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(54) **Title: MULTIPLE COMPARTMENT SYRINGE**

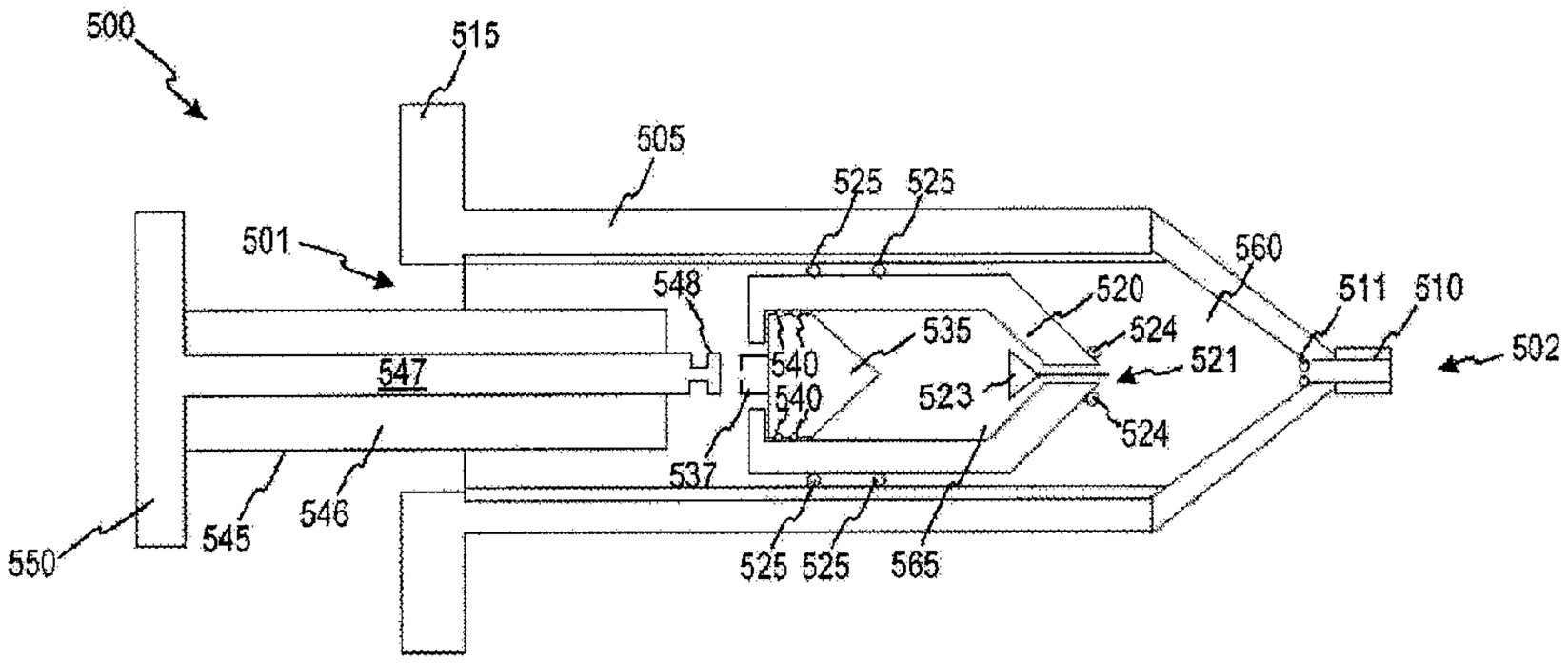

FIG. 5

(57) **Abrégé/Abstract:**
Various syringe systems are disclosed. One illustrative syringe system may include a syringe body having a hollow lumen and a distal end. The syringe body may be configured to house a plurality of fluids therein. A first plunger may be positioned in the hollow lumen of the syringe body, forming a first seal with an inner wall of the syringe body, and forming a first compartment between the first plunger and the distal end of the syringe. A second plunger may be positioned proximal to the first plunger in the hollow lumen of the syringe body, forming a second seal with the inner wall of the syringe body, and forming a second compartment between the first plunger and the second plunger. A plurality of recesses may be disposed about the inner wall of the syringe body near the distal end of the syringe body.

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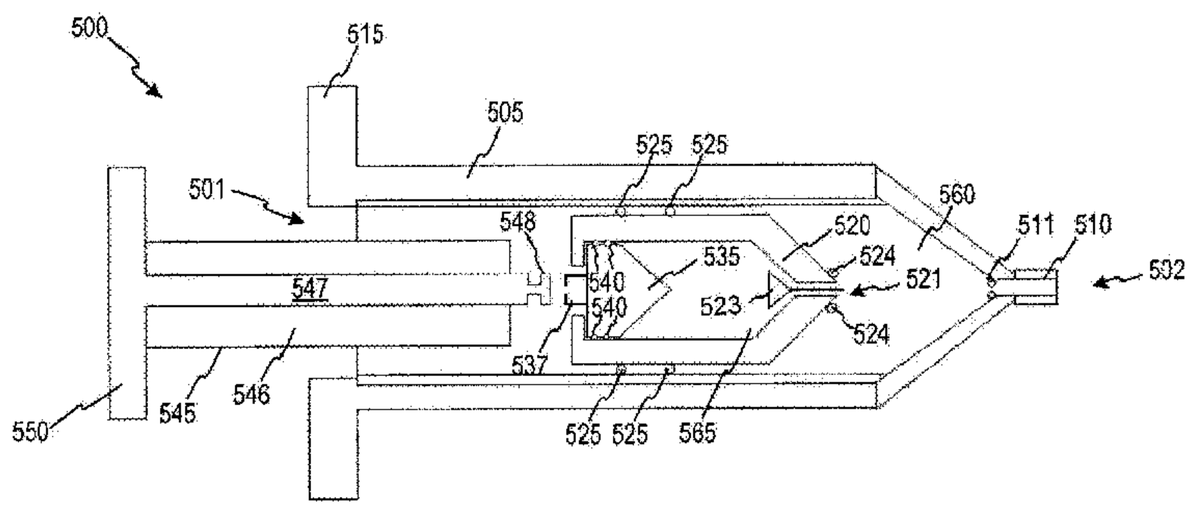

FIG. 5

(57) **Abstract**: Various syringe systems are disclosed. One illustrative syringe system may include a syringe body having a hollow lumen and a distal end. The syringe body may be configured to house a plurality of fluids therein. A first plunger may be positioned in the hollow lumen of the syringe body, forming a first seal with an inner wall of the syringe body, and forming a first compartment between the first plunger and the distal end of the syringe. A second plunger may be positioned proximal to the first plunger in the hollow lumen of the syringe body, forming a second seal with the inner wall of the syringe body, and forming a second compartment between the first plunger and the second plunger. A plurality of recesses may be disposed about the inner wall of the syringe body near the distal end of the syringe body.

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TITLE: MULTIPLE COMPARTMENT SYRINGE

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of United States Application No. 13/802,372, filed March 13, 2013 and entitled "Multiple Compartment Syringe," and which is incorporated herein in its entirety.

BACKGROUND

[0002] During a radiological procedure, a contrast medium may be administered to provide improved imaging of anatomical features in a patient. A physician may typically order a specific amount of contrast medium deemed necessary to view these anatomical features. Since the contrast medium may be expensive, it may be important to make sure that the complete dose is administered and that little or no waste is generated. In addition, the contrast medium may need to be pushed to a region of interest or diluted to avoid too much contrast in a region of interest.

[0003] Previous attempts to ensure complete contrast medium administration, pushing to a region of interest, and/or dilution involved injecting a flushing material, such as saline solution and/or the like, immediately after the contrast medium in order to flush the administration tube of all residual contrast medium, push the contrast to a region of interest, or dilute the contrast. In some radiological procedures, this may be completed by means of an automated device. However, in some radiological procedures, a manual device may be used for various reasons, such as, for example, an automated device is not available or the procedure does not require the level of delivery control that can be afforded by an automated device. However, the manual devices currently used in the art lack an ability to control delivery in a manner similar to an automated device, thus leading to waste of contrast medium, improperly delivered contrast medium, and/or improperly diluted contrast medium.

[0004] Furthermore, it may be necessary to assure that the access vein of the patient remains open when the contrast medium is not actively being delivered. For some patients with diseased vasculature, the vein may collapse when not being actively supplied by contrast medium. In such a condition, some amount of fluid, such as saline solution and/or the like, may be delivered to the vein to keep the vein open ("KVO").

SUMMARY

[0005] In an embodiment, a syringe may include a syringe body having a hollow lumen and a distal end, and the syringe body may be configured to house a plurality of fluids therein. A first plunger may be positioned in the hollow lumen of the syringe body, forming a first seal with an inner wall of the syringe body, and forming a first compartment between the first plunger and the distal end of the syringe. A second plunger may be positioned proximal to the first plunger in the hollow lumen of the syringe body, forming a second seal with the inner wall of the syringe body, and forming a second compartment between the first plunger and the second plunger. A plurality of recesses may be disposed about the inner wall of the syringe body near the distal end of the syringe body. In specific embodiments a fluid bypass may be disposed about the inner wall of the syringe body and the first plunger at or near the distal end of the syringe body, wherein a first fluid can flow through the fluid bypass to the second compartment. The syringe may further comprise a mechanism for proximally moving the first plunger to a position proximal to the fluid bypass such that the first plunger forms the first seal. The mechanism may comprise a variety of mechanism such as one of a slidable end cap at the distal end of the syringe body, a push rod configured to push the first plunger in the proximal direction, and a sleeve comprising at least one magnet at or near the distal end of the sleeve and in magnetic communication with at least one magnet or ferromagnetic material in the first plunger.

[0006] In an embodiment, a syringe system may include a syringe body having a hollow lumen and a distal end comprising a syringe tip, and the syringe body may be configured to house a plurality of fluids therein. Additionally, a first plunger may be positioned in the hollow lumen of the syringe body, forming a first seal with an inner wall of the syringe body, and forming a first compartment between the first plunger and the distal end of the syringe. A second plunger may be positioned proximal to the first plunger in the hollow lumen of the syringe body, forming a second seal with the inner wall of the syringe body, and forming a second compartment between the first plunger and the second plunger. A transfer tube may be in fluid connection with the second compartment and the syringe tip.

[0007] In an embodiment, a syringe system may include a syringe body having a hollow lumen and a distal end having a syringe tip. The syringe body may be configured to house a plurality of fluids therein. The syringe system may also include a first plunger positioned in the hollow lumen of the syringe body. The first plunger may form a first seal with an inner wall of the syringe body, and may form a first compartment between the first plunger and the distal end of the syringe. A second plunger may be positioned proximal to

the first plunger in the hollow lumen of the syringe body, forming a second seal with the inner wall of the syringe body, and forming a second compartment between the first plunger and the second plunger. The syringe system may also include a transfer tube in fluid connection with the second compartment. The transfer tube may include a valve having an outlet, where the valve is in fluid communication with the syringe tip. The syringe system may also include an outlet port fluidly connected to an outlet of the valve. An orientation of the valve may include one of a first opening state to allow fluid flow from the syringe tip to the outlet port, a second opening state to allow fluid flow from the transfer tube to the outlet port, a third opening state to allow fluid flow from both the syringe tip and the transfer tube to the outlet port, and a closed state to block flow of fluid from the syringe tip and the transfer tube.

[0008] In an embodiment, a syringe system may include a syringe body having a hollow lumen and a distal end. The syringe body may be configured to house a plurality of fluids therein. The syringe system may also include a first plunger positioned in the hollow lumen of the syringe body, forming a first seal within an inner wall of the syringe body, and forming a first compartment between the first plunger and the distal end of the syringe, the first plunger comprising a hollow lumen therein. A second plunger may be positioned in the hollow lumen of the first plunger, forming a second seal within an inner wall of the first plunger, and forming a second compartment between the first plunger and the second plunger.

[0009] In an embodiment, a syringe system may include a syringe body having a first chamber, a second chamber, and an outlet fluidly connected to the first chamber and the second chamber. The first chamber may be positioned adjacent to the second chamber. The first chamber may have a diameter that is smaller than a diameter of the second chamber. The first chamber may be configured to house a first fluid and the second chamber may be configured to house a second fluid. The syringe system may also include a first plunger positioned in the first chamber and a second plunger positioned in the second chamber. The syringe system may also include an adjustable stop that is configured to stop distal movement of the first plunger after the first plunger has traversed a defined distance. The second plunger may be configured to move in a distal direction to push the second fluid out of the second chamber into an outlet. The first fluid may be drawn out of the first plunger via a Venturi effect upon distal movement of the second plunger.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] In the following detailed description, reference is made to the accompanying drawings, which form a part hereof. In the drawings, similar symbols typically identify similar components unless context dictates otherwise. The illustrative embodiments described in the detailed description, drawings, and claims are not meant to be limiting. Other embodiments may be utilized and other changes may be made, without departing from the spirit or scope of the subject matter presented herein. It will be readily understood that the aspects of the present disclosure, as generally described herein and illustrated in the figures, can be arranged, substituted, combined, separated, and designed in a wide variety of different configurations, all of which are explicitly contemplated herein

[0011] FIGS. 1A-1B depict a side view of a syringe according to an embodiment.

[0012] FIG. 2A depicts a side view of an alternative syringe having a transfer tube according to an embodiment.

[0013] FIG. 2B depicts a side view of the alternative syringe of FIG. 2A with an alternatively positioned transfer tube according to an embodiment.

[0014] FIG. 3 depicts various alternative orientations of a valve used in the syringe of FIGS. 2A and 2B according to an embodiment.

[0015] FIG. 4 depicts a side view of another alternative syringe according to an embodiment.

[0016] FIG. 5 depicts a side view of yet another alternative syringe according to an embodiment.

[0017] FIGS. 6A-6D depict movement of the various components of the syringe depicted in FIGS. 1A and 1B according to an embodiment.

[0018] FIGS. 7A-7C depict movement of the various components of the syringe depicted in FIG. 2A according to an embodiment.

[0019] FIGS. 8A-8C depict movement of the various components of the syringe depicted in FIG. 5 according to an embodiment.

[0020] FIGS 9A-9C depict movement of various components of a syringe according to an embodiment

[0021] FIGS. 10A and 10B depict an aspiration process of a syringe according to an embodiment.

[0022] FIGS. 11A and 11B depict an aspiration process of a syringe according to an embodiment.

DETAILED DESCRIPTION

[0023] This disclosure is not limited to the particular systems, devices and methods described, as these may vary. The terminology used in the description is for the purpose of describing the particular versions or embodiments only, and is not intended to limit the scope.

[0024] As used in this document, the singular forms "a," "an," and "the" include plural references unless the context clearly dictates otherwise. Unless defined otherwise, all technical and scientific terms used herein have the same meanings as commonly understood by one of ordinary skill in the art. Nothing in this disclosure is to be construed as an admission that the embodiments described in this disclosure are not entitled to antedate such disclosure by virtue of prior invention. As used in this document, the term "comprising" means "including, but not limited to."

[0025] For purposes of the description hereinafter, the terms "upper," "lower," "right," "left," "vertical," "horizontal," "top," "bottom," "lateral," "longitudinal," and derivatives thereof shall relate to the orientation of embodiments disclosed in the figures. However, embodiments may assume alternative variations and step sequences, except where expressly specified to the contrary. The specific devices and processes illustrated in the attached drawings and described in the following specification, are exemplary embodiments. Hence, physical characteristics related to the embodiments disclosed herein are not to be considered as limiting.

[0026] The word "proximal" refers to a direction relatively closer to a clinician or operator using the device described herein, and the word "distal" refers to a direction relatively further from the clinician or operator. For example, the end of a syringe placed nearest the body of a patient is considered a distal end of the syringe, while the end closes to the clinician is a proximal end of the syringe. The terms "axial" or "axially" refer generally to an axis around which the particular objects being referred to are preferably formed (although not necessarily symmetrically therearound). The term "radial" refers generally to a direction normal to the axis or along a radius of an object having a circular cross-section.

[0027] Various embodiments of the present disclosure may be directed to devices and methods of use thereof that use a manual device to deliver a bolus of contrast medium followed by an amount of saline solution. In various embodiments, this may serve to flush the line to ensure all of the contrast is delivered to the patient, to move the contrast to a region of interest, and/or to dilute the contrast concentration. In various embodiments, the devices and methods of use may further be capable of delivering a small amount of fluid to maintain vein patency during contrast medium administration.

[0028] FIG. 1A depicts a side view of a syringe, generally designated **100**, according to an embodiment. The syringe **100** may generally include a syringe body **105** having a hollow lumen **107**, a proximal end **101**, and a distal end **102** having a tip **110**. The syringe body **105** is not limited in shape or size by this disclosure, and may be any shape or size, particularly shapes and sizes of syringe bodies commonly known by those skilled in the art. In various embodiments, the syringe body **105** may substantially cylindrical. In various embodiments where the syringe **100** is configured for use in computed tomography (CT) applications and the like, the syringe body **105** may be configured to contain about 20 ml to about 150 ml of fluid therein. In particular embodiments, the syringe body may be configured to contain about 20 ml, about 25 ml, about 30 ml, about 50 ml, about 75 ml, about 100 ml, about 125ml, about 150 ml, or any value or range between any two of these values. In various embodiments where the syringe **100** is configured for use in magnetic resonance (MR) applications and the like, the syringe body **105** may be configured to contain about 5 ml to about 20 ml of fluid therein. In particular embodiments, the syringe body may be configured to contain about 5 ml, about 10 ml, about 12.5 ml, about 15 ml, about 20 ml, or any value or range between any two of these values.

[0029] In various embodiments, the hollow lumen **107** may include a plurality of plungers disposed therein. For example, in the present embodiment, the hollow lumen **107** may have a first plunger **120** and a second plunger **135**. However, those skilled in the art will recognize that more than two plungers may be used without departing from the scope of this disclosure. In various embodiments, the first plunger **120** may form a seal against the interior of the syringe body **105** by means of a first seal **125**. In some embodiments, the first seal **125** may be a separate component from the first plunger **120**, such as, for example, an added O-ring and/or the like. In these embodiments, the first seal **125** may be fixedly attached to the first plunger **120** by any means of attachment, including attachment apparatuses, adhesives, and/or the like, or the first seal may be removably attached to the first plunger. In other embodiments, the first seal **125** may be fabricated as a portion of the first plunger **120**. Similarly, in various embodiments, the second plunger **135** may form a seal against the interior of the syringe body **105** by means of a second seal **140**. In some embodiments, the second seal **140** may be a separate component from the second plunger **135**, such as, for example, an added O-ring and/or the like. In these embodiments, the second seal **140** may be fixedly attached to the second plunger **135** by any means of attachment, including attachment apparatuses, adhesives, and/or the like, or the second seal may be removably attached to the second plunger. In other embodiments, the second seal **140** may be fabricated as a portion of

the second plunger **135**. The first plunger **120**, the second plunger **135**, the first seal **125**, and the second seal **140** may each be made of any material now known or later developed that is known by those skilled in the art for use in plungers and/or seals. Specific examples may include polymers, rubber, and/or the like.

