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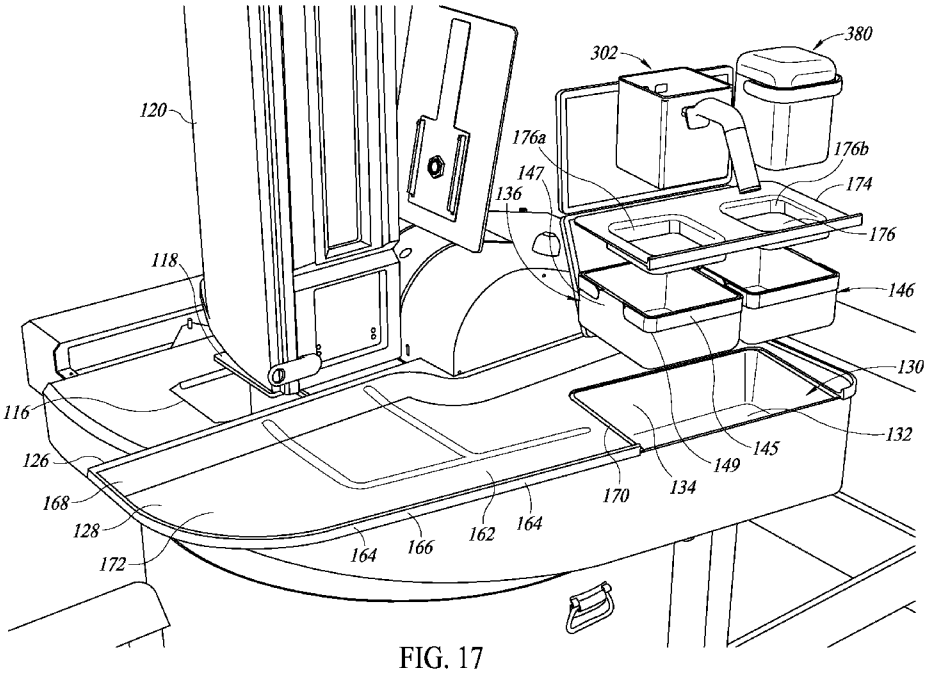


FIG. 17

(57) Abstract: A system and method facilitates transfers of specimen containers (e.g., vials with caps) between storage cassettes and carrier cassettes. The storage cassettes are designed to be stored in cryogenic refrigerators while the carrier cassettes are designed to be temporarily stored in a portable carrier. A workstation includes a well and removable buckets positioned in the well. The buckets are sized to hold the storage cassettes and carrier cassettes. One or more arrays of antennas underlie the well to allow interrogation of wireless transponders carried by the specimen containers. Improved storage cassettes and carrier cassettes are also described.

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WORKSTATION AND APPARATUS TO FACILITATE TRANSFER OF BIOLOGICAL SPECIMENS STORED AT CRYOGENIC CONDITIONS

Technical Field

The present disclosure generally relates to a workstation, apparatus and methods to transfer biological specimens (*e.g.*, eggs, sperm, embryos, other biological tissue) between a cryogenic freezer (*e.g.*, cryogenic storage tank or liquid nitrogen bath), which is typically fixed or stationary, and a portable thermally insulated carrier or cassette, and to facilitate identification of stored biological specimens and evidence chain-of-custody during handling.

BACKGROUND

Description of the Related Art

Long-term preservation of cells and tissues through cryopreservation has broad impacts in multiple fields including tissue engineering, fertility and reproductive medicine, regenerative medicine, stem cells, blood banking, animal strain preservation, clinical sample storage, transplantation medicine, and in vitro drug testing. This can include the process of vitrification in which a biological specimen or sample (*e.g.*, an oocyte, an embryo, a biopsy) contained in or on a storage device (*e.g.*, a cryopreservation straw, cryopreservation tube, stick or spatula) is rapidly cooled by placing the biological specimen and the storage device in a substance, such as liquid nitrogen. This results in a glass-like solidification or glassy state of the biological specimen (*e.g.*, a glass structure at the molecular level), which maintains the absence of intracellular and extracellular ice (*e.g.*, reducing cell damage and/or death) and, upon thawing, improves post-thaw cell viability. To ensure viability, the vitrified biological specimens must then be continuously stored in a liquid nitrogen dewar or other container containing the liquid nitrogen, which is at a temperature of negative 190 degrees Celsius.

There are, however, a number of concerns in how these biological specimens are being stored, identified, managed, inventoried, retrieved, etc.

