

FEATURES FOR ANGIOGRAPHY SYRINGE

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Patent Application No. 62/706,340, filed on August 11, 2020, and U.S. Provisional Patent Application No. 63/073,519, filed on September 2, 2020, the disclosures of which are incorporated by reference in their entireties.

BACKGROUND

Field of the Technology

[0002] The present disclosure is related generally to features associated with an angiography syringe. The described features provide strength to the distal end, help prevent fluid spillage from the tip, improve ease of use, and improve visualization processes.

Background

[0003] Syringe injection systems are among the medical devices used in medical imaging procedures for many years. Many such syringes are operated manually by advancing a plunger extension in operative connection with an internal plunger to pressurize the fluid within the syringe. In numerous medical injection procedures, however, accurate control and/or high pressures may be employed that cannot be achieved via manual syringe operation. A number of syringes and powered injectors for use therewith have, therefore, been developed for use in medical procedures such as angiography (CV), computed tomography (CT) and nuclear magnetic resonance (NMR)/magnetic resonance imaging (MRI). For example, U.S. Patent No. 5,383,858 discloses a front-loading syringe and powered injector in both pressure jacket and jacketless configurations, the disclosure of which is incorporated herein by reference.

[0004] In certain fluid injectors, such as high pressure fluid injectors including pressure jackets to surround the body of the syringe to prevent syringe expansion and/or failure under the high injection pressures, mounting the syringe on the fluid injector may include multiple steps to correctly engage the syringe with the fluid injector and pressure jacket. For example, some pressure jackets cover large portions of the distal end of the syringe to prevent failure of the distal end under high injection pressures. This may complicate loading of the syringe into the pressure jacket and subsequent engagement with the fluid injector. Similarly, the presence of the pressure jacket around the barrel and distal end of the syringe may make visualization of the syringe and contents difficult, for example ensuring that a liquid has been loaded into a syringe and that no air bubbles are present in the liquid.

[0005] Once the syringe is engaged with the fluid injector, to load syringes with contrast fluid or saline, a user typically connects a fill tube or spike to the front nozzle or discharge outlet of the syringe and places the other end of the tube/spike in fluid communication with a bottle or bag of contrast medium, saline, or other fluid. The plunger of the syringe is retracted (usually by means of an injector piston) to aspirate the fluid into the syringe until the desired amount is loaded into the syringe. After the syringe is filled, the fill tube is removed from the syringe tip. Often, small amounts of contrast or other fluid, such as saline, contained in the fill tube may drip therefrom onto the floor or injector. Fluid drips may also occur in multi-patient set-ups, where a first portion of the syringes and tubing may be used over multiple injection procedures and a second portion may be discarded after a single use and replaced with a new single-use portion before a subsequent injection procedure. Such fluid drips may contaminate and foul various injector components, drip on the floor creating a hazard for the technician and patient, and/or contaminate various surfaces within the fluid injection suite and should be minimized and avoided.

[0006] After the syringe is filled with fluid, a connector tube or priming tube is connected to the discharge outlet of the syringe and the syringe and connector tube are primed (typically by advancing the plunger in the syringe) to eject air from the syringe and the connector tube (i.e., to prevent air from being injected into the patient). While this technique may be effective in purging air from the tubing connected to the syringe, it is undesirable to have fluids dispensed from the end of the tube. Often, the fluids dispensed from the end of the tube foul the exterior surface of the tubing, syringe, and/or injector, drip, or leak from the various connections and fall onto the floor. When dealing with contrast media, this is particularly undesirable because the media is very sticky and tends to migrate to whatever surface the operator touches after purging the tube.

[0007] Furthermore, in some applications a direct vented spike is positioned on top of a syringe. The vented spike is used to pierce a bottle of contrast fluid or saline fluid to be delivered to the patient. In such applications, when the bottle and the spike is removed from the syringe, the fluid remaining in the spike can drip out onto the syringe tip.

[0008] Syringes for use in contrast enhanced imaging procedures that are easily engaged with the injector, allow ready viewing and characterization of the syringe fill state, and reduce the effects of contrast fouling and fluid drippage and enhanced features are desired.

SUMMARY

[0009] The present disclosure provides a syringe suitable for use in powered fluid injections in contrast enhanced imaging procedures, such as computed tomography (CT),

angiography (CV), and magnetic resonance imaging (MRI) that includes features that reduce the impact of fluid drips and further include other features that improve the syringe capabilities, as described herein.

[0010] According to one exemplary and non-limiting embodiment, a syringe may include a proximal end, a distal end, and a cylindrical sidewall extending between the proximal end and the distal end, wherein the distal end comprises a conical distal end wall and a fluid nozzle at a distal end of the conical distal end wall; a cylindrical load bearing wall extending axially from the cylindrical sidewall past a proximal end of the conical distal end wall; and a plurality of radial ribs positioned around a periphery of the conical distal end wall, wherein a longitudinal axis of the plurality of radial ribs extends radially inward from the cylindrical load bearing wall towards the fluid nozzle over at least a portion of the conical distal end wall.

[0011] According to one exemplary and non-limiting embodiment, the plurality of radial ribs may define plurality of fluid retention channels between each pair of adjacent radial ribs, wherein the plurality of fluid retention channels is configured to retain a volume of liquid by capillary adhesion when the syringe is rotated from a first upward facing position to a second downward facing position. The plurality of fluid retention channels may be configured to retain a volume of the liquid ranging from 0.1 to 0.8 milliliters. A volume of the liquid that the plurality of fluid retention channels holds may be at least partially determined from a distance between each adjacent pair of the plurality of radial ribs, a height of each adjacent pair of the plurality of radial ribs, and a distance that each pair of radial ribs distally extend radially inward from the conical distal end wall. The plurality of radial ribs may increase a load strength of the conical distal end wall. The plurality of radial ribs may increase a load strength of the cylindrical load bearing wall. At least one of the plurality of radial ribs may extend a different radial distance inward from the cylindrical load bearing wall over the conical distal end wall than the remaining radial ribs of the plurality of radial ribs. The cylindrical load bearing wall may be configured to abut a retaining surface of a retaining arm of a fluid injector to retain the syringe within a pressure jacket during a pressurized injection procedure. The cylindrical load bearing wall may extend axially from the cylindrical sidewall of the syringe at an angle of from 1 degree to 30 degrees relative to a longitudinal axis of the syringe. A distal surface of the cylindrical load bearing wall may be angled radially from a more proximal inner portion to a more distal outer portion relative to the longitudinal axis of the syringe. The angle of the distal surface of the cylindrical load bearing wall may be configured to prevent entry of fluid between the cylindrical sidewall of the syringe and a pressure jacket in which the syringe is placed. The angle of the distal surface of the cylindrical load bearing wall may be configured to increase a

radially inward force on the retaining arm of the fluid injector. At least one of the cylindrical load bearing wall and the plurality of radial ribs may enhance a refraction halo effect at a distal portion of the conical distal end wall of electromagnetic radiation emitted from at least one electromagnetic radiation source in a piston or plunger head of a fluid injector. A neck may be associated with the fluid nozzle at the distal end of the syringe, the neck including a fluid passageway having a plurality of fluid diverting ribs extending radially inward at least partially into the fluid passageway from an inner surface of the neck. The plurality of fluid diverting ribs may be configured to divert a fluid flowing through the neck into the syringe so that the fluid flows along an internal surface of the conical distal end wall and the cylindrical sidewall of the syringe. The plurality of fluid diverting ribs may be configured to minimize an amount of air bubbles in the fluid in the syringe. The amount of air bubbles in the fluid in the syringe may be minimized by the fluid flowing along the internal surface of the distal end wall and the cylindrical sidewall of the syringe. At least a portion of the plurality of fluid diverting ribs may have different profiles. At least a portion of the plurality of flow diverting ribs may extend from the inner surface at different distances into the fluid passageway. The plurality of radial ribs may extend along the conical distal end wall at an angle relative to a longitudinal axis of the syringe such that a distance between each adjacent pair of the plurality of radial ribs tapers from the cylindrical load bearing wall to the fluid nozzle.

[0012] According to one exemplary and non-limiting embodiment, a syringe may include a proximal end, a distal end, and a cylindrical sidewall extending between the proximal end and the distal end, wherein the distal end comprises a conical distal end wall and a fluid nozzle at a distal end of the conical distal end wall; a plurality of fluid diverting ribs extending inwardly from an inner surface of the fluid nozzle; and a plurality of radial ribs positioned around a periphery of the conical distal end wall, wherein a longitudinal axis of the plurality of radial ribs extends radially inward from the cylindrical load bearing wall towards the fluid nozzle over at least a portion of the conical distal end wall.