[0030] In various embodiments, a first compartment **160** may be formed between the first plunger **120** and the distal end **102** of the syringe body **105**. The first compartment **160** may be configured to contain a fluid therein. In particular embodiments, the fluid may include a contrast medium. In various embodiments, a second compartment **165** may be formed between the second plunger **135** and the first plunger **120**. The second compartment **165** may also be configured to contain a fluid therein. In particular embodiments, the fluid may include a flushing fluid. One such specific example of a flushing fluid may be saline. The volume of the first compartment **160** may be determined by the distance between the first plunger **120** and the distal end **102** of the syringe body **105**, as well as the circumference of the syringe body. The volume of the second compartment **165** may be determined by the distance between the first plunger **120** and the second plunger **135**, as well as the circumference of the syringe body **105**.

[0031] In various embodiments, the first plunger **120** and the second plunger **135** may be joined together by means of a connection piece **130**. The connection piece **130** may be constructed so that when force is applied on the second plunger **135**, some of the force is transferred to the first plunger **120** to effect movement of the first plunger along with the second plunger. In some embodiments, movement may be bidirectional, i.e., the force can be directed proximally or distally to move the first plunger **120** and the second plunger **135** in either a proximal or distal direction within the syringe. In these embodiments, the connection piece **130** may be constructed of a rigid material that does not bend or collapse when pressure is applied to it. The connection piece **130** may further be constructed of any material that does not impact any fluid that may come into contact with it. In other embodiments, movement may be unidirectional, i.e., a force that pushes the second plunger **135** in a distal direction may not be transferred to the first plunger **120** so that the first plunger stays in place, but when the opposite force in a proximal direction is placed on the second plunger, the force is transferred to the first plunger, causing it to move as well. In some embodiments, as shown in FIG. 1A, this unidirectional movement may be possible by using a connection piece **130'** that is constructed of a collapsible material. Specific examples of collapsible materials may include filaments, monofilaments, fibers, polymers, and the like. In some embodiments, the connection piece **130** (or **130'**) may include one or more magnets so that

the force on the second plunger **135** causes a force on the first plunger **120** due to magnetic attraction. In some embodiments, the connection piece **130** (or **130'**) may include a releasable pin or similar locking device that can lock or unlock the connection piece to effectuate a desired movement of the plungers **120**, **135** as described herein. As in the other constructions, the connection piece **130** (or **130'**) may further be constructed of any material that does not impact any fluid that may come into contact with it.

[0032] In various embodiments, particularly embodiments in which the connection piece is a collapsible material **130'**, the first plunger **120** may be moved towards the distal end **102** of the syringe body **105** under force from the fluid located within the second chamber **165**. For example, due to the actions of the second seal **140** and the first seal **125**, the fluid contained within the second compartment **165** does not leak or compress, but rather acts as a hydraulic lock, thereby transferring force from the second plunger **135** to the first plunger **120**. In this manner, the fluid located in the first compartment **160** may be pushed distally by the first plunger **120**, where, in some embodiments, it may be forced out the syringe tip **110**.

[0033] In various embodiments, the second plunger **135** may be connected to a piston **145** that may at least partially extend out of an opening in the proximal end **101** of the syringe body **105**. The second plunger **135** may be attached to the piston **145** by any means of attachment, including, but not limited to, any number of clips, fasteners, hooks, adhesives, and/or the like. In some embodiments, the second plunger **135** may be molded as a portion of the piston **145**. In some embodiments, the piston **145** may have a thumb piece **150** proximally attached thereto. The thumb piece **150** may generally provide a stable surface to allow the user of the syringe **100** to push and/or pull the piston **145**, and correspondingly the second plunger **135** and/or the first plunger **120**. The thumb piece **150** depicted herein is a generally flat surface; however, those skilled in the art will recognize that the shape and size of the thumb piece is not limited by this disclosure, and may include any number of rings, openings, contoured surfaces, and/or the like without departing from the scope of the present disclosure. Persons skilled in the art will also note that the term 'thumb piece' is not to be limiting; the user may use any object to manipulate the thumb piece **150** as described herein.

[0034] In various embodiments, the interior surface of the syringe body **105** may include a plurality of recesses **155** disposed therein, causing a void in portions of the interior surface at the location of each recess. In some embodiments, the plurality of recesses **155** may be disposed about the inner wall of the syringe body **105** near the distal end **102**. The shape and size of the recesses **155** is not limited by this disclosure, and may generally be any

shape and/or size that will break the seal between the syringe body **105** and the first seal **125** of the first plunger **120**. In some embodiments, the recesses **155** may be scalloped. In other embodiments, the recesses **155** may be crenelated. The recesses **155** may be located at any position on the inside wall of the syringe body **105**, and may be positioned so as to correspond to an amount of fluid that is desired in the first compartment **160** and/or the second compartment **165**. However, the recesses **155** cannot be located so far distal in the syringe body that the first seal **125** does not contact it, as the fluid in the second compartment **165** would not be released. In some embodiments, the recesses **155** may be positioned at a tapered transition point from the cylindrical syringe body **105** to the tip **110**.

[0035] In various embodiments, one or more finger guards **115** may be positioned at a location that is generally located at or near the proximal end **101** of the syringe body **105**. In some embodiments, the finger guards **115** may generally be located on an outside surface of the syringe body **105** and may generally extend from the outside surface of the syringe body. In some embodiments, the finger guards **115** may act to provide stability to the syringe **100** during operation. In some embodiments, a user may use the finger guards **115** to prevent movement of the syringe **100** during operation. In some embodiments, the user may use the finger guards **115** to prevent the syringe **100** from slipping out of the user's hand. In some embodiments, the user may use the finger guards **115** to protect the user's fingers. In some embodiments, the finger guards **115** may act as a stopping device to prevent the piston **145** from moving further distally inside the syringe body **105**. The shape and size of the finger guards **115** are not limited by this disclosure, and may be any shape and/or size known in the art. Specific examples of shapes may be ring shaped, wedge shaped, T-shaped, curved, curved with finger indentations, and/or the like.

[0036] FIG. 2A depicts a side view of an alternative syringe, generally designated **200**, according to an embodiment. Similar to the syringe **100** disclosed with respect to FIGS. 1A and 1B above, the syringe **200** may include a syringe body **205** having a proximal end **201** and a distal end **202**. The syringe body **205** may have a first plunger **220** and a second plunger **235** disposed within it. The first plunger **220**, the second plunger **235**, and a tip **210** may define a first compartment **260** and a second compartment **265** therein for storing two different types of fluid, as previously described herein. The first plunger **220** and the second plunger **235** may be moved within the syringe body **205** by applying a force to the thumb piece **250** portion of a piston **245**, as previously described herein. In some embodiments, movement of the first plunger **220** may be aided by the connection piece **230**, as described herein. In alternate embodiments, movement of the first plunger **220** may be aided by

transfer of force on the second plunger **235** to the first plunger **220** via a fluid located in the second compartment **265**, as also described herein.

[0037] In various embodiments, the alternative syringe of FIG. 2A may differ from the syringe of FIGS. 1A and 1B by including, among other things, a transfer tube **270**, a valve **275**, and one or more outlet ports **280**. In some embodiments, the recesses **255** may not be present. In some embodiments, the functions of these additional elements, as described herein, may allow for the syringe **200** to provide a "keep vein open" (KVO) function. The KVO function may be used during a long term injection procedure to ensure that access to a vein remains available for fluid injection and does not collapse when fluid is not being administered. In some embodiments, the functions of these additional elements may allow for the syringe **200** to provide functionality for delivering the fluid of the second compartment **265** before delivering the fluid of the first compartment **260** and vice versa. In some embodiments, the functions of these additional elements may allow for the syringe **200** to provide functionality for mixing at least a portion of the contents in the first compartment **260** with at least a portion of the contents in the second compartment **265** during delivery to a patient. In some embodiments, the functions of these additional elements may allow for the syringe **200** to be in an "off" state, thus preventing the contents from either compartment **260**, **265** from escaping, such as to prevent leakage when the syringe is not in use.

[0038] In various embodiments, the transfer tube **270** may be in fluid connection with the contents of the second compartment **265** within the syringe body **205**. Thus, in some embodiments, the syringe body **205** may contain an opening and/or a bore therein for attachment of the transfer tube **270** to allow for a fluid connection thereof. The construction of the transfer tube **270** is not limited by this disclosure and may be of any shape, size, and/or composition. In some embodiments, the transfer tube **270** may be generally hollow to allow transfer of a fluid therethrough, and may generally be made of a substance that does not impact the fluid flowing therethrough.

[0039] In alternative embodiments, such as the embodiment shown in FIG. 2B, the transfer tube **270'** may be in fluid connection with the contents of both the first compartment **260** and the second compartment **265**, depending on the positioning of the plungers **220**, **235**. In some embodiments, the transfer tube **270'** may act as an alternative to the recesses **255** (FIG. 2A). Thus, the transfer tube **270'** may allow for transfer of fluid to/from the first compartment **260** only when first compartment **260** is exposed to the transfer tube and the valve **275** is particularly positioned, as described in greater detail herein. Furthermore, the transfer tube **270'** may allow for transfer of fluid to/from the second compartment **265** only

when the second compartment **265** is exposed to the transfer tube and the valve **275** is particularly positioned, as described herein. In addition, because the recesses are not present in this embodiment, the first plunger **220** may continue to form a seal with the inner wall of the syringe body **205**, even as it is being forced in a distal direction, so fluids in the second compartment **265** will only be able to exit the syringe **200** via the transfer tube **270'** when the valve **275** is particularly positioned, as described herein.

[0040] As shown in either embodiment of FIGS. 2A and 2B, the transfer tube **270** may terminate in the valve **275**. In some embodiments, the valve **275** may be in fluid connection with the transfer tube **270**, the tip **210** and the outlet port **280**. In various embodiments, the valve **275** may be configured to be positioned in one of a plurality of states, in which it is open to any or none of the elements in which it is fluidly connected, as shown in FIG. 3. A first state, as depicted in position (a), allows contents to flow from both the tip **210** and the transfer tube **270** to the outlet port **280**. A second state, as depicted in position (b), only allows contents from the transfer tube **270** to be dispensed into the outlet port **280**, as it blocks the contents in the tip **210**. A third state, as depicted in position (c), only allows contents from the tip **210** to be dispensed into the outlet port **280**, as it blocks the contents in the transfer tube **270**. A fourth state, as depicted in position (d), does not allow the contents of either location to be dispensed into the outlet port **280** because the valve **275** is closed off to both the transfer tube **270** and the tip **210**. Those skilled in the art will recognize that contents may be drawn into the syringe **200** in a similar manner, as described in greater detail herein.

[0041] In various embodiments, the outlet port **280** may be configured to receive the contents from the first chamber **260**, the second chamber **265**, both chambers, or neither chamber depending on the orientation of the valve **275** and/or the location of the transfer tube **270** (or **270'**). The outlet port **280** may further be configured to output any contents received to a patient. In some embodiments, the outlet port **280** may be configured to securely attach to additional elements, such as tubes, needles, nozzles, valves, catheters, and the like to aid in delivery of the contents to the patient.

[0042] FIG. 4 depicts a side view of another alternative syringe system according to an embodiment. The syringe system **400** may include a syringe body **405** having a first chamber **410** and a second chamber **420**. Unlike in other embodiments depicted herein, the first chamber **410** and second chamber **420** may not be in line with each other. Rather, the chambers **410**, **420** may be positioned adjacent to each other, such as, for example, substantially parallel to each other. A distal end of each chamber **410**, **420** may be fluidly

connected to an output **445**. In some embodiments, the output **445** may be configured to transmit the contents of the first chamber **410** and/or the second chamber **420** to a subject. In some embodiments, the output **445** may be configured to attach to other devices, such as, for example, tubes, nozzles, needles, valves, catheters, and the like, as described in greater detail herein.

[0043] In various embodiments, the first chamber **410** may have a first plunger **415** and a cavity for housing and dispensing a first fluid therein. Similarly, the second chamber **420** may have a second plunger **425** and a cavity for housing and dispensing a second fluid therein. In some embodiments, a diameter of the first chamber **410** may be smaller than a diameter of the second chamber. The second plunger **425** may be actuated by receiving a force in a distal direction, as described in greater detail herein. Because the diameter of the second chamber **420** is larger than the diameter of the first chamber **410**, the force on the second plunger **425** that causes fluid to move out of the second chamber and into the output **445** may cause a Venturi effect on the fluid in the first chamber, causing it to be drawn out into the output with the fluid from the second chamber. In some embodiments, a constant force spring **440** may be configured to ensure that the force applied to the second plunger **425** is fluid and uniform to effectuate a smooth delivery of the contents of the chambers **410**, **420** to a subject.

[0044] In various embodiments, the syringe system **400** may include a stop **430**. In some embodiments, the stop **430** may be configured to block movement of the first plunger **415** after movement over a certain distance has occurred. The position of the stop **430** may be adjustable by actuating a stop adjustment screw **435**. By changing the positioning of the stop **430**, a user can dictate the amount of distance that the first plunger **415** can be moved before being stopped by the stop. In an illustrative example, a force may be applied to the second plunger **425** to cause the first plunger **415** and the second plunger to move distally in their respective chambers **410**, **420**, as described herein. Once the first plunger **415** reaches the stop **430**, additional distal movement of the first plunger may cease, thereby preventing additional fluid from exiting the first chamber **410**, while additional distal movement of the second plunger **425** may continue until all of the contents of the second chamber **420** have been displaced out of the second chamber.

[0045] FIG. 5 depicts a side view of yet another alternative syringe according to an embodiment. Similar to the syringe **100** disclosed with respect to FIGS. 1A and 1B above, the syringe **500** may include a syringe body **505** having a proximal end **501** and a distal end **502**. The syringe body **505** may have a first plunger **520** and a second plunger **535** disposed

within it, however, unlike the embodiments of FIGS. 1A and 1B, the second plunger may be located inside the first plunger, as will be described in greater detail herein. The first plunger **520** and the second plunger **535** may be moved within the syringe body **505** by applying a force to the thumb piece **550** portion of a piston **545**, as previously described herein.

[0046] In various embodiments, the first plunger **520** may form a seal against the interior of the syringe body **505** by means of the first seal **525**, as previously described herein. A first chamber **560** may be defined by the first plunger **520** and the tip **510**, as previously described herein. The first chamber **560** may further be configured to house a fluid therein, where the fluid is forced out of the tip **510** upon a force applied to the thumb piece **550**, as previously described herein.

[0047] In various embodiments, the first plunger **520** may be substantially hollow and configured to house at least the second plunger **535** and a check valve **523**, such as a one-way check valve or the like, therein. In some embodiments, the second plunger **535** may form a seal against the interior of the first plunger **520** by means of the second seal **540**. Accordingly, the second chamber **565** may be defined by the second plunger **535** and the remainder of the hollow space within the first plunger **520**. Furthermore, the second plunger **535** may be configured to slidably move within the first plunger **520** independently of movement of the first plunger within the syringe body **505**. In some embodiments, the check valve **523** may be configured to activate, thereby plugging an opening in a distal portion **521** of the first plunger **520**. In some embodiments, the check valve **523** may further be configured to release, thereby allowing the contents of the second chamber **565** to be released distally into the first chamber **560** and/or the tip **510**. In some embodiments, a third seal **524** positioned distally on the first plunger **520** may allow a distal portion of the first plunger to seal against a distal portion of the syringe body **505** so that the fluid from the second compartment **565** does not flow back into the syringe body when it is ejected, as described in greater detail herein.

[0048] In various embodiments, the second plunger **535** may be removably attached to at least a portion of the piston **545**. In some embodiments, the second plunger **535** may include a proximally located attachment member **537** affixed thereto. The attachment member **537** of the second plunger **535** may generally be configured to removably attach to an attachment member **548** of the piston **545**.

[0049] In various embodiments, the piston **545** may include at least an inner piston **547** and an outer sleeve **546**. In some embodiments, the inner piston **547** may extend from the thumb piece **550** to the attachment member **548**. In various embodiments, the inner

piston **547** may have a shape and size that, when the inner piston is actuated, it can move independently of the outer sleeve **546**, cause the attachment member **548** to attach to the attachment member **537** of the second plunger **535** without substantially contacting the first plunger **520**, and force the second plunger to move within the first plunger without causing movement of the first plunger within the syringe body **505**. In some embodiments, the outer sleeve **546** can be actuated independently of the inner piston **547** and can further move independently of the inner piston. In some embodiments, the outer sleeve **546** may have a shape and/or size that are configured to allow the outer sleeve to contact at least a portion of the proximal end of the first plunger **520** without substantially contacting the second plunger **535**. In some embodiments, a force may be applied to the outer sleeve **546** to cause the outer sleeve to force the first plunger **520** to move within the syringe body **505**, as described in greater detail herein. In some embodiments, the inner piston **547** and the outer sleeve **546** may be locked together with a locking mechanism (not shown) so that, when a force is applied to the thumb piece **550**, the entire piston **545** moves as one.

[0050] In various embodiments, the syringe body **505** may further include one or more valve actuators **511** positioned at a location within the inside surface of the syringe body. In the present example, the valve actuators **511** are located near the tip **510**; however, those skilled in the art will recognize that the valve actuators may be positioned at any location without departing from the scope of the present disclosure. In some embodiments, the valve actuators **511** may be configured to release the one-way check valve **523** upon contact between the valve actuators and the check valve. In some embodiments, the valve actuators **511** may be configured to activate the check valve **523** upon removal of contact between the valve actuators and the check valve.

[0051] FIGS. 6A-6D depict movement of the various components of the syringe **100** depicted in FIGS. 1A and 1B according to an embodiment. More particularly, FIG. 6A depicts an initial state of the syringe **100** when it is loaded with a first fluid in the first compartment **160** and a second fluid in the second compartment **165**. As previously described herein, a user may apply a force on the thumb piece **150** to force the piston **145** in a distal direction into the syringe body **105**. As a result, the piston **145** may mechanically force the second plunger **135** in the distal direction towards the syringe tip **110**. As previously described herein, due to the actions of the second seal **140** and the first seal **125**, the fluid located in the second compartment **165** may not leak or compress, but rather may act as a hydraulic lock, thereby transferring the force from the second plunger **135** to the first plunger **120**, causing the first plunger to also move in the distal direction towards the syringe tip **110**,

as shown in FIG. 6B. Accordingly, the fluid contained in the first compartment **160** may be forced out of the syringe tip **110**.

[0052] In various embodiments, the fluid located in the first compartment **160** may be pushed out through the tip **110** by the first plunger **120** until the mechanical force on the piston **145** (via the second plunger **135** and the force from the fluid in the second compartment **165**) drives the first plunger to the recesses **155**. In some embodiments, at the recesses **155**, the first seal **125** may no longer act as a fluid seal against the inner surface of the syringe body **105**. Because the hydraulic seal of the first plunger **120** against the interior of the syringe body **105** is broken in this state, the fluid located in the second compartment **165** may flow around the recesses **155**, through the remaining space in the first compartment **160**, and out the tip **110**. FIG. 6C depicts a cross sectional view of the syringe **100** as the first seal **125** contacts the recesses **155** according to various embodiments. In some embodiments, the first seal **125** may contact one or more cops **156**, but does not fill one or more crenels **157** of the recesses **155**. Thus, in some embodiments, the fluid from the second compartment **165** (FIG. 6B) may flow through the crenels **157** and out the tip **110** (FIG. 6B).