For example, each harvested embryo is loaded on a rigid specimen holder (*e.g.*, embryo straw, stick or spatula). In the case of a tubular specimen holder, the tube may be closed (*e.g.*, plugged) at one end and open at the other end. The cryopreservation storage devices (*e.g.*, specimen holders) containing or holding the embryos are cooled as quickly as possible by plunging the cryopreservation storage device with the biological material into a liquid nitrogen bath in a cryogenic freezer at a temperature of approximately negative 190 degrees Celsius, for example to achieve vitrification. More particularly, multiple cryopreservation storage devices are placed in a goblet for placement in the liquid nitrogen storage tank or freezer. The goblet attaches to the liquid nitrogen storage tank such that the multiple cryopreservation storage devices are suspended in the liquid nitrogen. Labels that are manually written-on using a suitable marker pen or printed using a custom printer are attached to the straw and/or the goblet. Such labels can include identification information corresponding to the individual that the embryo was harvested from and other suitable information (*e.g.*, a cryopreservation storage device number, a practitioner number, etc.).

Access to the biological specimens are required during normal operation. For example, a particular biological specimen or specimens may be required to perform a procedure (*e.g.*, implantation of a fertilized egg). Retrieval of cryopreservation storage devices and associated biological specimens from the cryogenic refrigerator or cryogenic tank in which the biological specimens are stored exposes the retrieved biological specimens to non-cryogenic conditions (*e.g.*, temperatures above negative 190° C, and depending on a duration of the exposure places the biological specimens at risk. Due to the way biological specimens are stored (*e.g.*, cryopreservation storage devices arrayed in cassettes, cassettes arrayed in stacks), retrieval of one or more desired biological specimens often requires retrieval of additional biological specimens that are not needed at that time, exposing such to risk. Additionally, transport of biological specimens from a cryogenic refrigerator to a site of an intended use (*e.g.*, fertilization, implantation) exposes the biological specimens to risk.

With regard to storage and management of these biological specimens, facilities employ personnel that are required to maintain the liquid nitrogen storage

tanks (*e.g.*, by refilling them with liquid nitrogen when needed) and manage the inventory of stored biological specimens (*e.g.*, by performing periodic accountings). There is, however, little recordkeeping with regard to the proper storage of these biological specimens. For example, subsequent identification or otherwise handling of the vitrified biological specimen or sample can involve removal of the specimen from temperature-controlled storage and exposure of the sample to ambient temperature, thus potentially risking the viability of the sample.

BRIEF SUMMARY

Accordingly, it is desirable to provide new work stations, apparatus and methods for transferring biological specimens (*e.g.*, eggs, sperm, embryos) between a cryogenic freezer or storage tank that holds a liquid nitrogen bath, which is typically a large, heavy piece of equipment and hence stationary, and a portable thermally insulated carrier. It is also desirable to provide new work stations, apparatus and methods to facilitate identification of stored biological specimens or samples and evidence chain-of-custody during handling.

A work station facilitates transfers of specimen containers (*e.g.*, vials with caps) into and out of a cryogenic freezer or dewar. A plurality of the specimen containers may be carried by a storage cassette, which is designed to be stored in a cryogenic refrigerator or dewar. Identification information is read from wireless transponders carried by the specimen containers, and optionally carried by storage cassette. Inventories of specimen containers and even specific specimen holders may be maintained, as or with proof of chain of custody. Automated storage and retrieval may be provided.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings, identical reference numbers identify similar elements or acts. The sizes and relative positions of elements in the drawings are not necessarily drawn to scale. For example, the shapes of various elements and angles are not drawn to scale, and some of these elements are arbitrarily enlarged and positioned to improve drawing legibility. Further, the particular shapes of the elements as drawn are not intended to convey any information regarding the actual

shape of the particular elements, and have been solely selected for ease of recognition in the drawings.

Figure 1 is a left side, front isometric view of a cryogenic storage system including a cryogenic freezer or storage tank that holds a liquid nitrogen bath, a robotic transfer system operable to transfer of biological specimens (*e.g.*, eggs, sperm, embryos) into and out of the cryogenic freezer or storage tank, and a workstation including an interface to handle and track the transfer of biological specimens into and out of the cryogenic freezer or storage tank and to maintain a chain of custody for the biological specimens, according to at least one illustrated embodiment.

Figure 2 is a front, elevation view of a specimen container, according to one embodiment.

Figure 3 is an exploded isometric view of the specimen container of Figure 2.