[0013] According to one exemplary and non-limiting embodiment, a cylindrical load bearing wall may extend axially from the cylindrical sidewall past a proximal end of the conical distal end wall. The plurality of radial ribs may define a plurality of fluid retention channels between each pair of adjacent radial ribs, wherein the plurality of fluid retention channels is configured to retain a volume of liquid by capillary adhesion when the syringe is rotated from a first upward facing position to a second downward facing position. The plurality of fluid retention channels may be configured to retain a volume of the liquid ranging from 0.1 to 0.8 milliliters. A volume of the liquid that the plurality of fluid retention channels holds may be at

least partially determined from a distance between each adjacent pair of the plurality of radial ribs, a height of each adjacent pair of the plurality of radial ribs, and a distance that each pair of radial ribs distally extend radially inward from the conical distal end wall.

[0014] According to one exemplary and non-limiting embodiment, a syringe may include a proximal end, a distal end, and a cylindrical sidewall extending between the proximal end and the distal end, wherein the distal end comprises a conical distal end wall and a fluid nozzle at a distal end of the conical distal end wall; and a plurality of fluid diverting ribs extending inwardly from an inner surface of the fluid nozzle, wherein the plurality of fluid diverting ribs enhances a refraction halo effect at a distal portion of the conical distal end wall of electromagnetic radiation emitted from at least one electromagnetic radiation source in a piston or plunger head of a fluid injector.

[0015] According to one exemplary and non-limiting embodiment, a cylindrical load bearing wall may extend axially from the cylindrical sidewall past a proximal end of the conical distal end wall. A plurality of radial ribs may be positioned around a periphery of the conical distal end wall, wherein a longitudinal axis of the plurality of radial ribs extends radially inward from the cylindrical load bearing wall towards the fluid nozzle over at least a portion of the conical distal end wall. The plurality of radial ribs may define a plurality of fluid retention channels between each pair of adjacent radial ribs, wherein the plurality of fluid retention channels is configured to retain a volume of liquid by capillary adhesion when the syringe is rotated from a first upward facing position to a second downward facing position. The plurality of fluid retention channels may be configured to retain a volume of the liquid ranging from 0.1 to 0.8 milliliters. A volume of the liquid that the plurality of fluid retention channels holds may be at least partially determined from a distance between each adjacent pair of the plurality of radial ribs, a height of each adjacent pair of the plurality of radial ribs, and a distance that each pair of radial ribs distally extend radially inward from the conical distal end wall.

[0016] In one aspect, a syringe with improved features is provided according to the following clauses.

[0017] Clause 1: A syringe comprising: a proximal end, a distal end, and a cylindrical sidewall extending between the proximal end and the distal end, wherein the distal end comprises a conical distal end wall and a fluid nozzle at a distal end of the conical distal end wall; a cylindrical load bearing wall extending axially from the cylindrical sidewall past a proximal end of the conical distal end wall; and a plurality of radial ribs positioned around a periphery of the conical distal end wall, wherein a longitudinal axis of the plurality of radial

ribs extends radially inward from the cylindrical load bearing wall towards the fluid nozzle over at least a portion of the conical distal end wall.

[0018] Clause 2: The syringe of Clause 1, wherein the plurality of radial ribs defines plurality of fluid retention channels between each pair of adjacent radial ribs, wherein the plurality of fluid retention channels is configured to retain a volume of liquid by capillary adhesion when the syringe is rotated from a first upward facing position to a second downward facing position.

[0019] Clause 3: The syringe of Clause 2, wherein the plurality of fluid retention channels are configured to retain a volume of the liquid ranging from 0.1 to 0.8 milliliters.

[0020] Clause 4: The syringe of Clause 2, wherein a volume of the liquid that the plurality of fluid retention channels holds is at least partially determined from a distance between each adjacent pair of the plurality of radial ribs, a height of each adjacent pair of the plurality of radial ribs, and a distance that each pair of radial ribs distally extend radially inward from the conical distal end wall.

[0021] Clause 5: The syringe of any of Clauses 1 to 4, wherein the plurality of radial ribs increases a load strength of the conical distal end wall.

[0022] Clause 6: The syringe of any of Clauses 1 to 5, wherein the plurality of radial ribs increases a load strength of the cylindrical load bearing wall.

[0023] Clause 7: The syringe of any of Clauses 1 to 6, wherein at least one of the plurality of radial ribs extends a different radial distance inward from the cylindrical load bearing wall over the conical distal end wall than the remaining radial ribs of the plurality of radial ribs.

[0024] Clause 8: The syringe of any of Clauses 1 to 7, wherein the cylindrical load bearing wall is configured to abut a retaining surface of a retaining arm of a fluid injector to retain the syringe within a pressure jacket during a pressurized injection procedure.

[0025] Clause 9: The syringe of any of Clauses 1 to 8, wherein the cylindrical load bearing wall extends axially from the cylindrical sidewall of the syringe at an angle of from 1 degree to 30 degrees relative to a longitudinal axis of the syringe.

[0026] Clause 10: The syringe of any of Clauses 1 to 9, wherein a distal surface of the cylindrical load bearing wall is angled radially from a more proximal inner portion to a more distal outer portion relative to the longitudinal axis of the syringe.

[0027] Clause 11: The syringe of Clause 10, wherein the angle of the distal surface of the cylindrical load bearing wall is configured to prevent entry of fluid between the cylindrical sidewall of the syringe and a pressure jacket in which the syringe is placed.

[0028] Clause 12: The syringe of Clause 10 or Clause 11, wherein the angle of the distal surface of the cylindrical load bearing wall is configured to increase a radially inward force on the retaining arm of the fluid injector.

[0029] Clause 13: The syringe of any of Clauses 1 to 12, wherein at least one of the cylindrical load bearing wall and the plurality of radial ribs enhances a refraction halo effect at a distal portion of the conical distal end wall of electromagnetic radiation emitted from at least one electromagnetic radiation source in a piston or plunger head of a fluid injector.

[0030] Clause 14: The syringe of any of Clauses 1 to 13, further comprising a neck associated with the fluid nozzle at the distal end of the syringe, the neck including a fluid passageway having a plurality of fluid diverting ribs extending radially inward at least partially into the fluid passageway from an inner surface of the neck.

[0031] Clause 15: The syringe of Clause 14, wherein the plurality of fluid diverting ribs are configured to divert a fluid flowing through the neck into the syringe so that the fluid flows along an internal surface of the conical distal end wall and the cylindrical sidewall of the syringe.

[0032] Clause 16: The syringe of Clause 14 or Clause 15, wherein the plurality of fluid diverting ribs are configured to minimize an amount of air bubbles in the fluid in the syringe.

[0033] Clause 17: The syringe of Clause 16, wherein the amount of air bubbles in the fluid in the syringe is minimized by the fluid flowing along the internal surface of the distal end wall and the cylindrical sidewall of the syringe.

[0034] Clause 18: The syringe of any of Clauses 14 to 17, wherein at least a portion of the plurality of fluid diverting ribs have different profiles.

[0035] Clause 19: The syringe of any of Clauses 14 to 18, wherein at least a portion of the plurality of flow diverting ribs extend from the inner surface at different distances into the fluid passageway.

[0036] Clause 20: The syringe of any of Clauses 1 to 19, wherein the plurality of radial ribs extend along the conical distal end wall at an angle relative to a longitudinal axis of the syringe such that a distance between the each adjacent pair of the plurality of radial ribs tapers from the cylindrical load bearing wall to the fluid nozzle.

[0037] Clause 21: A syringe comprising: a proximal end, a distal end, and a cylindrical sidewall extending between the proximal end and the distal end, wherein the distal end comprises a conical distal end wall and a fluid nozzle at a distal end of the conical distal end wall; a plurality of fluid diverting ribs extending inwardly from an inner surface of the fluid nozzle; and a plurality of radial ribs positioned around a periphery of the conical distal end

wall, wherein a longitudinal axis of the plurality of radial ribs extends radially inward from the cylindrical load bearing wall towards the fluid nozzle over at least a portion of the conical distal end wall.

[0038] Clause 22: The syringe of Clause 21, further comprising a cylindrical load bearing wall extending axially from the cylindrical sidewall past a proximal end of the conical distal end wall.

