximally of the locking rib **434**.

[00223] A proximal portion or end **432** of the hollow body **424** is monolithically formed with the distal portion or end **426** and may have an inner surface **436** with a longitudinal groove **438** configured for receiving a guiding pin **439** of the plunger engagement post **418** (**FIG. 9**). The longitudinal groove **438** has a distal stop **440** for delimiting a distal movement of the guiding pin **439**, and thereby delimiting a distal movement of the plunger engagement post **418** relative to the plunger engagement sleeve **414**. An outer surface **442** of the proximal portion or end **432** of the hollow body **424** may have a toothed portion **444** configured for interacting with one or more release tabs **380** on the plunger **326** during removal of the plunger **326** from the plunger engagement mechanism **412**.

[00224] With reference to **FIG. 11A-11B**, the plunger engagement mechanism **412** further includes a housing **446** configured for receiving the actuator **422**. As shown in **FIG. 11B**, the housing **446** may have a cylindrical structure having a connection member **448** configured for connecting with a connector **450** on the actuator **422**. In some embodiments, the connection member **448** on the housing **446** may be an internally threaded surface that is configured for threadably engaging an externally threaded connector **450** on the actuator **422**. In other embodiments, the connection member **448** may be an adhesive, a clip, an interference fit, a fastener, or any other connection feature for removably or non-removably connecting the housing **446** to the connector **450** on the actuator **422**.

[00225] With reference to **FIGS. 11A-11B**, the housing **446** has a proximal portion **452** connected to a distal portion **454**. In some embodiments, the distal portion **454** may have a smaller outer diameter than the proximal portion **452** such that a ledge **456** is defined at a transition between the proximal portion **452** and the distal portion **454**. In some embodiments, the ledge **456** may be configured for supporting a proximal end of a biasing member **496** configured for releasing the plunger **326** from the piston engagement mechanism **412** (**FIG. 9**) during disengagement of the plunger **326** from the piston **400**.

[00226] A plunger release sleeve **458** surrounds the distal portion **454** of the housing **446**. In some embodiments, the plunger release sleeve **458** has a cylindrical sidewall **460** having an opening **462** extending therethrough. The opening **462** may have a longitudinal surface **463** that is substantially parallel with a longitudinal axis **464** of the plunger release sleeve **458** and a ramped surface **466** that is contiguous with the longitudinal surface **463** and is angled downward relative to the longitudinal axis **464** of the plunger release sleeve **458** in a direction from a distal end **468** toward a proximal end **470**. As described herein, the longitudinal surface **463** is configured to guide the guiding pin **439** of the plunger engagement post **418** (**FIG. 9**) during movement of the plunger engagement post **418** in a longitudinal direction along the longitudinal axis **420** of the piston **400**, while the ramped surface **464** is configured to guide the guiding pin **439** during rotational movement of the plunger **326** relative to the piston **400**, such as during removal of the plunger **326** from the piston **400**. One or more lights **472** may be provided on a printed circuit board **474** connected to the distal end **468** of the plunger release sleeve **458**. The one or more lights **472** may be configured for illuminating at least a portion of the plunger **326**, as described herein.

[00227] With reference to **FIG. 11B**, the actuator **422** may be configured for having an engaged state for moving one of the plunger engagement sleeve **414** and the plunger engagement post **418** to the engaged position and a disengaged state for moving one of the

plunger engagement sleeve and the plunger engagement post to the disengaged position. In some embodiments, the actuator **422** may be automatically moved to the disengaged state, such as during power loss to the actuator **422**. In some embodiments, the actuator **422** may be in the engaged state only during proximal movement of the piston **400**. In some embodiments, the actuator **422** may be a solenoid configured to be predominantly in the disengaged state and may be in the engaged state only during connection of the plunger **326** to the piston **400**. In other embodiments, the actuator **422** may be a rotary electric motor, a linear electric motor, or a linear actuator. In some embodiments, the actuator **422** is a linear actuator that can be back driven manually in the event of a power loss to the injector.

[00228] With reference to **FIG. 9**, the plunger engagement sleeve **414** may be rotatable about the longitudinal piston axis **420** relative to the housing **446** and the plunger release sleeve **458** between a first position and a second position. In some embodiments, the plunger engagement sleeve **414** may be rotatable in a clockwise direction and a counterclockwise direction, or one of the clockwise and a counterclockwise direction. The plunger engagement sleeve **414** may be rotatable from the first position to the second position due to rotational movement of the plunger **326** around the longitudinal piston axis **420**. For example, the plunger engagement sleeve **414** may be rotatable around the longitudinal axis **420** due to interaction of the release tabs **390** on the plunger **326** with the toothed portion **444** on the piston engagement sleeve **414**. In certain embodiments, rotation of the plunger engagement sleeve **414** may move guiding pin **439** along ramped surface **466** of plunger release sleeve **458** to move plunger engagement post **418** to the disengaged or engaged position. A biasing member **496** may be provided to bias the plunger engagement sleeve **414** to the first position. In this manner, when the plunger engagement sleeve **414** is rotated from the first position toward the second position, the biasing member **496** builds potential energy therein, which is then used to assist in returning the plunger engagement sleeve **414** toward the first position. In some embodiments, the biasing member **496** may be a torsion spring having one end connected to the plunger engagement sleeve **414** and the other end connected to the housing **446** or the plunger release sleeve **458**.

[00229] With reference to **FIG. 12**, the plunger engagement post **418** is shown separate from the plunger engagement mechanism **412**. The plunger engagement post **418** has a shaft **472** having a proximal end **474** and a distal end **476**. The distal end **476** of the shaft **472** has a tapered end surface **478** configured for contacting the at least one flexible retaining member **368** on the plunger **326** when the plunger engagement post **418** is in an engaged position to lock the at least one catch **374** against the locking rib **434** of the plunger engagement sleeve **414** to prevent removal of the plunger **326** from the piston **400**. A seal **480** may be provided at

the distal end **478** for sealing against the inner surface **428** of the plunger engagement sleeve **414** (shown in **FIGS. 10A-10B**). The seal **480** may be an O-ring seal.

[00230] The plunger engagement post **418** further includes the guiding pin **439** that is configured for guiding the movement of the plunger engagement post **418** relative to the plunger engagement sleeve **412**. In some embodiments, the guiding pin **439** extends through the shaft **472** and is arranged substantially perpendicular to a longitudinal axis **482** of the shaft **472**. A resiliently elastic member **484** surrounds the shaft **472** and has a distal end **486** that abuts a ledge **488** on the distal end **478** of the shaft **472**. A proximal end **490** of the resiliently elastic member **484** may be configured for contacting the actuator **422** or the housing **446**. The resiliently elastic member **484** may be a compression spring that is configured for biasing the plunger engagement post **418** in a distal direction toward the engaged position, as described herein. In other embodiments, the resiliently elastic member **484** may be an extension spring that is configured for biasing the plunger engagement post **418** in a proximal direction toward the disengaged position.

[00231] Having described the structure of the plunger **326** and the piston **400** in accordance with one non-limiting embodiment of the present disclosure, a method of engagement and disengagement of the plunger **326** with and from the piston **400** will now be described with reference to **FIGS. 13A-13J**.

[00232] **FIG. 13A** shows the piston **400** with its plunger engagement mechanism **412** in an engaged position or state and prior to connection with a plunger **326**. In some embodiments, the default state of the plunger engagement mechanism **412** may be the engaged position or state. To connect the plunger **326** to the piston **400**, the syringe **300** is first connected to the injector **10, 100** (**FIGS. 1** and **3**). During connection of the syringe **300** to the injector **10, 100**, the piston **400** is withdrawn in the housing of the injector **10, 100**. After connecting the syringe **300** to injector **10, 100**, piston **400** can be advanced in a distal direction toward plunger **326**.

[00233] With reference to **FIG. 13B**, the actuator **422** is energized to retract the shaft **472** of the plunger engagement post **418** in a proximal direction indicated by arrow **A** from an engaged position or state to a disengaged position or state. Movement of the shaft **472** in the proximal direction opens the receiving space **415** between the plunger engagement sleeve **414** and the plunger engagement post **418** to permit insertion or removal of the one or more retaining members **368** of the plunger **326** into the receiving space **415**. Such movement also compresses the resiliently elastic member **484** between the ledge **488** on the distal end of the shaft **472** and the actuator **422**. Compression of the resiliently elastic member **484** builds potential energy

therein than, when released, can be used to guide the plunger engagement post **418** toward the engaged position or state.

[00234] In other embodiments, the actuator **422** may be de-energized, and the shaft **472** of the plunger engagement post **418** may be retracted in a proximal direction indicated by arrow **A** from an engaged position or state to a disengaged position or state due to an elastic restoring force of the resiliently elastic member **484**. In such embodiments, the resiliently elastic member **484** may be an extension spring that is stretched from a first state to a second state due to actuation of the actuator **422**. Once the actuator **422** is de-energized, the restoring force in the resiliently elastic member **484** urges the plunger engagement post **418** toward the disengaged position or state. In this manner, the plunger engagement post **418** is in a normally-disengaged position or state, which permits removal of the plunger **326** from the piston **400** in the event that the actuator **422** cannot be operated, such as due to a power loss.

[00235] With reference to **FIG. 13C**, the piston **400** can then be moved axially in a distal direction toward the plunger **326** (indicated by arrow **B)**. In some embodiments, the piston **400** may be advanced distally using the drive mechanism **402** operated by the controller **200** (**FIG. 2**). In other embodiments, the piston can be manually moved in the distal direction.

[00236] With reference to **FIG. 13D,** the piston **400** is advanced axially in a distal direction such that the at least one retaining member **368** of the plunger **326** is received within the central opening **416** of the plunger engagement sleeve **414**. Initially, the inner surface **428** of the central opening **416** contacts the catch **374** of the at least one retaining member **368**. Because the catch **374** protrudes radially outward relative to the at least one retaining member **368**, the catch **374** is positioned at a larger radial distance from the plunger longitudinal axis **334** than the ramp **430** of the central opening **416**. In this manner, continued distal movement of the piston **400** causes the at least one retaining member **368** to be deflected radially inward due to the contact between the catch **374** and the ramp **430**. In embodiments having a plurality of retaining members **368**, each of the retaining members **368** is deflected in the radially inward direction.

[00237] During continued axial movement of the piston **400** in a distal direction, the catch **374** is deflected over the locking rib **434** of the piston engagement sleeve **414**. After the catch **374** is positioned proximally relative to the locking rib **434**, distal movement of the piston **400** relative to the plunger **326** is stopped or contact between the distal portion or end **426** of plunger engagement sleeve **414** and the inner surface **352** of the interior cavity **340** of the plunger body **332** causes the plunger **326** to move distally together with piston **400**, and the at least one retaining member **368** can elastically deflect in a radially inward direction such that the catch **374** is positioned proximally of the locking rib **434**. In some embodiments, distal movement of

the piston **400** relative to the plunger **326** may be stopped upon engagement of a portion of the plunger engagement sleeve **414** with the drive shoulder **327** of the plunger **326**. While the at least one retaining member **368** is in the position shown in **FIG. 13D**, the plunger **326** is not in a locked engagement with the piston **400** because the at least one retaining member **368** can be deflected in a radially inward direction with proximal movement of the piston **400** or distal movement of the plunger **326** (such as due to removal of the syringe from the injector). With the plunger **326** connected to the piston **400**, the one or more release tabs **380** on the plunger **326** are aligned with the toothed portion **444** on the outer surface **442** of the plunger engagement sleeve **414**. In certain embodiments, the plunger **326** may not be in an engaged, locked position with piston **400** when piston **400** is moving in a distal direction and only moves to the engaged, locked position upon proximal movement of the piston **400**. Such a feature may allow easy removal of syringe **300** and plunger **326** after a short distal movement of piston **400** and may reduce wear on system components and/or motors by only requiring a locking engagement when the piston **400** is being retracted.

[00238] With reference to **FIG. 13E**, the actuator **422** is de-energized to permit movement of the shaft **472** of the plunger engagement post **418** in a distal direction indicated by arrow **C** from a disengaged position or state to an engaged position or state. In other embodiments, the actuator **422** may be energized to move the shaft **472** of the plunger engagement post **418** in the distal direction.

[00239] Movement of the shaft **472** in the distal direction closes the receiving space **415** between the plunger engagement sleeve **414** and the plunger engagement post **418** locking the at least one catch **374** against the locking rib **434** to prevent removal of the one or more retaining members **368** of the plunger **326** from the receiving space **415**, thus preventing removal of the plunger **326** from the piston **400**. The plunger engagement post **418** is moved from the disengaged position or state to the engaged position or state due to the release of the potential energy stored in the resiliently elastic member **484**. In other embodiments, the plunger engagement post **418** is moved from the disengaged position or state to the engaged position or state due to actuation of the actuator **422**, which builds potential energy in the resiliently elastic member **484**. Once the plunger engagement post **418** is moved to the engaged position or state, the at least one retaining member **368** of the plunger **326** is captured between the plunger engagement sleeve **414** and the plunger engagement post **418** such that axial movement of the piston **400** results in a corresponding axial movement of the plunger **326** within the syringe barrel. The piston **400** and the connected plunger **326** may then be moved reciprocally within the barrel **318** of the syringe **300** (**FIG. 5A-5B**). In specific embodiments, when the

piston **400** and the connected plunger **326** may be moved proximally within the barrel **318** and may be moved distally when the piston **400** is in either the engaged or disengaged position with the plunger **326.** In some embodiments, the piston **400** may be advanced distally to deliver the fluid from the syringe **300** or proximally to fill the syringe **300** with fluid using the drive mechanism **402** operated by the controller **200** (**FIG. 2**).