Figure 4 is a front, elevation view of a specimen container, according to one embodiment.

Figure 5 is a front, elevation view of a specimen container, according to one embodiment.

Figure 6 is an isometric view of a specimen container, according to one embodiment.

Figure 7 is an isometric view of a storage cassette supporting a number of the specimen containers illustrated in Figure 4.

Figure 8 is an isometric view of the storage cassette illustrated in Figure 7.

Figure 9 is a cross-sectional view of the storage cassette illustrated in Figure 8 supporting one of the specimen containers illustrated in Figure 4.

Figure 10 is an isometric exploded view of the storage cassette illustrated in Figure 8.

Figure 11 is an isometric view of the storage cassette illustrated in Figure 8 and a handle according to one embodiment.

Figure 12 is an isometric view of the handle illustrated in Figure 11.

Figure 13 is an exploded, isometric view of the handle illustrated in Figure 12.

Figure 14 is an isometric view of a specimen transporter according to one embodiment.

Figure 15 is a top, front, isometric view of a portion of the cryogenic storage system of Figure 1, better illustrating the workstation.

Figure 16 is a top plan view of the cryogenic storage system of Figure 1, further illustrating the workstation.

Figure 17 is a partially exploded top, front, isometric view of the portion of the cryogenic storage system of Figure 10, better illustrating portions of the workstation including a well, a pair of buckets receivable by the well, and a removable frame.

Figure 18 is an exploded view of a portion of the workstation illustrated in Figure 17, including the well, the pair of buckets, and arrays of antennas.

Figure 19 is a top plan view of a transportation bucket according to one embodiment.

Figure 20 is a cross-sectional view of the well enclosing the transportation bucket, which encloses the storage container, which supports the specimen container such that the specimen container is aligned with one antenna.

Figure 21 is a top, front, isometric view of a portion of a cryogenic storage system according to another implementation in which a front peripheral wall includes a pair of breaks therein to accommodate handles of the buckets when the buckets are positioned in the well of the workstation.

Figure 22 is a bottom view of the well of the workstation.

Figure 23 is a top view of an enclosure for the array of antennas.

Figure 24 is an isometric view of a bucket positioned in the well using an alignment structure according to one embodiment.

Figure 25 is a top, plan view of the bucket and alignment structure illustrated in Figure 24.

Figure 26 is an isometric view of a bucket positioned in the well using an alignment structure according to one embodiment.

Figure 27 is a top, plan view of the bucket and alignment structure illustrated in Figure 26.

Figure 28 is an isometric view of a bucket positioned in the well using an alignment structure according to one embodiment.

Figure 29 is a top, plan view of the bucket and alignment structure illustrated in Figure 28.

Figure 30 is a top, plan view of the bucket of the workstation supporting the storage cassette according to one embodiment.

Figure 31 is a top, plan view of the bucket of the workstation supporting the storage cassette according to one embodiment.

Figure 32 is an isometric view of a bucket positioned in the well using an alignment structure according to one embodiment.

Figure 33 is a side, elevation view of the bucket positioned in the well using the alignment structure illustrated in Figure 32.

Figure 34 is a cross-sectional view of the alignment structure illustrated in Figure 32.

Figure 35 is an isometric view of a bucket positioned in the well using an alignment structure according to one embodiment.

Figure 36 is a side, elevation view of the bucket positioned in the well using the alignment structure illustrated in Figure 35.

Figure 37 is an isometric view of a registration tray according to one embodiment.

Figure 38 is an isometric view of a registration tray according to another embodiment.

Figure 39 is an exploded view of a registration tray according to one embodiment.

Figure 40 is an isometric view of the cryogenic storage system illustrated in Figure 1 during one phase of assembly.

Figure 41 is an isometric view of the cryogenic storage system illustrated in Figure 1 during another phase of assembly.

Figure 42 is an isometric view of the cryogenic storage system illustrated in Figure 1 during another phase of assembly.

Figure 43 is an isometric view of the cryogenic storage system illustrated in Figure 1 during another phase of assembly.

Figure 44 is an isometric view of the cryogenic storage system illustrated in Figure 1 during another phase of assembly.

Figure 45 is an isometric view of the cryogenic storage system illustrated in Figure 1 during another phase of assembly.

Figure 46 is an isometric view of the cryogenic storage system illustrated in Figure 1 during another phase of assembly.

Figure 47 is a functional block diagram of a processor-based workstation of a cryogenic storage system, according to at least one embodiment.

