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(54) **SYSTEM FOR PROVIDING SCANNING MEDIUM**

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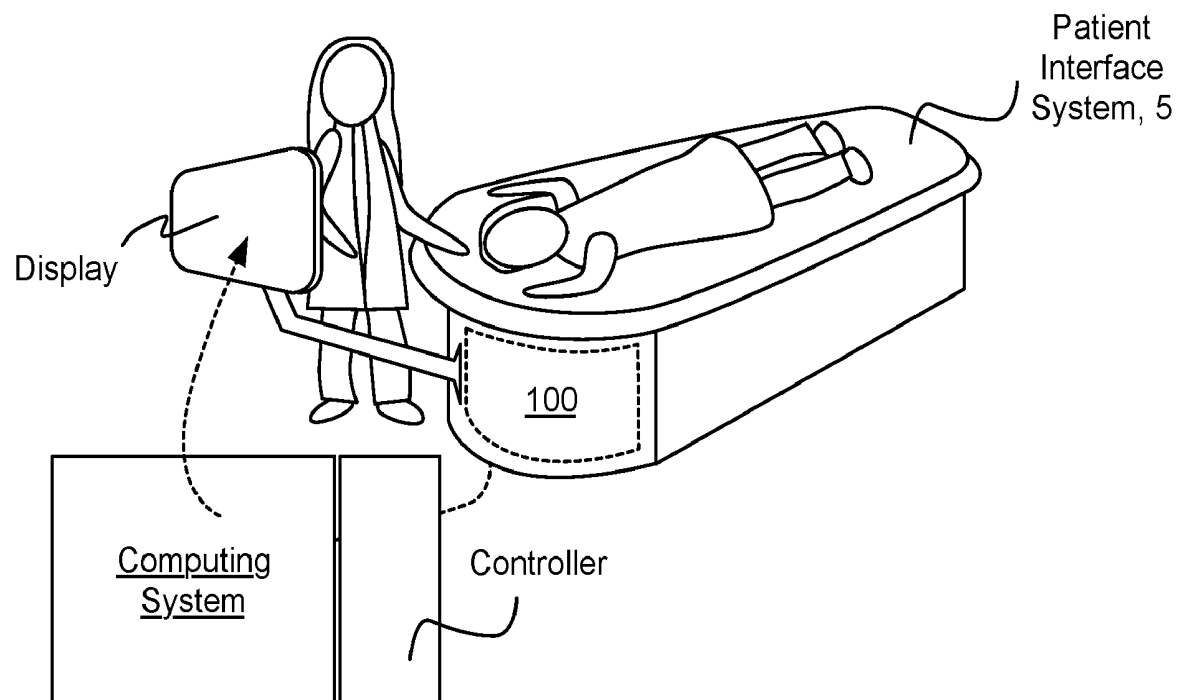
Related U.S. Application Data

(60) Continuation of application No. 16/113,863, filed on Aug. 27, 2018, now Pat. No. 10,251,622, which is a division of application No. 14/811,316, filed on Jul. 28, 2015, now Pat. No. 10,076,304.

(60) Provisional application No. 62/029,696, filed on Jul. 28, 2014.

(57) **ABSTRACT**

A system for providing scanning medium for scanning a volume of tissue comprising: an inner chamber that contains the scanning medium; a transducer mounted to the inner chamber and configured to move along a motion path, with the inner chamber, in scanning the volume of tissue; an outer chamber concentrically aligned about the inner chamber to guide the inner chamber along the motion path; a piston module defining a base surface within the inner chamber, the piston module comprising a medium inlet and a medium outlet for adjusting an amount of the scanning medium within the inner chamber; a detection subsystem coupled to the base surface of the piston module; and an actuator comprising a stationary portion mounted to the piston module and a moving portion coupled to the inner chamber and configured to produce motion of the inner chamber along the motion path.