[00240] In certain embodiments involving manual disengagement of the syringe, to unlock the syringe **300** from the syringe port of the injector and disengage the plunger **326** from the piston **400**, the syringe **300** may be rotated clockwise or counter-clockwise about the syringe longitudinal axis, relative to the syringe port. Because the plunger **326** is substantially free from rotation due to frictional interaction against the syringe barrel **318**, rotation of the syringe **300** also causes the plunger **326** to rotate relative to the piston **400** about the longitudinal piston axis **420**. Due to alignment of the one or more release tabs **380** on the plunger **326** with the toothed portion **444** on the outer surface **442** of the plunger engagement sleeve **414**, rotation of the plunger **326** also rotates the plunger engagement sleeve **414** relative to the plunger release sleeve **458** of the plunger engagement mechanism **412** from the first position to the second position. Because the guiding pin **439** on the plunger engagement post **418** is received within a longitudinal groove **438** of the plunger engagement sleeve **414**, the plunger engagement post **418** also rotates with rotation of the plunger engagement sleeve **414**. Rotation of the plunger engagement post **418** causes the guiding pin **439** to be guided along the ramped surface **466** of the plunger release sleeve **458** (see **FIG. 13F**) and compress the resiliently elastic member **484**. In addition, rotation of the plunger engagement sleeve **414** about the longitudinal piston axis **420** builds potential energy in the biasing member **496**.

[00241] In other embodiments, such as when the syringe in contained within a pressure jacket, rotation of the syringe and plunger to disengage the plunger **326** from piston **400** may not be possible. According to these embodiments, disengaged and engagement of the piston **400** with the plunger **326** may be accomplished electromechanically, for example by using a motorized or electrical actuator to disengage the plunger **326** from the piston **400.** As described herein the motor, such as a linear or rotary electrical motor, or electrical actuator, such as a solenoid, may be used to move the plunger engagement post **418** between the engaged and disengaged positions to engage and disengage the plunger **326** from the piston **400.** When the plunger **326** is in the disengaged position, such as at the end of an injection procedure, syringe **300** may be removed from the injector, and the injector may be readied for the next procedure.

[00242] With reference to **FIG. 13G**, movement of the guiding pin **439** along the ramped surface **466** of the plunger release sleeve **458** causes the plunger engagement post **418** to be

moved axially from the engaged position or state to the disengaged position or state in a proximal direction of arrow **D**. In some embodiments, the piston engagement post **418** can be moved in the proximal direction by energizing the actuator **422** to retract the shaft **472** of the plunger engagement post **418**. In this manner, the plunger engagement post **418** can be moved manually, such as via rotation of the plunger **326** relative to the piston **400**, or via actuation of the actuator **422**. Accordingly, in the event of a power failure, the plunger **326** can be removed from the piston **400**. Movement of the plunger engagement post **418** in the proximal direction opens the receiving space **415** between the plunger engagement sleeve **414** and the plunger engagement post **418** to permit removal of the one or more retaining members **368** of plunger **326** from receiving space **415**. Further, such a configuration where actuation of actuator **422** is only required for engagement may reduce wear on system components and/or motors by only requiring a locking engagement when piston **400** is being moved in a proximal direction.

[00243] With the plunger engagement mechanism **412** in the disengaged position or state, the syringe **300** can be pulled in the distal direction or the piston **400** can be retracted in the proximal direction to remove the plunger **326** from the piston **400** and to remove the syringe **300** and plunger **326** from the fluid injector. During such relative movement of the piston **326** to the plunger **400** in a direction away from each other, the catch **374** is deflected over the locking rib **434** of the piston engagement sleeve **414** to permit a removal of the one or more retaining members **368** from the piston **400**. The plunger **326** can then be freely pulled away from the piston **400**, such as shown in **FIG. 13H**.

[00244] With reference to **FIGS. 13I-13J**, after the plunger **326** is removed from the piston **400**, the plunger engagement sleeve **414** and the plunger engagement post **418** are automatically rotated about the longitudinal piston axis **420** (shown in **FIG. 9**) from the second position to the first position due to the restoring force provided by the biasing member **496**. With movement of the plunger engagement sleeve **414** and the plunger engagement post **418** to the first position, the guiding pin **429** is guided along the ramped surface **466** of the plunger release sleeve **458** toward a distal end of the plunger release sleeve **458** due to the restoring force provided by the resiliently elastic member **484**. This causes the plunger engagement post **418** to move in a distal direction of arrow **E**. The position of the plunger engagement mechanism **412** in **FIG. 13J** is identical to the position of the plunger engagement mechanism **412** in **FIG. 13A**.

[00245] With reference to **FIGS. 14A-14C**, a piston **500** and a plunger engagement mechanism **512** are shown in accordance with another embodiment of the present disclosure. The components of the piston **500** and the plunger engagement mechanism **512** shown in **FIGS.**

14A-14C are substantially similar or identical to the components of the piston **400** and the plunger engagement mechanism **412** described herein with reference to **FIGS. 9-13J**. Accordingly, reference numerals in **FIGS. 14A-14C** are used to illustrate identical components of the corresponding reference numerals in **FIGS. 9-13J**, with the exception that the leading number in reference numbers used in **FIGS. 14A-14C** has been changed from a "4" to a "5". For example, whereas a piston described in connection with **FIGS. 9-13J** is designated by a reference number "400", the piston in **FIGS. 14A-14C** is identified by reference number "500". As the previous discussion regarding the piston **400** and the plunger engagement mechanism **412** generally shown in **FIGS. 9-13J** is applicable to the piston **500** and the plunger engagement mechanism **512** shown in **FIGS. 14A-14C**, only the relative differences between the components shown in these figures are discussed hereinafter.

[00246] Whereas the piston **400** and the plunger engagement mechanism **412** shown in **FIGS. 9-13J** are configured to interact with a plunger **326** shown in **FIGS. 6-8B**, the piston **500** and the plunger engagement mechanism **512** of **FIGS. 14A-14C** are configured for interacting with the plunger **326** of **FIG. 8C**. In this manner, the at least one retaining member **368** shown in **FIGS. 6-8B** is configured for deflecting in a radially outward direction due to contact between the catch **374** and at least a portion of the plunger engagement mechanism **518** on the piston, as described herein. The at least one retaining member **368** shown in **FIGS. 6-8B** is configured to return toward its undeflected state by moving in a radially inward direction.

[00247] With continued reference to **FIG. 14A**, the plunger engagement mechanism **512** has a plunger engagement sleeve **514** having a central opening **516** and a plunger engagement post **518**. The plunger engagement post **518** has a proximal portion **519** that is rotatably connected to the plunger release sleeve **558** such that the plunger engagement post **518** is rotatable about the longitudinal piston axis **520**. With reference to **FIG. 15**, the proximal portion **519** may have a toothed portion **544** at its distal end. As with the toothed portion **444** of the plunger engagement mechanism **412** described herein with reference to **FIGS. 9-13J**, the toothed portion **544** is configured for interacting with the release tabs **380** on the plunger **326** (**FIGS. 8A, 8B,** and **14A**). The plunger engagement post **518** further has a post portion **521** that extends distally from the proximal portion **519**. In some embodiments, the proximal portion **519** and the post portion **521** may be monolithically formed to constitute a unitary part. One or more openings **523** may be formed in the plunger engagement post **518** through a connecting piece **525** connecting the proximal portion **519** to the post portion **521**. The opening **523** may be configured to receive a portion of the plunger engagement sleeve **514** therethrough. An upper surface of the connecting piece **525** defines an engagement surface for contacting at least a

portion of the plunger **326**, such as a drive shoulder **327** of the plunger **326**. The plunger engagement post **518** further has a longitudinal groove **538** configured for receiving the guiding pin **539**. The longitudinal groove **538** has a distal stop **540** for delimiting a distal movement of the guiding pin **539**, and thereby delimiting a distal movement of the plunger engagement sleeve **514** relative to the plunger engagement post **518**.

[00248] The plunger engagement post **518** in **FIGS. 14A-14C** is only rotatable about the piston longitudinal axis **520**. The plunger engagement post **518** may be rotatable about the longitudinal piston axis **520** and the plunger release sleeve **558** between a first position and a second position. In some embodiments, the plunger engagement post **518** may be rotatable in a clockwise direction and a counterclockwise direction, or one of the clockwise direction and a counterclockwise direction. The plunger engagement post **518** may be rotatable from the first position to the second position due to rotational movement of the plunger **326** around the longitudinal piston axis **520**. For example, the plunger engagement post **518** may be rotatable around the longitudinal axis **520** due to interaction of the release tabs **390** on the plunger **326** with the toothed portion **544** on the piston engagement post **518**. A biasing member (not shown), similar to the biasing member **496** shown in **FIG. 9**, may be provided to bias the plunger engagement post **518** to the first position. In this manner, when the plunger engagement post **518** is rotated from the first position toward the second position, the biasing member builds potential energy therein, which is then used to assist in returning the plunger engagement post **518** toward the first position. In some embodiments, the biasing member may be a torsion spring having one end connected to the plunger engagement post **518** and the other end connected to the plunger release sleeve **558**.

[00249] With continued reference to **FIG. 15**, the post portion **521** of the plunger engagement post **518** has a locking groove **527** that is configured to receive the catch **374** of the at least one flexible retaining member **368** of the plunger **326**. The distal end of post portion **521** may be shaped to deflect the at least one retaining member **368** in a radially outward direction due to contact of the catch **374** with an outer surface of the post portion **521**. In certain embodiments, the distal end of post portion **521** may include a ramp to further deflect the at least one retaining member **368** in a radially outward direction. In this manner, distal movement of the piston **500** relative to the plunger **326** causes the at least one retaining member **368** to be deflected radially outward due to the contact between the catch **374** and the outer surface of the post portion **521**. In embodiments having a plurality of retaining members **368**, each of the retaining members **368** is deflected in the radially outward direction.

[00250] With reference to **FIG. 14A**, a plunger release sleeve **558** is at least partially received within hollow body structures of the plunger engagement sleeve **514** and the plunger engagement post **518**. With reference to **FIG. 16**, the plunger release sleeve **558** has a cylindrical sidewall **560** having an opening **562** extending therethrough. The opening **562** may have a longitudinal surface **563** that is substantially parallel with a longitudinal axis **564** of the plunger release sleeve **558** and a ramped surface **566** that is contiguous with the longitudinal surface **563** and is angled downward relative to the longitudinal axis **564** of the plunger release sleeve **558** in a direction from a distal end **568** toward a proximal end **570**. As described herein, the longitudinal surface **563** is configured to guide the guiding pin **539** (**FIG. 14A**) during movement of the plunger engagement sleeve **514** in a longitudinal direction along the longitudinal axis **520** of the piston **500**, while the ramped surface **564** is configured to guide the guiding pin **539** during rotational movement of the plunger **326** relative to the piston **500** (or vice versa), such as during removal of the plunger **326** from the piston **500**.

[00251] With reference to **FIGS. 17A-17B**, the plunger engagement sleeve **514** is shown separate from the rest of the plunger engagement mechanism **512**. The plunger engagement sleeve **514** has a hollow body **524**, at least a portion of which is configured to be received within the proximal portion **519** of the plunger engagement post **518**. A distal portion or end **526** of the plunger engagement sleeve **514** is shaped to be received through the opening **523** on the plunger engagement post **518** (**FIG. 15**) and positioned within the interior cavity **340** of the plunger **326** (**FIG. 14A-14B**). At least a portion of the plunger **326**, such as the at least one retaining member **368**, is configured to be received within the central opening **516** and in the receiving space **515** between the post portion **521** of the plunger engagement post **518** and the distal portion or end **526** of the plunger engagement sleeve **514**. A portion of an inner surface **528** of the central opening **516** may have a ramp **530** such that an inner diameter of the opening **516** narrows in a direction from the distal end **526** of the hollow body toward a proximal portion or end **532**. The ramp **530** may be configured for deflecting the at least one retaining member **368** associated with the plunger **326** in a radially inward direction during connection of the plunger **326** to the piston **500** and creating a tight engaging interaction between the catch **374** of the at least one flexible retaining member **368** and the locking groove **527** of the plunger engagement post **518**.

[00252] With continued reference to **FIGS. 17A-17B**, the hollow body **524** of the plunger engagement sleeve **514** has a through hole **533** configured for receiving the guiding pin **539** therethrough. The plunger engagement sleeve **514** is configured to be rotated about its longitudinal axis **531** due to engagement between guiding pin **539** with ramped surface **566** of

the plunger release sleeve **558** due to the rotation of the plunger **326** and the plunger engagement post **518**.

[00253] Having described the structure of the plunger **326** and the piston **500** in accordance with one non-limiting embodiment of the present disclosure, a method of engagement and disengagement of the plunger **326** with and from the piston **500** will now be described with reference to **FIGS. 14A-14C**.

[00254] **FIG. 14B** shows the piston **500** with its plunger engagement mechanism **512** in a disengaged position or state and prior to a locking engagement with the plunger **326**. In **FIG. 14B** the piston **400** has been advanced in a distal direction toward the plunger **326**. In some embodiments, the piston **500** may be advanced distally using the drive mechanism **402** operated by the controller **200** (**FIG. 2**). In other embodiments, the piston can be manually moved in the distal direction.

[00255] With continued reference to **FIG. 14B**, the catch **374** on the at least one retaining member **368** of the plunger **326** is deflected in a radially outward direction due to contact with the outer surface of post portion **521**. After the catch **374** is positioned within the locking groove **527**, such as when the upper surface of the connecting piece **525** engages the drive shoulder **327** of the plunger **326**, distal movement of the piston **500** relative to the plunger **326** is stopped, and the at least one retaining member **368** can elastically deflect in a radially inward direction such that the catch **374** is positioned within the locking groove **527**. While the at least one retaining member **368** is in the position shown in **FIG. 14B**, the plunger **326** is not in a locked engagement with the piston **500** because, due to the flexibility of the material between the first distal end **370** and a second proximal end **372** (see **FIG. 7**), the at least one retaining member **368** can be deflected in a radially outward direction with proximal movement of the piston **500** or distal movement of the plunger **326** (such as due to removal of the syringe from the injector). With the plunger **326** contacting the piston **500** as shown in **FIG. 14B**, the one or more release tabs **380** on the plunger **326** are aligned with the toothed portion **544** on the plunger engagement post **518**.