Figure 48 is a first portion of a flow diagram showing a method of operation in a transfer system to transfer specimen containers that hold biological specimens from positions in a storage cassette, which can be stored in a cryogenic refrigerator, to positions in a portable thermally insulated carrier, according to at least one embodiment.

Figure 49 is a second portion of the flow diagram illustrated in Figure 48.

Figure 50 is a first portion of a flow diagram showing a method of operation in a transfer system to transfer specimen containers that hold biological specimens from positions in a portable thermally insulated carrier, to positions in a storage cassette, which can be stored in a cryogenic refrigerator, according to at least one embodiment.

Figure 51 is a second portion of the flow diagram illustrated in Figure 50.

DETAILED DESCRIPTION

In the following description, certain specific details are set forth in order to provide a thorough understanding of various disclosed embodiments. However, one skilled in the relevant art will recognize that embodiments may be practiced without one or more of these specific details, or with other methods, components, materials, etc. In other instances, well-known structures associated with computer systems, actuator systems, and/or communications networks have not been shown

or described in detail to avoid unnecessarily obscuring descriptions of the embodiments. In other instances, well-known computer vision methods and techniques for generating perception data and volumetric representations of one or more objects and the like have not been described in detail to avoid unnecessarily obscuring descriptions of the embodiments.

Unless the context requires otherwise, throughout the specification and claims which follow, the word “comprise” and variations thereof, such as, “comprises” and “comprising” are to be construed in an open, inclusive sense, that is as “including, but not limited to.”

Reference throughout this specification to “one embodiment” or “an embodiment” means that a particular feature, structure or characteristic described in connection with the embodiment is included in at least one embodiment. Thus, the appearances of the phrases “in one embodiment” or “in an embodiment” in various places throughout this specification are not necessarily all referring to the same embodiment. Furthermore, the particular features, structures, or characteristics may be combined in any suitable manner in one or more embodiments.

As used in this specification and the appended claims, the singular forms “a,” “an,” and “the” include plural referents unless the content clearly dictates otherwise. It should also be noted that the term “or” is generally employed in its sense including “and/or” unless the content clearly dictates otherwise.

The headings and Abstract of the Disclosure provided herein are for convenience only and do not interpret the scope or meaning of the embodiments.

Figure 1 shows a cryogenic storage system 100, according to at least one illustrated embodiment.

The cryogenic storage system 100 may take a large variety of forms, typically including cryogenic storage tank or freezer 102 which can store specimen containers in a cryogenic environment, for example immersed in a bath of liquid nitrogen at a temperature at or below about negative 190°C. The cryogenic storage tank or freezer 102 is typically highly thermally insulated, and may include stainless steel interior and exterior walls with a vacuum and/or other thermal insulating material therebetween.

The cryogenic storage system 100 may include a workstation 104 to facilitate identification of stored biological specimen and evidence chain-of-custody during handling of said stored biological specimen. According to one implementation, the workstation may be located adjacent, for example immediately adjacent, the cryogenic storage tank or freezer 102. The workstation 104 may include an elevated floor 105, which facilitates a shorter distance to a top of the cryogenic storage tank or freezer 102 for a user standing on the elevated floor 105 as opposed to standing on a non-elevated floor (e.g. the floor upon which the cryogenic storage tank or freezer 102 rests).

Referring to Figures 2 and 3, the cryogenic storage system 100 may include a specimen container 200, which is typically stored for long term storage via a cryogenic refrigerator. Each of the specimen containers 200 may include a vial 204, a cap 206, one or more wireless transponders (*e.g.*, radio frequency identification (RFID) transponders) 208, and an elongated specimen holder 209 (*e.g.*, straw, rod, spatula). Additionally, the specimen containers 200 may include one or more machine-readable symbols 210. The specimen containers 200, according to one example, may store specimens of biological tissue, for instance eggs, sperm or embryos. Various implementations of specimen containers are described in U.S. patent application 62/900,281, filed September 13, 2019; U.S. patent application 62/880,786, filed July 31, 2019; U.S. patent application 62/879,160, filed July 26, 2019; U.S. patent application 62/741,986, filed October 5, 2018; and U.S. patent application 62/741,998, filed October 5, 2018.

Referring to Figure 4, another embodiment of a specimen container 300 is shown. The specimen container 300 may include a vial 304, a cap 306, and one or more wireless transponders (*e.g.*, radio frequency identification (RFID) transponders) 308. The specimen container 300 may include an elongated specimen holder (*e.g.*, straw, rod, spatula) (not shown), which is similar to the specimen holder 209 described in reference to Figure 3. Additionally, the specimen container 300 may include one or more machine-readable symbols 310.