[0053] FIG. 6D depicts the result of the completed delivery by the syringe **100** of the fluid from both the first compartment **160** and the second compartment **165** according to various embodiments. In some embodiments, the thumb piece **150** may have been pushed completely to the end of the finger guards **115**. As a result, the piston **145** may have moved the length of its travel, and the second plunger **135** may be extended to its most distal position. In some embodiments, the second compartment **165** may have been compressed to a minimum volume, and the fluid previously contained therein may have been delivered around the first plunger **120** and through the first compartment **160**, as disclosed in greater detail herein. Although FIG. 6D illustrates a residual volume in the second compartment **165** due to the illustrated geometry of the first plunger **120** and the second plunger **135**, it may be appreciated that the two plungers may be fabricated so that the distal surface of the second plunger and the proximal surface of the first plunger allow for a minimal to zero volume when the second plunger is completely extended distally. FIG. 6D also illustrates that the connection piece **130** may be in an un-tensioned state at the end of fluid delivery. As previously described herein, the connection piece **130** may be designed to impart a force on the first plunger **120** when the second plunger **135** is withdrawn towards the proximal end **101** of the syringe body **105**, and may not transfer a force to the first plunger while the second plunger is pushed toward the distal end of the syringe.

[0054] In various embodiments, the syringe **100** may be filled by operating in a reverse order of delivery. Thus, in some embodiments, an empty syringe **100** may begin with both the first plunger **120** and the second plunger **135** at the distal end **102** of the syringe **105**. In some embodiments, the second fluid may be introduced first into the second compartment **165** from the tip **110** when a user moves the thumb piece **150** in a proximal motion away from the finger guard **115**. The proximal movement of the thumb piece **150** may cause the piston **145** and the mechanically coupled second plunger **135** to also move proximally. In some embodiments, the second plunger **135** may be withdrawn proximally into the syringe body **105**, thereby taking up the slack in the connection piece **130**. Once the second plunger **135** has moved sufficiently in a proximal direction into the syringe body **105** (see FIG. 6B), the connection piece **130** may be pulled taut and further proximal motion on the piston **145** may be transferred to the first plunger **120**. Once the first seal **125** is pulled into the syringe body **105** proximal to the recesses **155**, the second compartment **165** may be sealed, and no additional fluid may be introduced into the second compartment. At this point, the thumb piece **150** may be further retracted proximally. Once the first seal **125** of the first plunger **120** is engaged against the interior surface of the syringe barrel **105**, a first fluid introduced through the tip **110** may be delivered to the first compartment **160**.

[0055] FIGS. 7A-7C depict movement of the various components of the syringe **200** depicted in FIG. 2A according to an embodiment. As described in greater detail herein, pressure on the thumb piece **250** may be transferred through the piston **245** to the second plunger **235**. Barring any fluid path from the second compartment **265**, a hydraulic lock will force the first plunger **220** in the distal direction, as described in greater detail herein. Thus, if the valve **275** is in either the third or fourth states as shown in FIG. 3, no fluid may flow through the transfer tube **270** from the second compartment and in some embodiments, particularly if the valve **275** is in the third state, fluid from the first compartment **260** will be delivered through the tip **210** and the outlet port **280** in a similar manner as the embodiment shown in FIGS. 1A and 1B. FIG. 7B illustrates the result of the valve **275** in a second state. In some embodiments, when the valve **275** is in either the first or second states (FIG. 3), fluid from the second compartment **265** may travel through the transfer tube **270** as indicated by the directional arrow ***D*** and out the outlet port **280**. As a result, the hydraulic lock between the second plunger **235** and the first plunger **220** may be released, and the first plunger is no longer driven by the second plunger until they come in physical contact with each other, as shown in FIG. 7C. In some embodiments, because the second plunger **235** can move

independently of the first plunger **220**, the connection piece **230** may lose tension, as illustrated in FIGS. 7B and 7C.

[0056] In various embodiments, it may be appreciated that the syringe **200** may be filled by operating in a reverse order of the delivery, as previously described herein. The valve **275** may be adjusted according to whether it is desired to fill the first compartment **260** or the second compartment **265**, and the plungers may be forced in a proximal direction to effect intake of fluid into the respective compartments.

[0057] FIGS. 8A-8C depict movement of the various components of the syringe **500** depicted in FIG. 5 according to various embodiments. In some embodiments, the inner piston **547** may be released from the outer sleeve **546** to slide distally, bring the attachment member **548** of the piston in contact with the attachment member **537** of the second plunger **535** and lock the two attachment members together. The inner piston **547** may be locked to the outer sleeve **546** so that they are configured to move in unison and, upon receipt of a force on the thumb piece **550**, cause the first plunger **520** to move in a substantially distal direction toward the tip **510**. The movement of the first plunger **520** may cause a first fluid contained within the first compartment **560** to be ejected from the tip **510**.

[0058] In various embodiments, once the first plunger **520** comes into contact with a distal portion of the syringe body **505**, it may form a third seal **524** with the distal portion of the syringe body to prevent a second fluid in the second compartment **565** from escaping in a proximal direction around the outside of the first plunger. In some embodiments, the valve actuators **511** may apply a force upon contacting the check valve **523**, causing the check valve to actuate. In particular embodiments, the valve actuators **511** may apply the force in a proximal direction, thus forcing the check valve **523** to actuate by moving the check valve proximally into the second compartment **565**. By forcing the check valve into the second compartment **565**, a passageway may open between the second compartment **565** and the tip **510**, thus allowing the second fluid from the second compartment to flow to the tip. In various embodiments, the inner piston **547** may once again be unlocked from the outer sleeve **546** so that it can move independently of the outer sleeve. A force may be applied to the inner piston **547** to cause the second plunger **535** to move in a distal direction within the first plunger **520**, thereby forcing the second fluid out of the second compartment **565** and through the tip **510**.

[0059] In various embodiments, it may be appreciated that the syringe **500** may be filled by operating in a reverse order of the delivery, as previously described herein. The second plunger **535** may be forced in a proximal direction by the inner piston **547**, thereby

drawing the second fluid into the second compartment **565**. Once the second plunger **535** contacts a proximal portion of the first plunger **520**, the proximally directed force may draw the first plunger in a proximal direction as well. Removal of the first plunger **520** from the distal portion of the syringe body **505** may cause the valve actuators **511** to allow the check valve **523** to slide distally within the first plunger, thereby sealing the contents of the second compartment **565** therein. Further force upon the first plunger **520** in a proximal direction may allow the first fluid to be drawn into the first compartment **560**, as previously described herein.

[0060] Still other embodiments of the multiple compartment syringe system may comprise a syringe body comprising a hollow lumen and a distal end, the syringe body being configured to house a plurality of fluids therein; a first plunger positioned in the hollow lumen of the syringe body, forming a first seal with an inner wall of the syringe body, and forming a first compartment between the first plunger and the distal end of the syringe; a second plunger positioned proximal to the first plunger in the hollow lumen of the syringe body, forming a second seal with the inner wall of the syringe body, and forming a second compartment between the first plunger and the second plunger; a fluid bypass disposed about the inner wall of the syringe body and the first plunger at or near the distal end of the syringe body, wherein a first fluid can flow through the fluid bypass to the second compartment; and a mechanism for proximally moving the first plunger to a position proximal to the fluid bypass such that the first plunger forms the first seal, the mechanism comprising one of a slidable end cap at the distal end of the syringe body, a push rod configured to push the first plunger in the proximal direction, and a sleeve comprising at least one magnet at or near the distal end of the sleeve and in magnetic communication with at least one magnet or ferromagnetic material in the first plunger.

[0061] Certain embodiments of the multiple compartment syringe are illustrated in FIGS 9A-9B. According to these embodiments, the syringe **900** may comprise a reversibly slidable end cap **940** which selectively controls fluid connection between a first volume compartment **950** and a second volume compartment **955**. The syringe comprises cylindrical syringe body **910** having a hollow lumen and end cap **940** comprising a circumferential wall **941** slidably retained in the inner wall of the distal end of syringe body **910** and having syringe tip **942** having a fluid intake/egress passage **945**. The syringe tip **942** may further include a conventional connector known in the art, such as, for example a luer connector, to connect the tip to any conventional fluid delivery device, such as a needle, catheter, or tube. The syringe further comprises a distal first plunger **930** and a proximal second plunger **920**,

wherein second plunger **920** is connected to a thumb piece **965** by piston **960**. The area between the second plunger **920** and the first plunger **930** defines the first volume compartment **950** and the area between the first plunger **930** and the end cap **940** defines fluid passage **955'** when first plunger **930** and end cap **940** are in the fully distal position (as illustrated in FIG. 9A) and defines a second volume compartment **955** when first plunger **930** is drawn proximally away from end cap **940** (as illustrated in FIG. 9B). FIG. 9A also illustrates fluid bypass **915** which fluidly connects passage **945** with the first volume compartment **950** via fluid passage **955'** when end cap **940** is in the distal position. Applying a proximal force "b" to thumb piece **965** moves piston **960** and second plunger **920** is a proximal direction which will cause a first fluid, such as a flushing fluid, for example, saline, to flow from a flushing fluid source through passages **945** and **955'** and fluid bypass **915** into the first volume compartment **950**. According to certain non-limiting embodiments, the fluid bypass may comprise a plurality disposed about the inner wall of the syringe body at or near the distal end of the syringe, such as, for example, scalloped or crenelated recesses. Once the desired volume of flushing fluid has been drawn into first volume compartment **950**, the syringe may be shifted to a second mode to draw in a second fluid, such as a pharmaceutical solution, for example, a medicament, contrast agent or radiopharmaceutical, into second volume compartment **955** (shown in FIG. 9B). Shifting to the second mode is accomplished by applying a proximal force "a" on syringe end cap **940**, such as by pushing end cap **940** against a surface. Force "a" causes end cap **940** and circumferential wall **941** to slide in a proximal direction to seal against an edge of the inner wall of syringe body **910**, thereby closing and sealing bypass **915**. Syringe tip **942** is attached to a source of the second fluid and the second fluid is drawn into volume compartment **955** by applying proximal force "b" to thumb piece **965** which moves piston **960** and second plunger **920** in a proximal direction and also moves first plunger **930** proximally by hydraulic force from a hydraulic lock. Once aspiration of the second fluid is complete and the desired amount of the second fluid has been drawn into second volume compartment **955**, the syringe may be used to deliver the second fluid in volume compartment **955** to a patient followed by delivery of the flushing fluid in volume compartment **950** to flush the fluid delivery device and ensure complete delivery of the second fluid. As shown in FIG. 9C, application of distal force "b'" to thumb piece **965** forces piston **960** and second plunger **920** in a distal direction which forces first plunger **930** in a distal direction by the hydraulic lock delivering the second fluid through passage **945**. Once the distal edge of the first plunger **930** meets the inner surface of end cap **940** and the second fluid has substantially been delivered through passage **945**, the first plunger **930** then

forces end cap **940** distally to the end of the syringe body (force "a'") thereby unsealing and opening up fluid bypass **915**. Continued application of distal force on thumb piece **965** results in delivery of flushing fluid in volume compartment **950** through fluid bypass **915** and fluid passages **955'** and **945**. By this method, the various embodiments of this syringe may sequentially aspirate a flushing fluid and pharmaceutical and deliver the pharmaceutical followed by flushing with the flushing fluid.

[0062] In another embodiment, illustrated in FIGS. 10A and 10B, syringe **1000** may allow sequential aspiration of a flushing fluid and a pharmaceutical and delivery of the pharmaceutical followed by flushing with the flushing fluid. According to this embodiment, the syringe **1000** may comprise a push rod **1080** which selectively controls fluid connection between a first volume compartment **1050** and a second volume compartment **1055**. The syringe comprises cylindrical syringe body **1010** having a hollow lumen and a T-connector **1070** comprising push rod **1080** at the distal end of syringe body **1010** and having syringe tip **1042** having a fluid intake/egress passage **1045**. The syringe tip **1042** may further include a conventional connector known in the art, such as, for example a luer connector, to connect the tip **1042** to any conventional fluid delivery device, such as a needle, catheter, or tube, after loading the syringe. The syringe further comprises a distal first plunger **1030** and a proximal second plunger **1020**, wherein second plunger **1020** is connected to a thumb piece **1065** by piston **1060**. The area between the second plunger **1020** and the first plunger **1030** defines the first volume compartment **1050** and the area between the first plunger **1030** and the distal end of the syringe defines fluid passage **1055'** when first plunger **1030** is in the fully distal position (as illustrated in FIG. 10A) and defines a second volume compartment **1055** when first plunger **1030** is drawn proximally away from the distal end of the syringe (as illustrated in FIG. 10B). T-connector **1070** fluidly connects fluid passage **1045** with fluid inlet **1075**. FIG. 10A also illustrates fluid bypass **1015** which fluidly connects passage **1045** with the first volume compartment **1050** via fluid passage **1055'** when first plunger **1030** is in the distal position. Applying a proximal force to thumb piece **1065** moves piston **1060** and second plunger **1020** in a proximal direction which causes a first fluid, such as a flushing fluid, for example, saline, to flow from a flushing fluid source through passages **1075**, **1045** and **1055'** and fluid bypass **1015** into the first volume compartment **1050**. Once the desired volume of flushing fluid has been drawn into first volume compartment **1050**, the syringe may be shifted to a second mode to draw in a second fluid, such as a pharmaceutical solution, for example, a medicament, contrast agent or radiopharmaceutical, into second volume compartment **1055** (shown in FIG. 10B). Shifting to the second mode is accomplished by

applying a proximal force on push rod **1080**. Proximal force on push rod **1080** forces first plunger **1030** in a proximal direction until sealing means **1035** contact and seal against an edge of the inner wall of syringe body **1010**, thereby sealing volume compartment **1050** from bypass **1015**. Syringe tip **1042** is attached to a source of the second fluid, for example, via passage **1075** in T-connector **1070** and the second fluid is drawn into volume compartment **1055** by applying proximal force to thumb piece **1065** which moves piston **1060** and second plunger **1020** in a proximal direction and also moves first plunger **1030** proximally by a hydraulic lock. In addition, the second fluid may be drawn into volume compartment **1050** upon pushing first plunger **1030** with push rod **1080**. Push rod **1080** is sealed with the inner walls of T-connector **1070** by sealing means **1072** to prevent fluid leakage therethrough. Once aspiration of the second fluid is complete and the desired amount of the second fluid has been drawn into second volume compartment **1055**, the syringe may be used to deliver the second fluid in volume compartment **1055** to a patient followed by delivery of the flushing fluid in volume compartment **1050** to flush the fluid delivery device and ensure complete delivery of the second fluid. In one embodiment, fluid delivery may be through a fluid delivery device attached to fluid passage **1075** of T-connector **1070**. In another embodiment fluid delivery may be though a fluid delivery device attached to fluid passage **1045** after removal of T-connector **1070**. Sequential delivery of the second fluid and flushing fluid may occur in a manner similar to the syringe of FIG. 9C, described herein. That is, application of a distal force on thumb piece **1065** pushes piston **1060** and the second plunger **1020** in a distal direction which forces the first plunger **1030** in a distal direction, thus delivering the second fluid through passage **1042**. Once the plunger sealing means **1035** reach the fluid bypass **1015**, generally upon delivery of substantially all of the second fluid, the volume compartment **1050** is fluidly connected to fluid bypass **1015** and the first flush fluid may pass through fluid bypass **1015** and passages **1055'** and **1045** for delivery to a patient with concurrent flushing of the second fluid from the syringe and fluid delivery device.

[0063] Another embodiment of the multi-compartment syringe may comprise a syringe having an arrangement of magnets to control selective aspiration and infusion of a first and second fluid. As illustrated in FIGS. 11A and 11B, syringe **1100** may allow sequential aspiration of a flushing fluid and a pharmaceutical and delivery of the pharmaceutical followed by flushing with the flushing fluid. According to this embodiment, the syringe **1100** which selectively controls fluid connection between a first volume compartment **1150** and a second volume compartment **1155**. The syringe comprises

cylindrical syringe body **1110** having a hollow lumen and sleeve **1170** circumferentially surrounding syringe body **1110** and comprising at least one magnet **1185** in magnetic communication with one or more magnets or ferromagnetic materials **1180** in a distal first plunger **1130** and a proximal second plunger **1120** and having syringe tip **1142** having a fluid intake/egress passage **1145**. The syringe tip **1142** may further include a conventional connector known in the art, such as, for example a luer connector, to connect the tip to any conventional fluid delivery device, such as a needle, catheter, or tube, after loading the syringe. The second plunger **1120** may be connected to a thumb piece **1165** by piston **1160**. The area between the second plunger **1120** and the first plunger **1130** defines the first volume compartment **1150** and the area between the first plunger **1130** and the distal end of the syringe defines fluid passage **1155'** when first plunger **1130** is in the fully distal position (as illustrated in FIG. 11A) and defines a second volume compartment **1155** when first plunger **1130** is drawn proximally away from the distal end of the syringe (as illustrated in FIG. 11B). Sleeve **1170** surrounds the outer body of syringe **1110** and comprises one or more magnets **1185** and/or **1185'** in magnetic communication with one or more magnets or ferromagnetic material **1180** in one or both of the first plunger **1130** and second plunger **1120**. FIG. 11A also illustrates fluid bypass **1115** which fluidly connects passage **1145** with the first volume compartment **1150** via fluid passage **1155'** when first plunger **1130** is in the distal position. Applying a proximal force to thumb piece **1165** moves piston **1160** and second plunger **1120** is a proximal direction which causes a first fluid, such as a flushing fluid, for example, saline, to flow from a flushing fluid source through passages **1145** and **1155'** and fluid bypass **1115** into the first volume compartment **1150**. Once the desired volume of flushing fluid has been drawn into first volume compartment **1150**, the syringe may be shifted to a second mode to draw in a second fluid, such as a pharmaceutical solution, for example, a medicament, contrast agent or radiopharmaceutical, into second volume compartment **1155** (shown in FIG. 11B). Shifting to the second mode may be accomplished by sliding sleeve **1170** in a proximal direction, for example by the user manually drawing sleeve **1170** in a proximal direction or by a proximal force on proximal magnets **1185'** from magnets **1180** in second plunger **1120** as described herein. Distal magnets **1185** in sleeve **1170** are in magnetic communication with distal magnets or ferromagnetic material **1180** in first plunger **1130** and proximal movement of sleeve **1170** also moves first plunger **1130** in a proximal direction until sealing means **1135** contact and seal against an edge of the inner wall of syringe body **1110**, thereby sealing volume compartment **1150** from bypass **1115**. In certain embodiments, the proximal magnets **1185'** in sleeve **1170** may be in magnetic communication with the