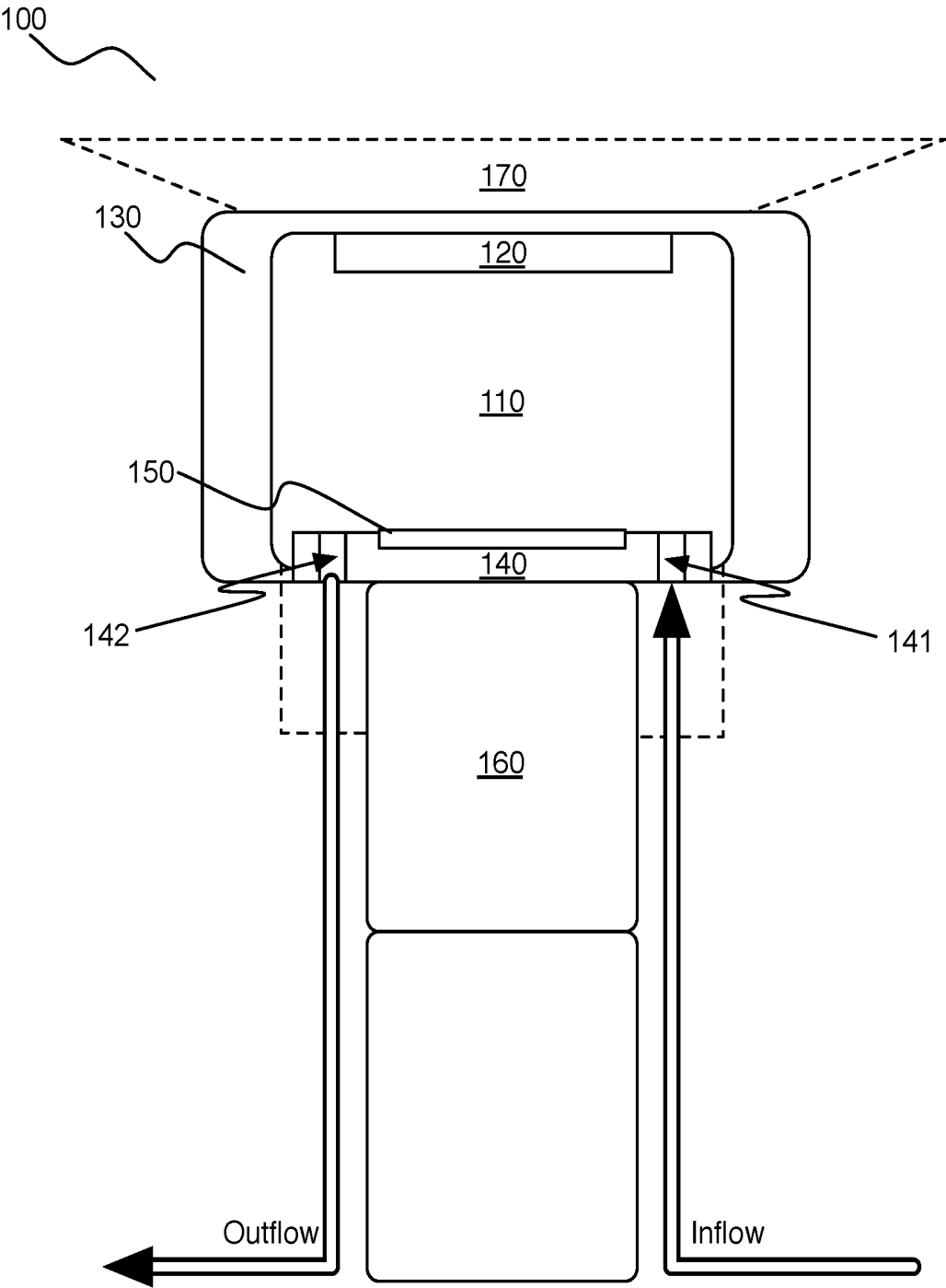


FIG.1A

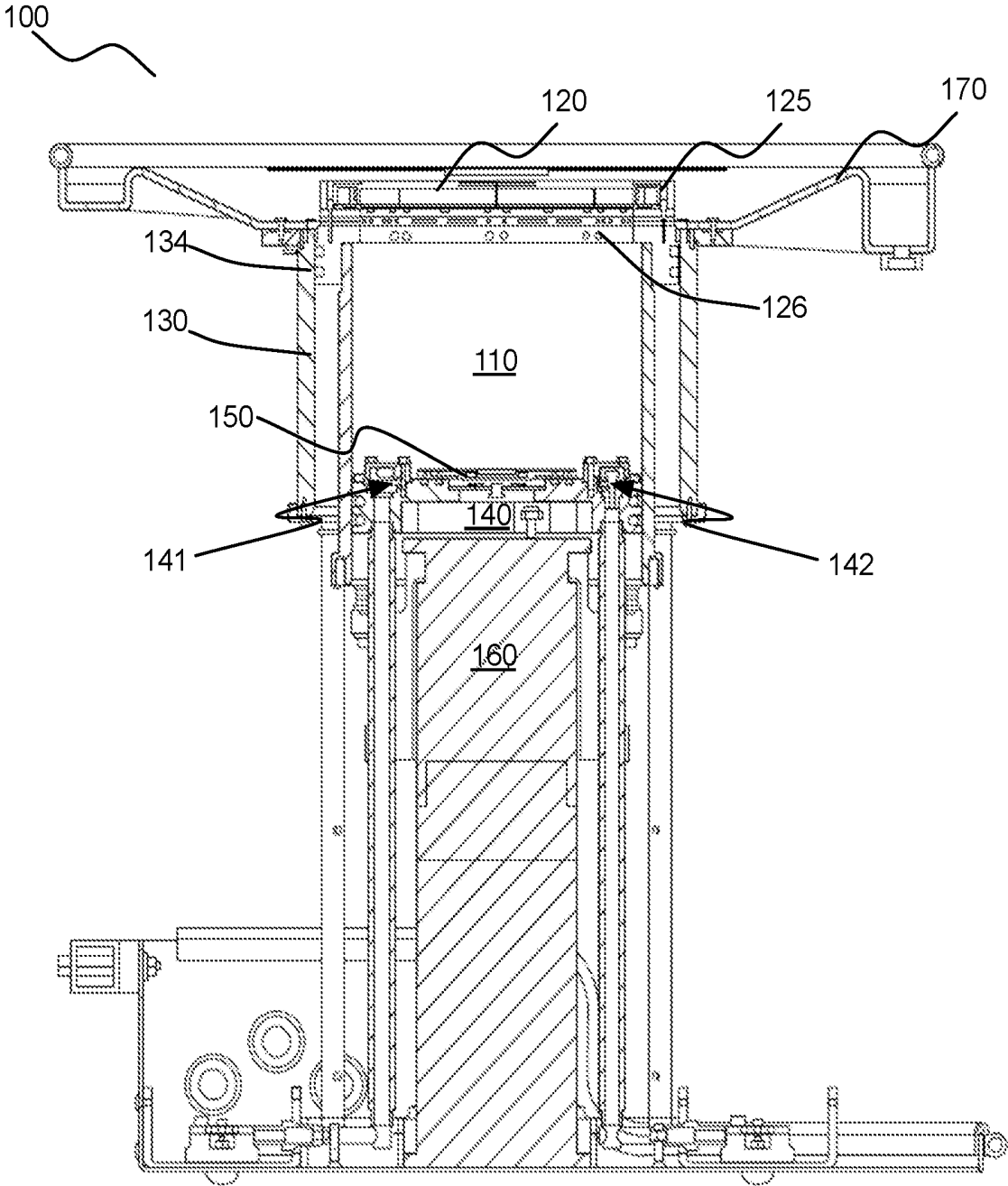
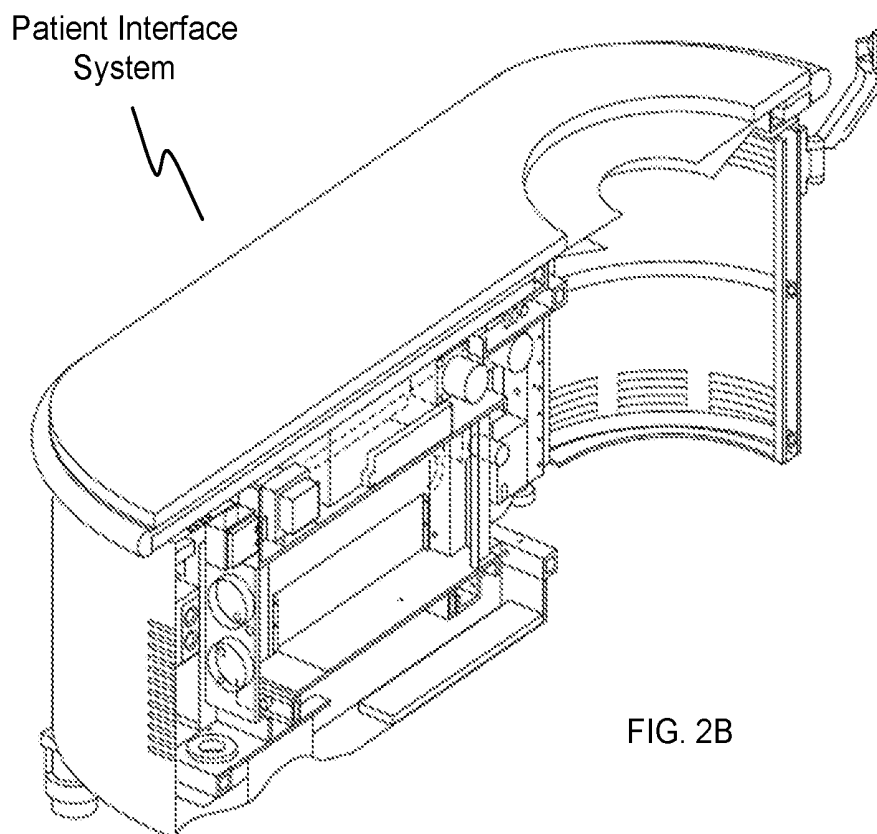
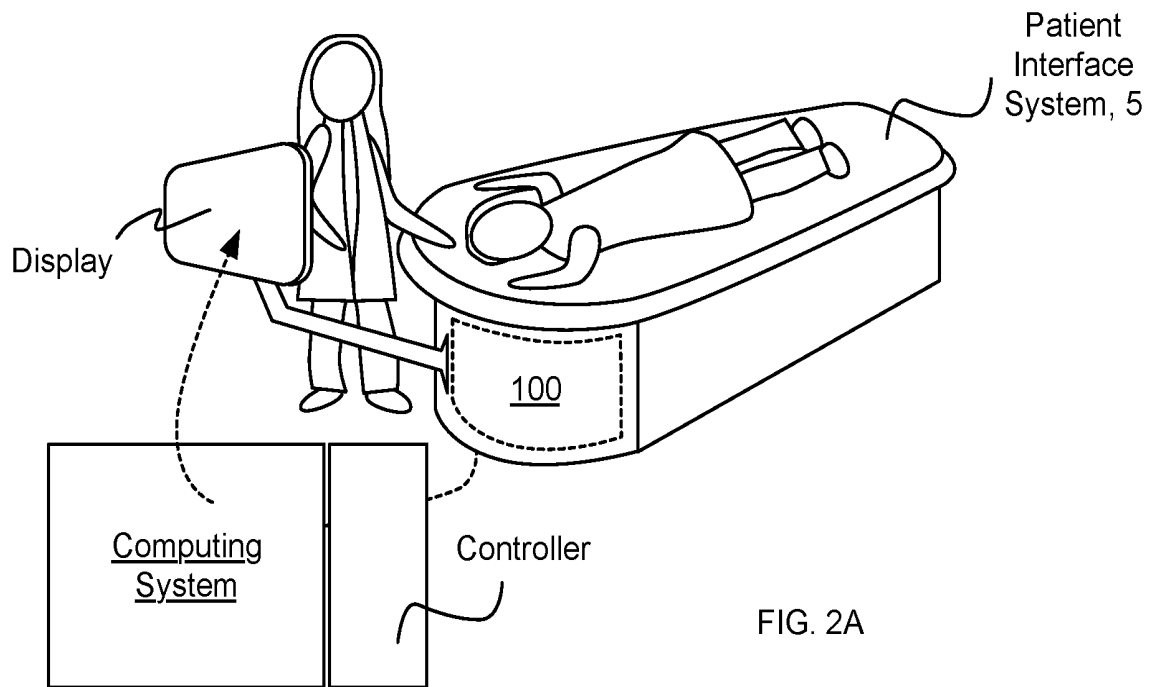