Referring to Figure 5, an embodiment of a specimen container 250, similar to the specimen containers 200 and 300, may include a thermal mass 252 and a thermal insulator 254 that at least partially surrounds the thermal mass 252 to

prevent or inhibit thermal conduction. The thermal mass 252 may be located in an interior cavity 256 of a vial 258 of the specimen container 250. The thermal mass 252 may have a larger thermal mass than a thermal mass associated with a sample cryopreservation storage device(s) 260 of the specimen container 250 and any biological material(s) 262 held by the sample cryopreservation storage device(s) 260.

The thermal mass 252 may take the form of a piece of non-ferrous metal or a metal impregnated polymer where the metal is in the form of small pieces, particles or strands that are sufficiently small and discontinuous as to prevent or retard the formation of currents therethrough. The thermal insulator 254 may take a variety of forms, including but not limited to an aerogel (e.g., a microporous solid in which the dispersed phase is a gas, a gel in which the liquid component is replaced with a gas, for instance silica-based, alumina-based, chromiabased, tin oxide-based and carbon based aerogels).

The thermal mass 252 may be spaced from one or more wireless transponders carried by the specimen container, for example a first wireless transponder 264a and a second wireless transponder 264b by at least a minimum defined distance (e.g., 3 mm) to prevent interference with wireless communications via the wireless transponders 262a and 262b.

Referring to Figure 6 an embodiment of a specimen container 1100, similar to the specimen container 200, 250, and 300, for holding biological samples. The specimen container 1100 may include a vial 1104, a 1106 cap, and a jacket 1107. As shown, the vial 1104 may be at least partially covered by the outer jacket 1107, also called an outer sleeve or frame. The cap 1106 is sized and shaped to removably close an opening 1120 at a first end 1112a of the vial 1104. The vial 1104 includes the first end 1112a, a second end 1112b, and a side wall 1114. The second end 1112b is opposed from the first end 1112a across a length of the vial 1104, and the side wall 1114 extends between the first end 1112a and the second end 1112b to delimit an interior of the vial 1104 from an exterior thereof.

The second end 1112b may be closed or sealable. The vial 1104 may take the form of a tube, which may have a circular profile or cross section, or alternatively may have other shapes (e.g., rectangular, hexagonal, octagonal). The

opening 1120 of the vial 1104 may, for example, be circular, although the opening 1120 may have other shapes. The second end 1112b of the vial 1104 may, for example, terminate in a semi-spherical tip or may be frustoconical, terminating in a flat surface 1122 which is perpendicular to a longitudinal axis of the vial 1104.

The jacket 1107 may cover at least a portion of an exterior surface of the vial 1104, as shown. According to one implementation, the jacket 1107 is shaped and sized to allow the vial 1104 to be received within a top opening of the jacket 1107. Both the vial 1104 and the jacket 1107 may have, for example, a circular cross-section such that the circumference of an exterior surface of the vial 1104 is approximately equal to a circumference of an inner surface of the jacket 1107. Such a configuration allows for a snug fit between the vial 1104 and the jacket 1107. In implementations, the second end 1112b of the vial 1104, e.g., the frustoconical tip which terminates in a flat surface 1122, may extend from a bottom opening of the jacket 1107.

The inner surface of the jacket 1107 may be attached to the exterior surface of the vial, e.g., friction fitted, heat fitted, and/or via adhesive, in implementations in which the jacket 1107 is to remain associated with a particular vial throughout the lifecycle of the specimen container 1100. In some implementations, the inner surface of the jacket 1107 may be removably attached to the exterior surface of the vial 1104 to allow removal and replacement of the jacket 1107, e.g., if the jacket 1107 is to be associated with more than one vial 1104 (or vice versa). In such a case, there may be an elastic compression fit and/or a friction fit between the vial 1104 and the jacket 1107.

In implementations, the inner surface of the jacket 1107 and/or the exterior surface of the vial 1104 may include deformable protrusions (not shown) which compress elastically to form a compression fit between the vial 1104 and the outer jacket 1107. In implementations, the inner surface of the jacket 1107 and/or the exterior surface of the vial 1104 may include opposing threads or ridges to secure the vial 1104 within the jacket 1107 (or, in other words, to secure the jacket 1107 to the vial 1104). In implementations, the jacket 1107 may be manufactured separately from the vial 1104 and, for example, retrofitted onto existing vials 1104.