magnets or ferromagnetic material **1180** in the second plunger **1130** and moving sleeve **1170** in a proximal direction may be affected as second plunger **1130** is drawn in a proximal direction. Syringe tip **1142** is then attached to a source of the second fluid and the second fluid is drawn into volume compartment **1155** by applying proximal force to thumb piece **1165** which moves piston **1160** and second plunger **1120** in a proximal direction and also moves first plunger **1130** proximally by the hydraulic lock. According to another embodiment, the volume of the first fluid in the volume compartment **1150** may be determined by the relative distance between distal magnets **1185** and proximal magnets **1185'** on sleeve **1170**. According to this embodiment, the first plunger **1130** is in the fully distal position (as shown in FIG 11A) and the second plunger **1120** is also in the fully distal position in contact with the first plunger. As the thumb piece **1165** is drawn proximally, first plunger **1120** is drawn in a proximal direction with volume compartment **1150** being filled with the first fluid. When the magnets or ferromagnetic material **1180** in the second plunger **1120** reach the position of proximal magnets **1185'** of sleeve **1170**, a magnetic attraction is formed and further proximal withdrawal of the second plunger **1120** also causes sleeve **1170** to be withdrawn in a proximal direction, which causes the first plunger **1130** to move proximally past fluid bypass **1115** and thereby draw up the second fluid into volume chamber **1155** (as shown in FIG. 11B). In a further embodiment the volume of the first fluid drawn into syringe **1100** relative to the volume of the second fluid may be controlled by changing the distance between proximal magnets **1185'** and distal magnets **1185**. For example, according to one embodiment sleeve **1170** may comprise an adjustable means for changing the distance between magnets **1185** and **1185'**, such as having a threaded attachment between a distal section and a proximal section of sleeve **1170** where the threaded attachment can be turned in a clockwise or counter-clockwise direction to lengthen or shorten the distance between magnets **1185** and **1185'**, thereby making the volume of volume compartment **1150** larger or smaller when the first and second plunger magnets or ferromagnetic materials **1180** are in communication with sleeve magnets **1185** and **1185'**, respectively. Once aspiration of the second fluid is complete and the desired amount of the second fluid has been drawn into second volume compartment **1155**, the syringe may be used to deliver the second fluid in volume compartment **1155** to a patient followed by delivery of the flushing fluid in volume compartment **1150** to flush the fluid delivery device and ensure complete delivery of the second fluid. Fluid delivery may be though a fluid delivery device attached to fluid passage **1145**. Sequential delivery of the second fluid and flushing fluid may occur in a manner similar to the syringe of FIG. 9C, described herein. That is, application of a distal force on

thumb piece **1165** pushes piston **1160** and the second plunger **1120** in a distal direction which forces the first plunger **1130** in a distal direction using a hydraulic lock and/or the magnetic connection between the first and second plungers, thus delivering the second fluid through passage **1145**. Once the plunger sealing means **1135** reach the fluid bypass **1115**, generally upon delivery of substantially all of the second fluid, the volume compartment **1150** is fluidly connected to fluid bypass **1115** and the first flush fluid may pass through fluid bypass **1115** and passages **1155'** and **1145** for delivery to a patient with concurrent flushing of the second fluid from the syringe and fluid delivery device. It will be understood in those embodiments comprising magnets and ferromagnetic material, interchanging the relative positions of the magnets and ferromagnetic material is within the scope of the present disclosure.

[0064] Although various embodiments have been described in detail for the purpose of illustration, 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 this 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.

CLAIMS

What is claimed is:

1. A syringe system comprising:

a syringe body comprising a hollow lumen and a distal end, the syringe body being configured to house a plurality of fluids therein;

a first plunger positioned in the hollow lumen of the syringe body, forming a first seal with an inner wall of the syringe body, and forming a first compartment between the first plunger and the distal end of the syringe;

a second plunger positioned proximal to the first plunger in the hollow lumen of the syringe body, forming a second seal with the inner wall of the syringe body, and forming a second compartment between the first plunger and the second plunger;

a fluid bypass disposed about the inner wall of the syringe body and the first plunger at or near the distal end of the syringe body, wherein a first fluid can flow through the fluid bypass to the second compartment; and

a mechanism for proximally moving the first plunger to a position proximal to the fluid bypass such that the first plunger forms the first seal, the mechanism comprising one of a slidable end cap at the distal end of the syringe body, a push rod configured to push the first plunger in the proximal direction, and a sleeve comprising at least one magnet at or near the distal end of the sleeve and in magnetic communication with at least one magnet or ferromagnetic material in the first plunger.

2. The syringe system of claim 1, wherein the mechanism comprises a slidable end cap having a circumferential wall comprising the inner wall of the distal end of the syringe body.

3. The syringe system of claim 2, wherein applying a proximal force to the slidable end cap causes the end cap to slide in a proximal direction and fluidly seal the fluid bypass.

4. The syringe system of claim 1, wherein the mechanism comprises the push rod, and further comprises a T-connector connected to a distal tip of the syringe body which directs the push rod into the first compartment to connect with the first plunger.

5. The syringe system of claim 4, wherein the T-connector is fluidly connected to at least one fluid source.

6. The syringe system of claim 1, wherein the mechanism comprises the sleeve comprising the at least one magnet at or near the distal end of the sleeve, wherein sliding the sleeve in a proximal direction slides the first plunger in the proximal direction.

7. The syringe system of claim 6, wherein the sleeve is configured to slide by applying a proximal force to the outer wall of the sleeve.

8. The syringe system of claim 6, further comprising at least one proximal magnet at or near the proximal end of the sleeve and adapted to be in magnetic communication with a magnet or ferromagnetic material in the second plunger.

9. The syringe system of claim 8, wherein when the at least one proximal magnet is in magnetic communication with the magnet or ferromagnetic material in the second plunger, movement of the second plunger in the proximal direction causes the sleeve and first plunger to move in the proximal direction.

10. The syringe system of claim 1, further comprising a piston connected to the second plunger, wherein the piston is configured to be activated by a thumb piece.

11. The syringe system of claim 1, wherein the first compartment comprises a contrast medium therein and the second compartment comprises a flushing fluid therein.

12. A syringe system comprising:

a syringe body comprising a hollow lumen and a distal end comprising a syringe tip, the syringe body being configured to house a plurality of fluids therein;

a first plunger positioned in the hollow lumen of the syringe body, forming a first seal with an inner wall of the syringe body, and forming a first compartment between the first plunger and the distal end of the syringe;

a second plunger positioned proximal to the first plunger in the hollow lumen of the syringe body, forming a second seal with the inner wall of the syringe body, and forming a second compartment between the first plunger and the second plunger; and

a transfer tube in fluid connection with the second compartment and the syringe tip.

13. The syringe system of claim 12, wherein the transfer tube comprises a valve in fluid communication with the syringe tip.

14. The syringe system of claim 13, further comprising an outlet port fluidly connected to an outlet of the valve.

15. The syringe system of claim 14, wherein the outlet port is configured to output a fluid from one or more of the first compartment and the second compartment depending on an orientation of the valve.

16. The syringe system of claim 15, wherein the orientation of the valve comprises one of a first opening state to allow fluid flow from the syringe tip to the outlet port, a second opening state to allow fluid flow from the transfer tube to the outlet port, a third opening state to allow fluid flow from both the syringe tip and the transfer tube to the outlet port, and a closed state to block flow of fluid from the syringe tip and the transfer tube.

17. The syringe system of claim 12, further comprising a plurality of recesses disposed about the inner wall of the syringe body near the distal end of the syringe body.

18. The syringe system of claim 17, wherein the plurality of recesses are scalloped or crenelated.

19. The syringe system of claim 17, wherein the first plunger, upon contacting the plurality of recesses, breaks the first seal with the inner wall of the syringe body, causing fluid contents of the second compartment to flow distally into the first compartment.

20. The syringe system of claim 12, further comprising a piston connected to the second plunger, wherein the piston is configured to be activated by a thumb piece.

21. A syringe system comprising:

a syringe body comprising a hollow lumen and a distal end comprising a syringe tip, the syringe body being configured to house a plurality of fluids therein;

a first plunger positioned in the hollow lumen of the syringe body, forming a first seal with an inner wall of the syringe body, and forming a first compartment between the first plunger and the distal end of the syringe;

a second plunger positioned proximal to the first plunger in the hollow lumen of the syringe body, forming a second seal with the inner wall of the syringe body, and forming a second compartment between the first plunger and the second plunger;

a transfer tube in fluid connection with the second compartment, the transfer tube comprising a valve having an outlet, wherein the valve is in fluid communication with the syringe tip; and

an outlet port fluidly connected to an outlet of the valve,

wherein an orientation of the valve comprises one of a first opening state to allow fluid flow from the syringe tip to the outlet port, a second opening state to allow fluid flow from the transfer tube to the outlet port, a third opening state to allow fluid flow from both the syringe tip and the transfer tube to the outlet port, and a closed state to block flow of fluid from the syringe tip and the transfer tube.

22. A syringe system comprising:

a syringe body comprising a hollow lumen and a distal end, the syringe body being configured to house a plurality of fluids therein;

a first plunger positioned in the hollow lumen of the syringe body, forming a first seal within an inner wall of the syringe body, and forming a first compartment between the first plunger and the distal end of the syringe, the first plunger comprising a hollow lumen therein; and

a second plunger positioned in the hollow lumen of the first plunger, forming a second seal within an inner wall of the first plunger, and forming a second compartment between the first plunger and the second plunger.

23. The syringe system of claim 22, further comprising a check valve positioned within a distal opening in the hollow lumen of the first plunger, wherein the check valve is configured to release contents of the second compartment when actuated.

24. The syringe system of claim 22, further comprising a piston having an inner piston and an outer sleeve, wherein the inner piston is removably connected to the second plunger and the outer sleeve is removably connected to the first plunger, and wherein the inner piston

is configured to move independently of the outer sleeve or locked to the outer sleeve so that the inner piston and outer sleeve move in unison.

25. The syringe system of claim 24, wherein the piston is configured to be activated by a thumb piece.

26. The syringe system of claim 22, wherein the first compartment comprises a contrast medium therein and the second compartment comprises a flushing fluid therein.

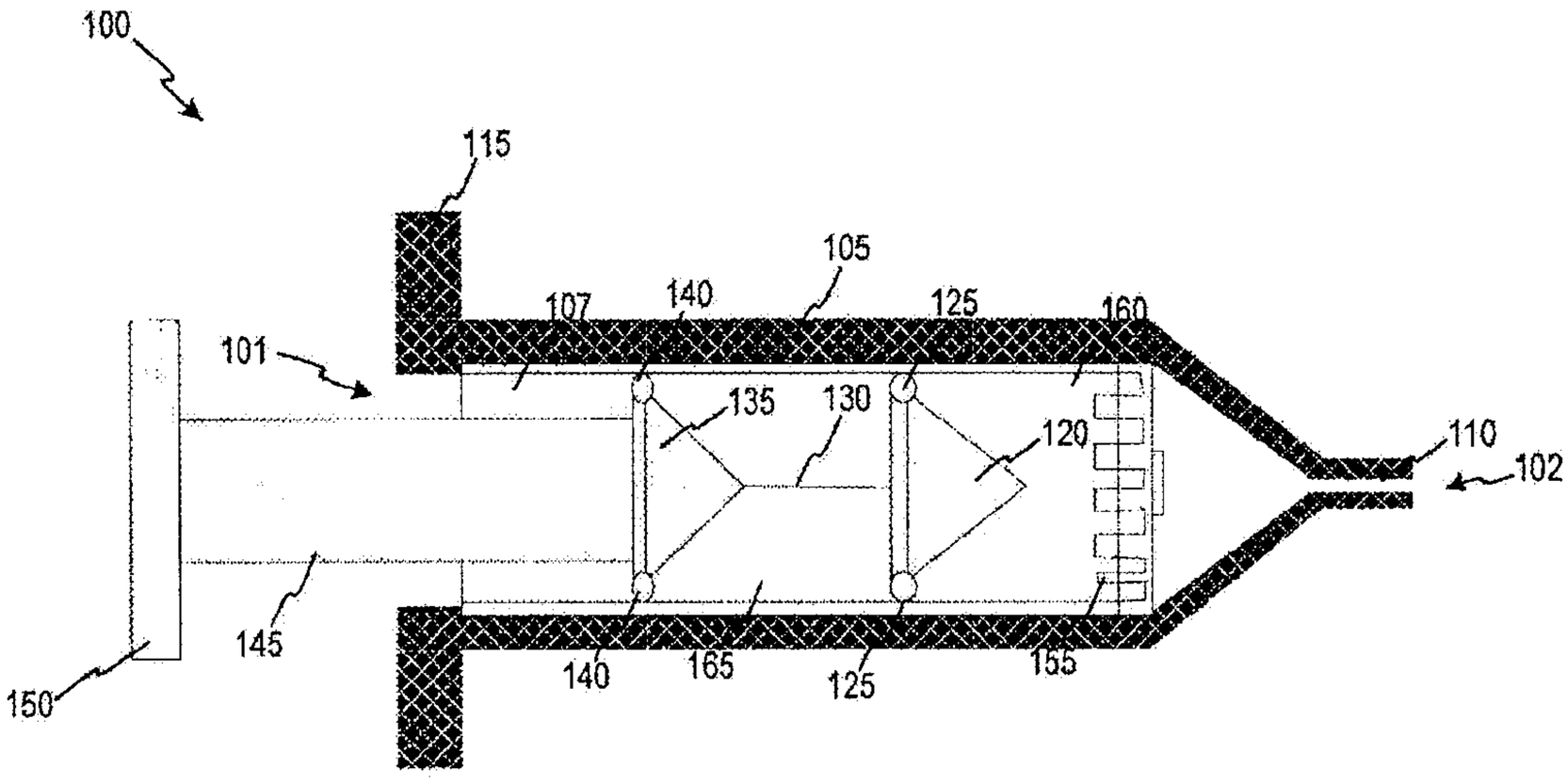
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FIG. 1A

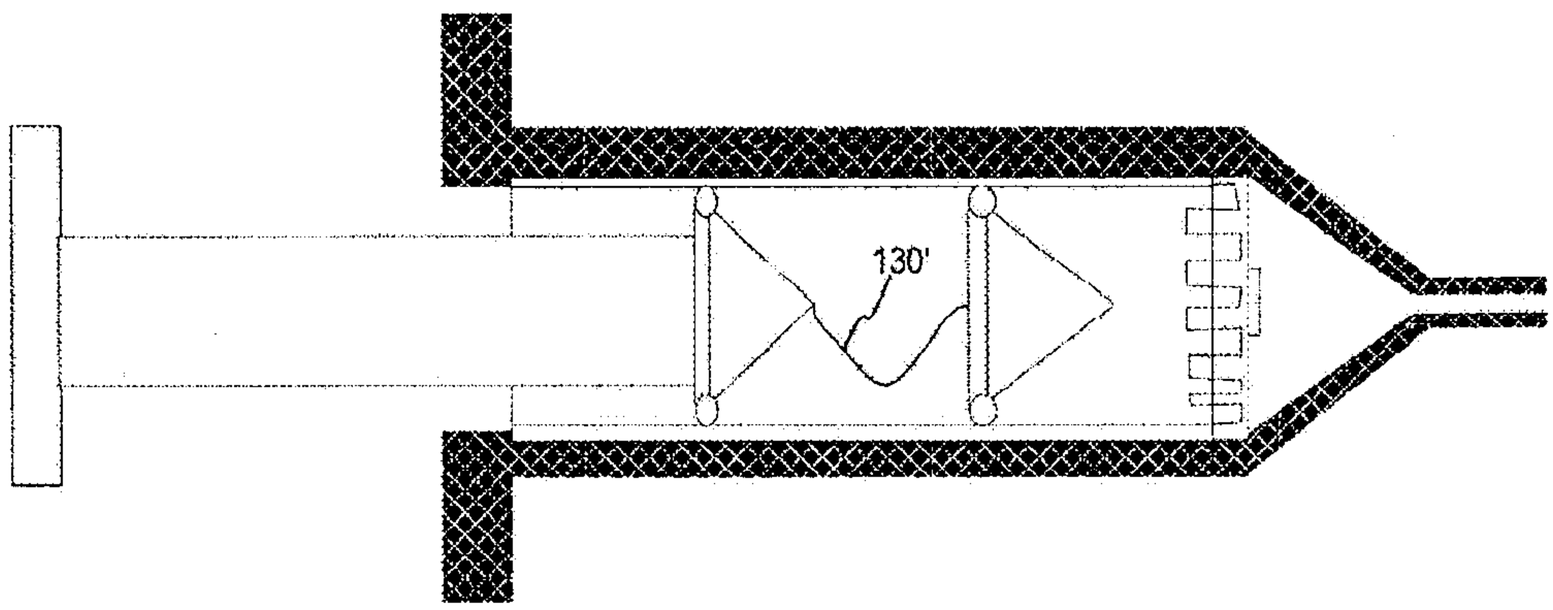
130'

FIG. 1B

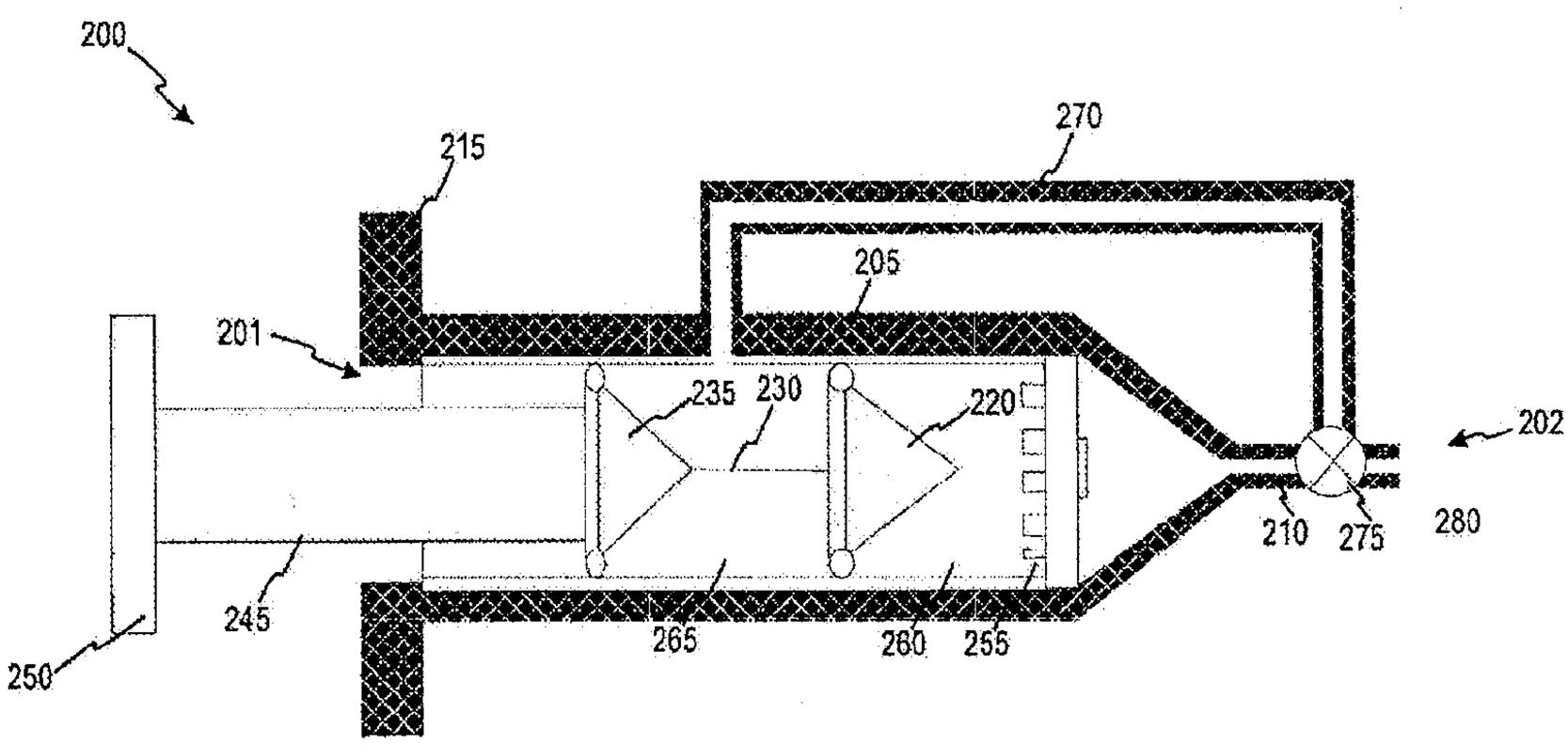
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FIG. 2A