FIG. 1B



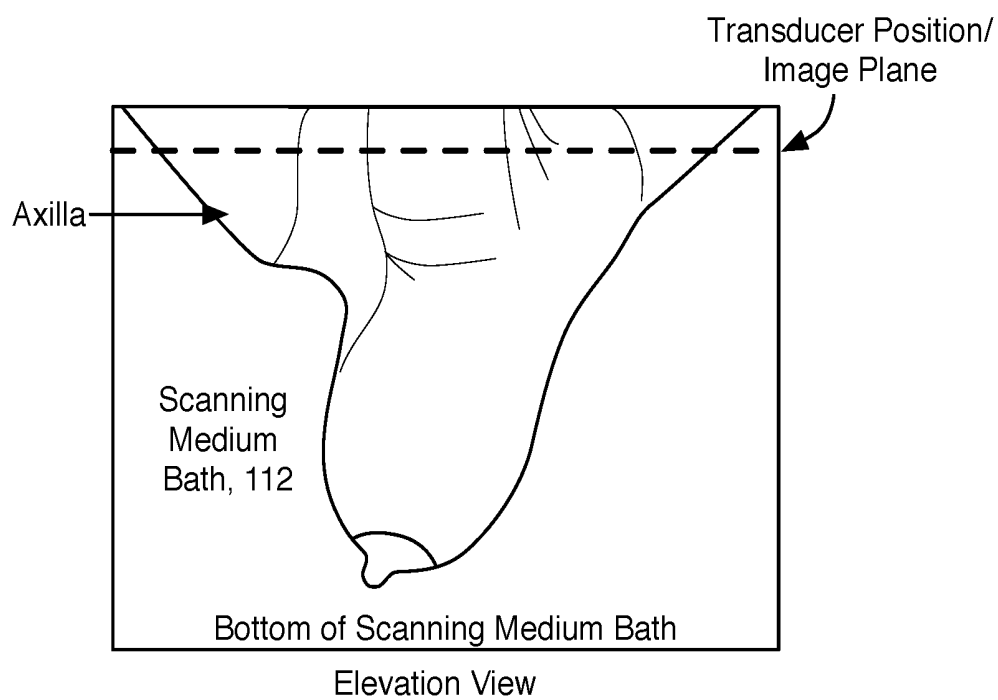


FIG. 2C

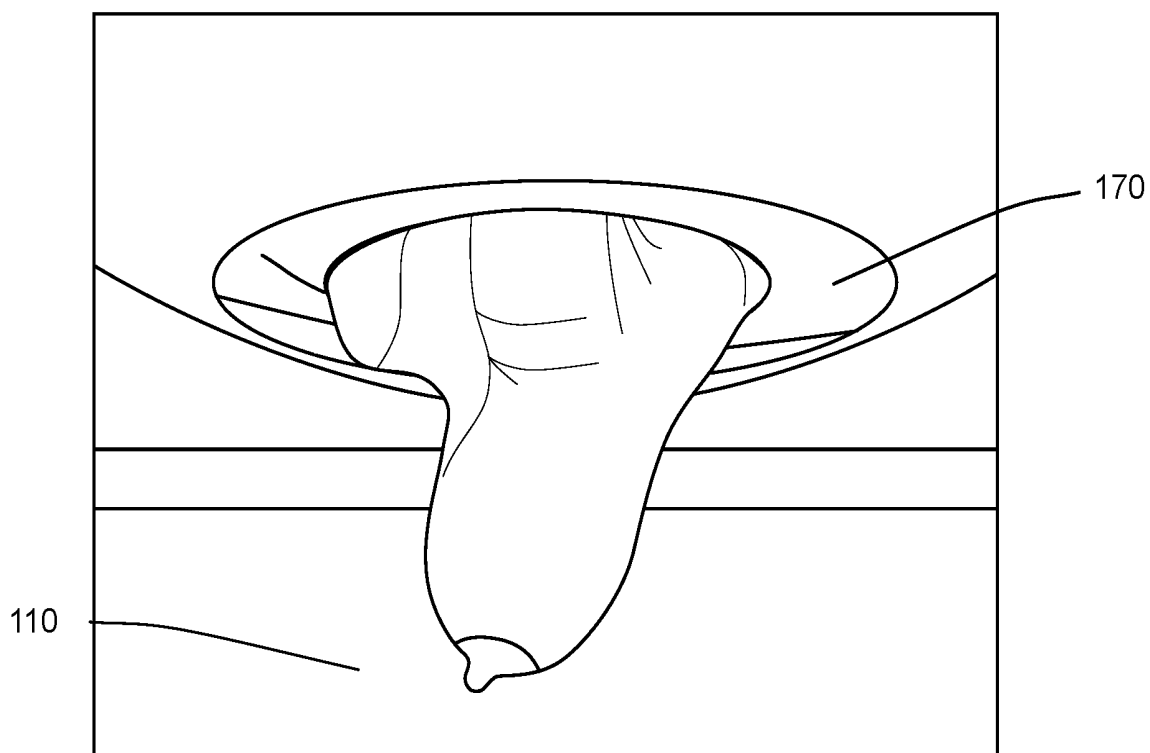


FIG. 2D

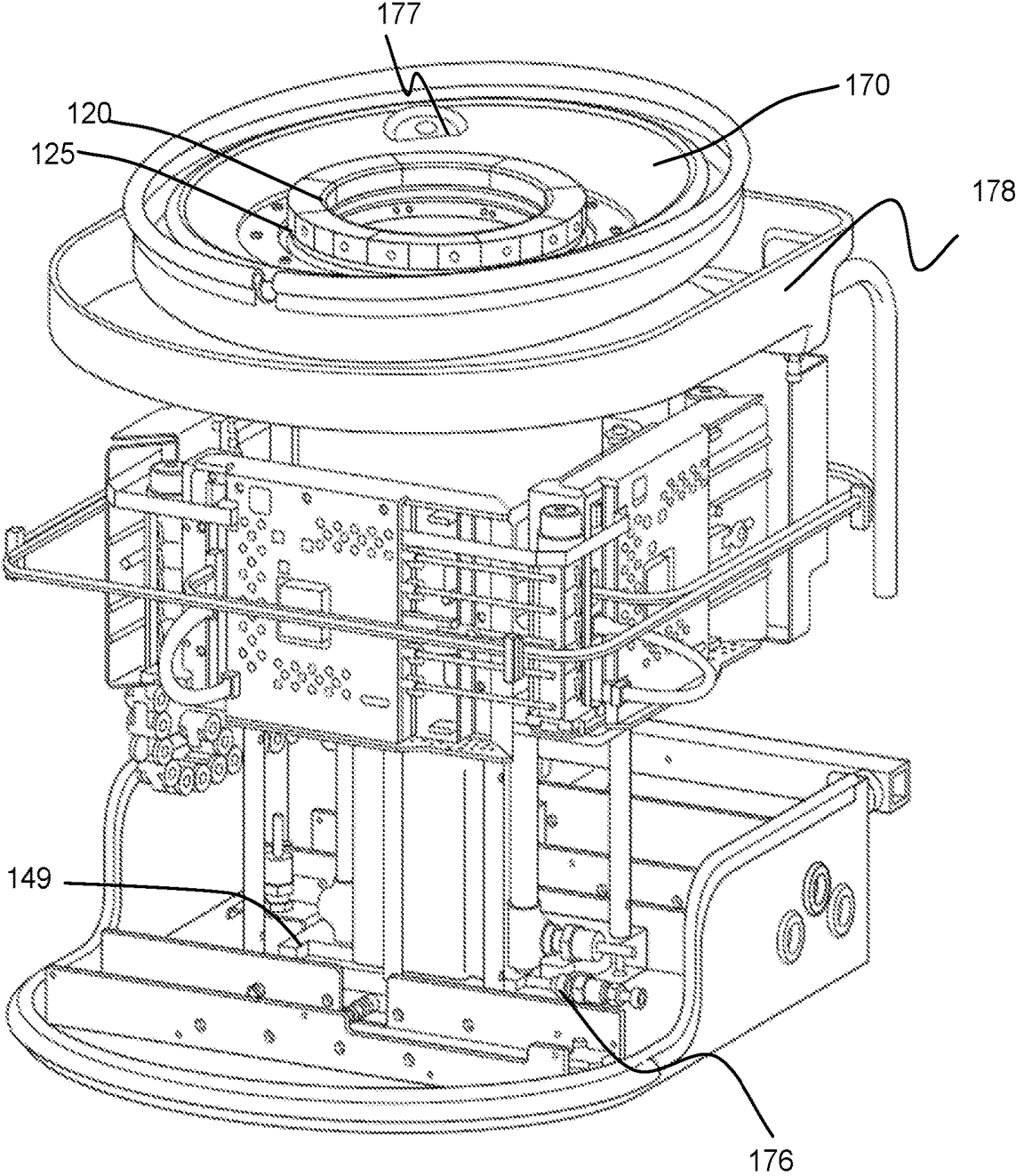


FIG. 3A

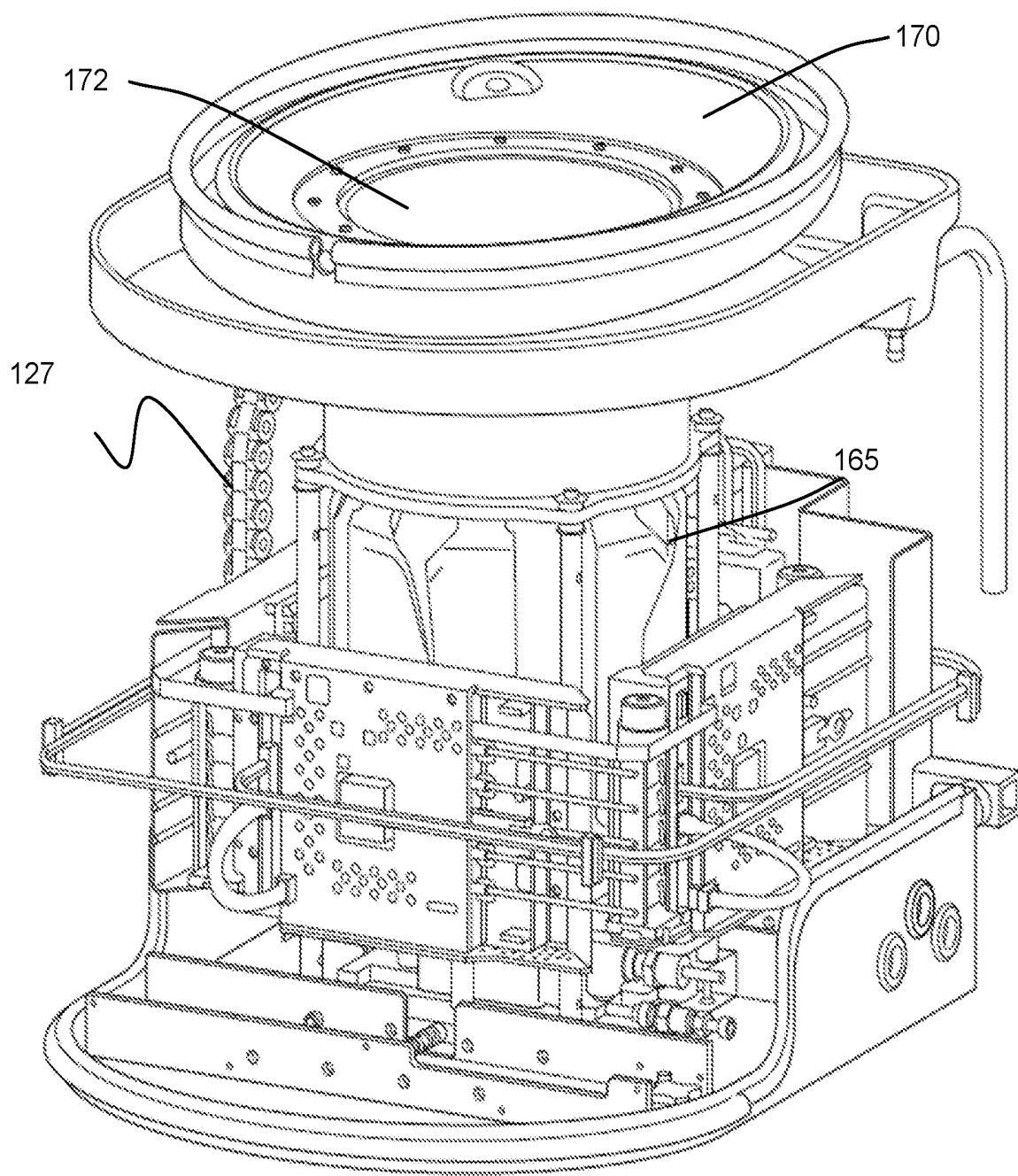


FIG. 3B

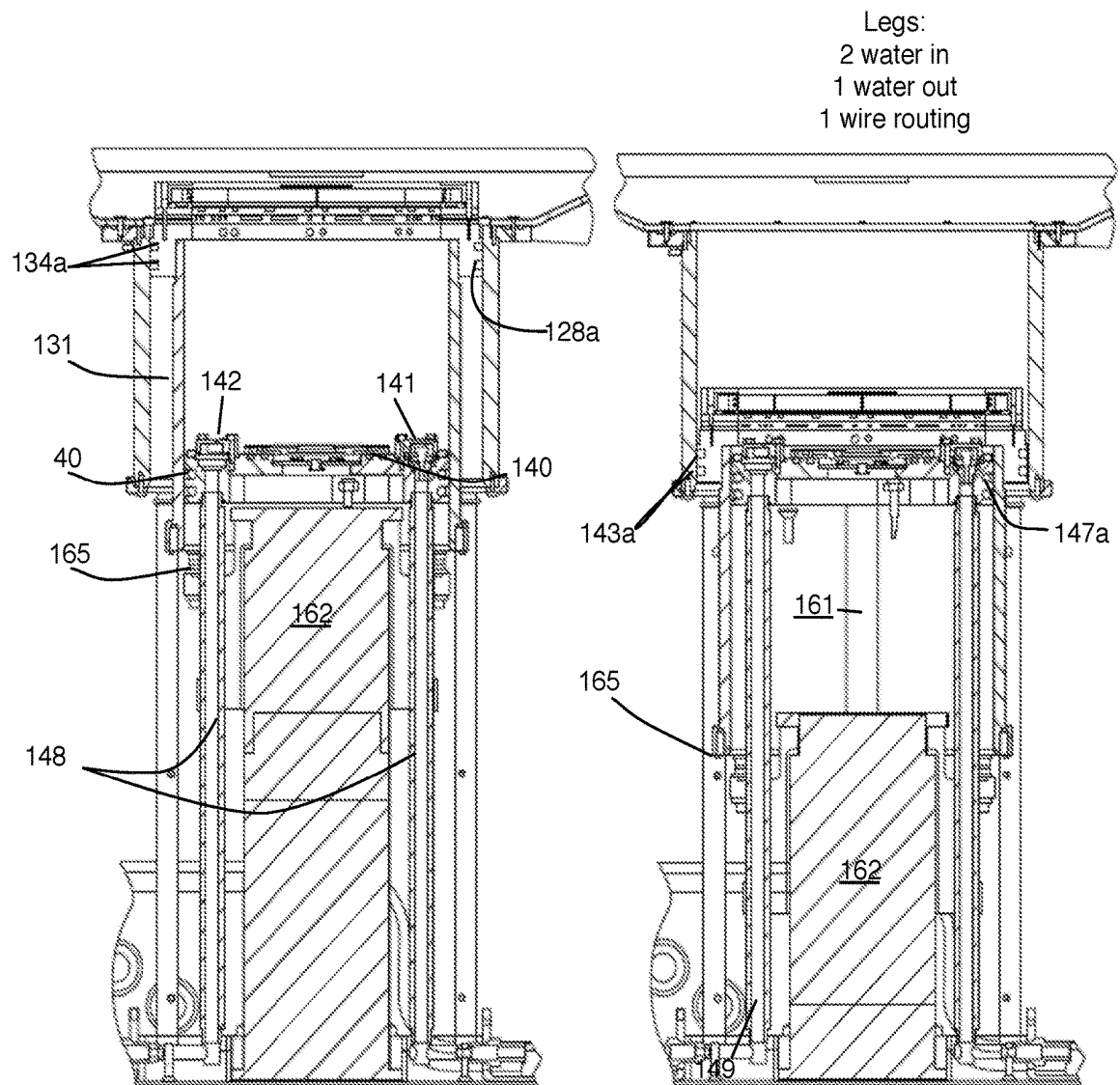


FIG. 4A

MOVING INNER CHAMBER-MOVING SEAL

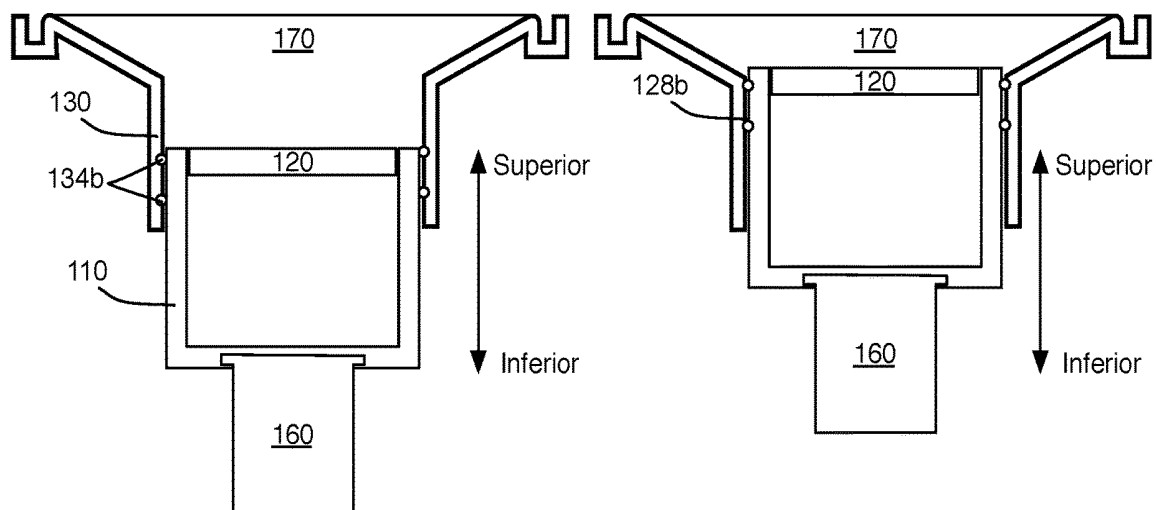


FIG. 4B

MOVING INNER CHAMBER-STATIONARY SEAL

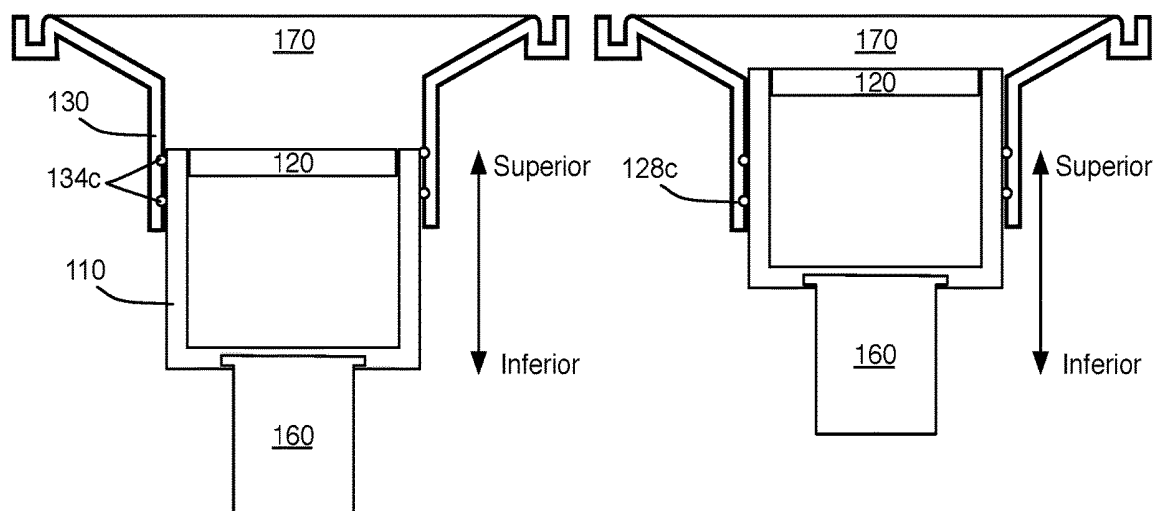


FIG. 4C

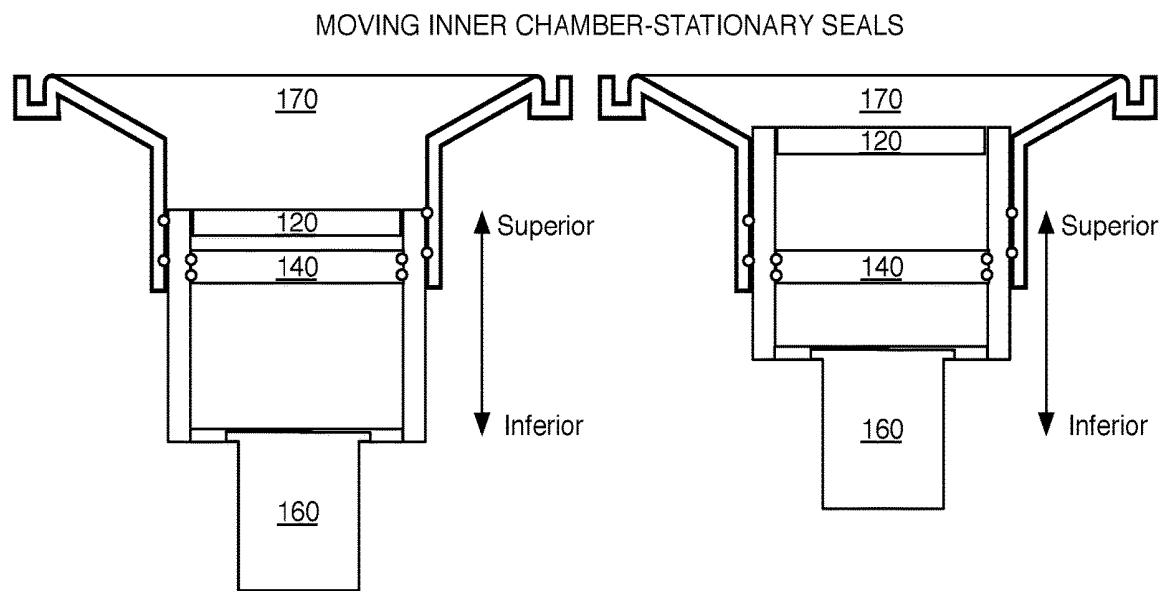


FIG. 4D