[0039] Clause 23: The syringe of Clause 21 or Clause 22, wherein the plurality of radial ribs defines plurality of fluid retention channels between each pair of adjacent radial ribs, wherein the plurality of fluid retention channels is configured to retain a volume of liquid by capillary adhesion when the syringe is rotated from a first upward facing position to a second downward facing position.

[0040] Clause 24: The syringe of Clause 23, wherein the plurality of fluid retention channels are configured to retain a volume of the liquid ranging from 0.1 to 0.8 milliliters.

[0041] Clause 25: The syringe of Clause 23, wherein a volume of the liquid that the plurality of fluid retention channels holds is at least partially determined from a distance between each adjacent pair of the plurality of radial ribs, a height of each adjacent pair of the plurality of radial ribs, and a distance that each pair of radial ribs distally extend radially inward from the conical distal end wall.

[0042] Clause 26: A syringe comprising: a proximal end, a distal end, and a cylindrical sidewall extending between the proximal end and the distal end, wherein the distal end comprises a conical distal end wall and a fluid nozzle at a distal end of the conical distal end wall; and a plurality of fluid diverting ribs extending inwardly from an inner surface of the fluid nozzle, wherein the plurality of fluid diverting ribs enhances a refraction halo effect at a distal portion of the conical distal end wall of electromagnetic radiation emitted from at least one electromagnetic radiation source in a piston or plunger head of a fluid injector.

[0043] Clause 27: The syringe of Clause 26, further comprising a cylindrical load bearing wall extending axially from the cylindrical sidewall past a proximal end of the conical distal end wall.

[0044] Clause 28: The syringe of Clause 26 or Clause 27, further comprising a plurality of radial ribs positioned around a periphery of the conical distal end wall, wherein a longitudinal axis of the plurality of radial ribs extends radially inward from the cylindrical load bearing wall towards the fluid nozzle over at least a portion of the conical distal end wall.

[0045] Clause 29: The syringe of Clause 28, wherein the plurality of radial ribs defines plurality of fluid retention channels between each pair of adjacent radial ribs, wherein the

plurality of fluid retention channels is configured to retain a volume of liquid by capillary adhesion when the syringe is rotated from a first upward facing position to a second downward facing position.

[0046] Clause 30: The syringe of Clause 29, wherein the plurality of fluid retention channels are configured to retain a volume of the liquid ranging from 0.1 to 0.8 milliliters.

[0047] Clause 31: The syringe of Clause 29, wherein a volume of the liquid that the plurality of fluid retention channels holds is at least partially determined from a distance between each adjacent pair of the plurality of radial ribs, a height of each adjacent pair of the plurality of radial ribs, and a distance that each pair of radial ribs distally extend radially inward from the conical distal end wall.

[0048] The foregoing is a summary and thus may contain simplifications, generalizations, inclusions, and/or omissions of detail; consequently, those skilled in the art will appreciate that the summary is illustrative only and is NOT intended to be in any way limiting. Other aspects, features, and advantages of the devices, and/or processes, and/or other subject matter described herein will become apparent in the teachings set forth herein. In addition to the illustrative aspects and features described above, further aspects and features will become apparent by reference to the drawings and the following detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

[0049] The novel features described herein are set forth with particularity in the appended claims. Such features, however, both as to organization and methods of operation may be better understood by reference to the following description, taken in conjunction with the accompanying drawings.

[0050] **FIG. 1** is a perspective view of a syringe according to one example of the present disclosure.

[0051] **FIG. 2** is a side view of the syringe of **FIG. 1**.

[0052] **FIG. 3** is a cross-sectional view of the syringe of **FIG. 1** along line A-A.

[0053] **FIG. 4** is a top view of the syringe of **FIG. 1**.

[0054] **FIG. 5** is a perspective view of a syringe according to another example of the present disclosure.

[0055] **FIG. 6** is a perspective view of a syringe according to another example of the present disclosure.

[0056] **FIG. 7A** is a cross-sectional view of a syringe held in a retaining arrangement according to one example of the present disclosure.

[0057] **FIG. 7B** is a cross-sectional view of the syringe of **FIG. 7A** being inserted into the retaining arrangement.

[0058] **FIG. 8** is a side view of a syringe according to one example of the present disclosure.

[0059] **FIG. 9** is a close-up side view of distal tip of the syringe of **FIG. 8**.

DETAILED DESCRIPTION

[0060] In the following detailed description, reference is made to the accompanying drawings, which form a part hereof. The illustrative features shown and described in the detailed description, drawings, and claims are not meant to be limiting. Other features may be utilized, and other changes may be made, without departing from the scope of the subject matter presented here.

[0061] Before explaining the various aspects of the syringe assembly and various features thereof in detail, it should be noted that the various aspects disclosed herein are not limited in their application or use to the details of construction and arrangement of parts illustrated in the accompanying drawings and description. Rather, the disclosed devices may be positioned or incorporated in other devices, variations, and modifications thereof, and may be practiced or carried out in various ways. Accordingly, aspects of the syringe and syringe features disclosed herein are illustrative in nature and are not meant to limit the scope or application thereof. Furthermore, unless otherwise indicated, the terms and expressions employed herein have been chosen for the purpose of describing the various aspects of the syringe and syringe features for the convenience of the reader and are not to limit the scope thereof. In addition, it should be understood that any one or more of the components of the syringe and syringe features, expressions thereof, and/or examples thereof, can be combined with any one or more of the other components, expressions thereof, and/or examples thereof, without limitation.

[0062] Also, in the following description, it is to be understood that terms such as front, back, inside, outside, top, bottom and the like are words of convenience and are not to be construed as limiting terms. As used herein, the term “proximal” when used to describe a portion of a syringe is generally used to indicate the portion of the syringe closer to the injector and the term “distal” when used to describe a portion of a syringe is generally used to indicate the portion of the syringe closer to the patient (i.e., the nozzle end of the syringe). Terminology used herein is not meant to be limiting insofar as devices described herein, or portions thereof, may be attached or utilized in other orientations. The various aspects of the syringe and syringe features will be described in more detail with reference to the drawings.

[0063] The present disclosure is drawn to a syringe design for use with a powered fluid injector used in medical imaging procedures. According to various embodiments, certain medical imaging procedures may include injection of a contrast media or agent that highlights certain features in the medical image. Known as contrast enhanced medical imaging, the process generally involves injection of a contrast media with a suitable flushing agent, such as saline, prior to or during the imaging process. Powered fluid injectors have been used to control injection of the fluids and are typically designed with one or more syringes for holding and dispensing the contrast media, the flushing fluid, and other medical fluids administered prior to or during the imaging procedure. For example, U.S. Patent Nos. 5,383,858; 6,652,489; 7,563,249; 8,945,051; 9,173,995; and 10,507,319 disclose front-loading syringes and powered injectors in pressure jacket and jacketless examples, the disclosure is incorporated by this reference. Common contrast enhanced medical imaging procedures include computed tomography (CT), magnetic resonance imaging (MRI), positron emission tomography (PET, SPECT), and angiography (CV). Due to the viscosity and need to deliver volumes of contrast during a short period of time through small diameter tubing sets and/or catheters, to provide a “tight bolus,” certain injection procedures may be performed at high injection pressures, such as pressures up to 300 psi for CT and MRI, and pressures up to 1200 psi for CV procedures. The injector may be configured to inject or dispense the fluid medium contained in the first, second, and/or further syringes in a controlled manner, such as may be employed in medical procedures such as angiography, CT, PET, and NMR/MRI.

[0064] During the injection process, many potential issues may occur that should or must be avoided, for example, difficult or slow loading of the syringe into the pressure jacket, deformation or failure of the syringe or disengaging of syringe from fluid injector due to high injection pressures, dripping of contrast or saline that may foul one or more surfaces on the syringe or injector components, intake of air into the syringe and potential injection of air into the patient, slow fill rates with bubble formation, inability to view syringe contents, among other problems. The presently described syringe and features mitigate or prevent one or more of these issues.

[0065] According to a first embodiment, the present disclosure provides a syringe **2** that may include a proximal end **4**, a distal end **6**, and a cylindrical sidewall **8** extending between the proximal end **4** and the distal end **6**. The distal end **6** may include a fluid nozzle **10** at the distal end **12** of a conical distal end wall **14**, as shown in **FIGS. 1-3**. In various embodiments of the present disclosure, the syringe **2** may include an embodiment of a tubing or spike clip **16** as described in International PCT Application No. PCT/US2021/018523, the disclosure of

which is incorporated in its entirety by this reference. In other embodiments, the syringe may include a luer-type connector (not shown) or other connector mechanism for connecting the syringe to a tubing set and/or spike.