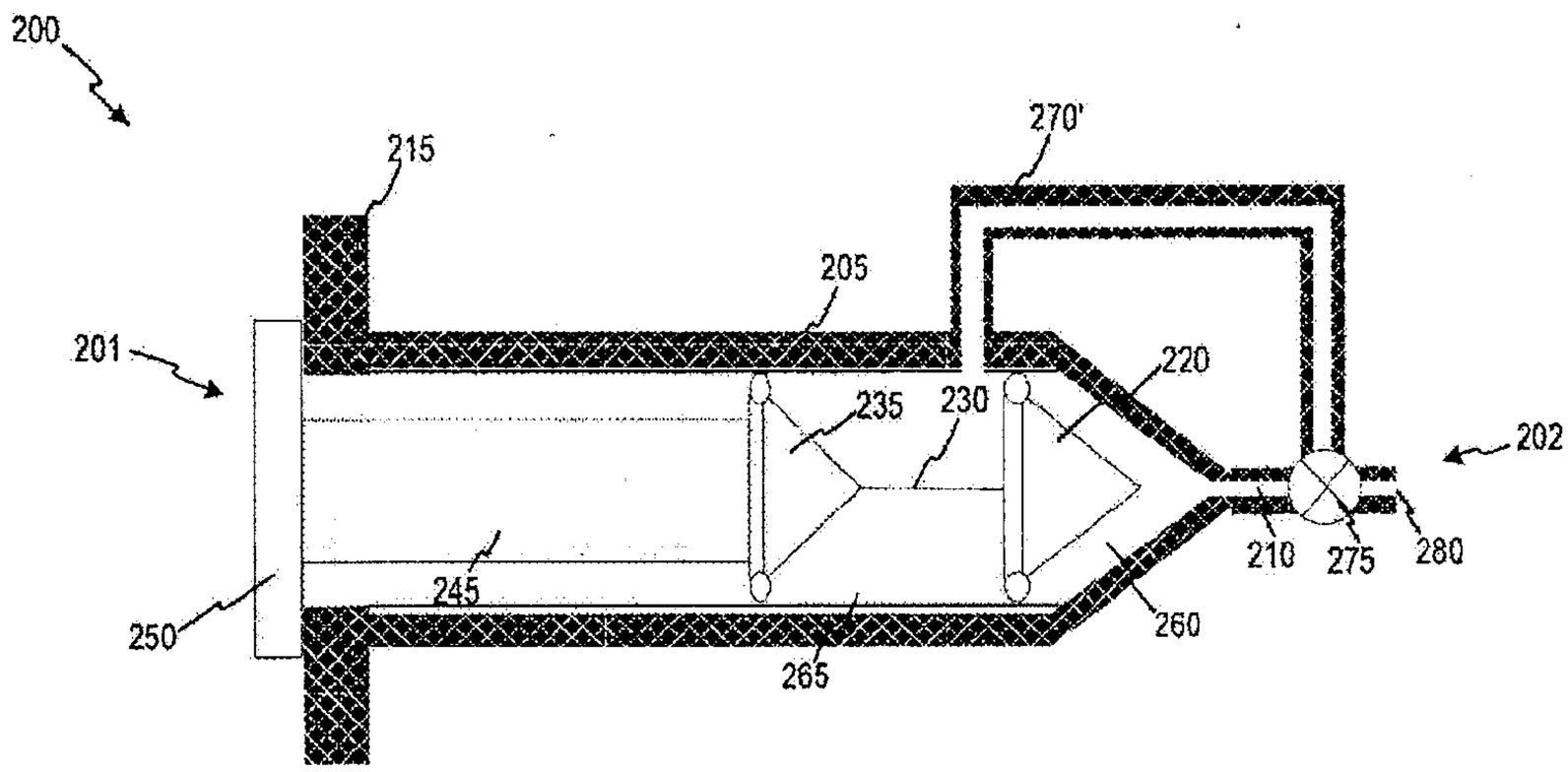
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FIG. 2B

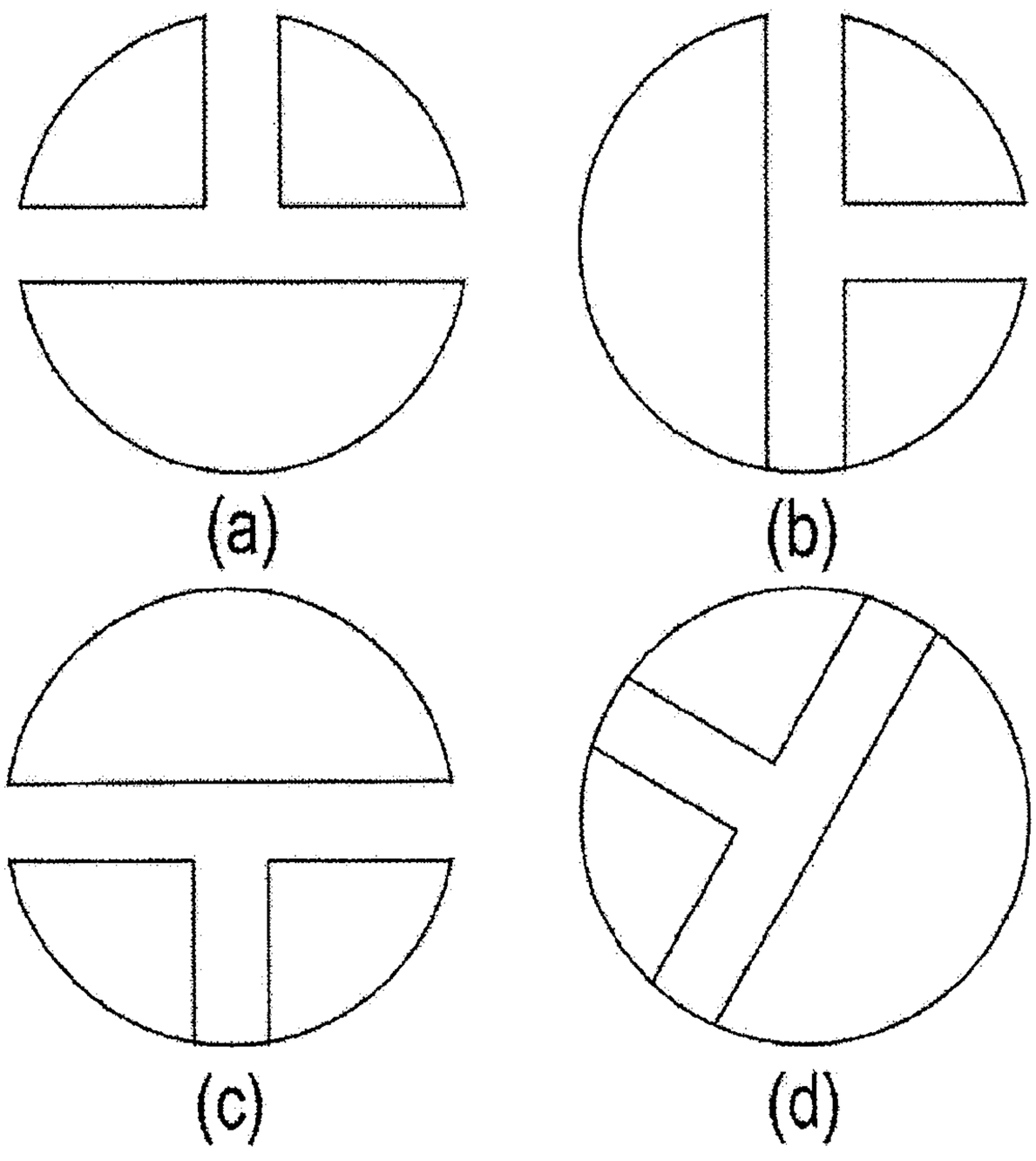

FIG. 3

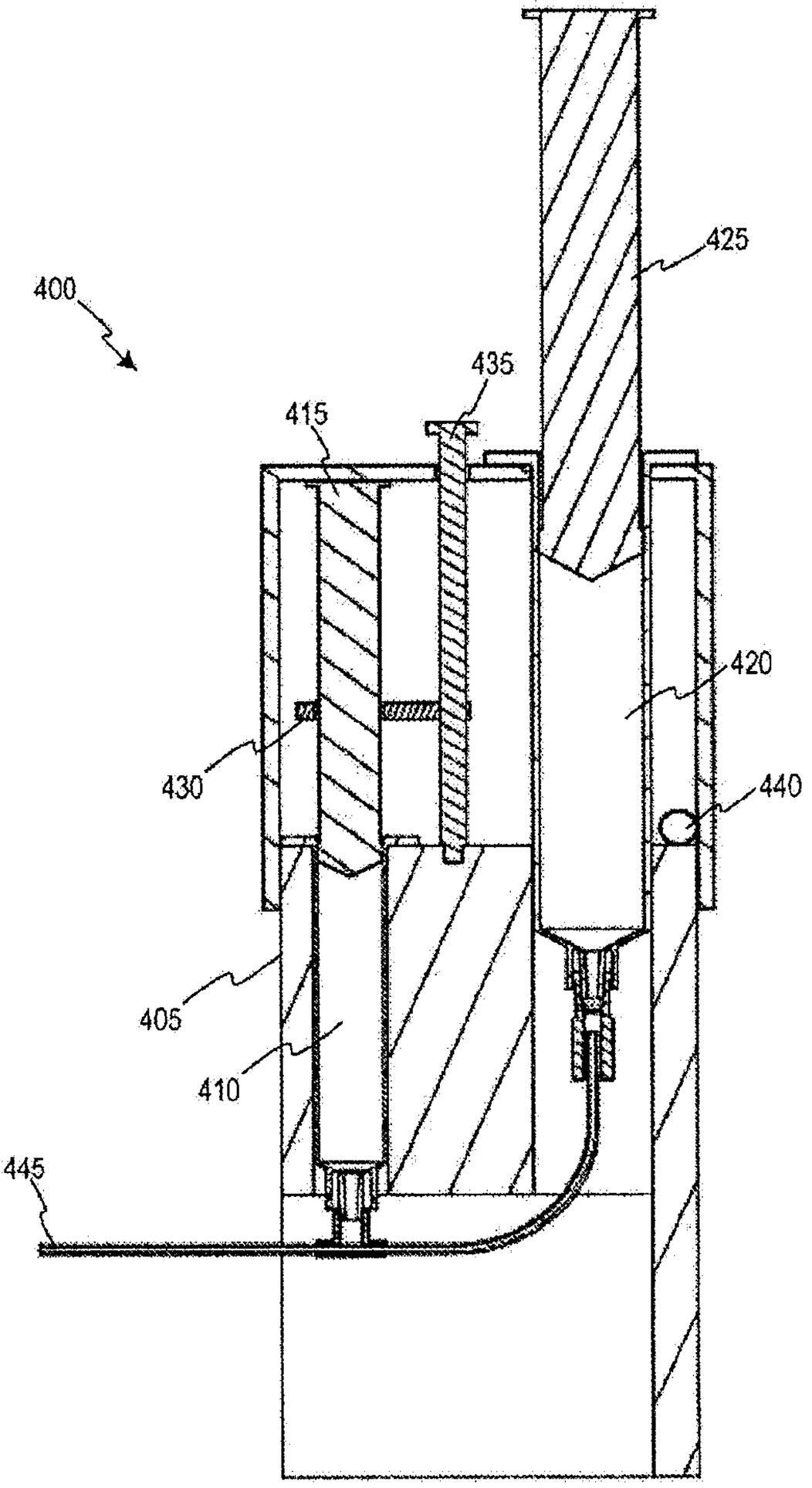

FIG. 4

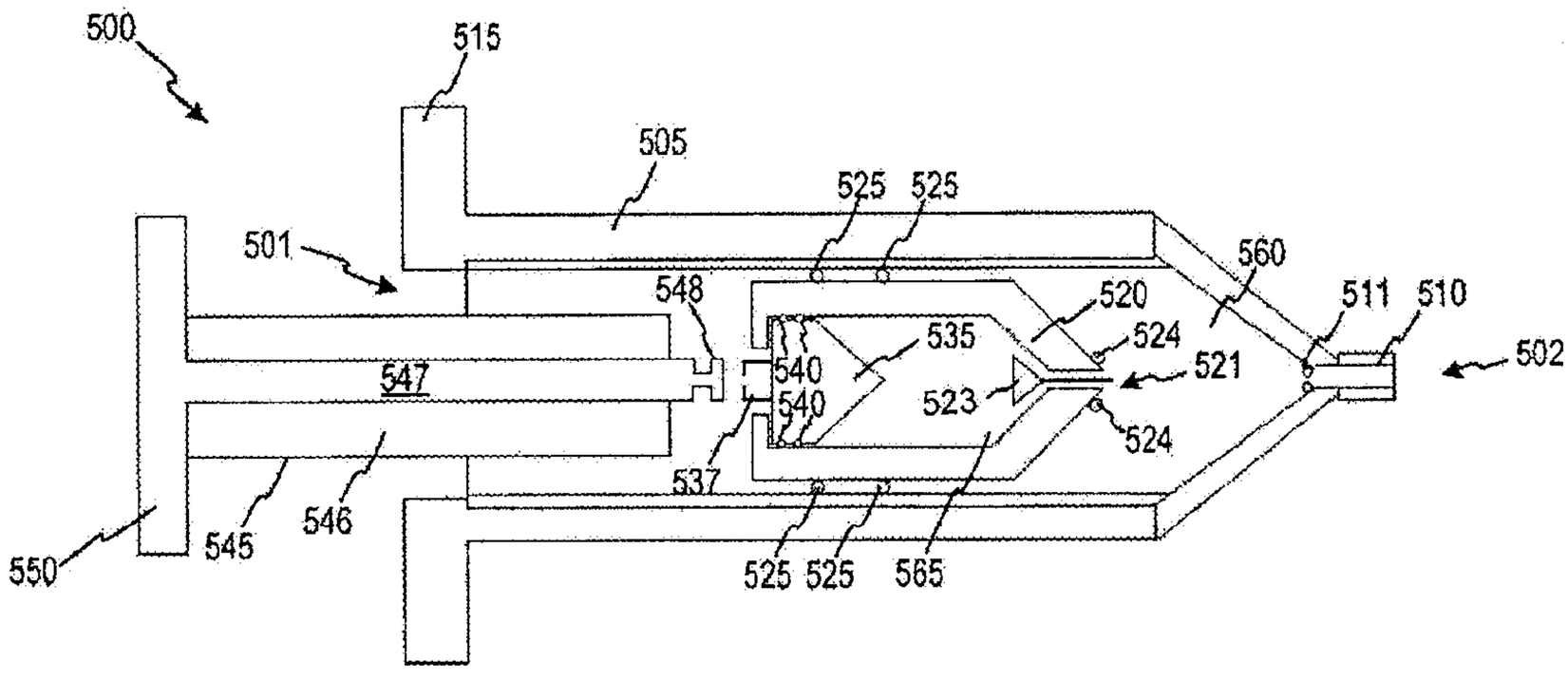
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FIG. 5

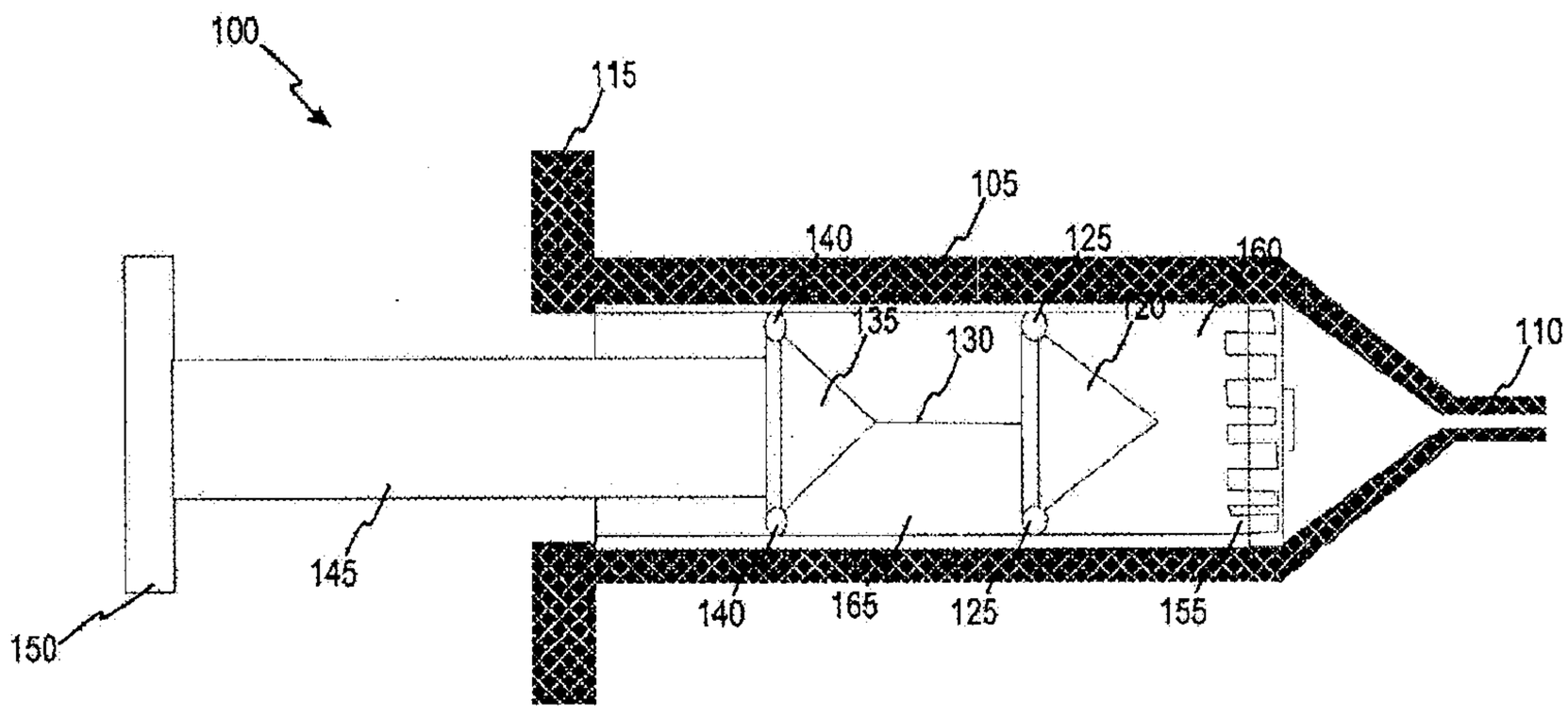
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FIG. 6A