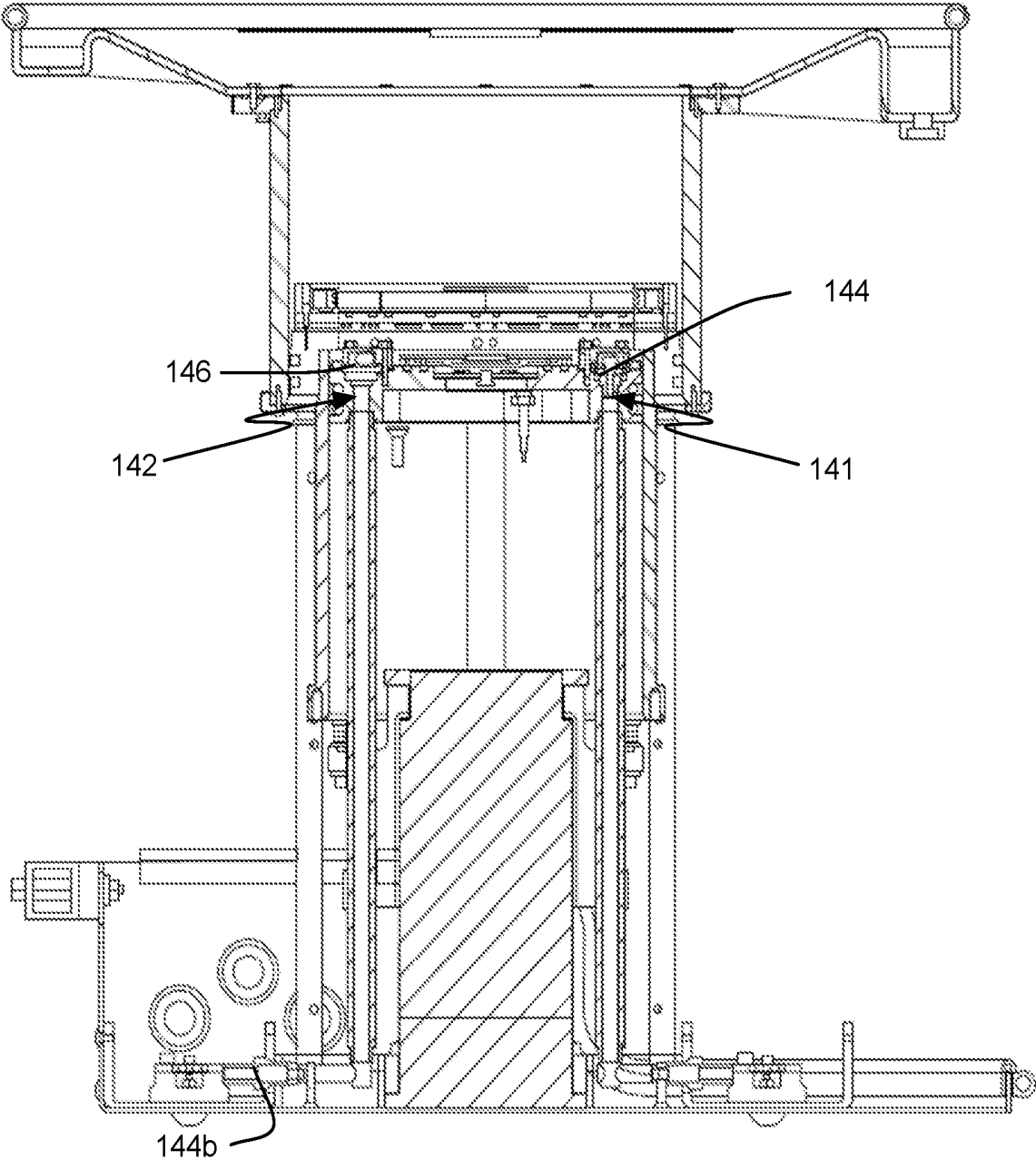


FIG. 5

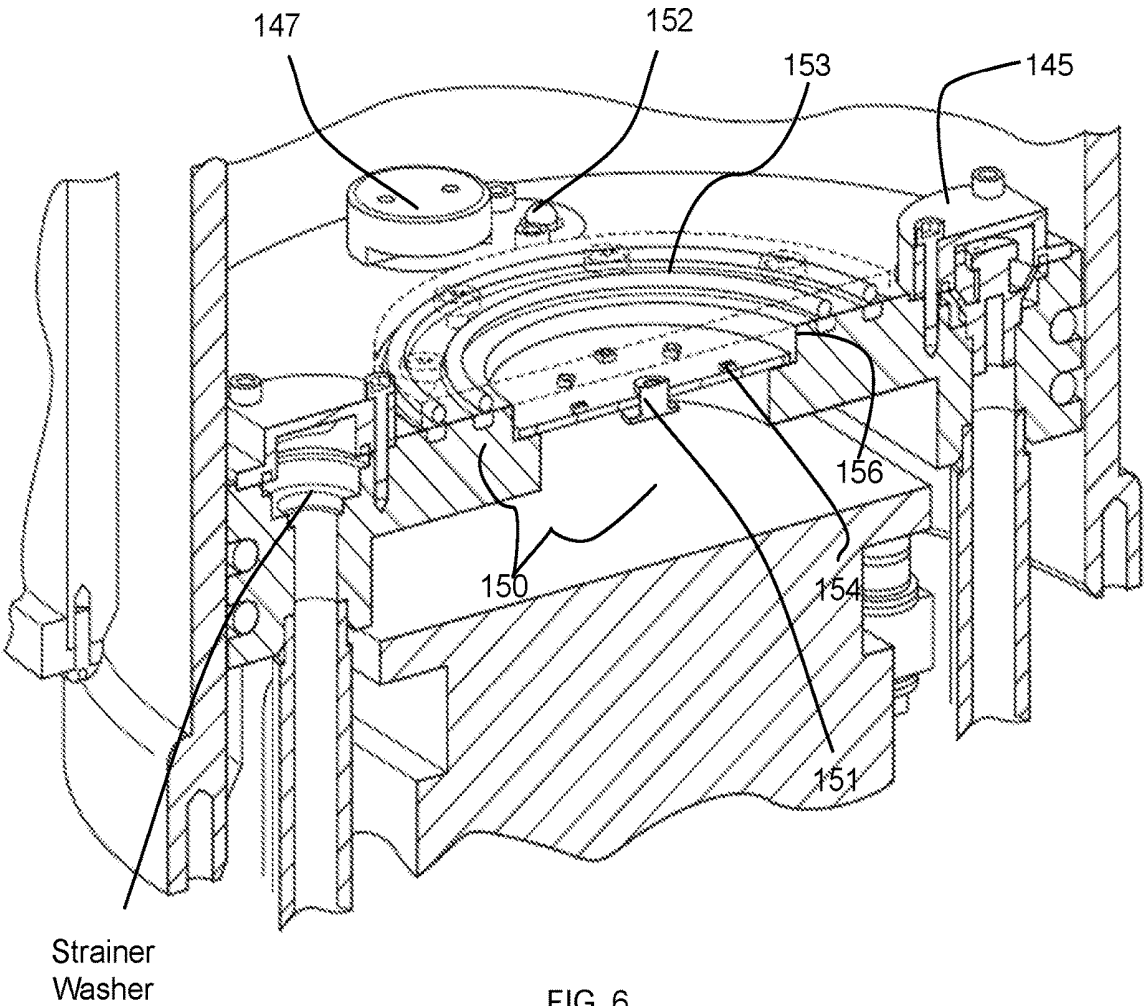


FIG. 6

SYSTEM FOR PROVIDING SCANNING MEDIUM

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is a continuation of U.S. patent application Ser. No. 16/113,863, filed Aug. 27, 2018, which is a divisional application of U.S. patent application Ser. No. 14/811,316, filed Jul. 28, 2015, which claims the benefit of U.S. Provisional Application No. 62/029,696, filed Jul. 28, 2014, which are incorporated in their entirety herein by reference.