[0066] According to certain embodiments, the syringe **2** may include a cylindrical load bearing wall **18** extending from the cylindrical sidewall **8** distally past a proximal end **20** of the conical distal wall **14**. The cylindrical load bearing wall **18** may protrude along a longitudinal axis **L** and provides a distal surface **22** configured to abut an inner proximal surface **100** of one or more retaining elements **102** at a distal end of one or more retaining arms **103** (see FIGS. **7A** and **7B**) to retain the syringe **2** within the pressure jacket, keep the syringe **2** engaged with the fluid injector, and bear a load associated by a pressurized fluid delivery (e.g., a load produced by a motor of the fluid injector as it pressurizes the fluid using a motorized piston). For example, in a CT injection protocol, the cylindrical load bearing wall **18** may be configured to bear a load of at least 300 psi. According to other embodiments during a CV injection protocol, the cylindrical load bearing wall **18** may be configured to bear a load associated with the high pressures of an angiography injection. For example, in certain angiography injections, the fluid within the syringe **2** may be pressurized up to 1200 psi. The high pressures may be necessary to deliver the viscous contrast agent or less viscous saline solution through a small diameter catheter typically associated with a CV injection procedure. As the cylindrical load bearing wall **18** abuts the inner wall of the distal end of the pressure jacket, the load from the syringe **2** is transferred to the one or more retaining elements **102** at a distal end of one or more retaining arms **103** and ultimately to frame features of the fluid injector. The cylindrical load bearing wall **18** may be continuous or discontinuous around the circumference of the distal end **6** of the syringe **2**. In certain embodiments, the cylindrical load bearing wall **18** is continuous around the circumference of the distal end **6** of the syringe **2**.

[0067] In certain embodiments, as shown in FIGS. **2** and **3**, the cylindrical load bearing wall **18** extends from and flares out from the cylindrical sidewall **8** toward the distal end, such that the distal outer diameter of the load bearing wall **18** is greater than the outer diameter of the cylindrical sidewall **8**. According to certain embodiments, the cylindrical load bearing wall **18** may flare out at an angle of from 1° to 30° relative to the longitudinal axis **L** of the syringe **2**. The flared cylindrical load bearing wall **18** may allow ready installation of the syringe **2** into the pressure jacket **104** and engagement of the syringe **2** and corresponding plunger with the piston of the fluid injector. To be clear, the flared surface **19** flares from the outer surface of the cylindrical sidewall **8** up to the distal surface **22** of the load bearing wall **18**. For example, as illustrated in FIGS **7A** and **7B**, as the syringe is lowered into the pressure jacket past the one

or more retaining elements **102**, the flared cylindrical load bearing wall **18** may push the one or more retaining elements **102** and corresponding retaining arms **103** outward. A user may have to apply a certain amount of downward force (for example, the fluid injector and pressure jacket assembly may be in the vertical position with the open end of the pressure jackets pointing vertically upwards) to allow the downward force to move the one or more retaining elements **102** outwards against a biasing restoring force. Once the distal most end of the cylindrical load bearing wall **18** is pushed past the inner proximal surface **100** of one or more retaining elements **102**, the biasing restoring force may snap the one or more retaining elements **102** back to an initial position where the inner proximal surface **100** of one or more retaining elements **102** abuts the distal angled surface of the cylindrical load bearing wall **18** when the syringe **2** and plunger are placed under load by the piston of the fluid injector. In this manner, a technician may install the syringe **2** into the injector by simply applying a downward force onto the syringe **2** until it snaps into the pressure jacket assembly. In certain embodiments, an audible indication, such as a click or snapping sound, may be heard as the one or more retaining elements snap closed to indicate that the syringe has been correctly installed. Snapping closed may also provide a visual indication to the technician that the syringe is correctly installed. Removal of the syringe **2** may be affected by outward movement of the one or more retaining elements **102** and corresponding retaining arms **103**, either manually by the technician or by a motor of the injector. Suitable embodiments of the retaining arm mechanism are described in International PCT Application No. PCT/US2020/049885, the disclosure of which is incorporated herein by this reference.

[0068] In various embodiments, the outer diameter of the flared cylindrical load bearing wall **18** may closely abut the sidewall of the pressure jacket **104** and/or the one or more retaining elements **102** and substantially prevent entry of any spilled medical fluid, such as contrast or saline, between the cylindrical sidewall **8** of the syringe **2** and the pressure jacket **104** (see FIG. 7A). In certain embodiments, the pressurization of the syringe **2** and associated compliance due to swelling of the sidewall **8** and distal end wall **14** of the syringe **2** under pressurization may further seal the cylindrical sidewall **8** of the syringe **2** against the pressure jacket **104** and/or the one or more retaining elements **102**, further increasing the sealing nature of the interaction. According to various embodiments, an elastomeric coating or material may be placed on the inner proximal surface **100** of one or more retaining elements **102** and/or on the distal surface **22** of the cylindrical load bearing wall **18** to form a fluid tight seal therebetween when the syringe closely abuts the one or more retaining elements **102**.

[0069] Referring to **FIGS. 1-4**, the distal end **6** of the syringe **2** may further include a plurality of radial ribs **24** positioned around a periphery of the conical distal end wall **14**. The plurality of radial ribs **24** extend inward from an inner edge of the cylindrical load bearing wall **18** over at least a portion of the conical distal end wall **14** towards the fluid nozzle **10**. In certain embodiments, the radial ribs **24** may be provided at different lengths along the cylindrical load bearing wall **18**. In other embodiments, the plurality of radial ribs may extend only a short distance along the conical distal end wall **14**, for example, less than 1.5 cm. In the event shorter radial ribs **24** are used, may be easier for a user to identify one or more air bubbles in the syringe **2** since the radial ribs **24** do not significantly block the user's view into the syringe **2**, for example when the fluid injector is in the upright vertical position and the natural buoyancy of the one or more air bubbles causes the air bubbles to rise toward the distal end of the conical end wall **14**. According to various embodiments, the plurality of radial ribs **24** define a plurality of fluid retention channels **26** therebetween. Each fluid retention channel **26** may be located between each pair of adjacent radial ribs **24**. The plurality of fluid retention channels **26** may be configured to retain a volume of liquid that has previously dripped from the fluid nozzle **10**. For example, fluid in the fluid retention channels **26** will be retained within the fluid retention channels **26** when the syringe **2** is rotated from a first vertically upward facing position to a second angled downward facing position. Capillary adhesion (also known as capillary action) and surface tension of the fluid may allow the volume of liquid to be retained in the plurality of fluid retention channels **26** against the force of gravity. Further, the plurality of radial ribs **24** may abut the inner wall of the cylindrical load bearing wall **18** to further retain the fluid. For example, in certain embodiments, the syringe **2** may be filled with a fluid, such as a contrast agent, saline, or other medical fluid, with the injector head and distal end **6** of the one or more syringes **2** in the upright position, for example, for ease of filling the fluid through a spike and/or for controlling and visualizing the amount of air that is taken into the syringe **2** during a filling process. In certain embodiments, during filling through a spike or fluid path, switching between the filling fluid path and a delivery fluid path, or purging of air, a small amount of fluid may seep or drip out of the fluid nozzle **10** of the syringe **2**, such as when the spike or fluid path is removed after filling or purging.

[0070] During many conventional fluid injection procedures, after the upright-configured filling process, an injector head may be rotated so that the distal ends **6** of the one or more syringes **2** are angled downward, for example to ensure that buoyancy causes any air that may remain in the syringe **2** to rise to the proximal end **4** of the syringe **2**, thereby reducing the chance of air injection and embolism. For conventional syringe designs, the volume of dripped

fluid may flow down an outer surface of the syringe, fouling or contaminating various surfaces of the fluid injector. In specific examples, small volumes of fluid may drip off the syringe onto the floor creating a hazard for the technician and patient, and/or contaminate various surfaces within the fluid injection suite. Further, since many contrast agents are sticky and viscous solutions, this may result in a sticky film accumulating on the flooring and other surfaces, potentially creating a safety hazard, and may further increase unnecessary contact with the contrast or other medical fluid and require additional cleaning operations.