[00256] With reference to **FIG. 14A** and **14C**, the plunger engagement sleeve **514** is moved from a disengaged position or state to an engaged position or state. Such movement of the plunger engagement sleeve **514** may be due to de-energizing the actuator and permitting the resiliently elastic member, such as the resiliently elastic member **484** described herein with reference to **FIGS. 9-13J**, to urge the plunger engagement sleeve **514** axially in a distal direction. In other embodiments, such movement of the plunger engagement sleeve **514** may be due to energizing of the actuator to urge the plunger engagement sleeve **514** axially in a

distal direction. For example, the actuator may be actuated by a rotary or linear motor to move the actuator from a disengaged position to an engaged position in a distal direction. Energizing the actuator in this manner causes the plunger engagement sleeve **514** to be moved in the distal direction and builds an elastic restoring force in the resiliently elastic member. Movement of the plunger engagement sleeve **514** in the distal direction closes the receiving space **515** between the plunger engagement sleeve **514** and the plunger engagement post **518** to prevent removal of the one or more retaining members **368** of the plunger **326** from the receiving space **515** and the catch **374** of the one or more flexible retaining member **368** and the locking groove **527**. Once the plunger engagement sleeve **514** is moved to the engaged position or state, the at least one retaining member **368** of the plunger **326** is captured between the plunger engagement sleeve **514** and the plunger engagement post **518** such that proximal axial movement of the piston **500** results in a corresponding proximal axial movement of the plunger **326** within the syringe barrel. The piston **500** and the connected plunger **326** may then be moved reciprocally within the barrel **318** of the syringe **300**.

[00257] To unlock the syringe **300** from the syringe port of the injector and disengage the plunger **326** from the piston **500**, the syringe **300** is rotated clockwise or counter-clockwise about the syringe longitudinal axis, relative to the syringe port. Because the plunger **326** is substantially free from rotation within the syringe barrel **318** due to frictional forces, rotation of the syringe **300** also causes the plunger **326** to rotate relative to the piston **500** about the longitudinal piston axis **520**. Due to alignment of the one or more release tabs **380** on the plunger **326** with the toothed portion **544** on the plunger engagement post **518**, rotation of the plunger **326** also rotates the plunger engagement post **518** relative to the plunger release sleeve **558** from the first position to the second position. Because the guiding pin **539** on the plunger engagement sleeve **514** is received within a longitudinal groove **538** of the plunger engagement post **518**, the plunger engagement sleeve **514** also rotates with rotation of the plunger engagement post **518**. Rotation of the plunger engagement sleeve **514** causes the guiding pin **539** to be guided along the ramped surface **566** of the plunger release sleeve **558** (see **FIG. 16**) moving the plunger engagement sleeve **514** in a proximal direction and compressing the resiliently elastic member, in a manner similar to the operation of the resiliently elastic member **484** described herein with reference to **FIGS. 9-13J**. In addition, rotation of the plunger engagement post **518** about the longitudinal piston axis **520** may build potential energy in the biasing member in a manner similar to the operation of the biasing member **496** described herein with reference to **FIGS. 9-13J**.

[00258] Movement of the guiding pin **539** along the ramped surface **566** of the plunger release sleeve **558** causes the plunger engagement sleeve **514** to be moved axially in a proximal direction from the engaged position or state to the disengaged position or state shown in **FIG. 14A**. In some embodiments, the plunger engagement sleeve **514** can be moved in the proximal direction by energizing or de-energizing the actuator to retract the plunger engagement sleeve **514**. Movement of the plunger engagement sleeve **514** in the proximal direction opens the receiving space **515** between the plunger engagement sleeve **514** and the plunger engagement post **518** to permit removal of the catch **374** of the one or more flexible retaining member **368** and the locking groove **527** and allow removal of the one or more retaining members **368** of the plunger **326** from the receiving space **515**.

[00259] With reference to **FIGS. 18A-18B**, a piston **600** and a plunger engagement mechanism **612** are shown in accordance with another embodiment of the present disclosure. The components of the piston **600** and the plunger engagement mechanism **612** shown in **FIGS. 18A-18B** are substantially similar or identical to the components of the piston **400** and the plunger engagement mechanism **412** described herein with reference to **FIGS. 9-13J**. Accordingly, reference numerals in **FIGS. 18A-18B** are used to illustrate identical components of the corresponding reference numerals in **FIGS. 9-13J**, with the exception that the leading number in reference numbers used in **FIGS. 18A-18B** has been changed from a "4" to a "6". For example, whereas a piston described in connection with **FIGS. 9-13J** is designated by a reference number "400", the piston in **FIGS. 18A-18B** is identified by reference number "600". As the previous discussion regarding the piston **400** and the plunger engagement mechanism **412** generally shown in **FIGS. 9-13J** is applicable to the piston **600** and the plunger engagement mechanism **612** shown in **FIGS. 18A-18B**, only the relative differences between the components shown in these figures are discussed hereinafter.

[00260] With reference to **FIG. 18A**, the plunger engagement mechanism **612** has a plunger engagement sleeve **614** having a central opening **616** and a plunger engagement post **618** that is reciprocally movable within the central opening **616** of the plunger engagement sleeve **614** along a direction of a longitudinal piston axis **620**. The plunger engagement post **618** is reciprocally driven by an actuator, such as an actuator **422** shown in described herein with reference to **FIG. 9**. In some embodiments, the actuator may be a solenoid configured to be predominantly in the disengaged state and may be in the engaged state only during connection of the plunger **326** to the piston. In other embodiments, the actuator may be a rotary electric motor, a linear electric motor, or a linear actuator. In some embodiments, the actuator is a linear actuator that can be back driven manually in the event of a power loss to the injector.

[00261] The plunger engagement mechanism **612** is operable between an engaged position or state, and a disengaged position or state. In the engaged position or state, the plunger engagement post **618** may be positioned within the plunger engagement sleeve **614** to capture at least one retaining member **368** associated with the plunger **326** in a receiving space **615** between the plunger engagement sleeve **614** and the plunger engagement post **618**. Conversely, in the disengaged position or state, the plunger engagement post **618** may be positioned proximally relative to the plunger engagement sleeve **614** to permit removal of the at least one retaining member **368** associated with the plunger **600** from the receiving space **615** between the plunger engagement sleeve **614** and the plunger engagement post **618**.

[00262] With continued reference to **FIG. 18A**, plunger engagement sleeve **614** has a hollow body **624**, wherein at least a portion of an outer surface of the hollow body **624** defines at least a portion of the piston head **606**. A distal portion or end **626** of the plunger engagement sleeve **614** is shaped to be received within the interior cavity **340** of the plunger **326**, while at least a portion of the plunger **326**, such as the at least one retaining member **368**, is configured to be received within the central opening **616**. The central opening **616** extends through the hollow body **624** of the plunger engagement sleeve **614**. An inner surface of the central opening **616** may have a ramp **630** such that an inner diameter of the opening **616** narrows in a direction from the distal end of the hollow body **624** toward a proximal portion or end. The ramp **630** may be configured for deflecting the at least one retaining member **368** associated with the plunger **326** in a radially inward direction during connection of the plunger **326** to the plunger engagement sleeve **614** by contacting the catch **374** of the one or more flexible retaining member **368** as the piston head **606** moves distally relative to the plunger **326**. The ramp **630** may terminate at a locking rib **634**. An outer surface **642** of the plunger engagement sleeve **614** may have a toothed portion **644**, similar to the toothed portion **444** described herein with reference to **FIGS. 9-13J**. The toothed portion **644** may be configured for interacting with the one or more release tabs **380** on the plunger **326** during rotation of the plunger **326** relative to the piston **600** (shown in **FIG. 8C**).

[00263] With reference to **FIG. 18B**, the plunger engagement post **618** is shown separate from the plunger engagement mechanism **612**. The plunger engagement post **618** has a shaft **672** having a proximal end **674** and a distal end **676**. The distal end **676** of the shaft **672** has a tapered end surface **678** configured for contacting the at least one retaining member **368** on the plunger **326** when the plunger engagement post **618** is in an engaged position to prevent removal of the plunger **326** from the piston **600**. The proximal end **674** of the shaft **672** is configured for connecting to an actuator, similar to the actuator **422** described herein with

reference to **FIGS. 9-13J** for moving the plunger engagement post **618** relative to the plunger engagement sleeve **614** between an engaged position or state and a disengaged position or state.

[00264] With continued reference to **FIG. 18B**, the plunger engagement post **618** further includes at least one groove **665** recessed into the body of the shaft **672** at the distal end **676**. In some embodiments, the at least one groove **665** may be configured to receive the at least one retaining member **368** of the plunger **326** when the plunger engagement post **618** is rotated about a longitudinal axis **667**. The at least one groove **665** may be linearly or curvilinearly contiguous between a ledge **679** near the proximal end **674** and the distal end **676** of the shaft **672**. In some embodiments, the at least one groove **665** may extend in a direction parallel to the longitudinal axis **667** of the plunger engagement post **618**.

[00265] With continued reference to **FIG. 18B**, a plurality of grooves **665** are spaced apart radially from the longitudinal axis **667** along a circumference of the distal end **676** of the shaft **672**. In embodiments where more than two grooves **665** are provided, the grooves **665** may be evenly spaced apart from each other and separated from each other by an outer surface **667** of the shaft **672**. In some embodiments, the number and spacing of grooves **665** may correspond to the number and spacing of the retaining members **368** on the plunger **326**. In one exemplary and non-limiting aspect with six retaining members **368** having equal angular separation therebetween, such as shown in **FIG. 8C**, the corresponding plunger engagement post **618** has six grooves **665** separated by 60 degrees from the grooves **665** adjacent on either side.

[00266] With reference to **FIG. 18A**, the proximal end **674** of the shaft **672** is received within a rotating mechanism **671** that is slidably mounted within the hollow body **624** of the plunger engagement sleeve **614**. In some embodiments, the rotating mechanism **671** may have a first portion **673** that is slidably mounted within the hollow body **624** and is fixed from rotating relative to the plunger engagement sleeve **614** and a second portion **675** that is fixed to the plunger engagement post **618** and is rotatable relative to the first portion **673** and the plunger engagement sleeve **614**. In some embodiments, the rotating mechanism **671** may be configured for one-way rotation, such as in a clockwise or a counter-clockwise direction about the longitudinal axis **620**. For example, the rotating mechanism **671** may be a one-way clutch.

[00267] Having described the structure of the plunger **326** and the piston **600** in accordance with one non-limiting embodiment of the present disclosure, a method of engagement and disengagement of the plunger **326** with and from the piston **600** will now be described.

[00268] **FIG. 18A** shows the piston **600** with its plunger engagement mechanism **612** in an engaged position or state with the plunger **326**. As described herein with reference to **FIGS. 13A-13J**, the plunger **326** can be connected to the piston **600** by moving the piston **600** distally

to permit insertion of the one or more retaining members **368** of the plunger **326** into the receiving space **615** between the plunger engagement sleeve **614** and the plunger engagement post **618**. In some embodiments, the piston **600** may be advanced distally using the drive mechanism **402** operated by the controller **200** (**FIG. 2**). In other embodiments, the piston **600** can be manually moved in the distal direction.

[00269] The piston **600** is advanced axially in a distal direction such that the at least one retaining member **368** of the plunger **326** is flexibly received within the central opening **616** of the plunger engagement sleeve **614** such that the at least one retaining member **368** is deflected radially inward due to the contact between the catch **374** and the ramp **630**. In embodiments having a plurality of retaining members **368**, each of the retaining members **368** is deflected in the radially inward direction. In some embodiments, there may be guiding surfaces on sides of tapered end surface **678** to assist with rotation of the plunger engagement post **618** into correct orientation to self-align with retaining members **368** on the plunger **326**.

[00270] During continued axial movement of the piston **600** in a distal direction, the catch **374** is deflected radially inward over the locking rib **634** of the piston engagement sleeve **614**. After the catch **374** is positioned proximally relative to the locking rib **634**, distal movement of the piston **400** relative to the plunger **326** is stopped, such as when the drive shoulder **327** of the plunger **326** engages a corresponding drive ledge **637** on the piston **600**, and the at least one retaining member **368** can elastically deflect in a radially outward direction such that the catch **374** is positioned proximally of the locking rib **634**. In this configuration, the plunger engagement post **618** is still in the disengaged position or state, such as due to activation of the actuator described herein with reference to **FIGS. 9-14C**. With the plunger **326** connected to the piston **600**, the one or more release tabs **380** on the plunger **326** are aligned with the toothed portion **644** on the outer surface **642** of the plunger engagement sleeve **614**.

[00271] With distal movement of the plunger engagement post **618** from the disengaged state or position to the engaged state or position, the receiving space **615** between the plunger engagement sleeve **614** and the plunger engagement post **618** is closed to prevent removal of the one or more retaining members **368** of the plunger **326** from the receiving space **615**. As the plunger engagement post **618** is moved to the engaged position or state, the catch **374** of the at least one retaining member **368** of the plunger **326** is captured between the plunger engagement sleeve **614** and the outer surface **667** of the plunger engagement post **418** proximal to the locking rib **634** . The piston **600** and the connected plunger **326** may then be moved reciprocally within the barrel **318** of the syringe **300**). In some embodiments, the piston **600**

may be advanced distally to deliver the fluid from the syringe **300** or proximally to fill the syringe **300** with fluid using the drive mechanism **402** operated by the controller **200** (**FIG. 2**).

[00272] To unlock the syringe **300** from the syringe port of the injector and disengage the plunger **326** from the piston **600**, the syringe **300** may be rotated clockwise or counter-clockwise about the syringe longitudinal axis, relative to the syringe port. Due to alignment of the one or more release tabs **380** on the plunger **326** with the toothed portion **644** on the plunger engagement sleeve **614**, rotation of the plunger **326** also rotates the plunger engagement sleeve. Because the plunger engagement post **618** is connected to the plunger engagement sleeve **614** via the rotating mechanism **671**, the plunger engagement post **618** does not rotate with rotation of the plunger engagement sleeve **614**. In this manner, the retaining members **368** of the plunger **326** slide into the grooves **665** on the plunger engagement post **618**.

[00273] With the retaining members **368** of the plunger **326** positioned in the grooves **665** on the plunger engagement post **618**, the receiving space **615** between the plunger engagement sleeve **614** and the plunger engagement post **618** is opened to permit removal of the one or more retaining members **368** of the plunger **326** from the receiving space **615** by flexing distal movement of the catch **374** of the at least one retaining member **368** over the locking rib **634**. The syringe **300** can be pulled in the distal direction or the plunger **600** can be retracted in the proximal direction to remove the plunger **326** from the piston **600**. During such relative movement of the piston **326** to the plunger **600** in a direction away from each other, the catch **374** is deflected over the locking rib **634** of the piston engagement sleeve **614** to permit a removal of the one or more retaining members **368** from the piston **600**.