TECHNICAL FIELD

[0002] This invention relates generally to the medical technology field, and more specifically to a new and useful system for controlling scanning medium in the medical technology field.

BACKGROUND

[0003] Early detection of breast cancer and other types of cancer typically result in a higher survival rate. Despite a widely accepted standard of mammography screenings for breast cancer detection, there are many reasons that cancer is often not detected early. One reason is low participation in breast screening, as a result of factors such as fear of radiation and discomfort. In particular, the mammography procedure involves compression of the breast tissue between parallel plates to increase the X-ray image quality by providing a more uniform tissue thickness and stabilizing the tissue. However, this compression is typically uncomfortable, or even painful. Mammography has additional drawbacks, such as limited performance among women with dense breast tissue and a high rate of “false alarms” that lead to unnecessary biopsies that are collectively expensive and result in emotional duress in patients.

[0004] Ultrasound tomography is one imaging modality in development that may be a practical alternative to mammography. However, there is a need in ultrasound tomography applications to provide a system that controls provision of a scanning medium in a robust manner. This invention provides such a new and useful system for providing scanning medium.

BRIEF DESCRIPTION OF THE FIGURES

[0005] FIG. 1A and FIG. 1B depict schematics of embodiments of a system for providing scanning medium;

[0006] FIG. 2A and FIG. 2B depict schematics of embodiments of a patient interface system that interfaces with a system for providing scanning medium;

[0007] FIG. 2C and FIG. 2D depict elevation views of a volume of tissue of a patient within a portion of an embodiment of the system for providing scanning medium;

[0008] FIG. 3A and FIG. 3B depict specific examples of a portion of an embodiment of a system for providing scanning medium;

[0009] FIG. 4A depicts a specific example of two configurations of a system for providing scanning medium;

[0010] FIG. 4B, FIG. 4C, and FIG. 4D depict variations of a portion of a system for providing scanning medium;

[0011] FIG. 5 depicts specific examples of elements of an embodiment of a system for providing scanning medium; and

[0012] FIG. 6 depicts specific examples of a piston module and detection subsystem of an embodiment of a system for providing scanning medium.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0013] The following description of preferred embodiments of the invention is not intended to limit the invention to these preferred embodiments, but rather to enable any person skilled in the art to make and use this invention.

1. System

[0014] As shown in FIG. 1A and FIG. 1B, an embodiment of a system **100** for providing a scanning medium in facilitating scanning of a volume of tissue of a patient includes: an inner chamber **110** defining a medium volume for containment of the scanning medium **112**; a transducer **120** mounted to the inner chamber **110** and configured to move along a motion path, with the inner chamber, in scanning the volume of tissue; an outer chamber **130** concentrically aligned about the inner chamber **110** to guide the inner chamber along the motion path; a piston module **140** defining a base surface **142** within the inner chamber **110**, the piston module **140** comprising a medium inlet **141** and a medium outlet **142** for adjusting an amount of the scanning medium within the inner chamber; a detection subsystem **150** coupled to the base surface of the piston module **140**; and an actuator **160** comprising a stationary portion mounted to the piston module, and a moving portion coupled to the inner chamber and configured to produce motion of the inner chamber along the motion path. The system **100** can further comprise a patient support surface **170** coupled to the outer chamber **130** and having an opening that facilitates reception of the volume of tissue into the inner chamber **110**.

[0015] The system **100** functions to control a tissue scanning device (e.g., an ultrasound transducer), in communication with a volume of a scanning medium, in order to facilitate scanning of a volume of tissue submerged in the scanning medium. In particular, the system **100** is configured to enable motion of a chamber containing a scanning medium relative to a volume of tissue of a patient, while preventing leakage of the scanning medium and other system malfunctions. The system **100** can also function to facilitate a reduction in the amount of unnecessary scans taken (e.g., due to patient misalignment). In one embodiment, as shown in FIG. 2A and FIG. 2B, the system **100** can be provided along with a patient interface system **5** configured interface with (e.g., be placed over, surround) the system **100** for providing a scanning medium, which receives the volume of tissue extending through an aperture of the patient interface system. The system **100**, as shown in FIG. 2A, can further be in communication with a controller and a computing system configured to process information from the system **100** and render information derived from the system **100** at a display. As shown in FIG. 2C and FIG. 2D, embodiments of the system **100** preferably allow access to a patient's chest wall and axilla, in order to facilitate scanning of a protruding tissue of the patient (e.g., breast tissue). However, the system **100** can additionally or alternatively coordinate with any other suitable element(s) that facilitate scanning of a volume of tissue of a patient. Furthermore, the system **100** is preferably configured to facilitate ultrasound scanning of a volume of tissue of a

patient, but variations of the system 100 can additionally or alternatively be configured to facilitate any other suitable modality of tissue scanning making use of a scanning medium in which the volume of tissue is at least partially submerged. In variations, the system 100 can include or otherwise interface with elements of the patient interface system described in U.S. patent application Ser. No. 14/208,181 entitled "Patient Interface System" and filed on Mar. 13, 2014, some variations of which are described in further detail below; however, the system 100 can additionally or alternatively interface with any other suitable element(s) that facilitate scanning of a volume of tissue of the patient.

1.1 System—Inner Chamber and Transducer

[0016] The inner chamber 110 defines a medium volume for containment of the scanning medium 112 (shown in FIG. 2C), and is preferably mounted to a transducer 120 that scans the volume of tissue along a motion path. The inner chamber 110 functions to provide a volume of scanning medium that surrounds one or more regions of the volume of tissue undergoing scanning, and further to allow actuation of the transducer 120 in relation to the volume of tissue being scanned. The scanning medium is preferably water, such that the inner chamber 110 provides a water bath for acoustic coupling with the volume of tissue in operation; however, the scanning medium can additionally or alternatively comprise any other suitable acoustic coupling medium that facilitates ultrasound scanning. For instance, the scanning medium can comprise a hydrogel material or any other suitable scanning medium. In variations of the system 100 adapted for imaging modalities aside from ultrasound, the scanning medium can comprise any other suitable scanning medium, or alternatively, the system 100 can omit use of a scanning medium (e.g., other than air).

[0017] The inner chamber 110 preferably defines a substantially cylindrical volume to contain the scanning medium and to receive the volume of tissue of the patient; however, the inner chamber 110 can alternatively define any other suitable volume morphology for scanning medium containment and/or tissue volume reception. The medium volume defined by the inner chamber 110 is preferably substantially larger (e.g., 5-10× larger) than the volume of tissue intended to be scanned; however, the medium volume can alternatively have any other suitable volumetric capacity. The inner chamber 110 is further preferably composed of a material that is one or more of: able to be sanitized or cleaned (e.g., after each patient interaction, etc.), resistant to damage by the scanning medium being used (e.g., corrosion proof, corrosion resistant), low friction (e.g., to facilitate motion of the inner chamber 110 during actuation), and characterized with sufficient mechanical properties (e.g., stiffness, compliance, thermal expansion coefficient, etc.) to support the weight of the scanning medium within the inner chamber 110. However, the inner chamber 110 can additionally or alternatively have any other suitable properties. In a specific example, the inner chamber 110 is a cylindrical chamber composed having a low friction and corrosion-proof inner surface that supports the scanning medium during actuation of the inner chamber 110 relative to other elements of the system 100, and that has a suitable coefficient of thermal expansion to maintain necessary waterproof seals at interfaces between the inner chamber 110 and other elements of the system 100.

[0018] The inner chamber 110 is preferably configured to move along a linear path, as enabled by the actuator 160 described below, in transmitting the transducer 120 along a linear motion path. As such, motion of the inner chamber 110, with the transducer 120, in a posterior-anterior direction relative to a volume of tissue of the user, can enable scanning of an entire volume of tissue of a patient in a consistent manner. However, the inner chamber 110 can alternatively be configured to move along any other suitable path(s) in relation to other elements of the system 100, in facilitating scanning of the patient's tissue. For instance, the inner chamber 110 can be guided along a non-linear path that corresponds to a shape of a volume of tissue being scanned.

[0019] The transducer 120 is preferably an ultrasound ring transducer comprising elements configured to emit acoustic signals toward a volume of tissue within the inner chamber 110 and/or elements configured to receive acoustic signals (e.g., scattered acoustic signals, reflected acoustic signals, transmitted acoustic signals, etc.) from the volume of tissue, in order to generate a rendering of the volume of tissue. The elements of the ring transducer 120 can be configured to form an enclosed perimeter about the volume of tissue (e.g., within a scanning plane), and in one specific example, can form a circular perimeter about the volume of tissue. However, the elements of the transducer 120 can alternatively be configured in any other suitable manner. For instance, the elements can form one or more of: a closed boundary (e.g., polygonal boundary, ellipsoidal boundary, etc.), an open boundary (e.g., semi-circular boundary, open curvilinear boundary, open linear boundary, etc.), and a surface about the volume of tissue.

[0020] In variations of the transducer 120 comprising an ultrasound ring transducer, the transducer elements can comprise any one or more of: piezoelectric elements, capacitive elements (e.g., capacitive micromachined ultrasonic transducer elements), and any other type of ultrasound element. However, the transducer 120 can be configured with any other suitable elements that enable generation of a rendering of the volume of tissue. The transducer 120 can be an embodiment of a transducer 120 as described in one or more of: U.S. patent application Ser. No. 13/368,169 entitled "System and Method for Imaging a Volume of Tissue" and filed on Feb. 7, 2012, U.S. patent application Ser. No. 13/756,851 entitled "System and Method for Imaging a Volume of Tissue" and filed on Feb. 1, 2013, and U.S. patent application Ser. No. 13/894,202 entitled "System and Method for Performing an Image-Guided Biopsy" and filed on May 14, 2013, which are each incorporated herein in its entirety by this reference, or any other suitable transducer 120. Furthermore, embodiments of the system 100 can additionally or alternatively enable access to and scanning of any other suitable tissue (e.g., non-breast tissue) of a patient.