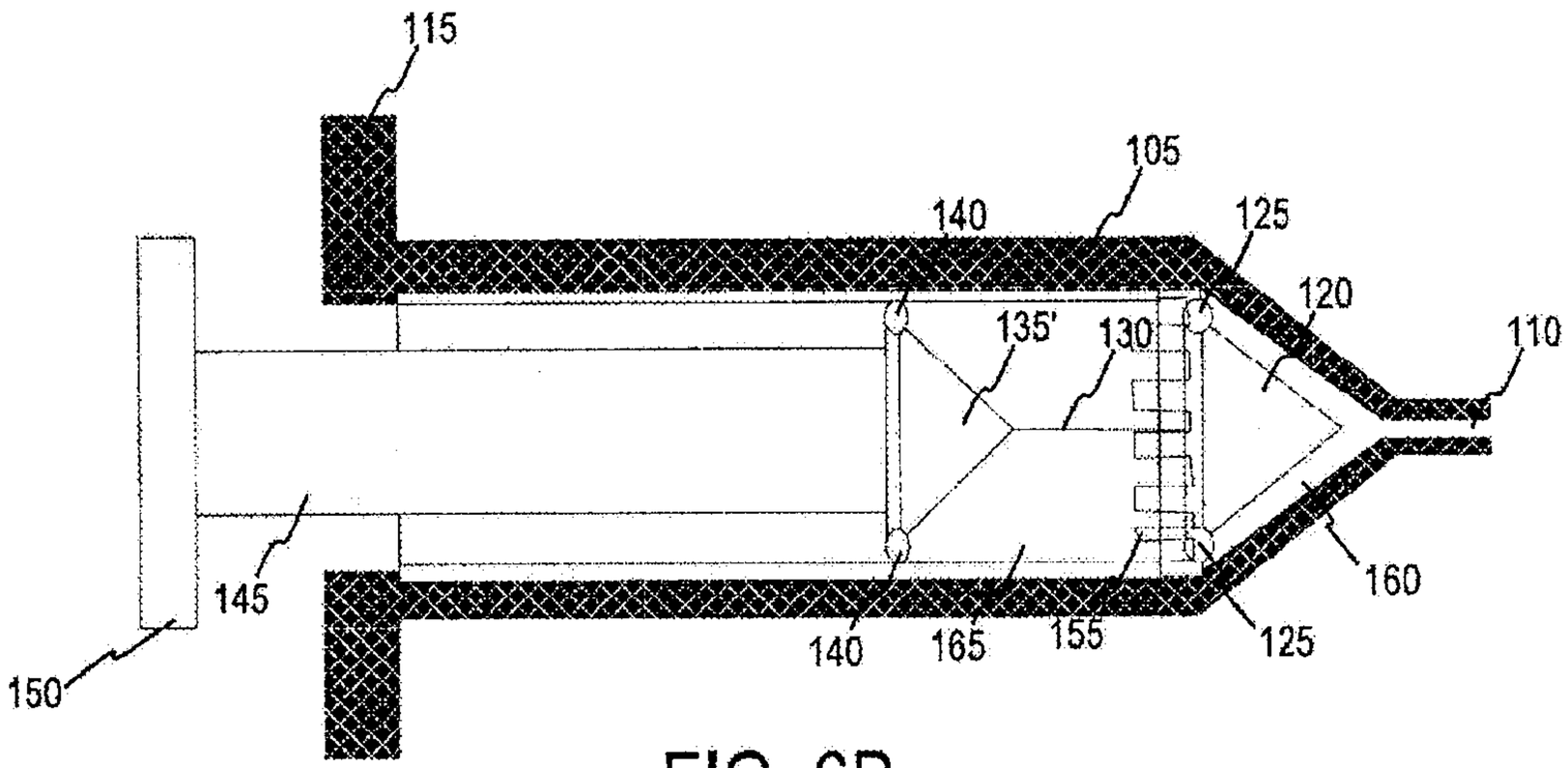
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FIG. 6B

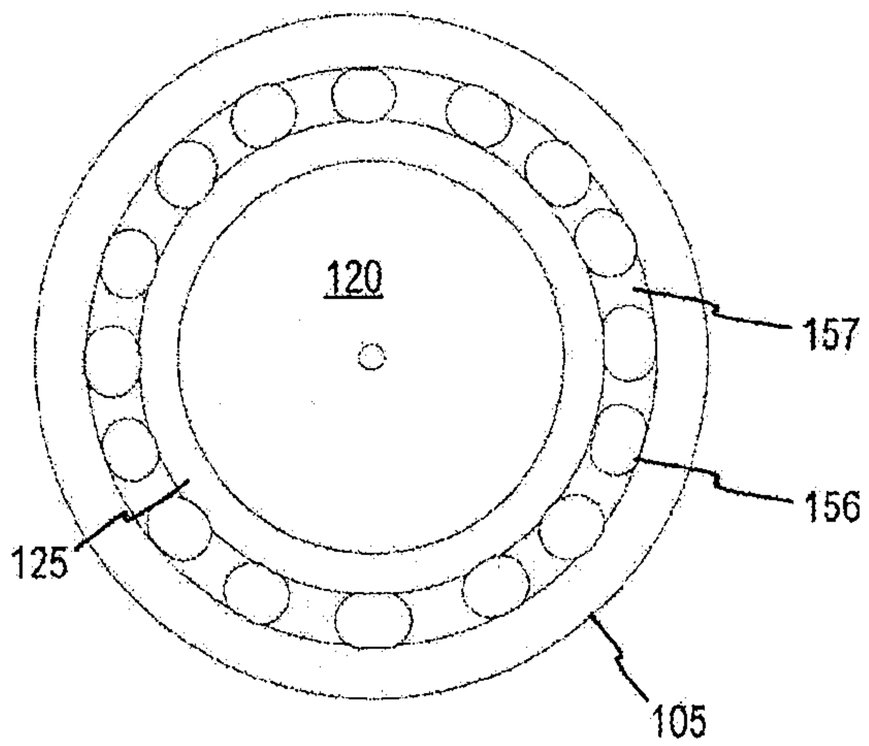
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FIG. 6C

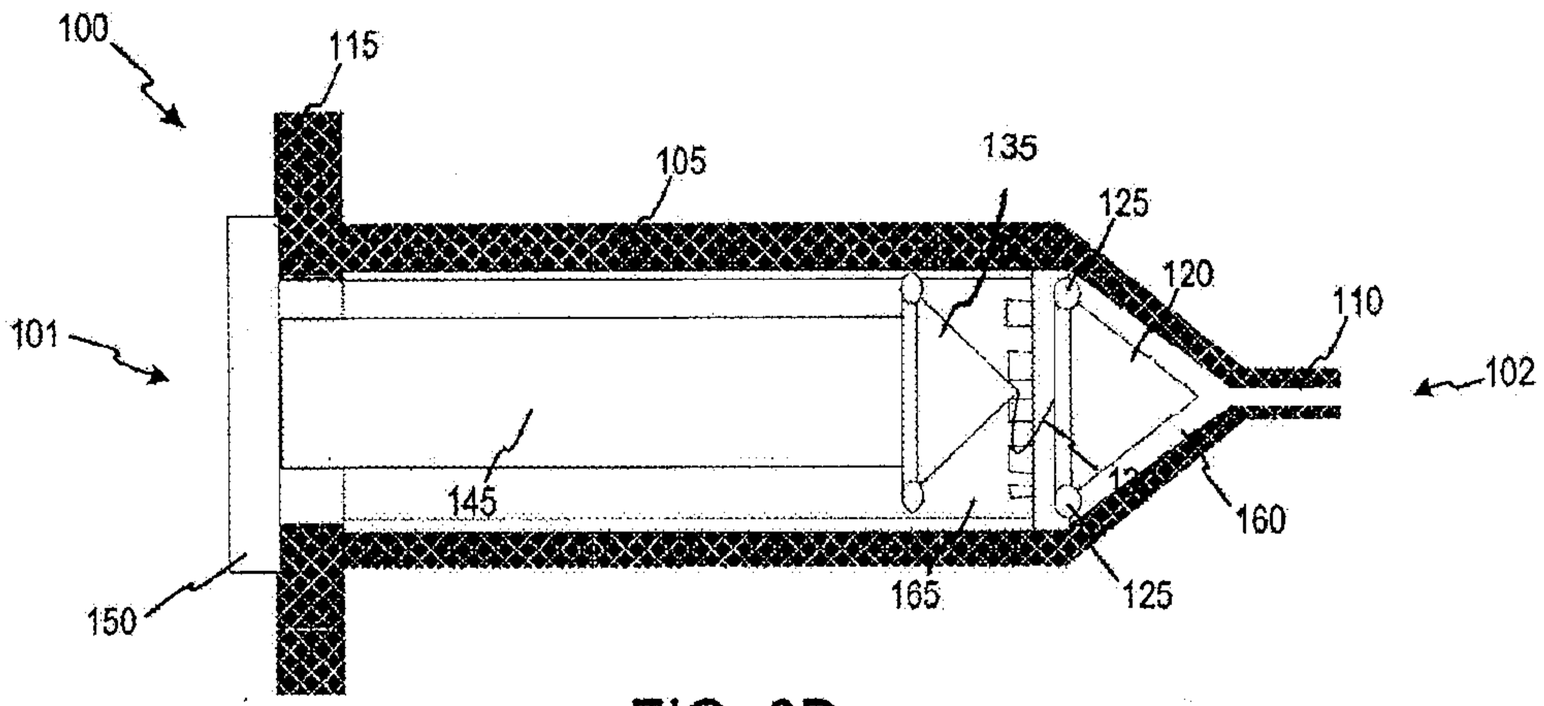
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FIG. 6D

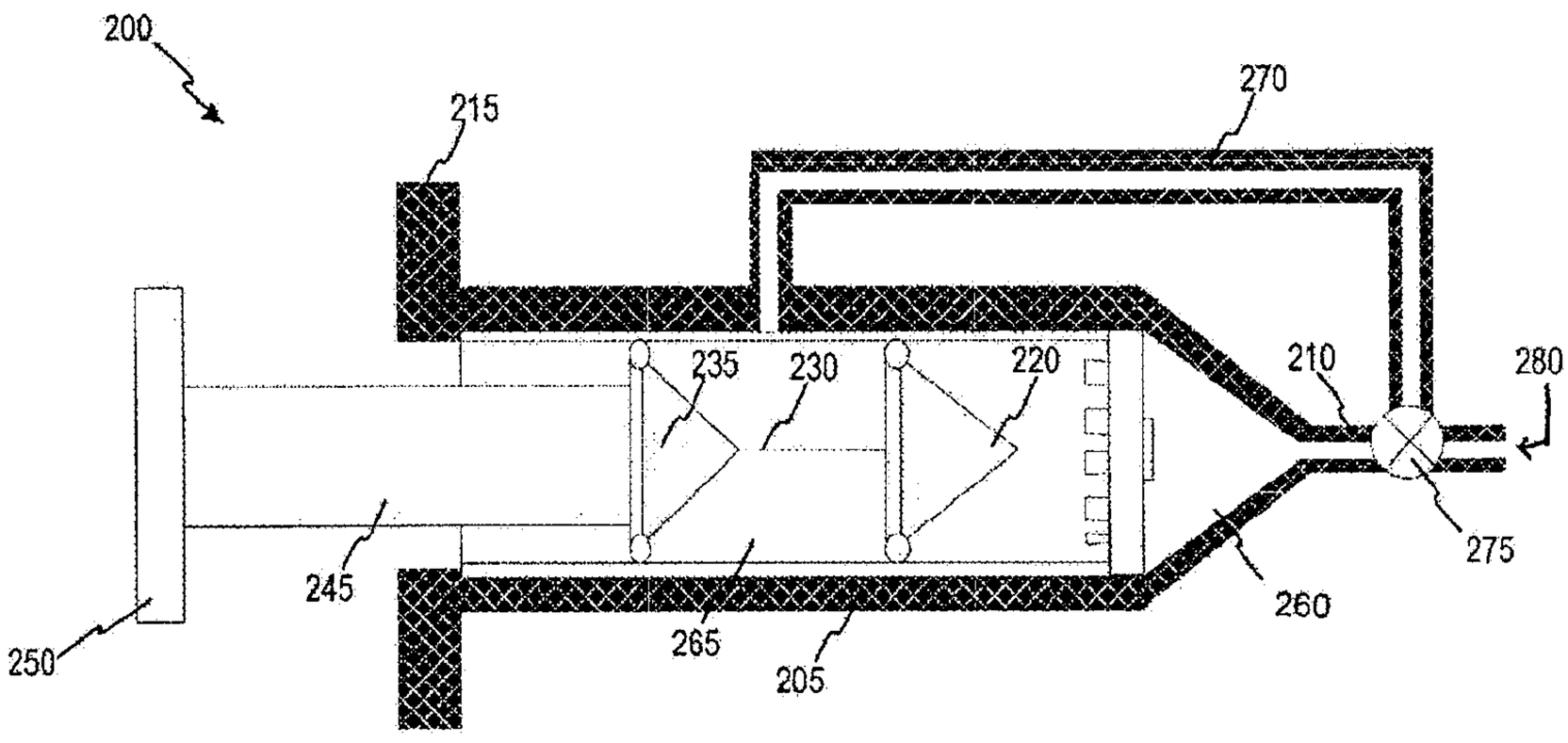
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FIG. 7A

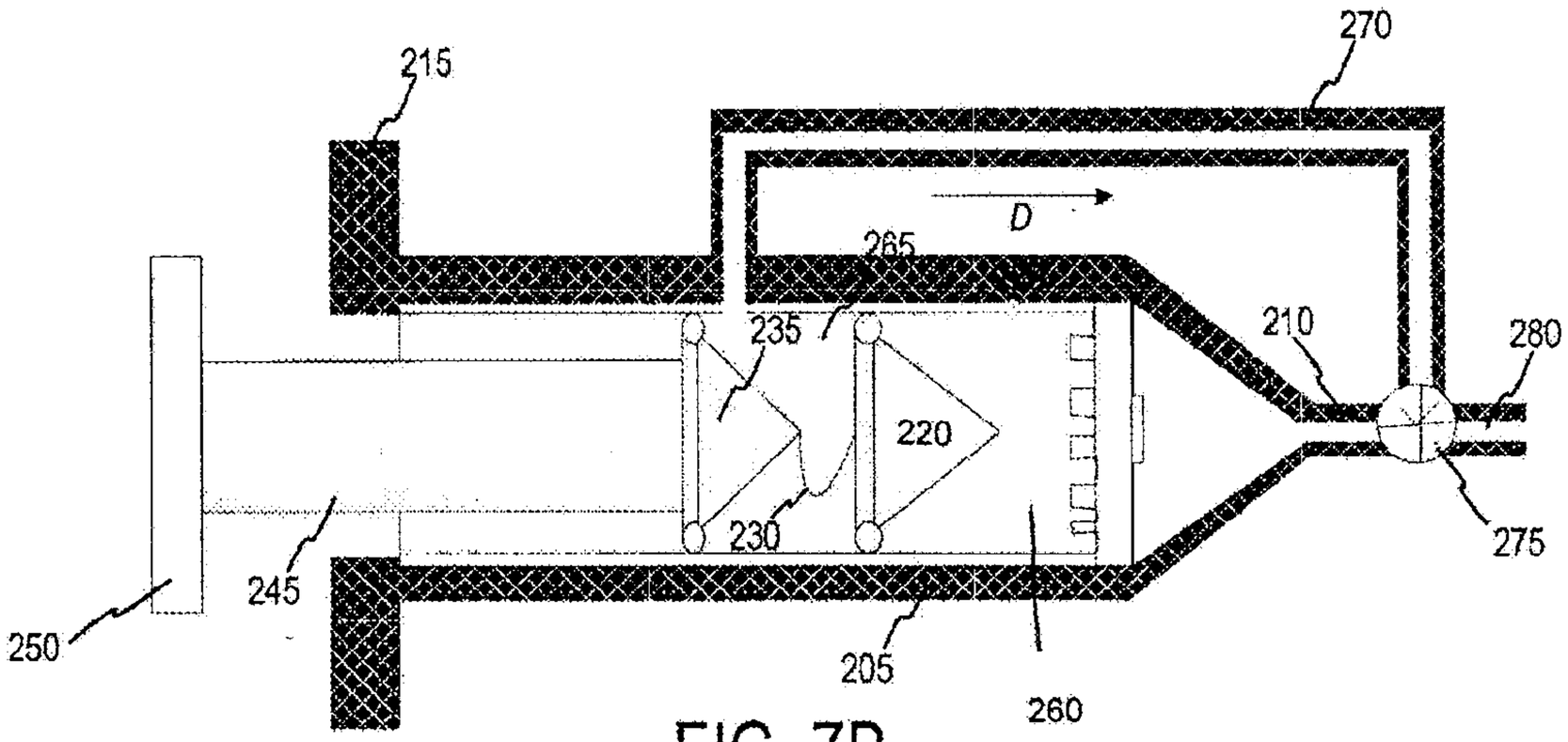
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FIG. 7B