[00274] With reference to **FIGS. 19-21B**, a piston **700** and a plunger engagement mechanism **712** are shown in accordance with another embodiment of the present disclosure. The components of the piston **700** and the plunger engagement mechanism **712** shown in **FIGS. 19-21B** are substantially similar or identical to the components of the piston **400** and the plunger engagement mechanism **412** described herein with reference to **FIGS. 9-13J**. Accordingly, reference numerals in **FIGS. 19-21B** are used to illustrate identical components of the corresponding reference numerals in **FIGS. 9-13J**, with the exception that the leading number in reference numbers used in **FIGS. 19-21B** has been changed from a “4” to a “7”. As the previous discussion regarding the piston **400** and the plunger engagement mechanism **412** generally shown in **FIGS. 9-13J** is applicable to the piston **700** and the plunger engagement mechanism **712** shown in **FIGS. 19-21B**, only the relative differences between the components shown in these figures are discussed hereinafter.

[00275] With initial reference to **19**, the piston **700** and the plunger engagement mechanism **712** are shown in combination with a syringe port **16** of an injector, such as the injector **10** shown in **FIG. 1**. The piston **700** is reciprocally movable within the syringe port **16** in a direction of a longitudinal piston axis **720**, such as via drive mechanism **402** shown in **FIG. 2**.

[00276] With reference to **20**, an exploded view of the piston **700** and the plunger engagement mechanism **712** is shown. The piston **700** has a body **704** and a piston head **706** at a distal end of the body **704**. The piston head **706** is configured for removably connecting to a plunger of a syringe, such as the plunger **326** shown in **FIGS. 7-8B**. The plunger engagement mechanism **712** is integrated into the piston head **706**. In some embodiments, at least a portion of piston head **706** and/or plunger engagement mechanism **712** may be made from a transparent or translucent material that is configured to permit a passage of light emitted by one or more lights in piston **700** for illuminating at least a portion of plunger **326** and/or syringe **300**.

[00277] With continued reference to **20**, the piston **700** has a sensing member **705**, such as a pin **707** and a sensor **709**. The pin **707** has a proximal end **713** configured for contacting the sensor **709** when a distal end **715** of the pin **707** is urged in a proximal direction, such as due to contact between the plunger **326** and the distal end **715** of the pin **707**. The pin **707** may extend along a longitudinal axis **720** of the piston **700** and may protrude through at least a portion of the piston head **706**. The pin **707** may be operative for sensing contact with a surface, such as a surface of the plunger **326**, and send one or more signals to controller **200** (**FIG. 2**) to control a movement of the piston **700** based on the sensed condition. For example, an initial contact between the distal end **715** of the pin **707** and the plunger **326** may cause the pin **707** to be moved in a proximal direction such that it contacts the sensor **709**. The sensor **709** may be operatively connected to controller **200** such that, upon activation of the sensor **709** by the pin **707**, the sensor **709** controls the movement of the drive mechanism of piston **700**. For example, the drive mechanism may be stopped or slowed from a first rate to a second, slower rate and the distal end **715** of the pin **707** and the plunger **326**. The pin **707** may be biased to its distal position by a spring **711**.

[00278] With continued reference to **20**, the plunger engagement mechanism **712** has a plunger engagement sleeve **714** having a central opening **716** and a plunger engagement post **718**. The plunger engagement post **718** is translatable along the direction of the longitudinal piston axis **720** relative to the plunger engagement sleeve **714** due to activation of an actuator **722** (shown in **FIGS. 21A-21B**). In some embodiments, the plunger engagement post **718** may be axially movable between an engaged position, in which the plunger **326** is in a locked engagement with the piston **700** due to capture of the at least one retaining member **368** of the

plunger **326** between the plunger engagement sleeve **714** and the plunger engagement post **718**, and a disengaged portion, in which the plunger **326** can be removed from the piston **700**.

[00279] With continued reference to **20**, the plunger engagement post **718** has a post portion **721** that extends distally from a proximal portion **723**. The plunger engagement post **718** further has a radial groove **737** configured for receiving a guiding pin (not shown). The post portion **721** of the plunger engagement post **718** has a locking lip **729** that is configured to interact with the catch **374** of the at least one retaining member **368** of the plunger **326**. The post portion **721** may be shaped to deflect the at least one retaining member **368** in a radially outward direction due to contact of the catch **374** with an outer surface of the post portion **721** and/or the locking lip **729**. In this manner, distal movement of the piston **700** relative to the plunger **326** causes the at least one retaining member **368** to be deflected radially outward due to the contact between the catch **374** and the post portion **721**. In embodiments having a plurality of retaining members **368**, each of the retaining members **368** is deflected in the radially outward direction.

[00280] With continued reference to **20**, the plunger engagement sleeve **714** has a hollow body **724**, wherein at least a portion of an outer surface of the hollow body **724** defines at least a portion of the piston head **706**. A distal portion or end **726** of the plunger engagement sleeve **714** is shaped to be received within the interior cavity **340** of the plunger **326** (shown in **FIG. 21A**), while at least a portion of the plunger **326**, such as the at least one retaining member **368**, is configured to be received within the central opening **716**. The central opening **716** extends through the hollow body **724** of the plunger engagement sleeve **714**.

[00281] A portion of an inner surface **728** of the central opening **716** at the distal end of the opening **716** may have a stepped inner diameter that decreases in diameter in a direction from a distal end of the plunger engagement sleeve **726** to a proximal end of the plunger engagement sleeve **714**. For example, the opening **716** may have a first step **717** having a first inner diameter and a second step **719** positioned proximally of the first step **717** having a second diameter that is smaller than the first diameter of the first step **717**. A ramp **730** may be provided between the first and second steps **717, 719** for deflecting the at least one retaining member **368** associated with the plunger **326** in a radially inward direction during connection of the plunger **326** to the distal portion or end **726** of the plunger engagement sleeve **714**.

[00282] Having described the structure of the plunger **326** (see disclosure herein with reference to **FIGS. 6-8C**) and the piston **700** in accordance with one non-limiting embodiment of the present disclosure, a method of engagement and disengagement of the plunger **326** with and from the piston **700** will now be described with reference to **FIGS. 21A-21B**. A portion of the syringe **300** is shown in **FIGS. 21A-21B**.

[00283] **FIG. 21A** shows the piston **700** with its plunger engagement mechanism **712** in a disengaged position or state and prior to a locking engagement with the plunger **326**. In some embodiments, the piston **700** may be advanced distally using the drive mechanism **402** operated by the controller **200** (**FIG. 2**). In other embodiments, the piston can be manually moved in the distal direction.

[00284] As piston **700** may be advanced distally, the catch **374** on the at least one retaining member **368** of the plunger **326** is deflected in a radially outward direction due to contact with the locking lip **729** on the post portion **721**. The plunger engagement post **718** is in its disengaged position and is moved axially in a distal direction relative to plunger engagement sleeve **714** such that the retaining member **368** can deflect radially outward into the space defined by the first step **717**. After the catch **374** is positioned proximally relative to the locking lip **729**, the at least one retaining member **368** can elastically deflect in a radially inward direction, for example due to the elastic flexibility of retaining member **368** in combination with ramp **730** between the first and second steps **717, 719**. While the at least one retaining member **368** is in the position shown in **FIG. 21A**, the plunger **326** is not in a locked engagement with the piston **700** because the at least one retaining member **368** can be flexibly deflected in a radially outward direction with proximal movement of the piston **700** or distal movement of the plunger **326** (such as due to removal of the syringe from the injector), as described herein.

[00285] With reference to **FIG. 21B**, the plunger engagement post **718** is moved from a disengaged position or state to an engaged position or state by moving in a proximal direction along the longitudinal piston axis **720**. Such movement of the plunger engagement post **718** may be due to de-energizing the actuator and permitting a resiliently elastic member, such as the resiliently elastic member **484** described herein with reference to **FIGS. 9-13J**, to urge the plunger engagement post **718** axially in a proximal direction or, alternatively by energizing the actuator to move plunger engagement post **718** in the proximal direction. Movement of the plunger engagement post **718** in the proximal direction locks the at least one retaining member **368** and the catch **374** in the space defined by the second step **719** of the plunger engagement sleeve **714**. Due to the smaller second diameter of the second step **719** in combination with the increased diameter of locking lip **729**, the one or more retaining members **368** of the plunger **326** are captured within the receiving space **715** between the plunger engagement sleeve **714** and the plunger engagement post **718** such that reciprocal axial movement of the piston **700** results in a corresponding reciprocal axial movement of the plunger **326** within the syringe barrel **318**. To unlock the plunger **326** from the plunger engagement mechanism **712**, the

plunger engagement post **718** is moved to the disengaged position via axial movement of plunger engagement post **718** in the distal direction, moving locking lip **729** distally, permitting catch **374** of the one or more retaining members **368** to move around locking lip **729** in the first step **717** and allowing removal of the one or more retaining members **368** of plunger **326** from the receiving space **715** between the plunger engagement sleeve **714** and plunger engagement post **718**.

[00286] With reference to **FIGS. 22A-22E**, a piston **800** and a plunger engagement mechanism **812** are shown in accordance with another embodiment of the present disclosure. The components of the piston **800** and the plunger engagement mechanism **812** shown in **FIGS. 22A-22E** are substantially similar or identical to the components of the piston **400** and the plunger engagement mechanism **412** described herein with reference to **FIGS. 9-13J**. Accordingly, reference numerals in **FIGS. 22A-22E** are used to illustrate identical components of the corresponding reference numerals in **FIGS. 9-13J**, with the exception that the leading number in reference numbers used in **FIGS. 22A-22E** has been changed from a "4" to a "8". As the previous discussion regarding the piston **400** and the plunger engagement mechanism **412** generally shown in **FIGS. 9-13J** is applicable to the piston **800** and the plunger engagement mechanism **812** shown in **FIGS. 22A-22E**, only the relative differences between the components shown in these figures are discussed hereinafter.

[00287] With reference to **FIG. 22A**, the piston **800** has a body **804** and a piston head **806** at a distal end of the body **804**. The piston head **806** is configured for removably connecting to a plunger of a syringe, such as the plunger **326** shown in **FIG. 8C**. The plunger engagement mechanism **812** is integrated into the piston head **806**. In some embodiments, at least a portion of the piston head **806** and/or plunger **326** may be made from a transparent or translucent material that is configured to permit a passage of light emitted by one or more lights **803** in the piston **800** for illuminating at least a portion of the plunger **326** and/or the syringe **300**.

[00288] The piston **800** has a sensing member **805**, such as a sensing sleeve **807** and a sensor **809**. The sensing sleeve **807** has a proximal end **813** configured for interacting with the sensor **809** when a distal end **815** of the sensing sleeve **807** is urged in a proximal direction, such as due to contact between the one or more retaining members **368** of the plunger **326** and the distal end **815** of the sensing sleeve **807**. The sensing sleeve **807** may extend along a longitudinal axis **820** of the piston **800** and may be recessed within the piston head **806**. The sensing sleeve **807** may be operative for sensing contact with a surface, such as a surface of the plunger **326**, and a controller **200** may be signaled to control a movement of the piston **800** based on the sensed condition. In some embodiments, the distal end **815** of the sensing sleeve **807** may be

configured for contacting the one or more retaining members **368** of the plunger **326** when the plunger **326** is connected to the piston **800**. An initial contact between the distal end **815** of the sensing sleeve **807** and the one or more retaining members **368** of the plunger **326** may cause the sensing sleeve **807** to be retracted in a proximal direction such that sensing sleeve **807** activates the sensor **809**. The sensor **809** may be operatively connected to controller **200** and the drive mechanism of the piston **800** such that, upon activation of the sensor **809** by the sensing sleeve **807**, the sensor **809** signals controller **200** to control the movement of the drive mechanism. For example, the drive mechanism may be stopped or slowed from a first rate to a second, slower rate. The sensing sleeve **807** may be biased to its distal position by a biasing member, such as spring **817**.

[00289] The plunger engagement mechanism **812** has a plunger engagement sleeve **814** having a central opening **816** and a plunger engagement post **818**. The plunger engagement post **818** is translatable along the direction of the longitudinal piston axis **820** relative to the plunger engagement sleeve **814** due to activation of an actuator, such as an actuator **422** described herein with reference to **FIGS. 9-13J**. In some embodiments, the plunger engagement post **818** may be axially movable between an engaged position, in which the plunger **326** is in a locked engagement with the piston **800** due to capture catch **374** of the at least one retaining member **368** of the plunger **326** under locking rib **834** on the plunger engagement sleeve **814** and the plunger engagement post **818**, and a disengaged portion, in which the plunger **326** can be removed from the piston **800**.

[00290] Plunger engagement sleeve **814** has a hollow body **824**, wherein at least a portion of an outer surface of the hollow body **824** defines at least a portion of the piston head **806**. A distal portion or end **826** of the plunger engagement sleeve **814** is shaped to be received within the interior cavity **340** of the plunger **326**, while at least a portion of the plunger **326**, such as the at least one retaining member **368**, is configured to be received within the central opening **816**. The central opening **816** extends through the hollow body **824** of the plunger engagement sleeve **814**.

[00291] An inner surface of the central opening **816** has a locking rib **834** that protrudes radially inward from the inner surface **828**. The locking rib **834** is configured for deflecting the at least one retaining member **368** associated with the plunger **326** in a radially inward direction during connection of the plunger **326** to the distal portion or end of the plunger engagement sleeve **814**. In some embodiments, the locking rib **834** extends continuously or discontinuously around the inner surface **828** of the hollow body **824** of the plunger engagement sleeve **814** and defines a surface that engages the at least one catch **368** on the at least one retaining member

368 on the plunger **326** to prevent removal of the plunger **326** from the piston **800** when the plunger **326** is in locked engagement with the plunger engagement mechanism **812**, as described herein.

[00292] Having described the structure of the plunger **326** and the piston **800** in accordance with one non-limiting embodiment of the present disclosure, a method of engagement and disengagement of the plunger **326** with and from the piston **800** will now be described with reference to **FIGS. 22A-22E**.

[00293] **FIG. 22A** shows the piston **700** with its plunger engagement mechanism **812** in a disengaged position or state and prior to a locking engagement with the plunger **326**. In some embodiments, the piston **800** may be advanced distally using the drive mechanism **402** operated by the controller **200** (**FIG. 2**). In other embodiments, the piston can be manually moved in the distal direction.