[0021] The transducer 120, in cooperation with motion of the inner chamber 110 preferably provides complete access to the volume of tissue being scanned. For instance, the transducer 120 can be configured to provide access to a volume of breast tissue from the nipple region entirely to the chest wall of the patient. In one variation, the ring transducer 120 can be coupled to a superior portion of the inner chamber 110 (e.g., in the orientation shown in FIG. 1A and FIG. 1B), by way of a transducer mount 125, as shown in FIG. 3A. In this variation, the transducer mount 125 or the inner chamber 110 can circumscribe the other one of the inner chamber 110 and the transducer mount 125, wherein

the transducer mount **125** couples to the transducer **120** while enabling the volume of tissue to access the inner chamber **110**, through the transducer **120**. Furthermore, the transducer mount **125** can include a set of openings **126** that allow scanning medium drainage and/or prevent scanning medium trapping (e.g., between elements of the system) as the inner chamber **110** travels along the motion path. In a specific example, the transducer mount **125** includes a set of openings **126** circumferentially arranged between a superior portion of the inner chamber **110** and the transducer **120**, such that scanning medium weeping can occur from a region inferior to the transducer **120** (in the orientation shown in FIG. 1B). The set of openings **126** can, however, be arranged relative to the transducer **120**, the transducer mount **125**, and the inner chamber **110** in any other suitable manner.

[0022] Additionally, in variations wherein the transducer **120** is configured to move along a motion path (e.g., as enabled with the inner chamber), the ring transducer **120** can be electrically coupled to a control module for the system by way of an electromechanical coupler **127** (e.g., cable carrier), as shown in FIG. 3B, configured to enable motion of the ring transducer while providing consistent electrical communication between the transducer **120** and the control module. However, the inner chamber **110**, the transducer **120**, and/or the transducer mount **125** can alternatively be configured in any other suitable manner. Furthermore, in relation to the volume of scanning medium within the inner chamber **110**, the volume of scanning medium can be adjusted as the transducer **120** moves along the motion path by way of a medium inlet **141** and/or a medium outlet **142** (as described in further detail below). For instance, in one variation, the system **100** can be configured to increase a level of the scanning medium within the inner chamber **110** as the transducer **120** moves in a superior direction, and the system **100** can be configured to decrease the level of the scanning medium within the inner chamber **110** as the transducer **120** moves in an inferior direction. As such, this variation, motion of the transducer **120** can be coordinated with the level of scanning medium within the inner chamber, in providing scanning medium that surrounds the volume of tissue in operation. Additionally or alternatively, the system **100** can be configured to maintain a substantially constant volume of the scanning medium within the inner chamber **110**.

1.2 System—Outer Chamber

[0023] The outer chamber **130** is configured to surround at least a portion of the inner chamber **120**, and functions to guide the inner chamber along the motion path, in facilitating scanning of the volume of tissue. Preferably, the outer chamber **130** is concentrically aligned about the inner chamber **110**; however, the outer chamber **130** and the inner chamber **110** can have any other suitable alternative relationship in relation to surrounding of the inner chamber **110**. Similar to the inner chamber **110**, the outer chamber **130** preferably defines a substantially cylindrical volume that surrounds the inner chamber **110**; however, the outer chamber **130** can alternatively define any other suitable volume morphology that allows the inner chamber **110** to be guided along the motion path. The outer chamber **130** is preferably a substantially stationary element of the system, and as such, is preferably not coupled to the actuator **160** described below; however, the outer chamber **130** can alternatively be

configured to move along any suitable path(s) in relation to other elements of the system **100**, in facilitating scanning of the patient's tissue.

[0024] The outer chamber **130** preferably defines a region **131**, as shown in FIG. 4A, that is at least partially isolated from the scanning medium. In variations, the region **131** can be defined between the inner chamber **110** and the outer chamber **130**, and in one variation, the interior wall (e.g., cylindrical wall) of the outer chamber **130** can be displaced from the exterior wall (e.g., cylindrical wall) of the inner chamber **110** (e.g., by a constant offset) to define the region **131**. As such, in the example shown in FIG. 4A, an annular prismatic (e.g., circular annular prismatic) region **131** between the outer chamber **130** and the inner chamber **110** can be isolated from scanning medium within the inner chamber **110**, thus providing a “dry” space for electrical coupling elements (e.g., an electromechanical coupler **127** and/or any other elements of the system suited for a dry environment. In one variation, as shown in FIG. 4A, electrical circuitry and electrical coupling elements of the transducer ring **120** can be configured to pass into an annular prismatic “dry” region defined by the outer chamber **130**, thus isolating them from the scanning medium. To further promote dryness in the region **131** defined between the outer chamber **130** and the inner chamber **110**, the outer chamber **130** can be coupled to or otherwise in communication with any suitable heating elements to heat the region **131** and evaporate any moisture within the region **131**. Additionally or alternatively, the region **131** can include a desiccant material (e.g., silica gel) that absorbs moisture in the event that moisture from the scanning medium enters the region **131**.

[0025] In variations wherein the outer chamber **130** defines a region **131** isolated from the scanning medium, at least one of the inner chamber **110**, the transducer piston **125** coupled to the transducer ring **120**, and the outer chamber **130** can include a seal **134**, as shown in FIG. 1B, configured circumferentially about a surface of one or more of: the inner chamber **110**, the transducer mount **125**, and the outer chamber **130** to provide a hermetic seal that prevents fluid leakage into the region **131**.

[0026] In one variation, as shown in FIG. 4A, the transducer mount **125** can include a circumferential groove **128a** at an outer surface configured to receive an X-ring seal **134a** that does not roll during motion of the inner chamber **110**, while providing a hermetic seal between the outer chamber **130** and the transducer mount **125**. As such, the seal **134a** in this configuration is indirectly coupled to the inner chamber **110** and in contact with the outer chamber **130**, to isolate the region **131** defined between the outer chamber **130** and the inner chamber **110** from the scanning medium as the inner chamber moves along the motion path. However, in alternatives of this variation, the seal **134** can be directly coupled between the inner chamber **110** and the outer chamber **130** in isolating the region **131** from scanning medium.

[0027] In another variation, as shown in FIG. 4B, the inner chamber **110** can include a circumferential groove **128b** at an outer surface configured to receive an O-ring or X-ring seal **134b** that provides a hermetic seal during motion of the inner chamber **110** along the motion path. Additionally or alternatively, in yet another variation, as shown in FIG. 4C, the outer chamber **130** can include a circumferential groove **128c** about an inner surface configured to receive an O-ring or X-ring seal **134c** that provides a hermetic seal during

motion of the inner chamber **110** (while the outer chamber **130** and its O-ring/X-ring are substantially stationary). The system **100** can, however, include any other suitable variation of the seal **134** in isolating the region **131** defined between the outer chamber **130** and the inner chamber **110** from the scanning medium. As such, the seal **134** can be configured to move with the inner chamber **110** along the motion path, or can be configured to be stationary during motion of the inner chamber **110** (e.g., relative to the piston module **140** and the outer chamber **130**), one example of which is shown in FIG. 4D.

[0028] Additionally or alternatively, the system **100** can include any other suitable sealing elements (e.g., sealing compounds, rolling diaphragms, etc.) configured to provide a hermetic seal to define a volume isolated from scanning medium within the inner chamber **110**. Furthermore, surfaces of the outer chamber **130**, transducer mount **125**, inner chamber **110**, and/or any other element of the system **100** involved in forming the isolated “dry” region **131** are preferably processed to reduce surface roughness, thereby reducing sliding friction produced between elements. In a specific example, such surfaces can be nickel-plated with Teflon impregnation; however, variations of the specific example can include any other suitable surface treatments or use of materials (e.g., stainless steel, plastic) that reduces sliding friction. Furthermore, the outer chamber **110**, transducer mount **125**, and/or the inner chamber **110** can alternatively be configured in any other suitable manner.

1.3 System—Piston Module and Detection Subsystem

[0029] As shown in FIG. 1A and FIG. 1B, the piston module **140** defines a base surface within the inner chamber **110**, and can comprise a medium inlet **141** and a medium outlet **142** that enable inflow and outflow of the scanning medium into and from the inner chamber **110**. In some variations, the piston module **140** can additionally or alternatively be coupled to a detection subsystem **150**.

[0030] The piston module **140** functions to facilitate regulation of an amount of scanning medium within the inner chamber **110**, and can additionally or alternatively function to facilitate sensing/indication of environmental parameters related to the system **110**. The piston module **140** is preferably a stationary element of the system **100**, such that the inner chamber **110** moves about a stationary piston module **140**; however, the piston module **140** can alternatively be configured to move along any suitable path. For instance, the piston module **140** can move, with the inner chamber **110**, in modulating a level of the scanning medium within the inner chamber **110**. Furthermore, the piston module **140** preferably defines an inferior base surface within the inner chamber **110**, but can additionally or alternatively define any other suitable surface in relation to the inner chamber **110**.

[0031] An interface **40** between the piston module **140** and the inner chamber **110** is preferably hermetically sealed to facilitate containment of the scanning medium within the inner chamber **110**. In particular, the interface between the piston module and the inner chamber is preferably hermetically sealed as the inner chamber moves along the motion path, such that the scanning medium does not leak from the inner chamber as the inner chamber **110** moves along the motion path. As such, the piston module **140** and/or the inner chamber **110** can include elements that facilitate generation of a hermetic seal at a junction between the inner chamber **110** and the piston module **140**. In a first variation, the piston

module **140** comprises a circumferential groove **147a** at an exterior portion of the piston module **140** configured to receive an X-ring or an O-ring seal **143a** that provides a hermetic seal to contain the scanning medium during motion of the inner chamber **110**. However, the piston module **140** and/or the inner chamber **110** can be configured to provide a hermetic seal with any other alternative or additional elements (e.g., sealing compounds, rolling diaphragms, etc.). Surfaces of the piston module **140** and/or the inner chamber **110** are preferably processed to reduce surface roughness, thereby reducing sliding friction produced between elements. In a specific example, similar to that described above in relation to relative motion of the inner chamber **110** and the outer chamber **130**, such surfaces can be nickel-plated with Teflon impregnation; however, variations of the specific example can include any other suitable surface treatments or use of materials (e.g., stainless steel, plastic) that reduces sliding friction. Furthermore, the piston module **140** and/or the inner chamber **110** can alternatively be configured in any other suitable manner.

[0032] The medium inlet **141** is preferably an opening into the inner chamber **110** through the piston module **140**, and functions to enable inflow of the scanning medium into the inner chamber **110**. As such, in the orientation shown in FIG. 4A and FIG. 5, the medium inlet **141** allows the inner chamber **110** to be filled from an inferior (e.g., bottom) portion of the inner chamber **110**. However, medium inlet **141** can additionally or alternatively be configured to deliver scanning medium into any other suitable portion of the inner chamber (e.g., through a vertical wall of the inner chamber, etc.). In variations wherein the medium inlet **141** is an opening of the piston module **140**, the medium inlet **141** can be defined through the thickness of the piston module **140**, or can alternatively define an opening into the inner chamber **110** in any other suitable manner. Preferably, the medium inlet **141** is positioned at a peripheral region of the piston module **140**, as shown in FIG. 4A and FIG. 5. However, the medium inlet **141** can alternatively be positioned at any other suitable non-peripheral region of the piston module **140**.