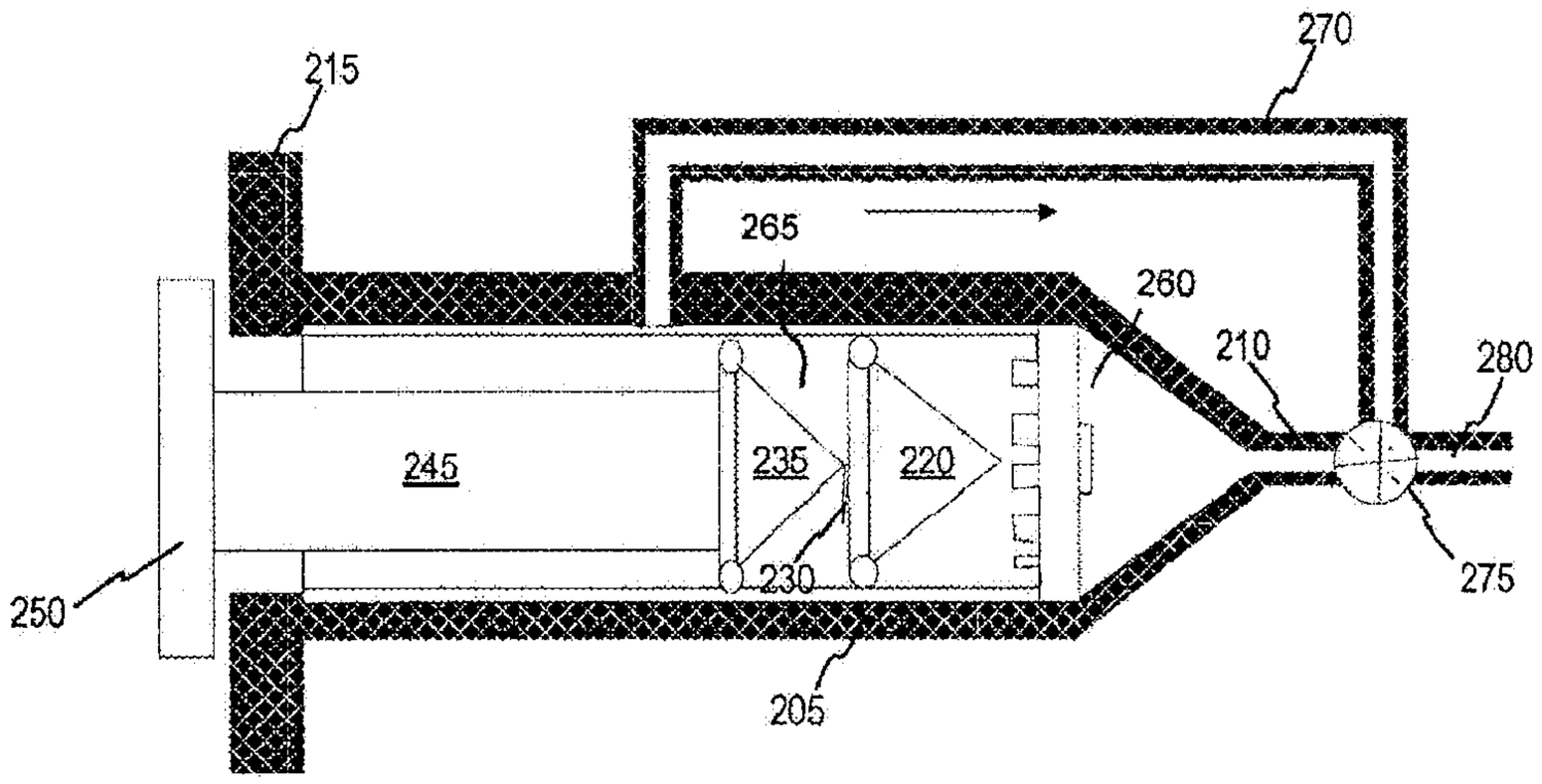
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FIG. 7C