[00294] Moving from **FIG. 22A** to **FIG. 22B**, as the piston **800** is advanced toward the plunger **326**, the at least one retaining member **368** on the plunger **326** contacts the sensing sleeve **807** such that the sensing sleeve **807** is moved proximally toward the sensor **809**. The catch **374** on the at least one retaining member **368** of the plunger **326** is deflected in a radially inward direction due to contact with the locking rib **834** on the plunger engagement sleeve **814**. The plunger engagement post **818** is in its disengaged position, for example retracted in the proximal direction. While the at least one retaining member **368** is in the position shown in **FIG. 22B**, the plunger **326** is not in a locked engagement with the piston **800** because the at least one retaining member **368** can be flexibly deflected in a radially inward direction with proximal movement of the piston **800** or distal movement of the plunger **326** (such as due to removal of the syringe from the injector).

[00295] With reference to **FIG. 22C**, as the sensing sleeve **807** is moved proximally due to contact with the at least one retaining member **368** of the plunger **326**, the sensor **809** detects the presence of the sensing sleeve **807** and actuates the actuator **822** to move the plunger engagement post **818** axially in a distal direction from a disengaged position or state to an engaged position or state. Such movement of the plunger engagement post **718** may be due to de-energizing the actuator **822**. In other embodiments, movement of the plunger engagement post **718** may be due to energizing the actuator **822**, such as a solenoid, or by operation of a motor to move the actuator.

[00296] With movement of the plunger engagement post **818** from the disengaged state or position to the engaged state or position, the receiving space **815** between the plunger engagement sleeve **814** proximal to the locking rib **834** and the plunger engagement post **818**

is closed to prevent removal of the catch **374** of the one or more retaining members **368** of the plunger **326** from the receiving space **815**. As the plunger engagement post **818** is moved to the engaged position or state, the catch **374** of the at least one retaining member **368** of the plunger **326** is captured between the locking rib **834** on the plunger engagement sleeve **814** and the plunger engagement post **818**. The piston **800** and the connected plunger **326** may then be moved reciprocally within the barrel **318** of the syringe. In some embodiments, the piston **800** may be advanced distally to deliver the fluid from the syringe **300** or proximally to fill the syringe **300** with fluid using the drive mechanism **402** operated by the controller **200** (**FIG. 2**).

[00297] With reference to **FIG. 22D**, to unlock the plunger **326** from the plunger engagement mechanism **812**, the plunger engagement post **818** is moved to the disengaged position via axial movement in the distal direction, for example by the actuator (as described herein) or a stored restoring force from a biasing member, which permits removal of the one or more retaining members **368** of the plunger **326** from the receiving space **815** between the plunger engagement sleeve **814** and the plunger engagement post **718**. Removal of the plunger **326** from the piston **800** permits the sensing sleeve **807** to be moved in a distal direction due to a restoring force provided by the spring **817** (**FIG. 22E**).

[00298] With reference to **FIGS. 23A-23G**, a piston **900** and a plunger engagement mechanism **912** are shown in accordance with another embodiment of the present disclosure. Certain components of the piston **900** and the plunger engagement mechanism **912** shown in **FIGS. 23A-23G** are substantially similar or identical to the components of the piston **400** and the plunger engagement mechanism **412** described herein with reference to **FIGS. 9-13J**. As certain features of the previous discussion regarding the piston **400** and the plunger engagement mechanism **412** generally shown in **FIGS. 9-13J** are applicable to the piston **900** and the plunger engagement mechanism **912** shown in **FIGS. 23A-23G**, only the relative differences between the components shown in these figures are discussed hereinafter.

[00299] With reference to **FIG. 23A**, the plunger **326** has at least one retaining member **368** with a catch **374** that protrudes radially outward relative to the plunger longitudinal axis **334**. The catch **374** is shaped to be received within at least a portion of the piston engagement mechanism **912**. In some embodiments, the catch **374** has a rounded or an angled catch surface **375** that is angled at an acute or obtuse angle relative to the plunger longitudinal axis **334**. The angled catch surface **375** is configured to interact with at least a portion of the plunger engagement mechanism **912** during engagement of the plunger **326** with the piston **900**, as described herein. The at least one retaining member **368** may also have at least rounded or one angled release surface **369**. The angled release surface **369** may be provided on at least a portion

of the catch **374**, such as opposite of the angled catch surface **375**. The rounded or angled release surface **369** is angled at an acute or obtuse angle relative to the plunger longitudinal axis **334** in a direction opposite to the arc or angle of the rounded or angled catch surface **375**. The rounded or angled release surface **369** is configured to interact with at least a portion of the plunger engagement mechanism **912** during disengagement of the plunger **326** from the piston **900**, as described herein. In various embodiments, the frictional and locking interaction between the rounded or angled release surface **369**b, without additional support, is insufficient to lockably engage the plunger **326** with the plunger engagement mechanism **912** of piston **900**.

[00300] Piston **900** is extendible and retractable from the housing of the fluid injector **10, 100** (**FIGS. 1** and **3**). The piston **900** includes a stem **901** and a piston head **920** formed on a distal end of the stem **900**. In certain embodiments, piston head **920** may extend radially outwardly beyond the radial edge of the stem **900**. The piston head **920** may be substantially cylindrical in structure with a piston cavity **940** configured for receiving at least a portion of the plunger **326** such as the at least one retaining member **368** when the plunger **326** is connected with the piston **900**. The piston cavity **940** may have at least one locking lip **950** protruding radially inward from an inner surface of the piston cavity **940**. The at least one locking lip **950** is configured for engaging at least a portion of the retaining member **368**, such as the catch **374**. The at least one locking lip **950** may be continuous or discontinuous in a circumferential direction around the piston cavity **940**.

[00301] In some examples, the at least one locking lip **950** has a rounded or angled distal surface **960** and a rounded or angled proximal surface **970**. The rounded or angled distal surface **960** is arced or angled in a same direction as the rounded or angled catch surface **375** of the plunger **326**. In this manner, the distal surface **960** engages the catch surface **375** during the connection process between the piston **900** and the plunger **326** to flexibly and resiliently deflect the one or more retaining members **368** in a radially inward direction toward the plunger longitudinal axis **334** to allow the plunger **326** to be inserted into the piston cavity **940**. The rounded or angled proximal surface **970** is arced or angled in an opposite direction to the rounded angled distal surface **960**. The rounded or angled proximal surface **970** is arced or angled in a same direction as the rounded or angled release surface **369** of the plunger **326**. In this manner, the proximal surface **970** engages the release surface **369** when the piston **900** and/or the plunger **326** is moved axially to disconnect the plunger **326** from the piston **900**. The engagement between the release surface **369** on the plunger **326** and the proximal surface **970** on piston **900** deflects the one or more retaining members **368** in a radially inward direction toward longitudinal axis **334** to allow plunger **326** to be withdrawn from piston cavity **940**.

[00302] With reference to **FIGS. 23A-23G**, the piston **900** has a locking member **980** configured for locking the plunger **326** relative to the piston **900**. The locking member **980** may be movable axially between a first position (**FIG. 23D**) and a second position (**FIG. 23E**). In some examples, the locking member **980** is movable such that it extends at least partially within the piston cavity **940**. When extended in the second position, the locking member **980** is inserted into the cavity **340** of the plunger **326** to prevent deflection of the at least one retaining member **368** in a radially inward direction. For example, in the second, engaged position, locking member **980** locks the catch **374** against the at least one locking lip **950** by holding release surface **369** on the plunger **326** against the proximal surface **970** on the piston **900** such that the catch **374** cannot move past the at least one locking lip **950**. In some embodiments, a sensing member (not shown), such as a spring-loaded pin connected to a sensor, may be provided for sensing contact with a surface, such as a surface of the plunger **326**, and control a movement of the piston **900** based on the sensed condition.

[00303] Having described the structure of the plunger **326** and the piston **900** in accordance with one non-limiting embodiment, the engagement and disengagement of the plunger **326** with and from the piston **900** will now be described with reference to **FIGS. 23A-23G**. The syringe **12**, shown in **FIG. 23A** is omitted from the remainder of **FIGS. 23B-23G** for clarity.

[00304] To engage the plunger **326** with the piston **900**, the syringe **12** is first inserted into the syringe port **16** of the fluid injector **10** (**FIG. 1**) or pressure jacket **15** (**FIG. 3**). Once the syringe **12** is inserted into the syringe port **16**, various locking mechanisms (not shown) may be used to retain the syringe **12** within the syringe port **16** or within a pressure jacket to prevent detachment of the syringe **12** from the syringe port **16**. Initially, the plunger **326** may be positioned at the proximal end **20** of the syringe barrel **18**. The piston **900** may then be advanced distally toward the plunger **326** for engagement of the piston head **920** with the plunger **326**.

[00305] With reference to **FIGS. 23A-23B**, the piston **900** is advanced axially in a distal direction (arrow **A** in **FIGS. 23A-23B**) such that the angled distal surface **960** of the piston head **920** contacts the at least one retaining member **368** of the plunger **326**. Initially, the angled distal surface **960** contacts the catch **374**, such as the catch surface **375**, of the at least one retaining member **368**. Because the catch **374** protrudes radially outward relative to the at least one retaining member **368**, the catch **374** is positioned at a greater radial distance from the plunger longitudinal axis **334** than the inner surface of the piston cavity **940** proximate to the angled distal surface **960**. In this manner, continued distal movement of the piston **900** causes the at least one retaining member **368** to be flexibly and resiliently deflected radially inward due to the contact between the catch surface **375** on the plunger **326** and the distal surface **960**

on the piston **900** (**FIG. 23B**). In examples with a plurality of retaining members **368**, each of retaining members **368** is deflected radially inward relative to plunger longitudinal axis **334**.

[00306] With reference to **FIGS. 23C**, during continued axial movement of the piston **900** in a distal direction, the catch **374** is advanced axially past the at least one lip **950** of the piston head **920**. Due to a restoring force created during a radial deflection of the flexible at least one retaining member **368**, the catch **374** is snapped radially outward into a recess **990** positioned proximally of the at least one locking lip **950** (**FIG. 23A**). The plunger **326** is thus releasably retained within the piston cavity **940**. To lock the plunger **326** with the piston **900** and prevent removal of the plunger **326** from the piston **900**, the locking member **980** is extended from the first position (**FIG. 23D**) to a second position (**FIG. 23E**) by moving the locking member **980** in the axial direction (arrow **B**). In the second position, the locking member **980** is positioned such that the retaining members **368** are locked between an inner surface of the piston cavity **940** and an outer surface of the locking member **980** and are unable to flexibly deflect inwardly to disengage. The locking member **980** prevents the retaining members **368** from moving in a radially inward direction, thereby preventing the plunger **326** from being disconnected from the piston **900**. In this manner, the piston **900** can be moved in a proximal or distal direction, which results in a corresponding movement of the plunger **326**. Locking member **980** may be moved between the disengaged and engaged positions by an electromechanical actuator, such as a solenoid actuator, a rotary motor, a linear motor, and the like. As shown in **FIGS. 23A-23B**, the locking member **980** may be reciprocally moved using a rotary motor to rotate intermeshed surfaces of a threaded, screw drive.

[00307] To unlock the syringe **12** from the syringe port **16** and disengage the plunger **326** from the piston **900**, the locking member **980** is moved from the second position to the first position by moving axially in a direction of arrow **C** shown in **FIG. 23F**. With the locking member **980** in the first position, the plunger **326** can be disconnected from the piston **900** by moving the plunger **326**, via the syringe **12**, in a distal direction (arrow **D** in **FIG. 23G**) and/or moving the piston **900** in a proximal direction. Such relative movement between the piston **900** and the plunger **326** causes the angled release surface **369** of the retaining members **368** to engage the angled proximal surface **970** of the piston **900**. Continued movement of the plunger **326** apart from the piston **900** causes the retaining members **368** to be deflected radially inward in order to clear the lip **950**. After clearing the lip **950**, retaining members **368** spring back in a radially outward direction, whereby plunger **326** is completely disengaged from piston **900**.

[00308] With reference to **FIGS. 24A-24C**, a piston **1000** and a plunger engagement mechanism **1012** are shown in accordance with another embodiment of the present disclosure.

The components of the piston **1000** and the plunger engagement mechanism **1012** shown in **FIGS. 24A-24C** are substantially similar or identical to the components of the piston **400** and the plunger engagement mechanism **412** described herein with reference to **FIGS. 9-13J**. Accordingly, reference numerals in **FIGS. 24A-24C** are used to illustrate identical components of the corresponding reference numerals in **FIGS. 9-13J**, with the exception that the leading number in reference numbers used in **FIGS. 24A-24C** has been changed from a "4" to a "10". As the previous discussion regarding the piston **400** and the plunger engagement mechanism **412** generally shown in **FIGS. 9-13J** is applicable to the piston **1000** and the plunger engagement mechanism **1012** shown in **FIGS. 24A-24C**, only the relative differences between the components shown in these figures are discussed hereinafter.

[00309] With reference to **FIG. 24B**, the plunger engagement mechanism **1012** has a plunger engagement sleeve **1014** having a central opening **1016** and a plunger engagement post **1018** that is reciprocally movable within the central opening **1016** of the plunger engagement sleeve **1014** along a direction of a longitudinal piston axis **1020**. The plunger engagement post **1018** is reciprocally driven by an actuator, such as an actuator **422** shown in described herein with reference to **FIG. 9** or the other embodiments of the plunger engagement mechanism described herein. The plunger engagement mechanism **1012** is operable between an engaged position or state, and a disengaged position or state. In the engaged position or state, the plunger engagement post **1018** may be positioned within the plunger engagement sleeve **1014** to capture at least one retaining member **368** associated with the plunger **326** in a receiving space **615** between the plunger engagement sleeve **1014** and the plunger engagement post **1018** (shown in **FIG. 24C**). Conversely, in the disengaged position or state, the plunger engagement post **1018** may be positioned relative to the plunger engagement sleeve **1014** to permit removal of the at least one retaining member **368** associated with the plunger **326** from the receiving space **1015** between the plunger engagement sleeve **1014** and plunger engagement post **1018**.