The outer jacket 1107 may have openings 1151 through which the exterior surface of the vial 1104 is visible, thereby allowing the contents of the vial 1104 to be seen in implementations in which the vial 1104 is transparent or translucent. The openings 1151 may have longer sides which run in a direction along a longitudinal axis of the jacket 1107 and shorter sides which run in a direction transverse to the longitudinal axis of the jacket 1107 and curve around the circumference of the vial 1104.

In implementations, an arrangement of arms 1152 may extend from the bottom opening of the jacket 1107 in a longitudinal direction of the jacket 1107 to support a platform 1150, e.g., a solid, disk-shaped platform, which is oriented in a plane which is transverse to the longitudinal axis of the jacket 1107. For example, there may be four arms 1152 at positions which are 90 degrees apart around the circumference of the jacket 1107. The arms 1152 and the platform 1150 may be positioned and sized so that an inner surface of the platform 1150 forms a bottom interior surface 1153 of the jacket 1107. The bottom interior surface 1153 of the jacket 1107 may be in contact with, or nearly in contact with, the bottom portion of the vial 1104 when the vial is received in the outer jacket 1107. The platform 1150 may be attached to the ends of the arms 1152 or may be integrally formed with the arms 1152, such as, for example, in a thermoplastic manufacturing process.

The specimen container 1100 may include one or more wireless transponders, e.g. a first wireless transponder 1108a, a second wireless transponder 1108b, etc. (collectively 1108). The first wireless transponder 1108a may be carried by the platform 1150, according to at least one implementation. The first wireless transponder 1108a may be fixed on an outer surface of the platform 1150.

In implementations, at least a portion of the platform 1150 itself may, for example, take the form of a radio frequency identification (RFID) button cell, which is attached to the arrangement of arms 1152 and which serves as the first wireless transponder 1108a. In some cases, a portion of the platform, e.g., a thin disk-like plate of a thickness less than that of the platform 1150 discussed above, may be attached to the arrangement of arms 1152 and have an RFID button cell mounted thereon. In either of these configurations, i.e., the transponder being fixed on the platform or at least a portion of the platform itself being an RFID button cell,

the first wireless transponder 1108a is fixed to the structure of the jacket 1107, as opposed to being received or positioned in a recess formed in the bottom of the vial 1104 or being otherwise directly fixed to the vial 1104.

In implementations, portions of the first wireless transponder 1108a, may be at least partially covered by a non-conductive label 1144a with machine-readable symbol(s) and/or human-readable information formed thereon so as to be visible on the bottom of the specimen container 1100. In implementations, the label 1144a may be applied to the outer surface of the platform 1150 without a wireless transponder being present. The label 1144a may be at least partially covered at a later time by attachable wireless transponder circuitry, such as, for example, circuitry formed on a carrier having an adhesive backing or a carrier which is attachable using adhesive, e.g., epoxy. The epoxy may encapsulate the first wireless transponder 1108a, or the combination of the platform 1150 and epoxy may encapsulate the first wireless transponder 1108a, to securely attach and provide environmental protection thereto. Alternatively, the first wireless transponder 1108a may be molded or encapsulated in a portion of the platform 1150 itself.

In implementations, the second wireless transponder 1108b may be fixed to a side of the jacket 1107. The second wireless transponder 1108b may be fixed to the jacket 1107 via any of the teachings above in reference to the first wireless transponder 1108a.

Referring to Figures 2 to 6, the features of each of the specimen containers 200, 250, 300, 1100 described herein may be combined with any features of others of the specimen containers 200, 250, 300, 1100 as described herein. For example, the specimen container 300 may include the thermal mass 252, the jacket 1107, or both the thermal mass 252 and the jacket 1107.

Referring to Figure 7, the specimen containers 300 (only one called out) may be arrayed in a storage cassette 302 of the cryogenic storage system 100, for example arrayed in a two-dimensional array (*e.g.*, 7 by 7, 10 by 10, 8 by 12, 14 by 14). The storage cassette 302 may be designed to remain in the cryogenic refrigerator expect for brief periods when removal is needed to retrieve a specimen.

Referring to Figures 7 to 10, the storage cassette 302 maintains cryogenic conditions for an array of the specimen containers 300, for example 49

separate ones of the specimen containers 300, according to at least one implementation. As shown in the illustrated embodiment, the storage cassette 302 may include a bulk container 312 having a top 314, a bottom 316 and at least one side wall 318. The bottom 316 may have an inner facing surface 320 and an outer facing surface 322. The at least one side wall 318 may have an inner facing surface 324 and an outer facing surface 326.