[0071] According to various embodiments, the plurality of fluid retention channels **26** may be configured to retain the volume of liquid that has dripped from the fluid nozzle **10**, for example, by capillary adhesion or action between the adjacent radial ribs **24**. As illustrated in **FIG. 4**, the gap width between the adjacent radial ribs **24** may be referred to as **d1**, **d2**, **d3**, wherein some aspects the gap width is constant such that **d1=d2=d3** and in other aspects the gap width is variable such that **d1≠d2≠d3**. In regard to the latter aspects, **d1<d2<d3** or **d1>d2>d3** or the appropriate gap width can be determined in some other manner, without limitation. In various embodiments, since the adjacent radial ribs **24** are arranged radially, the gap width may increase with radial distance from the central longitudinal axis **L** of the syringe **2**. Alternatively, the gap width may remain constant by increasing the width of the radial ribs **24** with radial distance from the central axis. According to various embodiments, the distance between two adjacent radial ribs **24** which define the gap associated with the fluid retention channels **26** (i.e., “d”) may range from 0.01 in to 0.25 in. Further details on capillary action are described in International PCT Publication No. WO 2017/091636, the disclosure of which is incorporated by reference herein.

[0072] According to certain embodiments, the plurality of fluid retention channels **26** may retain a maximum total volume of fluid ranging from 0.1 mL to 0.8 mL when the syringe **2** is rotated from a first upward facing position to a second angled downward facing position. Other embodiments may adjust the maximum total volume of fluid by changing the heights of the plurality of radial ribs and/or changing the distance between adjacent radial ribs. In particular embodiments, the capillary volume of fluid that the adjacent radial ribs **24** may hold is at least partially determined from the distance between each adjacent pair of the plurality of radial ribs **24**, the height of each adjacent pair of the plurality of radial ribs **24**, and a distance that each adjacent pair of the radial ribs **24** distally extend radially inward along the conical distal end wall **14**. That is, the volume of fluid may be determined by one or more of the distance between adjacent pairs of radial ribs **24**, the depth of the fluid retention channels **26** between the adjacent

pairs of radial ribs **24**, and the length of the adjacent pairs of radial ribs **24** and related length of the fluid retention channels **26**.

[0073] In certain embodiments, at least a portion of the plurality of radial ribs **24** extend for different distances from the cylindrical load bearing wall **18** over the conical distal end wall **14**. For example, in **FIG. 4**, the plurality of radial ribs **24** may extend from the cylindrical load bearing wall **18** over a portion of the conical distal end wall **14** of the syringe **2**. In other embodiments, as illustrated in **FIG. 5**, the plurality of radial ribs **24** may extend from the cylindrical load bearing wall **18** up the conical distal end wall **14** of the syringe **2** toward the fluid nozzle **10** of the syringe **2**.

[0074] As illustrated in **FIG. 5**, the plurality of radial ribs **24** may extend different distances from the cylindrical load bearing wall **18** and some of the radial ribs **24** may have different heights compared to others of the radial ribs **24** (see **FIG. 5**). As can be seen in the illustrations, in various embodiments, the plurality of radial ribs **24** abut the cylindrical load bearing wall **18** of the syringe **2**, thereby forming a reservoir on the distal end **6** of the syringe **2** that assists in directing the medical fluid into the fluid retention channels **26** and also provide a further volume to retain the fluid in the reservoir having the cylindrical load bearing wall **18** as a fluid retention wall.

[0075] In other embodiments, as shown in **FIG. 6**, the plurality of ribs **24** may be circumferential and arranged concentrically around the conical distal end wall **14**. The concentric circumferential ribs **28** may be arranged from the cylindrical load bearing wall **18** towards the fluid nozzle **10** of the syringe **2**.

[0076] In various embodiments, including the syringes **2** illustrated in **FIGS. 1-6**, the plurality of radial ribs **24** and/or the plurality of circumferential ribs **28** may increase a load strength of the conical distal end wall **14**. For example, the plurality of radial ribs **24** or circumferential ribs **28** may provide increased thickness to the conical distal end wall **14** where the radial ribs **24** or circumferential ribs **28** are located, thereby reinforcing the strength of the conical distal end wall **14**. In various embodiments, the increased wall strength may assist in withstanding and limiting compliance expansion of the conical distal end wall **14** during a pressurized fluid injection procedure. According to various embodiments, the increased thickness to the conical distal end wall **14** where the radial ribs **24** or circumferential ribs **28** are located may reduce the need for pressure jacket reinforcing of the conical distal end wall **14**. For example, as illustrated in **FIG. 7A**, the pressure jacket **104** may be substantially cylindrical, abutting the syringe retaining elements **102**, and the conical distal end wall **14** of syringe **2** may be able to withstand the high injection pressures (up to 1200 psi) without any reinforcement

from the pressure jacket **104** and/or syringe retaining elements **102**. This can allow easy visualization of the distal conical end wall **14** by the user, for example to check for liquid volume fill and the presence or absence of one or more air bubbles in the syringe **2**.

[0077] In certain embodiments, the plurality of radial ribs **24** may increase a load strength of the cylindrical load bearing wall **18**. For example, the plurality of radial ribs **24** abut and are connected to the cylindrical load bearing wall **18**. This can increase the load strength of the cylindrical load bearing wall **18**, for example by increasing a hoop strength of the wall. The connection between the plurality of radial ribs **24** and the cylindrical load bearing wall **18** may also increase the load strength of the cylindrical load bearing wall **18** by preventing inward or outward deformation or bending of the cylindrical load bearing wall **18** when the pressure load is applied to the syringe **2**.

[0078] As illustrated in **FIGS. 3** and **8**, according to one embodiment of the present disclosure, the proximal end **4** of the syringe **2** may have a wider diameter **D1** than a diameter **D2** of the remaining portion of the cylindrical sidewall **8**. In this example, the “working zone” **7** of the syringe **2** wherein a plunger **106** is pushed through the fluid passageway of the cylindrical sidewall **8** may have a smaller diameter **D2** compared to the diameter **D1** of the “plunger storage zone” **5** at the proximal end **4**. According to this embodiment, the plunger storage zone **5** is a region of the syringe where the plunger is placed during manufacturing and storage and the wider diameter **D1** prevents compression of the outer circumference of the rubber plunger cover during shipping and storage. This ensures a fluid tight seal between the syringe sidewall **8** and the rubber cover of the plunger when the plunger is moved from the wider diameter **D1** of the storage zone **5** to the narrower diameter **D2** of the working zone **7** of syringe **2**. In various embodiments of the present disclosure, a fluid injector in which the syringe **2** is held, may measure a force on a piston motor associated with pushing a plunger **106** through the fluid passageway of the syringe **2** and in particular the extra force required to move the plunger **106** from the wider diameter **D1** of the storage zone **5** to the narrower diameter **D2** of the working zone **7** of syringe **2**. Based on the forces being applied to the piston by the fluid injector, the fluid injector may determine the size of the syringe **2** being used in the fluid injector. For example, in a longer syringe **2** that holds 200 mL of fluid, the piston may push the plunger through the proximal end **4** of the syringe **2** from the plunger storage zone **5** that has the diameter **D1** into the working zone **7** that has a diameter **D2**. Due to **D1** being larger than **D2**, less force is required to push the piston through the proximal end **4** of the syringe **2** than through the working zone **7** of the syringe **2**. Therefore, the fluid injector may calibrate the piston position for when the plunger **106** is pushed into the working zone **7**

of the syringe **2** based on the change in force applied to the piston when moving from the storage zone **5** at the proximal end **4** with the diameter **D1** to the working zone **7** with the diameter **D2**. For longer, larger volume syringes that have a larger working zone **7**, the change in force applied to the piston will occur at a predetermined piston position corresponding to the closeness of the proximal end **4** of the syringe **2** to the injector head, whereas for shorter, smaller volume syringes that have a smaller working zone **7** (for example, 100 mL or 50 mL) that will be positioned more distally in the pressure jacket (i.e., when the distal end **6** of syringe **2** abuts the syringe retaining element **102**), the change in force applied to the piston will occur at a predetermined piston position where the piston is extended farther along the piston path, corresponding to the fact that the proximal end **4** and plunger of the syringe **2** is farther away from the injector head in the initial position.