[00310] With reference to **FIG. 24B**, plunger engagement sleeve **1014** has a hollow body **1024**, wherein at least a portion of an outer surface of the hollow body **1024** defines at least a portion of the piston head **1006**. A distal portion or end **1026** of the plunger engagement sleeve **1014** is shaped to be received within the interior cavity **340** of the plunger **326**, while at least a portion of the plunger **326**, such as the at least one retaining member **368**, is configured to be received within the central opening **1016**. The central opening **1016** extends through the hollow body **1024** of the plunger engagement sleeve **1014**. An outer surface **1042** of the plunger engagement sleeve **1014** may have a toothed portion **1044**. The toothed portion **1044** may be

configured for interacting with a corresponding toothed portion **329** on the plunger **326** during rotation of the plunger **326** relative to the piston **1000**.

[00311] The plunger engagement sleeve **1014** further includes at least one locking groove **1065** recessed into the inner surface of the central opening **1016**. In some embodiments, the at least one groove **1065** may be configured to receive a catch **374** of the at least one retaining member **368** of the plunger **326** when the plunger **326** is connected to the plunger engagement sleeve **1014**.

[00312] The plunger engagement post **1018** has a shaft **1072** having a proximal end **1074** and a distal end **1076**. The distal end **1076** of the shaft **1072** has a tapered end surface **1078** configured for contacting the at least one retaining member **368** on the plunger **326** to flexibly deflect the at least one retaining member **368** in a radially inward direction as the piston **1000** contacts the plunger **326.** When moved into the engaged position, the plunger engagement post **1018** prevents removal of the plunger **326** from the piston **1000** (shown in **FIG. 24C**), for example by locking catch **374** of the at least one retaining member **368** of the plunger **326** under locking groove **1065** on the plunger engagement sleeve **1014**. The proximal end **1074** of the shaft **1072** is configured for connecting to an actuator, similar to the actuator **422** described herein with reference to **FIGS. 9-13J** for moving the plunger engagement post **1018** relative to the plunger engagement sleeve **1014** between an engaged position or state and a disengaged position or state.

[00313] With reference to **FIG. 24C**, the proximal end **1074** of the shaft **1072** is received within a rotating mechanism **1071** that is slidably mounted within the hollow body **1024** of the plunger engagement sleeve **1014**. In some embodiments, the rotating mechanism **1071** may be configured for one-way rotation, such as in a clockwise or a counter-clockwise direction about the longitudinal piston axis **1020** as described according to various embodiments herein. For example, the rotating mechanism **1071** may be a one-way clutch.

[00314] Having described the structure of the plunger **326** and the piston **1000** in accordance with one non-limiting embodiment of the present disclosure, a method of engagement and disengagement of the plunger **326** with and from the piston **1000** will now be described.

[00315] **FIG. 24C** shows the piston **1000** with its plunger engagement mechanism **1012** in an engaged position or state with the plunger **326**. As described herein with reference to **FIGS. 13A-13J**, the plunger **326** can be connected to the piston **1000** by moving the piston **1000** distally to permit insertion of the one or more retaining members **368** of the plunger **326** into the receiving space **1015** between the plunger engagement sleeve **1014** and the plunger engagement post **1018** such that the catch **374** is within the locking groove **1065**. In some

embodiments, the piston **1000** may be advanced distally using the drive mechanism **402** operated by the controller **200** (**FIG. 2**). In other embodiments, the piston **1000** can be manually moved in the distal direction.

[00316] The piston **1000** is advanced axially in a distal direction such that the at least one retaining member **368** of the plunger **326** is received within the central opening **1016** of the plunger engagement sleeve **1014** such that the at least one retaining member **368** is deflected radially inward due to the contact between the catch **374** and the inner surface of the plunger engagement sleeve **1014**. In embodiments having a plurality of retaining members **368**, each of the retaining members **368** is deflected in the radially inward direction.

[00317] During continued axial movement of the piston **1000** in a distal direction, the catch **374** is deflected radially outward into the locking groove **1065** of the piston engagement sleeve **1014**. After the catch **374** is positioned within the locking groove **1065**, distal movement of the piston **1000** relative to the plunger **326** is stopped, such as due to engagement between the toothed portion **329** on the plunger **326** with the toothed portion **1044** on the outer surface **1042** of the plunger engagement sleeve **1014**. The plunger engagement post **1018** is in the disengaged position or state and the plunger **326** connected to the piston **1000**, the toothed portion **329** on the plunger **326** is aligned with the toothed portion **1044** on the outer surface **1042** of the plunger engagement sleeve **1014**.

[00318] With movement of the plunger engagement post **1018** from the disengaged state or position to the engaged state or position, the receiving space **1015** between the plunger engagement sleeve **1014** and the plunger engagement post **1018** is closed to prevent removal of the one or more retaining members **368** of the plunger **326** from the receiving space **1015** and the locking groove **1065**. As the plunger engagement post **1018** is moved to the engaged position or state, the at least one retaining member **368** of the plunger **326** is captured between the plunger engagement sleeve **1014** and the outer surface of the plunger engagement post **418**. The piston **1000** and the connected plunger **326** may then be moved reciprocally within the barrel **318** of the syringe **300**. In some embodiments, the piston **1000** may be advanced distally to deliver the fluid from the syringe **300** or proximally to fill the syringe **300** with fluid using the drive mechanism **402** operated by the controller **200** (**FIG. 2**).

[00319] To unlock the syringe **300** from the syringe port of the injector and disengage the plunger **326** from the piston **1000**, the syringe **300** is rotated clockwise or counter-clockwise about the syringe longitudinal axis, relative to the syringe port. Due to alignment of the toothed portion **329** on the plunger **326** with the toothed portion **1044** on the plunger engagement sleeve **1014**, rotation of the plunger **326** also rotates the plunger engagement sleeve **1014**. Because

the plunger engagement post **1018** is connected to the plunger engagement sleeve **1014** via the rotating mechanism **1071**, the plunger engagement post **1018** does not rotate with rotation of the plunger engagement sleeve **1014**. In some embodiments, the plunger engagement post **1018** may be movable between an engaged position and a disengaged position via an actuator, such as an actuator **424** described herein with reference to **FIGS. 9-13J**.

[00320] **FIGS. 25A** and **25B** illustrate embodiments of a piston-plunger engagement system according to another embodiment. **FIG. 25A** shows the system in a disengaged position where the plunger comprises an inwardly facing engagement flange or catch **2774** extending proximally from an inner surface of a plunger base. The piston includes at least one flexible retaining member **2750** having at least one retaining catch **2755** configured for engaging the corresponding engagement flange or catch **2774** of the plunger base. In the disengaged position, movable locking member **2798** is configured in the distal, first position such that the locking member **2798** is not engaged with the at least one flexible retaining member **2750** of the piston **2700**. As shown in **FIG. 25B**, the piston-plunger engagement system is in the engaged position, where movable locking member **2798** is moved in the proximal direction, for example by a motor, solenoid, or cam system. As locking member **2798** moves proximally, a proximal surface **2799**, for example the angled surface illustrated in **FIG. 25A** and **25B** contacts and engages the at least one flexible retaining member **2750** flexing the retaining member **2750** in a radially outward direction. As the retaining member **2750** moves radially outward, the at least one retaining catch **2755** engages the at least one inwardly facing engagement flange or catch **2774**, locking the plunger base to the piston. Generally, the at least one inwardly facing engagement flange or catch **2774** is substantially inflexible, for example due to structural strength or the outer surface of plunger engagement sleeve **2714** that prevents engagement flange or catch **2774** from flexing radially outward and disengaging from the at least one retaining catch **2755** of the at least one flexible retaining member **2750.** Moving the locking member **2798** in the distal direction releases the force applied to the at least one flexible retaining member **2750** allowing the retaining member **2750** to return to the non-flexed, disengaged position, where the at least one retaining catch **2755** does not contact or engage the at least one inwardly facing engagement flange or catch **2774** and allows the plunger to be removed from the piston.

[00321] In some embodiments, a resiliently elastic member **2784** may be configured for biasing the locking member **2798** toward the disengaged position or the engaged position. For example, the resiliently elastic member **2784** may be a compression spring that is configured for biasing the locking member **2798** in a distal direction toward the disengaged position. In

this manner, the locking member **2798** is in a normally-disengaged state such that, in the event of a power loss, the plunger can be disconnected from the locking member **2798**. In other embodiments, the resiliently elastic member **2784** may be an extension spring that is configured for biasing the locking member **2798** in a proximal direction toward the engaged position. In such embodiments, the locking member **2798** is in a normally-engaged position and must be moved to the disengaged position, such as using an actuator **422** described herein with reference to **FIG. 9** to permit removal of the plunger from the locking member **2798**.

[00322] Referring to **FIG. 26**, a piston **1100** having a plunger engagement mechanism **1112** is shown in accordance with another embodiment of the present disclosure. In some embodiments, the piston **1100** may be configured for use with injectors **10, 100** shown in **FIG. 1** and **3**. In other embodiments, the piston **1100** may be configured for use with any fluid injector configured for medical use such as injection of contrast and saline in a contrast enhanced imaging procedure. The piston **1100** is configured reciprocal movement within the housing of the injector via a drive mechanism. The drive mechanism may include, for example, an electric motor **402** (**FIG. 2**), hydraulic system, a pneumatic system, or any combination thereof. The controller **200** (**FIG. 2**) may be configured for controlling operation of the drive mechanism and, in turn, controlling reciprocal movement of the piston **1100**.

[00323] The piston **1100** has a body **1104** and a piston head **1106** at a distal end of the body **1104**. The piston head **1106** is configured for removably connecting to the plunger **326** of the syringe **300**. The piston head **1106** has a substantially cylindrical structure with a partially conical distal end configured to be received inside at least a portion of the interior cavity **340** of the plunger **326**. In some embodiments, at least a portion of the piston head **1106** and/or plunger **326** may be made from a transparent or translucent material that is configured to permit a passage of light emitted by one or more lights in the piston **1100** for illuminating at least a portion of the plunger **326** and/or the syringe **300**.

[00324] Piston head **1106** has a plunger engagement mechanism **1112** configured for releasably engaging the plunger **326** to facilitate reciprocally driving the plunger **326** within the barrel of the syringe **300** and ready removal of syringe **300** and plunger **326** from the piston head **1106** and fluid injector at the end of an injection procedure. The plunger engagement mechanism **1112** has a plunger engagement sleeve **1114** having a central opening **1116** and a plunger engagement post **1118** that is reciprocally movable within the central opening **1116** of the plunger engagement sleeve **1114** along a direction of a longitudinal piston axis **1120**. The plunger engagement post **1118** is reciprocally driven by an actuator **1122** of the fluid injector. The plunger engagement mechanism **1112** is operable between an engaged position or state,

and a disengaged position or state. In the engaged position or state, the plunger engagement post **1118** may be positioned within the plunger engagement sleeve **1114** to capture at least one retaining member **368** associated with the plunger **326** in a receiving space **1115** between the plunger engagement sleeve **1114** and the plunger engagement post **1118**. Conversely, in the disengaged position or state, the plunger engagement post **1118** may be positioned relative to the plunger engagement sleeve **1114** to permit removal of the at least one retaining member **368** associated with the plunger **1100** from the receiving space **1115** between the plunger engagement sleeve **1114** and the plunger engagement post **1118**.

[00325] The actuator **1122** may be configured for having an engaged state for moving one of the plunger engagement sleeve **1118** and the plunger engagement post **1118** to the engaged position and a disengaged state for moving one of the plunger engagement sleeve and the plunger engagement post to the disengaged position. In some embodiments, the actuator **1122** may be automatically moved to the disengaged state, such as during power loss to the actuator **1122**. In some embodiments, the actuator **1122** may be in the engaged state only during proximal movement of the piston **1100**. In some embodiments, the actuator **1122** may be a solenoid configured to be predominantly in the disengaged state and may be in the engaged state only during connection of the plunger **326** to the piston **1100**. In other embodiments, the actuator **1122** may be a rotary electric motor, a linear electric motor, or a linear actuator. In some embodiments, the actuator **1122** is a linear actuator that can be back driven manually in the event of a power loss to the injector. In various embodiments, moving one of the plunger engagement sleeve **1118** and the plunger engagement post **1118** to the disengaged state for removal of the plunger **326** from piston **1100** may be accomplished by rotation of the plunger **326** relative to the piston **1100** as described herein.

[00326] With reference to **FIG. 27A**, a plunger engagement sleeve **1114** according to an embodiment is described. The plunger engagement sleeve **1114** has a hollow body **1124**, wherein at least a portion of an outer surface of the hollow body **1124** defines at least a portion of the piston head **1106** (**FIG. 26**). In some embodiments, a distal portion or end **1126** of the hollow body **1124** may have a conical shape configured to correspond to the shape of interior cavity **340** of the conical-shaped portion of the plunger **326**. At least a portion of the plunger **326**, such as the at least one retaining member **368**, is configured to be received within the central opening **1116**. The central opening **1116** extends through the hollow body **1124** of the plunger engagement sleeve **1114**. A proximal end or portion **1132** of the hollow body **1124** may be configured to be received within a plunger release sleeve **1158** (shown in **FIG. 28**).

[00327] At least a portion of an outer surface **1142** of the hollow body **1124** has a toothed portion **1144** that is configured for interacting with one or more release tabs **380** on the plunger **326** during attachment and removal of the plunger **326** from the plunger engagement mechanism **1112**, as described herein. The toothed portion **1144** has one or more plunger release teeth **1145** protruding from the outer surface **1142**. The one or more plunger release teeth **1145** may protrude radially outward from the outer surface **1142** of the hollow body **1124**. The one or more plunger release teeth **1145** are separated from each other by portions of the outer surface **1142** of the hollow body **1124** such that grooves are formed between adjacent plunger release teeth **1145**. In embodiments where more than two plunger release teeth **1145** are provided, the plunger release teeth **1145** may be evenly spaced apart from each other. In some embodiments, the plunger release teeth **1145** may have unequal angular extension and/or unequal angular spacing. The radial spacing of the plunger release teeth **1145** may be selected to correspond to the spacing between the one or more release tabs **380** on the plunger **326**. A distal end **1147** of each of the plunger release teeth **1145** may have a pointed end **1149** that is configured for self-oriented guiding the one or more release tabs **380** on the plunger **326** during connection of the plunger **326** to the plunger engagement sleeve **1114**. As described herein, the one or more plunger release teeth **1145** are configured for interacting with one or more release tabs **380** on the plunger **326** to effect a release of the plunger **326** from the piston upon rotation of the plunger **326** about its longitudinal axis **334**, such as due to rotation of the syringe **300**.