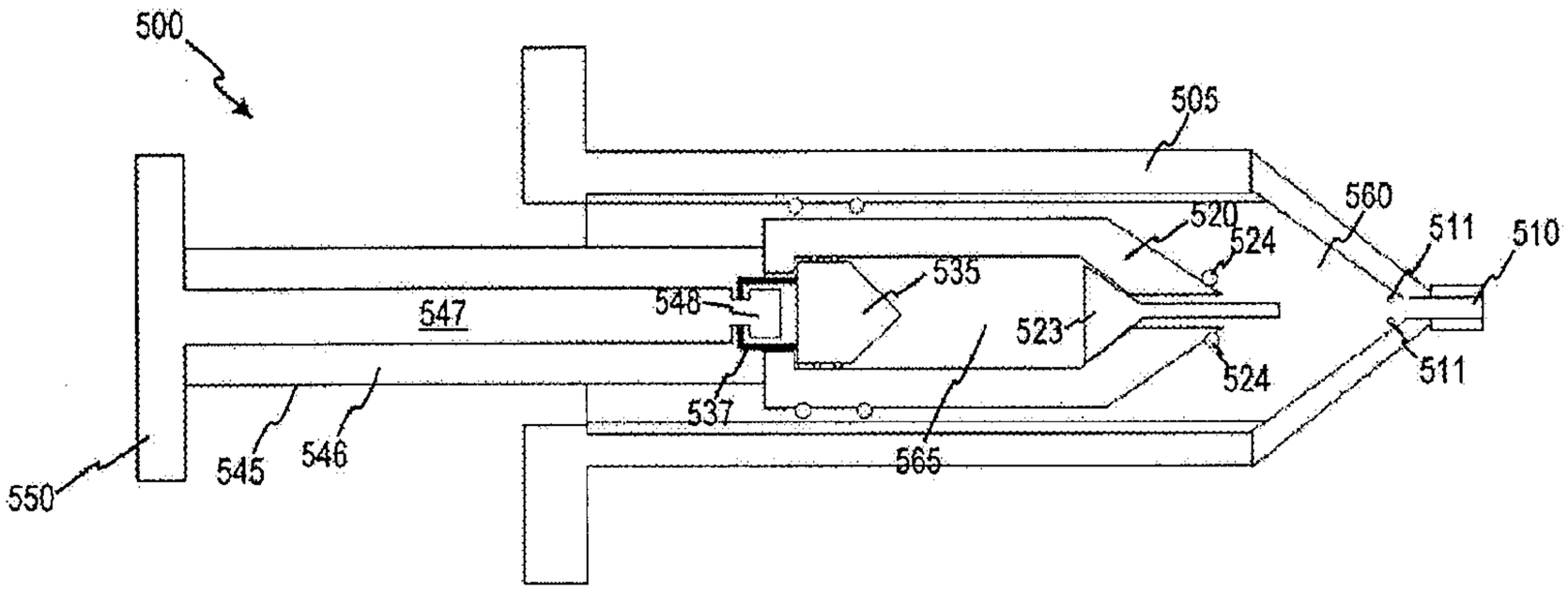

FIG. 8A

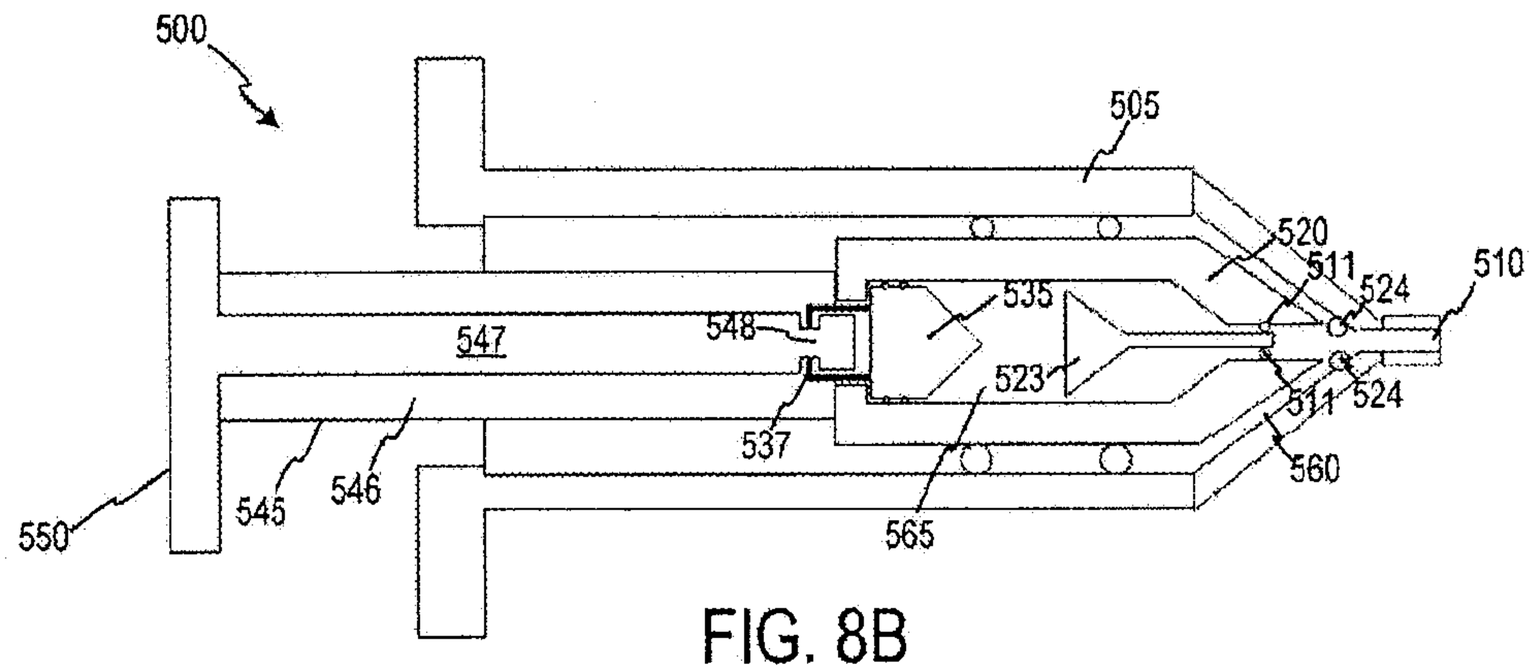

FIG. 8B

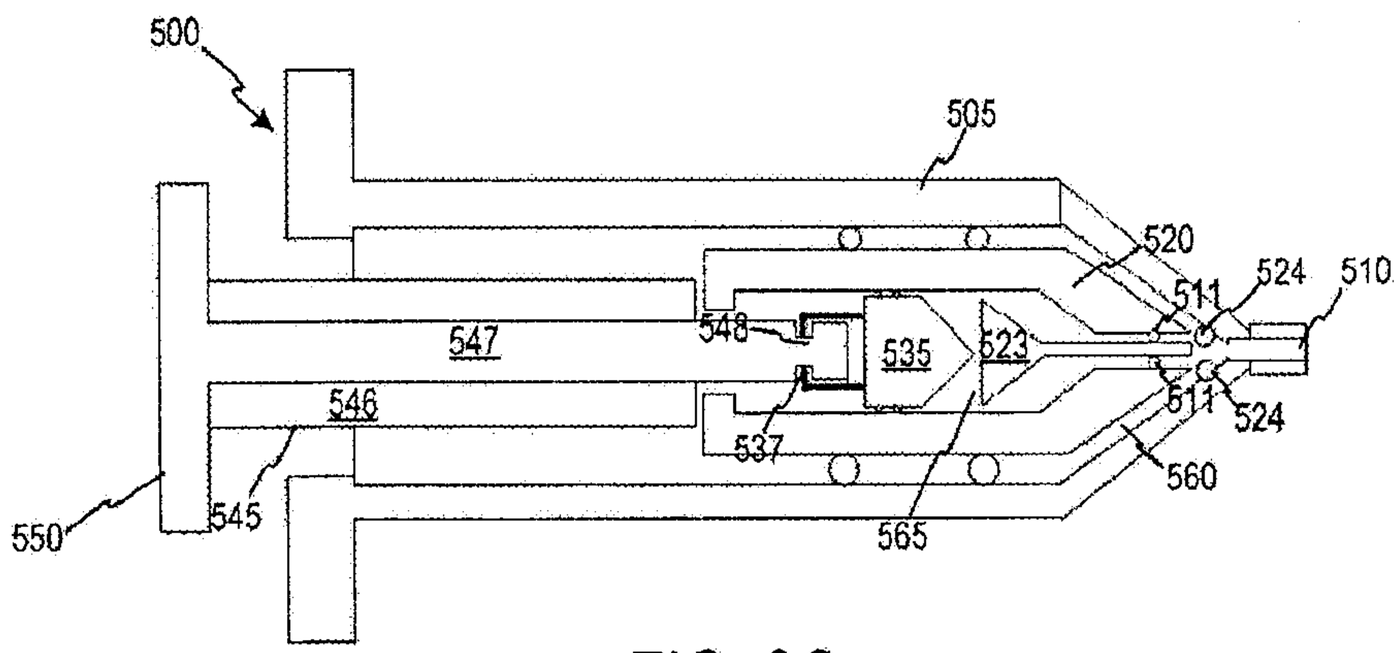

FIG. 8C

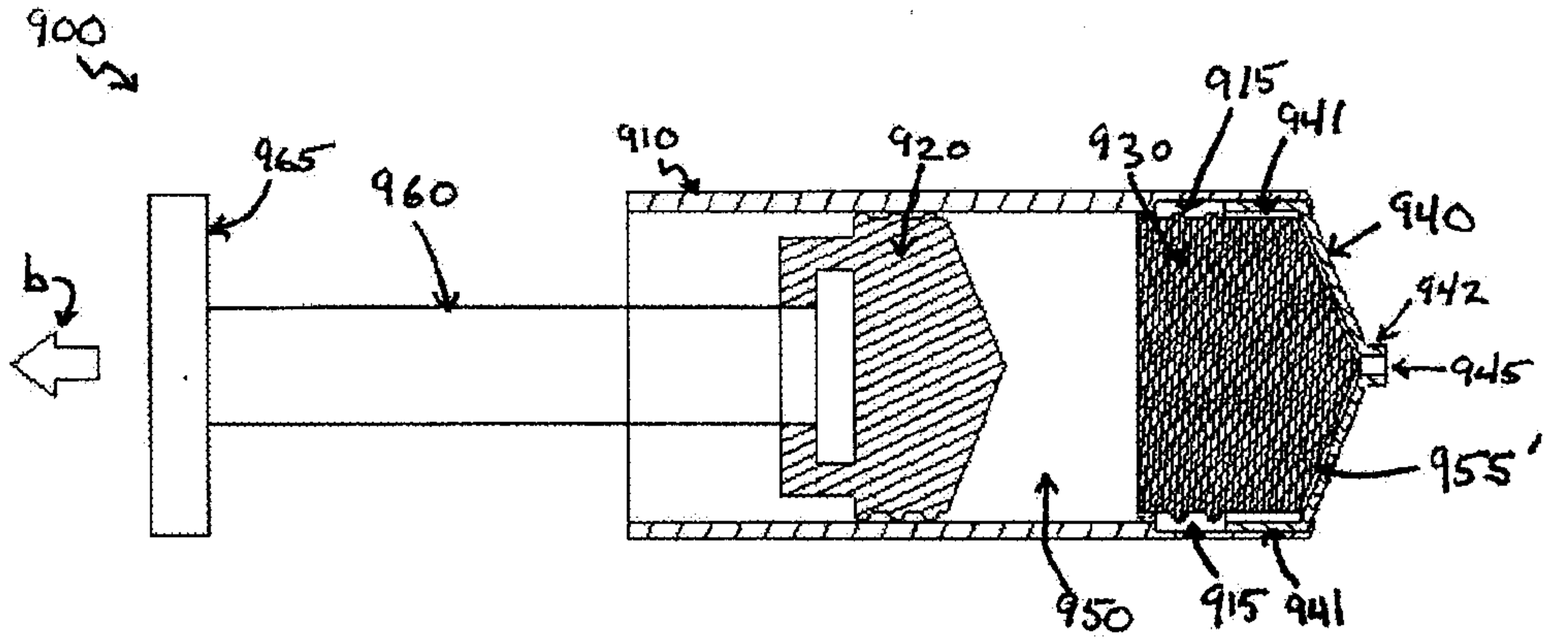

FIG. 9A

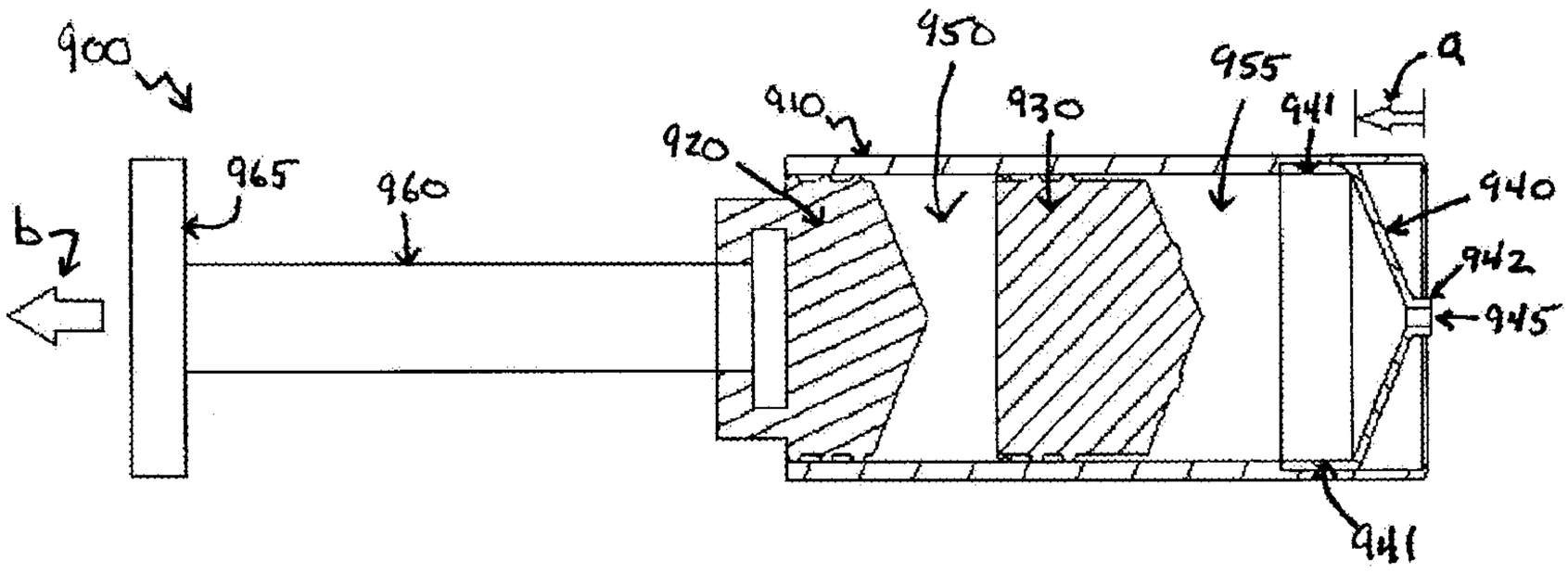

FIG. 9B

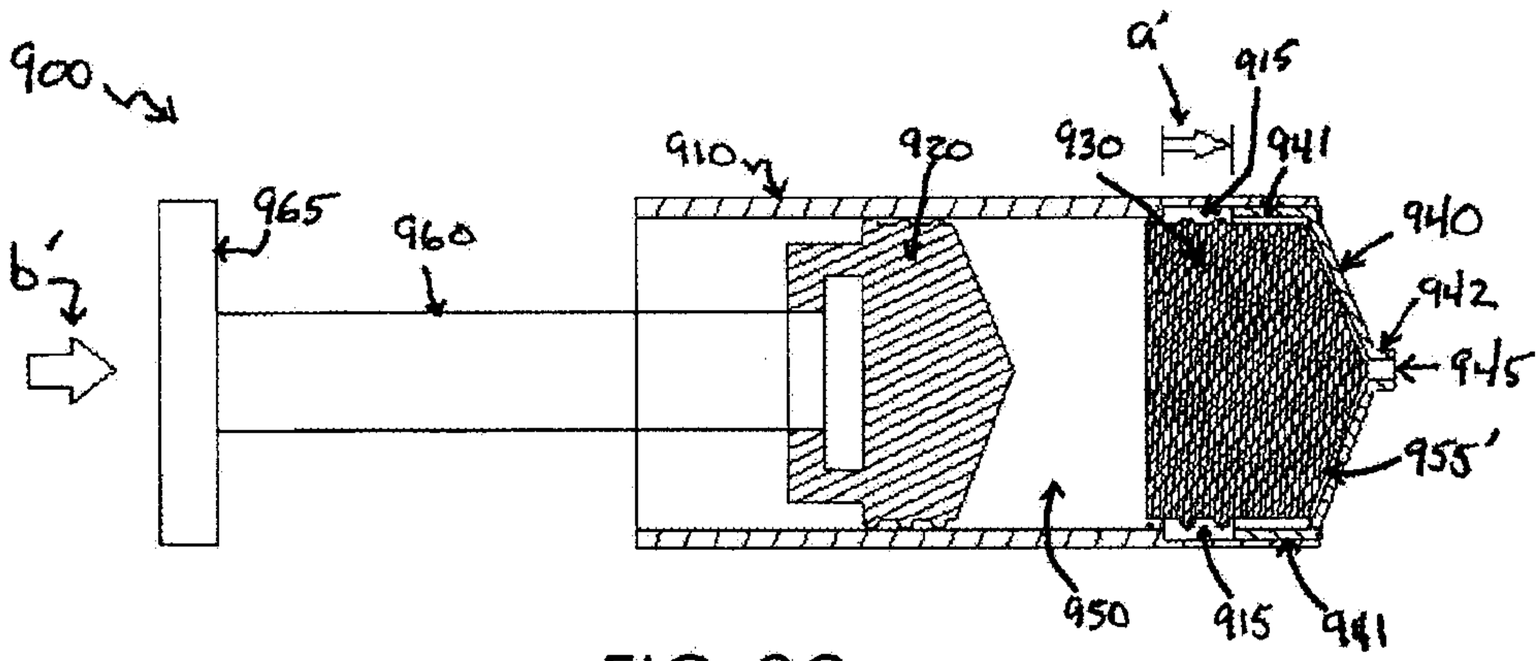

FIG. 9C

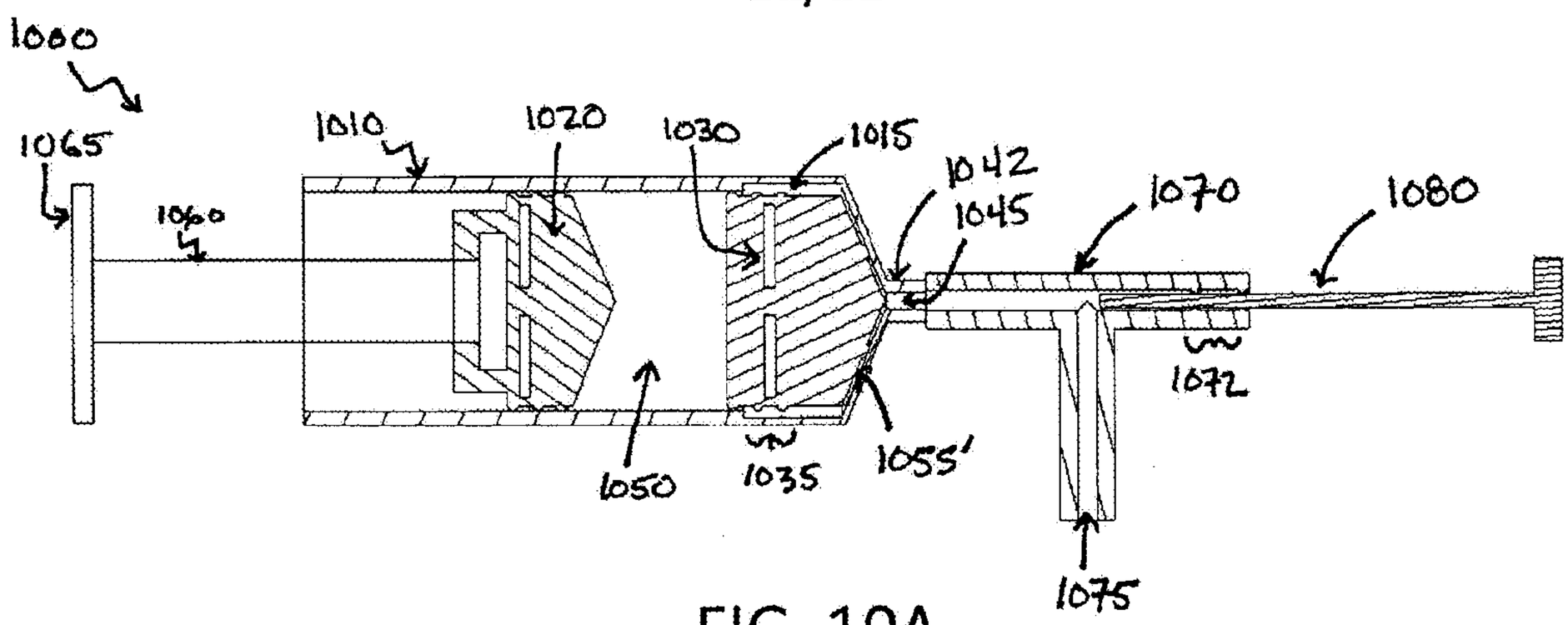

FIG. 10A

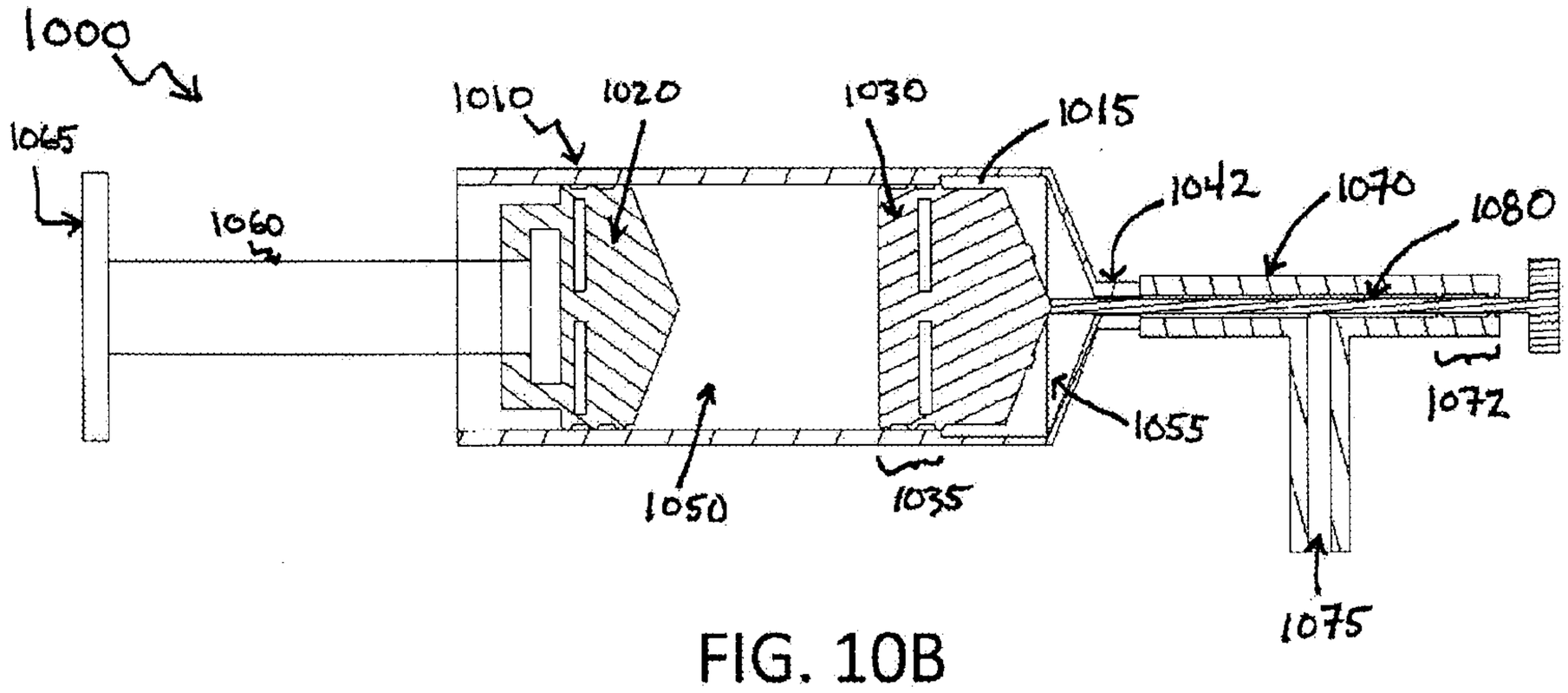

FIG. 10B

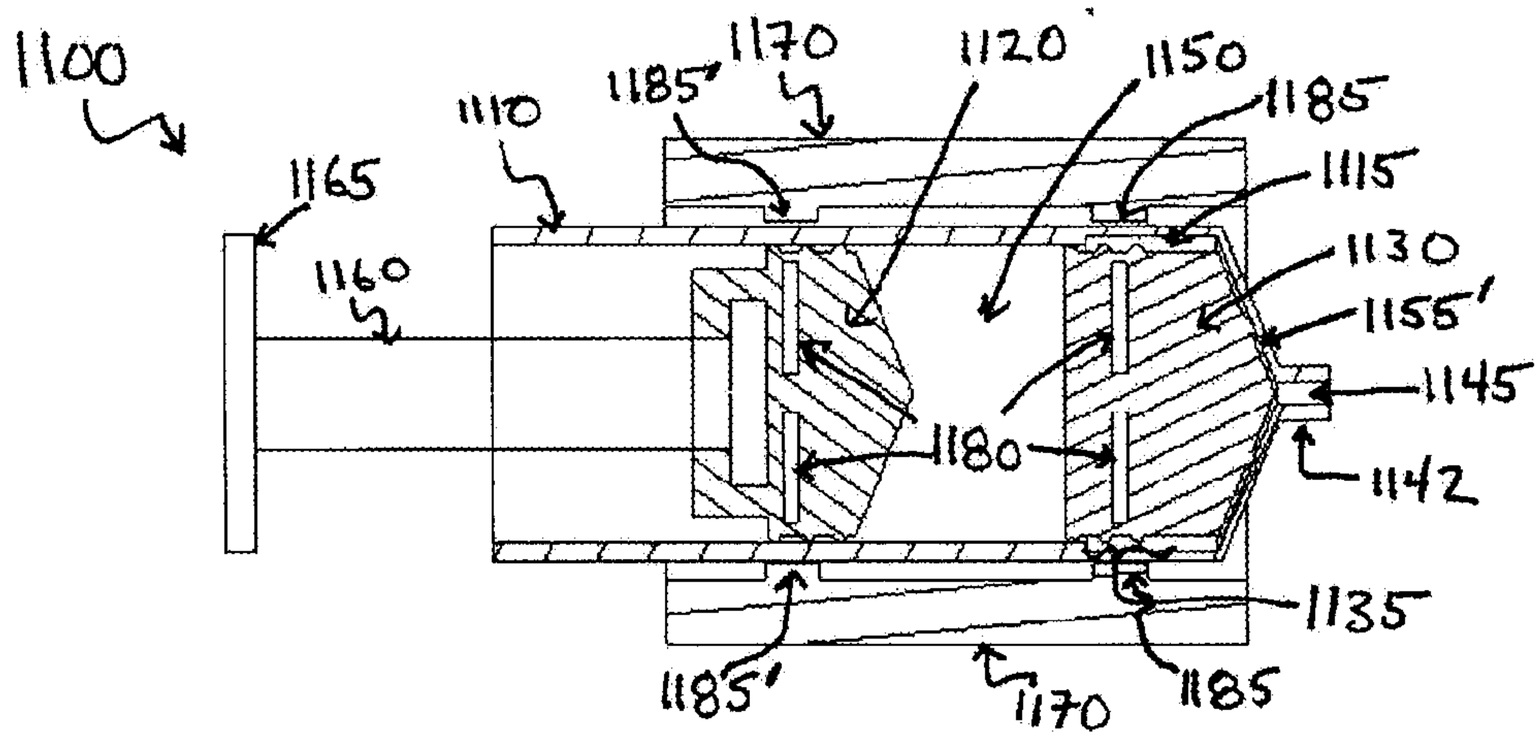

FIG. 11A

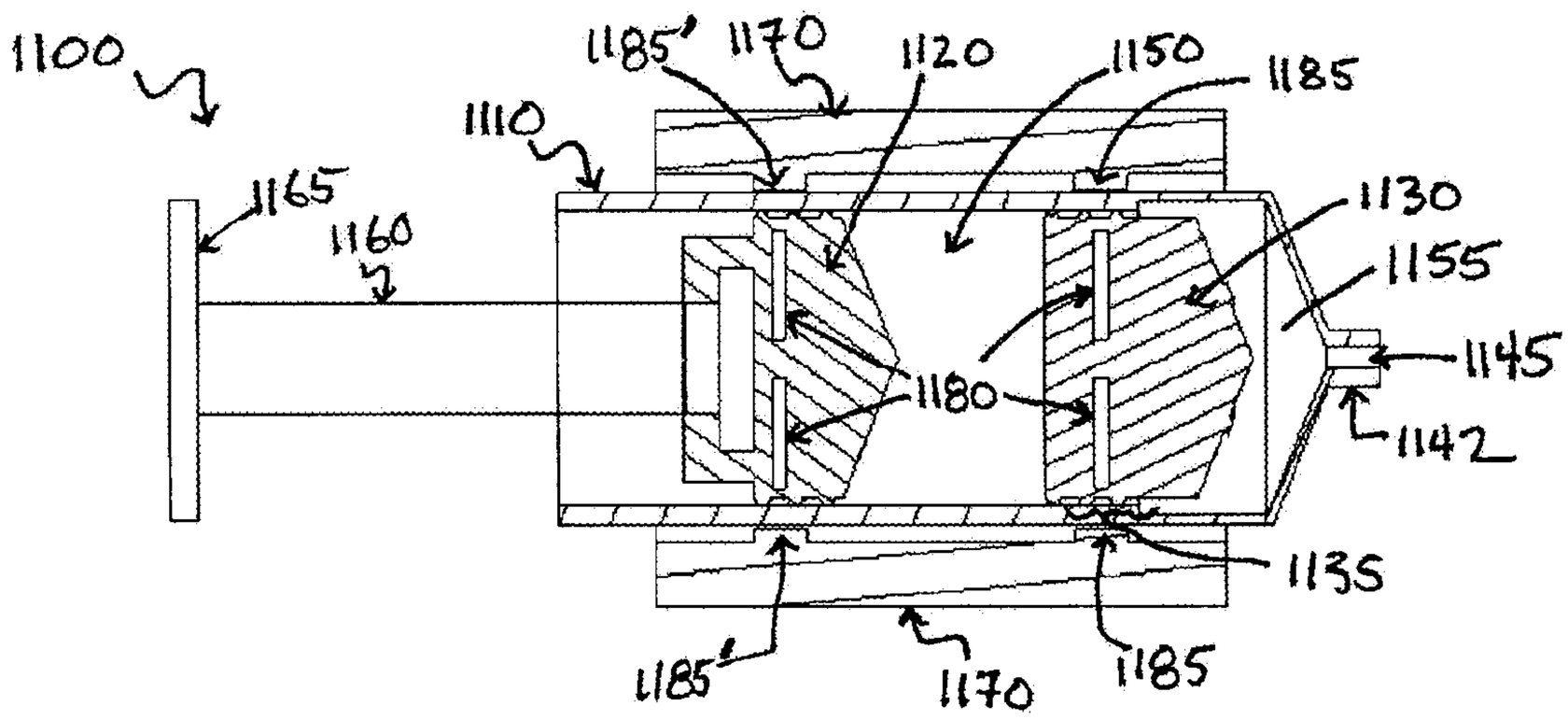

FIG. 11B

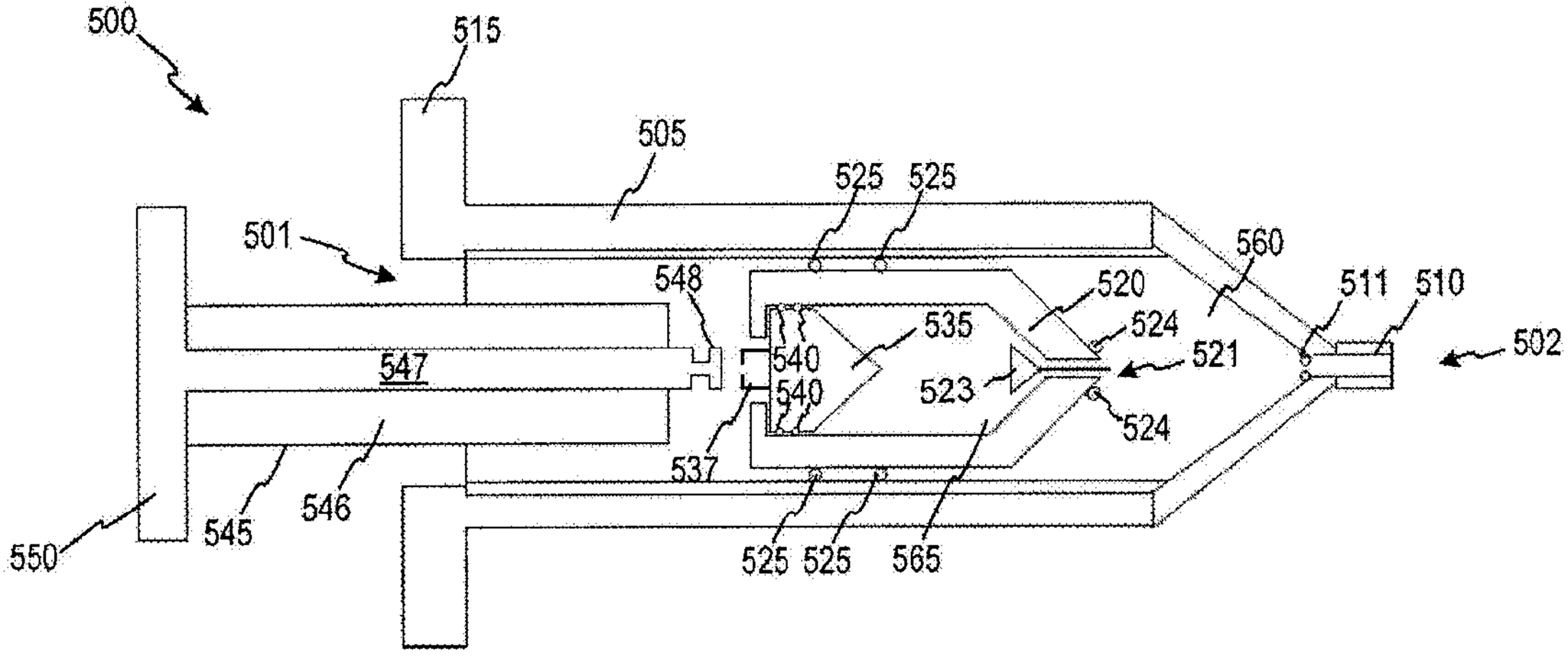
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FIG. 5