[0079] The position where the fluid injector registers the change in force applied to the piston due to moving the plunger from the storage zone **5** to the working zone **7** may allow the injector to determine the length and thus, the volume of the syringe that has been loaded into the pressure jacket and make various adjustments to any programmed injection procedure according to this information. Further, if the fluid injector notes that the piston force change does not occur or otherwise notes a deviation in an expected position of the force change, the fluid injector may stop the fluid injection procedure and notify the technician that an error has occurred. For example, if a syringe is inadvertently being reused, the plunger will likely not be in the initial storage zone **5** and the position of the force change will not be in the expected position, thus allowing the fluid injector to notify the technician and prevent inadvertent re-use of a syringe. Likewise, if the plunger has been inadvertently moved into the working zone **7**, for example during shipping, the fluid injector will note that the force change is missing and prevent use of a potentially damaged syringe (e.g., where the fluid seal between the plunger and syringe sidewall may be compromised).

[0080] In other embodiments, as shown in **FIG. 7A**, the cylindrical load bearing wall **18** may have a distal surface **22** configured for interfacing and abutting with a proximal surface **100** of a syringe retaining elements **102** of the syringe retention arms **103** of the fluid injector. According to specific embodiments, the distal surface **22** of the cylindrical load bearing wall **18** may be radially angled such that the inner circumferential edge of the distal surface **22** is proximal along the longitudinal axis relative to the outer circumferential edge of the distal surface **22**. According to this embodiment, the corresponding proximal surface **100** of the syringe retaining elements **102** is radially angled in the complementary similar direction than the radial angle of distal surface **22** of the cylindrical load bearing wall **18**. According to various

embodiments, the angle of the distal surface **22** may range from 1° to 89° and in particular embodiments from 1° to 30° with the angle of the corresponding proximal surface **100** being complementary. As such, when the radially angled distal surface **22** of the cylindrical load bearing wall **18** interfaces with the corresponding radially angled proximal surface **100** of the syringe retaining elements **102** when the syringe **2** is under load during a delivery process, the two surfaces **22** and **100** interact as the pressurized syringe **2** is urged in the distal direction along the longitudinal axis **L** such that a retaining force is established on the retention arms **103** that urges the retaining arms **103** radially inward to maintain the closed configuration. As such, the forces retaining the syringe **2** within the pressure jacket **104** and the retention mechanism of the fluid injector is increased during a pressurized delivery of fluid during a contrast injection procedure. In one non-limiting example, as the syringe **2** is inserted into the fluid injector, the cylindrical load bearing wall **18** may be configured to move the retaining arms **103** outwardly to open the retaining arms **103** to allow the syringe **2** to move into the fluid injector. After the syringe **2** has moved past the syringe retaining elements **102**, the retaining arms **103** may be configured to move inwardly to close in on one another to retain the syringe **2** in the fluid injector.

[0081] As described in U.S. Patent No. 10,420,902, the disclosure of which is incorporated by this reference, and shown in **FIGS. 8 and 9**, the presence of small amounts of air (up to 5% of total volume of syringe) in the syringe **2** may be visualized by the presence or absence of an illuminated halo **40a** at the conical distal end **6** of the syringe **2**. For example, electromagnetic radiation may be reflected and refracted from a colored surface or shown through a translucent or transparent plunger cap (from light sources in the piston head). If the syringe **2** is fully filled with a liquid fluid, the electromagnetic radiation will refract/reflect against the syringe sidewall **8** and conical distal end wall **14** to show a refraction halo effect in the form of an illuminated halo **40a** around the circumference of the distal portion of the conical distal end **6** of the syringe **2**. In the presence of small amounts of air (for example up to 5 mL or more), the illuminated halo **40a** is not observed. This provides a method for a technologist to visually determine if there is air in the syringe **2** and perform a purge/prime operation to remove the air and prevent injection of air into the patient. In certain embodiments, the visualization process may also be performed by the injector when fitted with an appropriate camera and associated software. According to various embodiments of the present disclosure, at least one of the cylindrical load bearing wall **18** and the plurality of radial ribs **24** may enhance an amount of electromagnetic radiation refracted at the distal end **6** of the syringe **2** when the syringe **2** is filled with a liquid. For example, the plurality of radial ribs **24** may act similar to a Fresnel lens and increase the

reflection/refraction of the electromagnetic radiation creating a brighter illuminated halo at the around the circumference of the distal portion of the conical distal end **6** of the syringe **2**. In other embodiments, the electromagnetic radiation may also reflect back from the distal conical end and illuminate a halo **40b** around at least a portion of the cylindrical load bearing wall **18**, for example around the plurality of radial ribs **24**. In specific embodiments, the electromagnetic radiation may be emitted from at least one electromagnetic radiation source in a piston head of a fluid injector. In other embodiments, the electromagnetic radiation may be reflected from at least a portion of a surface of a plunger **106** of a syringe **2**.

[0082] In certain embodiments, the syringes **2** of the present disclosure may include one or more features that improve fluid flow into and out of the syringe **2** during fluid fill and fluid delivery processes. According to various embodiment, the syringe **2** may include a neck associated with the fluid nozzle **10** at the distal end **6** of the syringe **2**. The neck may include a larger diameter than conventional syringes, for example to include a connector element as described in International PCT Application No. PCT/US2021/018523. The neck of syringe **2** may include a fluid passageway having a plurality of fluid diverting ribs **30** extending radially inward from an inner surface of the neck at least partially into the fluid passageway, as illustrated in **FIGS. 3** and **4**.

[0083] According to various embodiments, the plurality of fluid diverting ribs **30** may divert a fluid flowing through the fluid nozzle **10** into the syringe **2** during a filling procedure so that the fluid flows along internal surfaces of the conical distal end wall **14** and the cylindrical sidewall **8** of the syringe **2**. In certain embodiments, the plurality of fluid diverting ribs **30** may include ribs extending radially inward for different distances (compare ribs **30** and **31** in **FIG. 4**) and/or extend for different lengths along the longitudinal axis **L** of the fluid nozzle **10**. While not intending to be limited by any interpretation, the redirection of fluid flow through the syringe fluid nozzle **10** is believed to be a result of a Coanda effect, where the fluid diverting ribs **30** result in the fluid adhering to the internal sidewall of the conical distal end wall **14** and the cylindrical sidewall **8** of the syringe **2**. For example, capillary adhesion of the fluid against the walls of the fluid diverting ribs **30** may allow surface tension to hold the fluid against the internal sidewalls of the neck and continue into the internal sidewall of the conical distal end wall **14** and the cylindrical sidewall **8**. Flowing the fluid down the inner sidewalls of the syringe instead of allowing the fluid to flow into the syringe without contacting the inner sidewalls results in fewer air bubbles in the fluid during the filling procedure. In contrast, with conventional syringes without fluid diverting ribs **30**, the fluid may flow/drip down the middle of the syringe fluid nozzle **10** and drip to the plunger **106** resulting in formation of air bubbles

in the fluid. These air bubbles may adhere to the plunger **106** and sidewall surfaces and are typically difficult to remove during a priming sequence. The resulting air bubbles may increase the chances of air embolism by injection of small amounts of air, particularly in angiography procedures. As noted, particularly with high pressure CV imaging procedures, any air bubbles in the syringe and/or fluid path must be avoided to prevent air embolism. According to these embodiments, the fluid diverting ribs **30** minimize an amount of air bubbles in the fluid in the syringe **2**. Previous work had shown that a fluid diverter in the middle of the flow path through the nozzle reduces bubble formation during fill, see for example International PCT Publication No. WO 2017/0914643, the disclosure of which is incorporated by reference herein. The described fluid diverting ribs **30** provide a similar effect without the need for a fluid diverter feature in the flow path, thus simplifying manufacture and injection molding of the syringe **2**. The amount of air bubbles in the fluid in the filled syringe **2** may be minimized by the fluid flowing along the internal surfaces of the distal end wall **14** and the cylindrical sidewall **8** of the syringe **2**, rather than dripping/flowing directly from the syringe fluid nozzle **10** to the plunger surface. In one embodiment of the present disclosure, the fluid diverting ribs **30** may also increase the illuminated circumferential halo effect described herein to identify whether air bubbles are present in the syringe **2**. As observed with the plurality of radial ribs **24**, the fluid diverting ribs **30** may magnify and further reflect/refract incident electromagnetic radiation, increasing the brightness of the observed illuminated halo at the around the circumference of the distal portion of the conical distal end **6** of the syringe **2**. In specific embodiments, at least a portion of the plurality of fluid diverting ribs **30** may have different cross-sectional profiles. In other embodiments, at least a portion of the plurality of fluid diverting ribs **30** may extend from the inner surface of the fluid nozzle **10** for different distances into the distal portion of the conical distal end **6** of the syringe **2**.