[00328] With reference to **FIG. 27B**, a portion of an inner surface **1128** of the central opening **1116** at the distal end of the opening **1116** may have a ramp **1130** such that an inner diameter of the opening **1116** narrows in a direction from the distal end **1126** of the hollow body **1124** toward a proximal portion or end **1132**. in some embodiments, the ramp **1130** may be configured for deflecting at least a portion of the at least one retaining member **368** associated with the plunger **326** in a radially inward direction during connection of the plunger **326** to the distal portion or end **1126** of the plunger engagement sleeve **1114**. In other embodiments, the ramp **1130** may define a clearance space for at least a portion of the at least one retaining member **368**, such as the catch **374**, during connection of the plunger **326** to the plunger engagement sleeve **1114**. The inner surface **1128** of the central opening **1116** may have a ramped inner diameter that decreases in a direction from a distal end **1126** of the plunger engagement sleeve **1114** towards the proximal end of the plunger engagement sleeve **1114**. For example, the opening **1116** may have a first inner diameter proximally of the ramp **1130** and a second diameter that is smaller than the first diameter distally of the ramp **1130**. The inner surface **1128** of the central opening **1116** may be substantially cylindrical proximally of the

ramp **1130**. In other embodiments, one or both portions the inner surface **1128** before and after ramp **1130** may have a slight incline angled in the same direction as ramp **1130**.

[00329] With reference to **FIGS. 26** and **28**, a plunger release sleeve **1158** surrounds at least a portion of the plunger engagement sleeve **1114**. In some embodiments, the plunger release sleeve **1158** has a hollow body **1159** having an inner cavity **1161** configured for receiving the proximal end or portion **1132** of the plunger engagement sleeve **1114**. In some embodiments, the plunger release sleeve **1158** has a cylindrical sidewall **1160** having an opening **1162** extending therethrough. The opening **1162** may have a longitudinal surface **1163** that is substantially parallel with a longitudinal axis **1164** of the plunger release sleeve **1158** and a ramped surface **1166** that is contiguous with the longitudinal surface **463** and is angled downward relative to the longitudinal axis **1164** of the plunger release sleeve **1158** in a direction from a distal end **1168** toward a proximal end **1170**. As described herein, the longitudinal surface **1163** is configured to guide a guiding pin **1139** associated with the plunger engagement post **1118** during movement of the plunger engagement post **1118** in a longitudinal direction along the longitudinal axis **1120** of the piston **1100**, while the ramped surface **1164** is configured to guide the guiding pin **1139** to move the plunger engagement post **1118** during rotational movement of the plunger **326** relative to the piston **1100**, such as during removal of the plunger **326** from the piston **1100**.

[00330] With reference to **FIG. 29**, the plunger engagement mechanism **1112** further includes a housing **1146** configured for receiving the actuator **1122**. The housing **1146** has a proximal portion **1152** connected to a distal portion **1154**. In some embodiments, the distal portion **1154** may have a smaller outer diameter than the proximal portion **1152** such that a ledge **1156** is defined at a transition between the proximal portion **1152** and the distal portion **1154**. In some embodiments, the ledge **1156** may be configured for supporting a proximal end of a biasing member **1196** configured for releasing the plunger **326** from the piston engagement mechanism **1112** during disengagement of the plunger **326** from the piston **1100**. In some embodiments, the biasing member **1196** may be a torsion spring having a first end connected to the housing **1146** and a second end connected to the plunger release sleeve **1158**.

[00331] With reference to **FIG. 26**, the plunger engagement sleeve **1114** and the plunger release sleeve **1158** are fixed from rotating relative to each other, but are both rotatable about the longitudinal piston axis **1120** relative to the plunger release post **1118** between a first position and a second position, as described herein with reference to **FIGS. 30A-30D**. In some embodiments, the plunger engagement sleeve **1114** and the plunger release sleeve **1158** may be rotatable in a clockwise direction and a counterclockwise direction, or one of the clockwise

direction and a counterclockwise direction. The plunger engagement sleeve **1114** and the plunger release sleeve **1158** may be rotatable from the first position to the second position due to rotational movement of the plunger **326** around the longitudinal piston axis **1120**. For example, the plunger engagement sleeve **1114** and the plunger release sleeve **1158** may be rotatable around the longitudinal axis **1120** due to interaction of the release tabs **380** on the plunger **326** with the toothed portion **1144** on the piston engagement sleeve **1114**. The biasing member **1196** may be configured to bias the plunger engagement sleeve **1114** and the plunger release sleeve **1158** to the first position. In this manner, when the plunger engagement sleeve **1114** and the plunger release sleeve **1158** are rotated from the first position toward the second position, the biasing member **1196** builds potential energy therein, which is then used to assist in returning the plunger engagement sleeve **1114** and the plunger release sleeve **1158** toward the first position.

[00332] With reference to **FIG. 29**, the plunger engagement post **1118** is shown separate from the plunger engagement mechanism **1112**. The plunger engagement post **1118** has a shaft **1172** having a proximal end **1176** and a distal end **1174**. The proximal end **1176** of the shaft **1172** is connected to the housing **1146**. The distal end **1174** of the shaft **1172** has a tapered or rounded end surface **1178** configured for contacting the at least one retaining member **368** on the plunger **326** to flexibly deflect the at least one retaining member **368** radially outward as it passes by the end surface **1178**. A seal **1180** (**FIG. 26**) may be provided at the proximal end **1176** for sealing against the inner surface **1128** of the plunger engagement sleeve **1114**. The seal **1180** may be an O-ring seal.

[00333] Plunger engagement post **1118** further includes the guiding pin **1139** that is configured for guiding the movement of the plunger engagement post **1118** relative to the plunger engagement sleeve **1112** and the plunger release sleeve **1158**. In some embodiments, the guiding pin **1139** extends through the housing **1146** and is arranged substantially perpendicular to a longitudinal axis **1120** of the plunger engagement post **1118**.

[00334] Plunger engagement post **1118** has a locking groove **1127** that is configured to receive the catch **374** of the at least one retaining member **368** of the plunger **326**. The end surface **1178** may be shaped to deflect the at least one retaining member **368** in a radially outward direction due to contact of the catch **374** with an outer surface of the end surface **1178**. In this manner, distal movement of the piston **1100** relative to the plunger **326** causes the at least one retaining member **368** to be deflected radially outward due to the contact between the catch **374** and the rounded or tapered outer surface of the end surface **1178**.

[00335] Plunger engagement post **1118** has a sensing member **1105**, such as a pin **1107** and a sensor **1109**. The pin **1107** has a proximal end **1113** configured for contacting the sensor **1109** when a distal end **1117** of the pin **1107** is urged in a proximal direction, such as due to contact between the plunger **326** and the distal end **1117** of the pin **1107**. The pin **1107** may extend along a longitudinal axis **1120** of the piston **1100** and may protrude through at least a portion of the piston head **1106**. The pin **1107** may be operative for sensing contact with a surface, such as an inner surface of the plunger **326**, , and sending one or more signal to controller **200** of the fluid injector to control a movement of the piston **1100** based on the sensed condition. For example, an initial contact between the distal end **1117** of the pin **1107** and the plunger **326** may cause the pin **1107** to be retracted in a proximal direction such that it activates the sensor **1109**. The sensor **1109** may be operatively connected to controller **200** which controls the drive mechanism of the piston **1100** such that, upon activation of the sensor **1109** by the pin **1107**, the sensor **1109** controls the movement of the drive mechanism. For example, the drive mechanism may be stopped or slowed from a first rate to a second, slower rate. The pin **1107** may be biased to its distal position by a spring **1111**. A seal **1119** may be provided between the pin **1107** and the plunger engagement post **1118** to prevent fluid ingress.

[00336] With continued reference to **FIG. 29**, one or more lights **1173** may be provided on a printed circuit board **1175** on the base of the plunger engagement post **1118**. The one or more lights **1173** may be configured for illuminating at least a portion of the plunger **326** and the plunger engagement sleeve **1114**, as described herein.

[00337] Having described the structure of the plunger **326** and the piston **1100** in accordance with one non-limiting embodiment of the present disclosure, a method of engagement of the plunger **326** with and from the piston **1100** will now be described with reference to **FIGS. 30A-30D**. **FIGS. 31A-31D** show the plunger engagement mechanism **1112** during various stages of disengagement of the plunger **326** from the piston **1100**.

[00338] **FIG. 30A** shows the piston **1100** with its plunger engagement mechanism **1112** in a disengaged position or state and prior to connection with the plunger **326**. In some embodiments, the default state of the plunger engagement mechanism **1112** may be the engaged position or state. In other embodiments, the default state of the plunger engagement mechanism **1112** may be the disengaged position or state. To connect the plunger **326** to the piston **1100**, the syringe **300** is first connected to the injector. During connection of the syringe **300** to the injector, the piston **1100** is withdrawn in the housing of the injector. After connecting the syringe **300** to the injector, the piston **1100** can be advanced in a distal direction toward the plunger **326** within the bore of the syringe **300**.

[00339] With reference to **FIG. 30A**, the actuator **1122** (shown in **FIG. 26**) is operated to its disengaged position or state, wherein the plunger engagement post **1118** is positioned at its distal position. Movement of the plunger engagement post **1118** in the distal direction opens the receiving space **1115** between the plunger engagement sleeve **1114** and the plunger engagement post **1118** to permit insertion of the one or more retaining members **368** of the plunger **326** into the receiving space **1115**. The pin **1107** is in its distal position, while the guiding pin **1139** is at a distal end **1151** of the longitudinal surface **1163** of the opening **1162** (**FIG. 28**) on the plunger release sleeve **1158**.

[00340] With reference to **FIG. 30B**, the piston **1100** is moved axially in a distal direction toward the plunger **326** (indicated by arrow **A1**). In some embodiments, the piston **1100** may be advanced distally using the drive mechanism **402** operated by the controller **200** (**FIG. 2**) of the injector. In other embodiments, the piston can be manually moved in the distal direction. The piston **1100** is advanced axially in a distal direction such that the at least one retaining member **368** of the plunger **326** is received within the central opening **1116** of the plunger engagement sleeve **1114**. As the piston **1100** is advanced in the distal direction toward the plunger **326**, at least a portion of the one or more retaining members **368** on the plunger **326** contacts the tapered end surface **1178** of the plunger engagement post **1118**, which flexibly deflects the retaining members **368** in a radially outward direction. For example, because the catch **374** protrudes radially inward relative to the second end of each retaining member **368**, the catch **374** contacts the tapered surface **1178** of the plunger engagement post **1118**, which deflects the retaining members **368** in a radially outward direction. In embodiments having a plurality of retaining members **368**, each of the retaining members **368** is deflected in the radially outward direction.

[00341] With reference to **FIG. 30C**, during continued axial movement of the piston **1100** in the distal direction, the retaining member **328** is positioned such that the catch **374** can deflect into the locking groove **1127** of the piston engagement post **1118**. After the catch **374** is positioned in the locking groove **1127**, e at least one retaining member **368** can elastically deflect in a radially inward direction and the retaining member **328** may ride up ramp **1130** on the inner surface **1128** of the central opening **1116** and into the second diameter of inner surface **1128**. While the at least one retaining member **368** is in the position shown in **FIG. 30C**, the plunger **326** is not in a locked engagement with the piston **1100** because the at least one retaining member **368** can be deflected in a radially outward direction with proximal movement of the piston **1100** or distal movement of the plunger **326** (such as due to removal of the syringe from the injector), and catch **374** may move out of the locking groove **1127**. With the plunger

326 connected to the piston **1100**, the one or more release tabs **380** on the plunger **326** are aligned with the toothed portion **1144** on the outer surface **1142** of the plunger engagement sleeve **1114** (**FIG. 30A**). The pin **1107** of the sensing member **1105** is moved axially in a proximal direction due to contact with the plunger **326** such that the proximal end **1113** of the pin **1107** can be detected by the sensor **1109**, signaling controller **200** to stop further distal movement of the piston **1100**.

[00342] With reference to **FIG. 30D**, the actuator **1122** (**FIG. 26**) is operated to move the plunger engagement post **1118** in a proximal direction indicated by arrow **B1** from a disengaged position or state to an engaged position or state. Movement of the plunger engagement post **1118** in the distal direction closes the receiving space **1115** between the plunger engagement sleeve **1114** and the plunger engagement post **1118** locking the catch **374** within locking groove **1127** to prevent removal of the one or more retaining members **368** of the plunger **326** from disengaging and moving out of the receiving space **1115**. Once the plunger engagement post **1118** is moved to the engaged position or state, the at least one retaining member **368**, including the catch **374**, of the plunger **326** is captured between the plunger engagement sleeve **1114** and the plunger engagement post **1118** such that axial movement of the piston **1100** results in a corresponding axial movement of the plunger **326** within the syringe barrel. As the plunger engagement post **1118** is moved in the proximal direction, the guiding pin **1139** moves axially in the proximal direction from a distal end **1151** of the longitudinal surface **1163** of the opening **1162** (**FIG. 28**) on the plunger release sleeve **1158** to a proximal end **1153**.

[00343] The piston **1100** and the connected plunger **326** may then be moved reciprocally within the barrel **318** of the syringe **300**. In some embodiments, the piston **1100** may be advanced distally to deliver the fluid from the syringe **300** or proximally to fill the syringe **300** with fluid using the drive mechanism **402** operated by the controller **200** (**FIG. 2**).

[00344] With reference to **FIGS. 31A-31D**, to unlock the syringe **300** from the syringe port of the injector and disengage the plunger **326** from the piston **1100**, the syringe **300** may be rotated clockwise or counter-clockwise about the syringe longitudinal axis **315** (**FIG. 5B**), relative to the syringe port. Because the plunger **326** is substantially free from rotation within the syringe barrel **318** due to frictional contact therebetween, rotation of the syringe **300** also causes the plunger **326** to rotate relative to the piston **1100** about the longitudinal piston axis **1120**. Due to alignment of the one or more release tabs **380** on the plunger **326** with the plunger release teeth **1145** on the toothed portion **1144** of the plunger engagement sleeve **1114**, rotation of the plunger **326** also rotates the plunger engagement sleeve **1114** and the plunger release

sleeve **1158** relative to the plunger engagement post **1118** from the first position to the second position. Because the guiding pin **1139** on the plunger engagement post **1118** is received within the opening **1162** on the plunger release sleeve **1158**, and because the plunger engagement post **1118** is free from rotation about the longitudinal piston axis **1120**, rotation of the plunger engagement sleeve **1114** causes the guiding pin **439** to be guided along the ramped surface **1166** of the plunger release sleeve **1158** (see, also, **FIG. 28**) from a first position shown in **FIG. 30D** to a second position shown in **FIG. 31A** (e.g., from a proximal end of the ramped surface **1166** toward a distal end of the ramped surface **1166**). In addition, rotation of plunger engagement sleeve **1114** about longitudinal piston axis **1120** builds potential energy in the biasing member **1196**.