The bulk container 312 may include at least a first aperture 327 formed in the at least one side wall 318. The bulk container 312 may further include a second aperture 329 in the at least one side wall 318, for example such that the first aperture 327 is opposed to the second aperture 329 across a lateral dimension of the bulk container 312. As shown in the illustrated embodiment, the bulk container 312 may further include a third aperture 331 in the at least one side wall 318, for example such that the third aperture 331 is adjacent to the second aperture 329, and formed by the same at least one side wall 318 as the second aperture 329.

The inner facing surface 320 of the bottom 316 and the inner facing surface 324 of the at least one side wall 318 may delineate an interior compartment 328 of the bulk container 312. The interior compartment 328 may have an interior compartment profile, and the bulk container 312 may have an opening 330 at the top thereof, formed by the top 314, as shown in the illustrated embodiment. The at least one side wall 318 may be thermally insulated.

The storage cassette 302 may further include a thermal shunt 332 with a substrate 334. According to one embodiment, the substrate 334 includes a metal. As shown, the substrate 334 may include a first major face 336 and a second major face 338, the second major face 338 opposed from the first major face 336 across a thickness of the substrate 334. The substrate 334 may have an array of a plurality of through holes 340 that extend through the thickness of the substrate 334. Each of the through holes 340 of the substrate 334 may be shaped and sized to receive at least a portion of a respective vial 304 of the specimen containers 300.

As shown, the substrate 334 may be closely receivable in the interior compartment 328 of the bulk container 312. The thermal shunt 332 may have an outer profile that is asymmetrical to ensure that the thermal shunt 332 is positioned correctly in the interior compartment 328 of the bulk container 312. The thermal

shunt 332 may be made of any of a variety of materials, preferably having a relatively large thermal mass as compared to the materials to be stored in the storage cassette 302. Suitable materials for the thermal shunt 332 may include, for example, slabs of non-ferrous metals, or metal impregnated polymers where the metal is a non-ferrous metal or the metal is in the form of small pieces, particles or strands that are sufficiently small and discontinuous as to prevent or retard the formation of currents therethrough. In at least some implementations, the thermal shunt 332 takes the form of an aluminum plate, slab, or slug.

The storage cassette 302 may further include a thermally insulative material 342 closely receivable in the interior compartment 328 of the bulk container 312, the thermally insulative material 342 may have an array of a plurality of through holes 344 that extend there through. The thermally insulative material 342 reduces heat transfer (via conduction, convection, or both) outward from the thermal shunt 332 toward an external environment of the storage cassette 302.

According to one embodiment, each of the through holes 344 of the thermally insulative material 342 may be shaped and sized to receive at least a portion of a respective vial 304 of the specimen containers 300. According to one embodiment, the thermally insulative material 342 may include a first portion 346 and a second portion 348. As shown the first portion 346 and the second portion 348 may be securable to one another, for example with one or more fasteners 350.

The thermally insulative material 342 and the thermal shunt 332 may be stacked in the interior compartment 328 of the bulk container 312 such that each of the through holes 344 of the thermally insulative material 342 is axially aligned with a respective one of the through holes 340 of the thermal shunt 332. The through holes 340 and 344 may have matching shapes, or alternatively, the through holes 340 may have a shape that is different from that of the through holes 344. The through holes 340, the through holes 344, or both the through holes 340 and 344 may be circular. The through holes 340, the through holes 344, or both the through holes 340 and 344 may be square with rounded corners.

The bulk container 312 may include a number of set offs 352 that extend upwardly from the inner facing surface 320 of the bottom 316 into the interior compartment 328. As shown in the illustrated embodiment, the set offs 352 may be

positioned to support the thermal shunt 332 such that the thermal shunt 332 is spaced from inner facing surface 320 of the bottom 316 of the bulk container 312.

The storage cassette 302 may include a thickness of: the bottom 316, the thermal shunt 322, the thermally insulative material 342, the set offs 352, or any combination thereof, such that a portion of the specimen container 300, for example the wireless transponder 308, is within a defined distance 17 of the outer facing surface 322 of the bottom 316. According to one embodiment, specimen container 300 is supported directly by (i.e. is in direct contact with) the inner facing surface 320, such that the defined distance 17 is equal to a thickness of the bottom 316 of the bulk container 312 plus a thickness of a bottom of the specimen container 300.