[0033] As shown in FIG. 5, the medium inlet **141** is preferably a valved opening, and preferably comprises a check valve **144** configured to prevent backflow (e.g., of contaminated scanning medium) of contents of the inner chamber **110** from the inner chamber **110** in a reverse direction. However, the medium inlet **141** can alternatively omit a valve or can prevent backflow in any other suitable manner. In some variations, as shown in FIG. 6, the medium inlet **141** can be configured to transmit the scanning medium through a fitting **145** that directs the scanning medium laterally into the inner chamber **110**, thereby preventing a vertical stream of scanning fluid into the inner chamber that can disturb the scanning process, wherein the fitting **145** also functions to trap air bubbles that may be generated during scanning of the volume of tissue of the patient. However, the medium inlet **141** can be configured to transmit the scanning medium through any other fitting that directs fluid flow in any other suitable manner, or can be configured to transmit the scanning medium without a fitting.

[0034] Similar to the medium inlet **141**, the medium outlet **142** is preferably an opening from the inner chamber **110** through the piston module **140**, and functions to enable outflow of the scanning medium from the inner chamber **110**. As such, in the orientation shown in FIG. 4A and FIG.

5, the medium outlet 142 allows the inner chamber 110 to be drained from an inferior (e.g., bottom) portion of the inner chamber 110. However, medium outlet 142 can additionally or alternatively be configured to allow outflow of scanning medium from any other suitable portion of the inner chamber (e.g., through a vertical wall of the inner chamber, etc.). In variations wherein the medium outlet 142 is an opening through the piston module 140, the medium outlet 142 can be defined through the thickness of the piston module 140, or can alternatively define an opening from the inner chamber 110 in any other suitable manner. Preferably, the medium outlet 142 is positioned at a peripheral region of the piston module 140, as shown in FIG. 4A and FIG. 5. However, the medium outlet 142 can alternatively be positioned at any other suitable non-peripheral region of the piston module 140. Furthermore, as shown in FIG. 5, the medium outlet 142 can be in communication with a check valve 144b that prevents potentially contaminated scanning medium from backflowing into the system 100.

[0035] In some variations, a surface of the piston module 140 facing the interior of the inner chamber 110 can be configured to direct fluid flow toward the medium outlet 142, for instance, by providing a graded surface. The medium outlet 142 is preferably an opening with filtering capacity, and preferably comprises a strainer washer 146 configured to prevent undesired material within the inner chamber 110 from passing through the medium outlet 142, as shown in FIG. 6. As such, the strainer washer 146 prevents clogging of elements downstream of the medium outlet 142. However, the medium outlet 142 can alternatively omit a straining or filtering element. In some variations, the medium outlet 142 can be configured to cooperate with a fitting that prevents undesired fluid flow from the inner chamber, which can interfere with scanning of the volume of tissue. In one such variation, as shown in FIG. 6, the fitting can comprise an anti-vortex drain fitting 147 having a slotted opening that prevents fluid eddies from forming and prevents the fitting from drawing in air. As such, the anti-vortex drain fitting 147 can accelerate fluid drainage from the inner chamber 110 and trap air bubbles that may be generated during scanning of the volume of tissue of the patient. However, the medium outlet 142 can be configured to transmit the scanning medium from the inner chamber 110 through any other fitting that directs fluid flow in any other suitable manner, or can be configured to transmit the scanning medium without a fitting.

[0036] The piston module 140 can define multiple medium inlets and/or multiple medium outlets in regulating an amount of scanning medium within the inner chamber 110. Additionally or alternatively, one or more openings into the chamber can be configured to function as both a medium inlet 141 and a medium outlet 142 in a bi-functional manner. Furthermore, the medium inlet(s) 141 and/or the medium outlet(s) 142 can be routed through structural elements of the system (e.g., hollow support legs 148 coupled to an inferior surface of the piston module 140), for compactness of the system 100. In a specific example, as shown in FIG. 4A, the piston module 140 comprises two medium inlets 141 and a single medium outlet 142, wherein the medium inlets 141 and the medium outlet 142 are routed through three hollow support legs 148, respectively coupled the piston module 140, wherein a fourth support leg provides routing of electrical components (e.g., wiring) to support the detection subsystem 150 of the piston module 140.

[0037] Furthermore, in relation to the amount of scanning medium within the inner chamber 110, the medium inlet(s) 141 and/or the medium outlet(s) 142 can be configured to cooperate with a manifold 149 fluidly coupled to the medium inlet(s) 141 and the medium outlet(s) 142 and in communication with a fluid handling system that transmits scanning medium into the medium inlet(s) 141 and out from the medium outlet(s) 142, as shown in FIG. 3A. In a specific example, the manifold 149 can be welded to fluid conduits into the medium inlet(s) 141 and to fluid conduits into the medium outlet(s) 142 of the piston module 140, as shown in FIG. 1B and FIG. 4A. Furthermore, in the specific example, fluid delivery into the manifold 149 can involve the use of valves (e.g., drain check valves) to prevent backflow of fluid into any portion of the system 100 in an undesired manner, as shown in FIG. 5.

[0038] As indicated above, an amount of scanning medium within the inner chamber 110 can be configured to decrease as the inner chamber 110 and coupled ring transducer 120 move in a superior-to-inferior direction (e.g., in relation to the ground), such that scanning medium is only provided up to the region of the volume of tissue currently being scanned. In one such specific example, an amount of scanning medium within the inner chamber 110 can be configured to decrease at a rate of 1 gallon per inch of travel along a motion path of 6.5 inches in the superior-to-inferior direction in relation to the ground, as the transducer 120 moves in the superior-to-inferior direction. However, the amount of scanning medium can be maintained within the inner chamber 110 during scanning of the volume of tissue. In one such variation, the scanning medium can be pumped into and drained from the inner chamber 110 as the inner chamber 110 moves in a superior-to-inferior direction and an inferior-to-superior direction, respectively. In another such variation, a surface (e.g., base surface) within the inner chamber 110 can be configured to move in opposition to motion of the inner chamber 110, thereby maintaining a level of the scanning medium within the inner chamber 110. In yet another variation, the inner chamber 110 can contain a bladder of scanning medium that is filled with scanning medium as the inner chamber 110 moves in a superior-to-inferior direction. Yet alternatively, an amount of scanning medium within the inner chamber 110 can be configured to provide any suitable level of medium in relation to the volume of tissue being scanned, as the inner chamber 110 and coupled transducer 120 move in a superior-to-inferior direction, an inferior-to-superior direction, or along any other suitable motion path.

[0039] As shown in FIG. 1B and FIG. 6, the detection subsystem 150 is in communication with the interior of the inner chamber 110 and coupled to the piston module 140, and functions to enable environmental sensing within the inner chamber 110. Preferably, the detection subsystem 150 enables one or more of optical sensing of events within the inner chamber 110 and temperature sensing within the inner chamber 110. As such, the detection subsystem 150 can include an optical sensor 151 (e.g., of a camera) and/or a temperature sensor 152 configured to face the interior of the inner chamber 110. In one such variation, the detection subsystem 150 comprises an optical sensor 151 fluidly isolated from scanning medium within the inner chamber 110, but able to detect events within the inner chamber 110 by way of a transparent covering 153 that provides fluid isolation but light transmission. As such, the optical sensor

151 of this variation is configured to enable a volume of tissue within the inner chamber **110** to be observed (e.g., in relation to positioning of the volume of tissue within the inner chamber, etc.) during operation of the system **100**. The optical sensor **151** can be configured to provide video footage and/or still images of the interior of the inner chamber **110** (e.g., during operation, etc.); however, the optical sensor **151** can alternatively be configured to provide any other suitable type of image data of the interior of the inner chamber **110**.

[0040] The detection subsystem **150** can additionally or alternatively comprise indicators configured to indicate proper function of any element of the detection subsystem **150** and/or other elements of the system **100**. In one such variation, as shown in FIG. 6, the detection system can include a set of light emitters **154** (e.g., LEDs) fluidly isolated from scanning medium within the inner chamber **110**, but able to detect events within the inner chamber **110** by way of a transparent covering **153** that provides fluid isolation but light transmission. As such, the set of light emitters **154** can be configured proximal the optical sensor **151** for transmission of light through the transparent covering **153**. In this variation, the set of light emitters **154** can function as indicators (e.g., of proper function of the system **100**, of improper function of the system **100**), or can additionally or alternatively function to provide illumination that facilitates optical sensing by the optical sensor **151** of the detection subsystem **150**.

[0041] As noted above, the detection subsystem **150** can additionally or alternatively include a temperature sensor **152** that is in thermal communication with the interior of the inner chamber **110**, thereby enabling detection of thermal conditions within the inner chamber **110** and/or temperature regulation of contents (e.g., scanning medium) of the inner chamber **110**. In variations of the detection subsystem **150** comprising a temperature sensor **152**, the temperature sensor is preferably configured proximal at least one of the medium inlet **141** and the medium outlet **142**, thereby enabling detection of a temperature of the scanning medium as it enters/leaves the inner chamber **110**. However, the temperature sensor can alternatively be configured away from the medium inlet **141** and/or the medium outlet **142**, thereby enabling detection of an ambient temperature within the inner chamber **110**. As such, the detection subsystem **150** can comprise multiple temperature sensors **152** configured to provide holistic information regarding temperature within regions of the inner chamber **110**.

[0042] In a specific example, as shown in FIG. 6, the detection subsystem **150** comprises an optical sensor **151** centrally located within a recess **156** of a superior surface of the piston module **140**, wherein the recess is covered by a transparent covering **153** (e.g., glass covering, plastic covering) that hermetically seals the optical sensor from scanning medium within the inner chamber **110** by way of a set of face-sealing O-rings. In the specific example, the detection module **150** comprises an array of light emitting diodes **154** (LEDs) surrounding the optical sensor and configured to indicate proper/improper function of the sensors of the detection subsystem **150**, wherein the set of LEDs is also located proximal the optical sensor **151** within the recess. Furthermore, the detection subsystem **150** of the specific example comprises a temperature sensor **152** partially embedded at a superior surface of the piston module **140**, proximal the medium outlet **142**, thereby enabling detection

of a temperature of the scanning medium within the inner chamber **110**. Furthermore, the optical sensor **151** is configured to transmit an image dataset of the volume of tissue, during scanning, to a computing system, and the temperature sensor **152** is configured to transmit a temperature dataset associated with the scanning medium to the computing system. Thus, the computing system of the example can process the image dataset and the temperature dataset and generate an analysis, and provide information derived from the analysis to an entity associated with the patient. Other variations and examples of the detection subsystem **150** can, however, be configured in any other suitable manner relative to the piston module **140**.

[0043] Furthermore, the detection subsystem **150** can include any other suitable sensor modules configured to detect parameters of the scanning medium and/or environmental conditions within the inner chamber **110**. Additionally or alternatively, the detection subsystem **150**, the inner chamber **110**, and/or any other suitable elements of the system **100** in communication with the inner chamber **110** can facilitate retention of the volume of tissue in position during scanning.