[00345] With continued reference to **FIG. 31A**, movement of the guiding pin **1139** along the ramped surface **1166** of the plunger release sleeve **1158** causes the plunger engagement post **1118** to be moved axially from the engaged position or state to the disengaged position or state in a distal direction of arrow **C1**. Movement of the plunger engagement post **1118** in the distal direction opens the receiving space **1115** between the plunger engagement sleeve **1114** and the plunger engagement post **1118** to permit distal movement of the one or more retaining members **368** of the plunger **326** from the receiving space **1115** (see **FIG. 31B**).

[00346] With the plunger engagement mechanism **1112** in the disengaged position or state, the syringe **300** can be pulled in the distal direction or the piston **1100** can be retracted in the proximal direction to remove the plunger **326** from the piston **1100**. During such relative movement of the piston **326** to the plunger **1100** in a direction away from each other, the catch **374** of each of the at least one retaining members **368** engages the plunger engagement post **1118** distally of the locking groove **1127** such that each retaining member **368** is flexibly deflected in a radially outward direction (**FIG. 31C**). Continued movement of the piston **1000** relative to the plunger **326** allows the plunger **326** to be freely pulled away from the piston **1100**, such as shown in **FIG. 31D**, allowing removal of the syringe **300** from the injector port.

[00347] With reference to **FIG. 31D**, after the plunger **326** is removed from the piston **1100**, the plunger engagement sleeve **1114** and the plunger engagement post **1118** are automatically rotated about the longitudinal axis **1120** from the second position to the first position due to the restoring force provided by the biasing member **1196**. With movement of the plunger engagement sleeve **1114** and the plunger engagement post **1118** to the first position, the guiding pin **1129** is guided along a top surface **1179** within the opening **1162** of the plunger release sleeve **1158** due to the restoring force provided by the biasing member **1196**.

[00348] Next, referring to **FIGS. 32-35B**, an injector assembly **2000** in accordance with another aspect of the present disclosure is shown. Injector assembly **2000** comprises a housing **2002**, which houses an automated or powered fluid injector. The fluid injector is adapted to interface with and actuate one or more syringes, wherein each syringe may be independently filled with a medical fluid such as contrast media, saline solution, or any desired medical fluid, as is similarly described above with respect to **FIG. 1** or **FIG. 3**. For example, injector housing **2002** is configured to hold syringes **2006a, 2006b**, each containing a medical fluid therein.

[00349] As is known in the art, syringes **2006a, 2006b** are often made of polypropylene or a similar material having a certain minimum wall thickness. During certain procedures, such as angiography imaging procedures, syringes **2006a**, **2006b** may subject to pressures of up to 1200 psi when used to inject fluid into a patient, and thus wall thickness and resilience of the syringe are important in ensuring that the syringe does not radially expand, burst, disengage from the injector, or leak. To further combat possible radial expansion of syringes **2006a**, **2006b** when subject to high pressure injection, respective pressure jackets **2004a**, **2004b** may be utilized to enclose and retain syringes **2006a**, **2006b**. Pressure jackets **2004a**, **2004b** act to limit radial expansion of the syringe barrels. That is, during an injection procedure, exterior walls of syringes **2006a**, **2006b** expand against an interior wall of respective pressure jackets **2004a**, **2004b**, thereby limiting the radial expansion of the exterior walls of syringes that could otherwise lead to bursting or leakage.

[00350] Pressure jackets **2004a**, **2004b** may be separate elements or may be formed in a one-piece, monolithic design. Pressure jackets **2004a**, **2004b** are retained on an injector head of housing **2002** via respective attachment interfaces **2010a**, **2010b**. Suitable nonlimiting examples of pressure jackets including syringe retention features for use in a CV injection procedure are described in International PCT Application PCT/US2020/049885, incorporated herein by reference.

[00351] In addition to radial forces acting on syringes **2006a**, **2006b** and pressure jackets **2004a**, **2004b**, significant axial movement during high pressure injection is also possible due to the elastic nature of the structural components restraining syringes **2006a**, **2006b**. For example, a single 150 ml syringe having a cross-sectional area of 1.6 in^2 at 1200 psi may require a force of 2400 psi to restrain forward motion of the syringe. To restrict this axial motion of syringes **2006a**, **2006b**, respective caps **2008a**, **2008b** may be used to partially encapsulate the distal end of syringes **2006a**, **2006b** and retain syringes **2006a**, **2006b** within the injector and within pressure jackets **2004a**, **2004b** during high-pressure injection. Caps **2008a**, **2008b** may have an opening formed on a distal end thereof to allow at least a portion of a neck **2009a**,

2009b of syringes **2006a**, **2006b** to protrude therethrough, thereby allowing syringes **2006a**, **2006b** to be connected to fluid lines leading to the patient.

[00352] Due to the axial forces imparted on syringes **2006a**, **2006b**, it is desirable for the attachment interfaces between the pressure jackets **2004a**, **2004b** and the housing **2002** and/or between the caps **2008a**, **2008b** and the pressure jackets **2004a**, **2004b** to be of sufficient strength to resist undo axial movement or inadvertent detachment. However, while strength is key, it is also important for an operator to be able to easily remove the caps **2008a**, **2008b** and/or pressure jackets **2004a**, **2004b**, as it is necessary to remove or insert syringes **2006a**, **2006b**. Accordingly, it is desirable for the connection interface between pressure jackets **2004a**, **2004b** and housing **2002** to be sufficiently secure, yet allow for easy attachment and removal. Similarly, it is desirable for the connection interface between caps **2008a**, **2008b** and pressure jackets **2004a**, **2004b** to also be secure, yet allow for easy attachment and removal.

[00353] In order to achieve these desired attributes, attachment interfaces **2010a**, **2010b** of pressure jackets **2004a**, **2004b** may have connector features similar to those of the plunger **326** shown and described with respect to **FIGS**. **6-8C**, while attachment interfaces **2020a**, **2020b** of housing **2002**, shown in **FIG. 32**, may have connector features similar to those of various embodiments of the plunger engagement mechanisms shown and described with reference to **FIGS. 9-31D**. That is, attachment interfaces **2010a**, **2010b** may comprise one or more resiliently flexible retaining members having a catch, similar to the resiliently flexible retaining members **368** and the catch **374** shown and described with reference to **FIGS. 6-8C**, that are positioned circumferentially about an opening on the proximal end of pressure jackets **2004a**, **2004b**. Similarly, attachment interfaces **2020a**, **2020b** of housing **2002** may comprise one or more features, similar to the plunger engagement sleeve and plunger engagement post shown and described with respect **FIGS. 9-31D**.

[00354] In operation, attachment interfaces **2010a**, **2010b**, and **2020a**, **2020b** are configured to interact in manner substantially similar to the interaction between the plunger **326** and the plunger engagement mechanism, as shown and described in detail with respect to **FIGS. 9-31D**. That is, as attachment interfaces **2010a**, **2010b** are axially directed toward respective attachment interfaces **2020a**, **2020b** such that respective attachment interfaces **2010a**, **2010b** and attachment interfaces **2020a**, **2020b** interact to enable the pressure jackets **2004a**, **2004b** to be secured to housing **2002**. One or more retaining members within attachment interfaces **2020a**, **2020b**, which in certain embodiments may protrude inwardly from a distal end of attachment interfaces **2020a**, **2020b**, are then configured to engage a lip of an engagement ring

within each of attachment interfaces **2010a**, **2010b** to securely attach the pressure jackets **2004a**, **2004b** to housing **2002**.

[00355] To detach pressure jackets **2004a**, **2004b** from housing **2002**, pressure jackets **2004a**, **2004b** can be rotated (together or separately) relative to housing **2002**. Rotation of pressure jackets **2004a**, **2004b** allows the attachment interfaces **2010a**, **2010b** to interact with attachment interfaces **2020a**, **2020b**, similar to that which is described above with respect to **FIGS. 9-31D**. This interaction of acts to push the at least one retaining member radially outward or inward such that the at least one retaining member no longer engages the corresponding structure on the attachment interfaces **2010a**, **2010b**, at which point the pressure jackets **2004a**, **2004b** can be axially detached from housing **2002**.

[00356] Alternatively, upon insertion, the proximal end of the body of syringes **2006a**, **2006b** in pressure jackets **2004a**, **2004b** may act analogously to the plunger engagement post, locking the catches of the corresponding flexible retaining members of the pressure jackets in corresponding locking grooves or lips in the pressure jacket ports on the injector. Removal of syringes **2006a**, **2006b** from pressure jackets **2004a**, **2004b**, for example after completion of an injection protocol, may disengage the flexible retaining members of the pressure jackets from corresponding locking grooves or lips in the pressure jacket ports, allowing removal of the pressure jackets from the ports.

[00357] In accordance with an alternative aspect of the disclosure, the structural details of attachment interfaces **2010a**, **2010b** and **2020a**, **2020b** described above could be reversed. That is, attachment interfaces **2010a**, **2010b** of pressure jackets **2004a**, **2004b** could comprise, for example, the at least one retaining member and corresponding features, while the attachment interfaces **2020a**, **2020b** could comprise the features of the plunger engagement mechanism described herein with reference to **FIGS. 9-31D**.

[00358] Next, referring to **FIG. 34**, **FIG. 35A**, and **FIG. 35B**, an alternative aspect of the disclosure is shown. As discussed above with respect to **FIGS. 32-33**, caps **2008a**, **2008b** may generally be disposed about a distal end of respective pressure jackets **2004a**, **2004b** so as to axially retain the respective syringes therein. As shown in **FIG. 35A**, a cap **2008** may have an attachment interface **2014** for attachment to a pressure jacket, as well as an opening **2016** formed therein to allow a portion of the distal end of the syringe to extend therethrough.

[00359] To obtain a secure connection between pressure jackets **2004a**, **2004b** and caps **2008a**, **2008b**, it would be advantageous to configure the respective interfaces between pressure jackets **2004a**, **2004b** and caps **2008a**, **2008b** such that they interact in manner substantially similar to the interaction between various embodiments of the plunger **326** and

various embodiments of the plunger engagement mechanisms shown and described in detail with respect to **FIGS. 9-31D**. As shown in **FIG. 33**, pressure jackets **2004a**, **2004b** may have respective attachment interfaces **2012a**, **2012b** at distal ends thereof for engagement with respective caps **2008a**, **2008b**. Attachment interfaces **2012a**, **2012b** may include one or more plunger engagement mechanisms as shown and described with respect to **FIGS. 9-31D**. Similarly, attachment interface **2014** of cap **2008** shown in **FIG. 35A** may include one or more resiliently deflectable retaining members **368** along with a corresponding catch **374**, as shown and described with reference to **FIGS. 6-8C**. The engagement between attachment interfaces **2012a**, **2012b** of the pressure jackets **2004a**, **2004b** and the attachment interface **2014** of respective caps **2008** may be identical or substantially similar to the engagement between the plunger **326** and the plunger engagement mechanisms described above with respect to **FIGS. 9-31D**. In this way, caps **2008a**, **2008b** may be securely engageable with, and readily detachable from, the distal end of pressure jackets **2004a**, **2004b**.

[00360] As an alternative to a cap **2008** separate from and surrounding a portion of a syringe, **FIG. 35B** shows a syringe assembly **2030** having a syringe body **2032** with a cap **2036** integrated therewith. That is, cap **2036** may be molded or formed directly with syringe body **2032**. A neck portion **2034** extends from a distal surface of cap **2036** to provide a connection point for fluid lines leading to the patient. An attachment interface **2038**, similar to attachment interface **2014** shown and described with respect to **FIG. 35A**, is formed in cap **2038**. As similarly described above with respect to **FIGS. 32** and **35A**, attachment interface **2038** may include features which interact with one of corresponding attachment interface **2012a**, **2012a** of pressure jackets **2004a**, **2004b**. Again, the engagement between attachment interfaces **2012a**, **2012b** of the pressure jackets **2004a**, **2004b** and the attachment interface **2038** of respective syringe assemblies **2030** may be identical or substantially similar to that described above with respect to **FIGS. 9-31D**.

[00361] In accordance with an alternative aspect of the disclosure, the structural details of attachment interfaces **2012a**, **2012b**, and **2014** described above could be reversed. That is, attachment interfaces **2012a**, **2012b** of pressure jackets **2004a**, **2004b** could comprise, for example, the at least one retaining member and corresponding features, while the attachment interface **2014** of each cap **2008** could comprise the corresponding features associate with the plunger engagement mechanism described herein with reference to **FIGS. 9-31D**. Likewise, structural details of attachment interfaces **2012a**, **2012b**, and **2038** described above could be reversed.

[00362] While shown and described as being integrated with pressure jackets **2004a**, **2004b**, one or both of attachment interfaces **2010a**, **2010b** and **2012a**, **2012b** of pressure jackets **2004a**, **2004b** may alternatively be formed of a separate component attachable to the proximal or distal end of pressure jackets **2004a**, **2004b**. In this way, a conventional pressure jacket could be adapted with one or more separate attachment interfaces to enable the pressure jacket to securely interface with an appropriately-equipped housing, a cap similar to cap **2008**, and/or a syringe assembly having an integrated cap, similar to syringe assembly **2030** discussed above.

[00363] Although the disclosure has been described in detail for the purpose of illustration based on what are currently considered to be the most practical and preferred embodiments, it is to be understood that such detail is solely for that purpose and that the disclosure is not limited to the disclosed embodiments, but, on the contrary, is intended to cover modifications and equivalent arrangements. For example, it is to be understood that the present disclosure contemplates that, to the extent possible, one or more features of any embodiment can be combined with one or more features of any other embodiment.