[0084] According to various embodiments, the plurality of fluid diverting ribs **30** may also allow for increased filling speeds, for example potentially due to more laminar flow of the fluid into the syringe **2** as the fluid passes the fluid diverting ribs **30**. Thus, the time between procedures may be substantially decreased as the syringes may be filled faster than conventional syringes. In addition, the fill rate may be increased since the formation of bubbles during filling is reduced, resulting in smaller prime volumes and lower production of waste fluids associated with greater prime volumes.

[0085] According to various embodiments, the presently described features may increase the ease of injection molding a syringe **2**. For example, syringes **2** may be formed from a medical grade plastic, such as PET, polycarbonate, polyethylene, and blends thereof, and may

be formed into the syringe shape by an injection molding process. During injection molding, features may cause issues during removal of the item from the mold, such as the presence of undercuts due to the features. Further, certain features may require specific and expensive mold configurations that may still result in high rejection rates. According to various embodiments of the syringe **2** and features described therewith, the configuration of the plurality of radial ribs **24**, the fluid diverting ribs **30**, and the cylindrical load bearing wall **18** may eliminate undercuts from an injection mold for injection molding the syringe **2**.

[0086] Multiple beneficial features for a syringe **2** are described in the present disclosure. It is noted that various combinations of the described features may be incorporated into a syringe as required by the intended use of the syringe and the features of the fluid injector. For example a syringe may include at least one of the features and may include various other described features as necessary. For example, according to an embodiment, a syringe may include a plurality of radial ribs **24** around the periphery of the conical distal end wall **14** and a cylindrical load bearing wall **22** as described herein but not include a plurality of fluid diverting ribs **30**. According to another embodiment, a syringe may include a plurality of radial ribs **24** around the periphery of the conical distal end wall **14**, a cylindrical load bearing wall **22**, and a plurality of fluid diverting ribs **30** as described herein. According to another embodiment, a syringe may include, a cylindrical load bearing wall **22**, and a plurality of fluid diverting ribs **30** but not the plurality of radial ribs **24** as described herein. Thus, the various embodiments described in detail herein and illustrate in the attached figures are for illustration purposes only and are in no way limiting to the features incorporated into the syringe.

[0087] While various aspects of the syringe assembly and various features have been described in the context of syringes for powered medical injectors, the syringe assembly and various features described herein may also be incorporated into handheld syringes for delivering fluids at low injection pressures. For example, in many medical settings where a fluid is to be injected by a handheld syringe, the physician may draw a fluid into the syringe from a corresponding fluid container, such as a vial, and then may prime or purge the syringe of any air by holding the syringe in a vertical position and pressing on the plunger assembly to deliver a small amount of the fluid along with any air contained within the syringe. The ejected fluid may drip down the side of the needle and the syringe body, potentially exposing the physician to contact with the medical fluid. The syringe assembly and various features described herein may be utilized on a handheld syringe to prevent drips of the fluid, either that ejected during the priming process or fluid drips during an injection process, from contacting

the physician or dripping onto surfaces. Handheld syringes comprising various embodiments of the syringe assembly and various features are within the scope of this disclosure.

[0088] Still other aspects of the present disclosure relate to other medical devices comprising the syringe assembly and various features described herein. For example, any medical devices that deliver fluids which may include leaking or dripping of small amounts of fluid from a fluid aperture to a surface thereof may benefit from the fluid wicking flanges of the present disclosure. Examples of such medical devices include, but are not limited to, catheters (such as the distal end or those portions positioned immediately outside the patient's body), tubing sets, IV lines, tubing connectors and clips, shunts, fluid manifolds, valves, aspiration tubing, surgical tools, pump fluid outputs, and the like may all be modified to include the various features described herein.

[0089] It is worthy to note that any reference to "one aspect" or "an aspect" means that a particular feature, structure, or characteristic described in connection with the aspect is included in at least one aspect. Thus, appearances of the phrases "in one aspect" or "in an aspect" in various places throughout the specification are not necessarily all referring to the same aspect. Furthermore, the particular features, structures, or characteristics may be combined in any suitable manner in one or more aspects.

[0090] One skilled in the art will recognize that the herein described components (e.g., operations), devices, objects, and the discussion accompanying them are used as examples for the sake of conceptual clarity and that various configuration modifications are contemplated. Consequently, as used herein, the specific exemplars set forth and the accompanying discussion are intended to be representative of their more general classes. In general, use of any specific exemplar is intended to be representative of its class, and the non-inclusion of specific components (e.g., operations), devices, and objects should not be taken as limiting.

[0091] With respect to the use of any plural and/or singular terms herein, those having skill in the art can translate from the plural to the singular and/or from the singular to the plural as is appropriate to the context and/or application. The various singular/plural permutations are not expressly set forth herein for sake of clarity.

[0092] The herein described subject matter sometimes illustrates different components contained within, or connected with, other different components. It is to be understood that such depicted architectures are merely exemplary, and that, in fact, many other architectures may be implemented which achieve the same functionality. In a conceptual sense, any arrangement of components to achieve the same functionality is effectively "associated" such that the desired functionality is achieved. Hence, any two components herein combined to

achieve a particular functionality can be seen as “associated with” each other such that the desired functionality is achieved, irrespective of architectures or intermediate components. Likewise, any two components so associated can also be viewed as being “operably connected,” or “operably coupled,” to each other to achieve the desired functionality, and any two components capable of being so associated can also be viewed as being “operably couplable,” to each other to achieve the desired functionality. Specific examples of operably couplable include, but are not limited to, physically mateable and/or physically interacting components, and/or wirelessly interactable, and/or wirelessly interacting components, and/or logically interacting, and/or logically interactable components.

[0093] Some aspects may be described using the expression “coupled” and “connected” along with their derivatives. It should be understood that these terms are not intended as synonyms for each other. For example, some aspects may be described using the term “connected” to indicate that two or more elements are in direct physical or electrical contact with each other. In another example, some aspects may be described using the term “coupled” to indicate that two or more elements are in direct physical or electrical contact. The term “coupled,” however, also may mean that two or more elements are not in direct contact with each other, but yet still co-operate or interact with each other.

[0094] In some instances, one or more components may be referred to herein as “configured to,” “operative,” “adapted,” etc. Those skilled in the art will recognize that “configured to” can generally encompass active-state components, and/or inactive-state components, and/or standby-state components, unless context requires otherwise.

[0095] While particular aspects of the subject matter described herein have been shown and described, it will be apparent to those skilled in the art that, based upon the teachings herein, changes and modifications may be made without departing from the subject matter described herein and its broader aspects and, therefore, the appended claims are to encompass within their scope all such changes and modifications as are within the scope of the subject matter described herein. It will be understood by those within the art that, in general, terms used herein, and especially in the appended claims (e.g., bodies of the appended claims) are generally intended as “open” terms (e.g., the term “including” should be interpreted as “including but not limited to,” the term “having” should be interpreted as “having at least,” the term “includes” should be interpreted as “includes but is not limited to,” etc.). It will be further understood by those within the art that if a specific number of an introduced claim recitation is intended, such an intent will be explicitly recited in the claim, and in the absence of such recitation no such intent is present. For example, as an aid to understanding, the following

appended claims may contain usage of the introductory phrases “at least one” and “one or more” to introduce claim recitations. However, the use of such phrases should not be construed to imply that the introduction of a claim recitation by the indefinite articles “a” or “an” limits any particular claim containing such introduced claim recitation to claims containing only one such recitation, even when the same claim includes the introductory phrases “one or more” or “at least one” and indefinite articles such as “a” or “an” (e.g., “a” and/or “an” should typically be interpreted to mean “at least one” or “one or more”); the same holds true for the use of definite articles used to introduce claim recitations.

[0096] In addition, even if a specific number of an introduced claim recitation is explicitly recited, those skilled in the art will recognize that such recitation should typically be interpreted to mean at least the recited number (e.g., the bare recitation of “two recitations,” without other modifiers, typically means at least two recitations, or two or more recitations). Furthermore, in those instances where a convention analogous to “at least one of A, B, and C, etc.” is used, in general such a construction is intended in the sense one having skill in the art would understand the convention (e.g., “a system having at least one of A, B, and C” would include but not be limited to systems that have A alone, B alone, C alone, A and B together, A and C together, B and C together, and/or A, B, and C together, etc.). In those instances where a convention analogous to “at least one of A, B, or C, etc.” is used, in general such a construction is intended in the sense one having skill in the art would understand the convention (e.g., “a system having at least one of A, B, or C” would include but not be limited to systems that have A alone, B alone, C alone, A and B together, A and C together, B and C together, and/or A, B, and C together, etc.). It will be further understood by those within the art that typically a disjunctive word and/or phrase presenting two or more alternative terms, whether in the description, claims, or drawings, should be understood to contemplate the possibilities of including one of the terms, either of the terms, or both terms unless context dictates otherwise. For example, the phrase “A or B” will be understood to include the possibilities “A” or “B” or “A and B.”