1.4 System—Actuator and Patient Interface

[0044] The actuator **160** comprises a stationary portion **161** mounted to the piston module **140**, and a moving portion **162** coupled to the inner chamber **110** and configured to produce motion of the inner chamber along the motion path. The actuator **160** functions to enable positioning of the inner chamber **110**, with the scanning medium and the transducer **120**, relative to the volume of tissue being scanned in a controllable manner. The moving portion **162** of the actuator **160** is preferably a linear actuator that produces vertical motion of the inner chamber **110** and coupled transducer **120** along a vertical axis, such that the inner chamber **110** can move in a superior-to-inferior direction and an inferior-to-superior direction (e.g., in relation to the ground) along the vertical axis. However, the actuator **160** can be configured to produce motion along any other suitable motion path (e.g., a non-linear motion path, a motion path in multiple coordinate directions). Furthermore, the moving portion **162** can be coupled to plates that couple the moving portion **162** to electronic components of the system (e.g., electromechanical coupler **127**, wires, etc.). In a first variation, the actuator **160** comprises a motor and lead screw mechanism, as the moving portion **162** coupled to the inner chamber **110**, that provides motion of the inner chamber **110** and coupled transducer **120** along a vertical axis. In another variation, the moving portion **162** of the actuator **160** is configured to produce motion hydraulically. In yet another variation, the actuator **160** can comprise a scissor lift, as the moving portion **162**, that produces linear motion. However, other variations of the actuator **160** can be configured to produce motion by any other suitable mechanism.

[0045] Travel along the motion path can be controlled using any one or more of limit switches, position encoders, and any other suitable element that tracks motion. For instance, the actuator **160** can be configured to cooperate with one or more limit switches that govern endpoints of the motion path, wherein the endpoints can be adjustable. Additionally or alternatively, the actuator **160** can be configured to cooperate with a position encoder (e.g., linear encoder, rotary encoder, Hall-effect sensor, etc.) configured to enable identification of a position of travel along the motion path.

The actuator **160** can, however, be configured to cooperate with any other suitable element in order to produce motion along the motion path in a controllable manner. Furthermore, in some variations, a base **166** of the actuator **160** can be coupled to an adjustable mount that allows the actuator **160** to be positioned in a plane (e.g., an X-Y plane) and/or allows adjustment of pitch/yaw of the actuator **160**.

[0046] As shown in FIG. 1B, the stationary portion **161** of the actuator **160** is preferably mounted to the piston module **140**, such that the piston module **140** is substantially fixed in space. As such, the stationary portion **161** of actuator **160** preferably couples the piston module **140** to a support structure of the system **100**, and in variations of the system **100** including a manifold **149**, the stationary portion **161** can couple the piston module **140** to the manifold **149**. However, the stationary portion **161** can additionally or alternatively couple the piston module **140** to any other suitable portion of the system **100** that is substantially non-moving. Furthermore, the moving portion **162** of the actuator **160** is preferably mounted to the inner chamber (e.g., using a coupling plate), such that the inner chamber **110** and coupled transducer **120** can move along the motion path enabled by the actuator **160**. As such, the piston module **140** preferably does not move as the inner chamber **110** moves along the motion path, while hermetic seals are maintained using elements as described above. However, variations of the actuator **160** can alternatively produce motion of any or both of the inner chamber **110** and the piston module **140**.

[0047] In some variations, the actuator **160** can be coupled to the inner chamber **110** and/or other moving elements of the system **100** with one or more isolation mounts **165** that allow motion in at least one direction or plane, while constraining other forms of motion. For instance, in one variation, as shown in FIG. 4A, the inner chamber **110** can be coupled to peripherally located isolation mounts **165** which are coupled to the moving portion of the actuator **160** (e.g., using a plate coupler), wherein the isolation mounts **165** allow the inner chamber **110** to “float” laterally with some freedom while constraining motion of the inner chamber **110** along a vertical axis (in the orientation shown in FIG. 4A). In this variation, such a configuration prevents the piston module **140** from being over constrained and/or binding during motion of the inner chamber **110**. Other variations of the system **100** can include isolation mounts **165** coupled to any other suitable element of the system (e.g., the outer chamber **130**, as shown in FIG. 3B) in order to allow freedom of motion in one or more directions, while constraining motion of others.

[0048] As shown in FIG. 1A and FIG. 1B, the system **100** can further comprise a patient support surface **170** coupled to the outer chamber **130** and having an opening **172** (as shown in FIG. 3B) that facilitates reception of the volume of tissue into the inner chamber **110**. The patient support surface **170** is preferably configured to interface with a patient interface system that receives a prone patient in a configuration that allows protruding tissue of the patient to enter the opening of the patient support surface **170** for scanning. As such, in some embodiments, the system **100** can interface with the patient interface system described in U.S. patent application Ser. No. 14/208,181, entitled “Patient Interface System” and filed on Mar. 13, 2014, which is incorporated herein in its entirety by this reference; however, the system **100** can additionally or alternatively be configured to interface with any other suitable system to

facilitate scanning of a volume of tissue protruding from a patient’s body. In some variations, wherein the patient support surface **170** is configured to interface with a variation of the patient interface system described in U.S. patent application Ser. No. 14/208,181, the patient support surface **170** can comprise a frustoconical surface with a centrally located opening **172** that aligns with the patient interface system and facilitates reception of the volume of tissue. In a specific example, the patient support surface **170** can be welded to the outer chamber **130** with face-sealing rings (e.g., O-rings) to provide a hermetic seal against scanning medium that leaves the inner chamber and enters a region defined by the patient support surface; however, the patient support surface **170** can alternatively be coupled to any other element(s) of the system **100** in any other suitable manner.

[0049] Embodiments of the system **100** can include any other suitable elements that facilitate provision of scanning medium and a transducer **120** to enable scanning of a volume of tissue of a patient in a controlled manner. For instance, system **100** can include one or more level sensors that facilitate identification of one or more amounts of scanning medium within the system **100**. In one example, as shown in FIG. 3A, the system **100** can include a first level sensor **176** in communication with an inlet into the inner chamber **110**, and a second level sensor **177** coupled to a patient support surface **170**, such that the first level sensor **176** enables identification of an empty state and the second level sensor **177** enables identification of a full state in relation to scanning medium within the inner chamber. The level sensors can, however, be coupled to or otherwise able to detect a level of the scanning medium in any other suitable manner.

[0050] In some variations, an example of which is shown in FIG. 3A, the system **100** can additionally or alternatively include a chamber **178**, coupled about one or more of the inner chamber **110**, the outer chamber **130**, and the patient support surface **170**, that functions as a reservoir for splash overflow protection, in the event that scanning medium enters a region of the system **100** in an undesirable manner. As such, in the example, the chamber **178** can capture any portion of the scanning medium that spills over the patient support surface **170**, thereby preventing scanning medium from adversely affecting other components of the system **100**. The system **100** can, however, include any other suitable element(s).

[0051] Embodiments of the system **100** and variations thereof can be embodied and/or implemented at least in part by a machine configured to receive a computer-readable medium storing computer-readable instructions. The instructions are preferably executed by computer-executable components preferably integrated with the system **100** and one or more portions of a processor and/or a controller. The computer-readable medium can be stored on any suitable computer-readable media such as RAMs, ROMs, flash memory, EEPROMs, optical devices (CD or DVD), hard drives, floppy drives, or any suitable device. The computer-executable component is preferably a general or application specific processor, but any suitable dedicated hardware or hardware/firmware combination device can alternatively or additionally execute the instructions.

[0052] The FIGURES illustrate the architecture, functionality and operation of possible implementations of systems, methods and computer program products according to preferred embodiments, example configurations, and variations

thereof. In this regard, each block in a flowchart or block diagram may represent a module, segment, or portion of code, which comprises one or more executable instructions for implementing the specified logical function(s). It should also be noted that, in some alternative implementations, the functions noted in the block can occur out of the order noted in the FIGURES. For example, two blocks shown in succession may, in fact, be executed substantially concurrently, or the blocks may sometimes be executed in the reverse order, depending upon the functionality involved. It will also be noted that each block of the block diagrams and/or flowchart illustration, and combinations of blocks in the block diagrams and/or flowchart illustration, can be implemented by special purpose hardware-based systems that perform the specified functions or acts, or combinations of special purpose hardware and computer instructions.

[0053] As a person skilled in the art will recognize from the previous detailed description and from the figures and claims, modifications and changes can be made to the preferred embodiments of the invention without departing from the scope of this invention defined in the following claims.

1.-2. (canceled)

3. A system for scanning a volume of tissue of a patient, the system comprising:

- a chamber containing a scanning medium;
- a transducer configured to move along a first motion path within the chamber thereby scanning the volume of tissue, wherein the transducer comprises an array of ultrasound elements configured to surround the volume of tissue;
- an actuator comprising a portion of a base surface of the chamber, wherein the actuator is configured to move along a second motion path within the chamber;
- an opening into the chamber proximate the actuator, wherein an amount of the scanning medium is configured to flow through the opening.

4. The system of claim 3, wherein the amount of the scanning medium is adjusted in response to movement of the transducer or the actuator within the chamber.

5. The system of claim 3, wherein the actuator is coupled to a module, wherein the module comprises a detection subsystem comprising at least one of an optical sensor module and a temperature sensor module.

6. The system of claim 3, further comprising a frustoconical patient interface surface including an aperture configured to receive the volume of tissue.

7. The system of claim 5, wherein the aperture is sized and shaped to receive the volume of tissue.

8. The system of claim 5, wherein the frustoconical patient interface comprises a patient support surface that aligns with the frustoconical patient interface and facilitates reception of the volume of tissue.

9. The system of claim 3, wherein the transducer is a ring transducer and wherein the ring transducer is configured to move along a posterior-to-anterior axis of the volume of tissue.

10. The system of claim 5, wherein an interface between the module and the chamber is hermetically sealed as the module moves along the second motion path.

11. The system of claim 3, wherein an interface between the transducer and the chamber is hermetically sealed as the transducer moves along the first motion path.

12. The system of claim 3, further comprising a hydrogel, wherein the hydrogel is in contact with the actuator.

13. The system of claim 3, wherein the amount of the scanning medium is coordinated with the motion of the transducer.

14. The system of claim 3, wherein the amount of the scanning medium is coordinated with the motion of the actuator.

15. The system of claim 3, wherein a subsystem of the actuator is configured to facilitate retention of the volume of tissue in position during scanning.

16. The system of claim 3, wherein the first motion path or the second motion path is a non-linear motion path or a motion path in multiple coordinate directions.

17. The system of claim 5, wherein the actuator is configured to produce motion of the chamber or the module.

18. The system of claim 5, wherein the module or the actuator is coupled to the chamber via isolation mounts, wherein the isolation mounts allow freedom of motion of the module or the actuator.

19. The system of claim 3, wherein the chamber comprises an inner chamber and an outer chamber configured to move telescopically along the first or the second motion path.

20. The system of claim 3, wherein the chamber is connected to a base, wherein the chamber receives the volume of tissue of a prone patient supported by the base.

21. The system of claim 3, wherein the system further comprises a controller operable to control a position of the transducer or the actuator.

22. The system of claim 3, wherein the volume of tissue is a patient breast.

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摘要(译)

一种用于提供用于扫描组织体积的扫描介质的系统,包括:容纳扫描介质的内腔;以及容纳所述扫描腔的内腔。换能器,其安装到内腔并被配置为沿着运动路径与内腔一起移动以扫描组织的体积;外腔围绕内腔同心地对准以沿着运动路径引导内腔;活塞模块,其在内腔内限定底面,该活塞模块包括介质入口和介质出口,用于调节内腔内的扫描介质的量。检测子系统,其耦合到活塞模块的底表面;致动器包括:固定部分,该固定部分安装至活塞模块;以及移动部分,其连接至内部腔室,并构造产生内部腔室沿运动路径的运动。