[0097] In summary, numerous benefits have been described which result from employing the concepts described herein. The foregoing disclosure has been presented for purposes of illustration and description. It is not intended to be exhaustive or limiting to the precise form disclosed. Modifications or variations are possible in light of the above teachings. It is intended that the claims submitted herewith define the overall scope of the present disclosure.

CLAIMS:

We Claim:

1. A syringe comprising:
 - a proximal end, a distal end, and a cylindrical sidewall extending between the proximal end and the distal end, wherein the distal end comprises a conical distal end wall and a fluid nozzle at a distal end of the conical distal end wall;
 - a cylindrical load bearing wall extending axially from the cylindrical sidewall past a proximal end of the conical distal end wall; and
 - a plurality of radial ribs positioned around a periphery of the conical distal end wall, wherein a longitudinal axis of the plurality of radial ribs extends radially inward from the cylindrical load bearing wall towards the fluid nozzle over at least a portion of the conical distal end wall.
2. The syringe of claim 1, wherein the plurality of radial ribs defines plurality of fluid retention channels between each pair of adjacent radial ribs, wherein the plurality of fluid retention channels is configured to retain a volume of liquid by capillary adhesion when the syringe is rotated from a first upward facing position to a second downward facing position.
3. The syringe of claim 2, wherein the plurality of fluid retention channels are configured to retain a volume of the liquid ranging from 0.1 to 0.8 milliliters.
4. The syringe of claim 2, wherein a volume of the liquid that the plurality of fluid retention channels holds is at least partially determined from a distance between each adjacent pair of the plurality of radial ribs, a height of each adjacent pair of the plurality of radial ribs, and a distance that each pair of radial ribs distally extend radially inward from the conical distal end wall.
5. The syringe of any of claims 1 to 4, wherein the plurality of radial ribs increases a load strength of the conical distal end wall.
6. The syringe of any of claims 1 to 5, wherein the plurality of radial ribs increases a load strength of the cylindrical load bearing wall.

7. The syringe of any of claims 1 to 6, wherein at least one of the plurality of radial ribs extends a different radial distance inward from the cylindrical load bearing wall over the conical distal end wall than the remaining radial ribs of the plurality of radial ribs.
8. The syringe of any of claims 1 to 7, wherein the cylindrical load bearing wall is configured to abut a retaining surface of a retaining arm of a fluid injector to retain the syringe within a pressure jacket during a pressurized injection procedure.
9. The syringe of any of claims 1 to 8, wherein the cylindrical load bearing wall extends axially from the cylindrical sidewall of the syringe at an angle of from 1 degree to 30 degrees relative to a longitudinal axis of the syringe.
10. The syringe of any of claims 1 to 9, wherein a distal surface of the cylindrical load bearing wall is angled radially from a more proximal inner portion to a more distal outer portion relative to the longitudinal axis of the syringe.
11. The syringe of claim 10, wherein the angle of the distal surface of the cylindrical load bearing wall is configured to prevent entry of fluid between the cylindrical sidewall of the syringe and a pressure jacket in which the syringe is placed.
12. The syringe of claim 10 or claim 11, wherein the angle of the distal surface of the cylindrical load bearing wall is configured to increase a radially inward force on the retaining arm of the fluid injector.
13. The syringe of any of claims 1 to 12, wherein at least one of the cylindrical load bearing wall and the plurality of radial ribs enhances a refraction halo effect at a distal portion of the conical distal end wall of electromagnetic radiation emitted from at least one electromagnetic radiation source in a piston or plunger head of a fluid injector.
14. The syringe of any of claims 1 to 13, further comprising a neck associated with the fluid nozzle at the distal end of the syringe, the neck including a fluid passageway having a plurality of fluid diverting ribs extending radially inward at least partially into the fluid passageway from an inner surface of the neck.

15. The syringe of claim 14, wherein the plurality of fluid diverting ribs are configured to divert a fluid flowing through the neck into the syringe so that the fluid flows along an internal surface of the conical distal end wall and the cylindrical sidewall of the syringe.
16. The syringe of claim 14 or claim 15, wherein the plurality of fluid diverting ribs are configured to minimize an amount of air bubbles in the fluid in the syringe.
17. The syringe of claim 16, wherein the amount of air bubbles in the fluid in the syringe is minimized by the fluid flowing along the internal surface of the distal end wall and the cylindrical sidewall of the syringe.
18. The syringe of any of claims 14 to 17, wherein at least a portion of the plurality of fluid diverting ribs have different profiles.
19. The syringe of any of claims 14 to 18, wherein at least a portion of the plurality of flow diverting ribs extend from the inner surface at different distances into the fluid passageway.
20. The syringe of any of claims 1 to 19, wherein the plurality of radial ribs extend along the conical distal end wall at an angle relative to a longitudinal axis of the syringe such that a distance between the each adjacent pair of the plurality of radial ribs tapers from the cylindrical load bearing wall to the fluid nozzle.
21. A syringe comprising:
a proximal end, a distal end, and a cylindrical sidewall extending between the proximal end and the distal end, wherein the distal end comprises a conical distal end wall and a fluid nozzle at a distal end of the conical distal end wall;
a plurality of fluid diverting ribs extending inwardly from an inner surface of the fluid nozzle; and
a plurality of radial ribs positioned around a periphery of the conical distal end wall, wherein a longitudinal axis of the plurality of radial ribs extends radially inward from the cylindrical load bearing wall towards the fluid nozzle over at least a portion of the conical distal end wall.

22. The syringe of claim 21, further comprising a cylindrical load bearing wall extending axially from the cylindrical sidewall past a proximal end of the conical distal end wall.

23. The syringe of claim 21 or claim 22, wherein the plurality of radial ribs defines plurality of fluid retention channels between each pair of adjacent radial ribs, wherein the plurality of fluid retention channels is configured to retain a volume of liquid by capillary adhesion when the syringe is rotated from a first upward facing position to a second downward facing position.

24. The syringe of claim 23, wherein the plurality of fluid retention channels are configured to retain a volume of the liquid ranging from 0.1 to 0.8 milliliters.

25. The syringe of claim 23, wherein a volume of the liquid that the plurality of fluid retention channels holds is at least partially determined from a distance between each adjacent pair of the plurality of radial ribs, a height of each adjacent pair of the plurality of radial ribs, and a distance that each pair of radial ribs distally extend radially inward from the conical distal end wall.

26. A syringe comprising:

a proximal end, a distal end, and a cylindrical sidewall extending between the proximal end and the distal end, wherein the distal end comprises a conical distal end wall and a fluid nozzle at a distal end of the conical distal end wall; and

a plurality of fluid diverting ribs extending inwardly from an inner surface of the fluid nozzle,

wherein the plurality of fluid diverting ribs enhances a refraction halo effect at a distal portion of the conical distal end wall of electromagnetic radiation emitted from at least one electromagnetic radiation source in a piston or plunger head of a fluid injector.

27. The syringe of claim 26, further comprising a cylindrical load bearing wall extending axially from the cylindrical sidewall past a proximal end of the conical distal end wall.

28. The syringe of claim 26 or claim 27, further comprising a plurality of radial ribs positioned around a periphery of the conical distal end wall, wherein a longitudinal axis of the

plurality of radial ribs extends radially inward from the cylindrical load bearing wall towards the fluid nozzle over at least a portion of the conical distal end wall.

29. The syringe of claim 28, wherein the plurality of radial ribs defines plurality of fluid retention channels between each pair of adjacent radial ribs, wherein the plurality of fluid retention channels is configured to retain a volume of liquid by capillary adhesion when the syringe is rotated from a first upward facing position to a second downward facing position.

30. The syringe of claim 29, wherein the plurality of fluid retention channels are configured to retain a volume of the liquid ranging from 0.1 to 0.8 milliliters.

31. The syringe of claim 29, wherein a volume of the liquid that the plurality of fluid retention channels holds is at least partially determined from a distance between each adjacent pair of the plurality of radial ribs, a height of each adjacent pair of the plurality of radial ribs, and a distance that each pair of radial ribs distally extend radially inward from the conical distal end wall.