The storage cassette 302 may include a thickness of the thermal shunt 322, the set offs 352, or both, such that a specimen 317 within the specimen container 300, is surrounded by the thermal shunt 332 and the thermal shunt is paced upward and away from the wireless transponder 308.

The bulk container 312 may include at least one aperture 353, which permits ingress and egress of a cryo-fluid into and out of the interior compartment 328 of the bulk container 312. As shown, the at least one aperture 353 may be formed in the bottom 316 of the bulk container 312. The set offs 352 may position the thermal shunt 332 upward and away from the bottom 316 thereby providing improved flow of a cryo-fluid through the at least one aperture 353.

Referring to Figure 11, the cryogenic storage system 100 may include a specimen transporter 380. The specimen transporter 380 is similar to the storage cassette 302, as described in reference to Figures 7 to 10, such that any of the description of the storage cassette 302 is applicable to the specimen transporter 380, with differences called out below.

Rather than carrying a plurality of specimen containers to be stored in the cryogenic storage tank or freezer 102 as the storage cassettes 302, the specimen transporter 380 may hold one or more of the specimen containers as they are transported to or from the cryogenic storage tank or freezer 102, e.g. after harvesting or prior to implantation. As shown, the specimen transporter 380 may include a cover 382 to seal the opening 330. The at least one side wall 318 may be devoid of any apertures, for example the first, second, and third apertures 327, 329,

and 331, and the bottom 316 may be devoid of any apertures, for example the at least one aperture 353, such that when the cover 382 seals the opening 330, the interior compartment 328 is completely sealed from the external environment. Thus, the interior compartment 328 of the specimen transporter 380 may be filled with an amount of cryo-fluid and then sealed to maintain an acceptable temperature for any specimen containers contained therein. The specimen transporter 380 may include a double layer wall to ensure thermal stability of the interior compartment 328 when sealed from the external environment. The cover 382 may be permanently, for example pivotally, attached to the bulk container 312. The cover 382 may include a transparent portion 384 that provides visibility to the interior compartment 328 when the cover 382 is closed and sealing the opening 330.

The specimen transporter 380 may further include a thermal shunt that transfers colder air from the bottom of the interior compartment 328 to the top of the interior compartment 328 to maintain an even temperature throughout the interior compartment 328.

Referring to Figures 7 to 16, the storage cassette 302 may include a handle 354 that is removably coupleable to the bulk container 312, for example via the first aperture 327. As shown in Figures 11 to 13, the handle 354 may be used to manipulate the storage cassette 302. According to one embodiment, the handle 354 includes a head portion 355 that engages the storage cassette 302. As shown, the head portion 355 includes a flange 357 insertable through the aperture 327 to releasably couple the handle 354 to the storage cassette 302. The handle 354 includes a grip 359 that is sized to be held in the hand of an operator to facilitate manipulation of the storage cassette 302 via movement of the handle 354.

The head portion 355 and the grip 359 may include separate pieces that are releasably coupleable to one another. The grip 359 may include a removable sheath 361 that has a surface, e.g. a textured surface, which improves friction between the operator's hand and the handle 354.

As shown in Figures 14 to 16, the specimen transporter 380 may include a handle 356 that is permanently, for example pivotally, coupled to the bulk container 312.

The storage cassettes 302 may be stored in the cryogenic storage tank or freezer 102 in vertical stacks, the vertical stacks also called racks. The stacks or racks of storage cassettes 302 may be annularly arrayed in the cryogenic storage tank or freezer 102 about a central axis of the cryogenic storage tank or freezer 102. The cryogenic storage tank or freezer 102 may include a turntable or conveyer in the interior thereof, on which the stacks or racks of storage cassettes 302 are carried. This allows respective stacks or racks of storage cassettes 302 to be aligned with an opening 116 of the cryogenic refrigerator for placement or removal.

The cryogenic storage tank or freezer 102 may include an opening 116 and a door or cover 118 to selectively open and close the opening 116, to respectively provide access to the interior of the cryogenic storage tank or freezer 102 from an exterior thereof, and to prevent access, as well as seal, for example hermetically seal, the interior from the exterior to maintain the cryogenic temperature in the interior of the cryogenic storage tank or freezer 102.

The stacks or racks of storage cassettes 302 may be selectively placed into the interior of the cryogenic storage tank or freezer 102 for storage at cryogenic temperatures and removed from the interior of the cryogenic storage tank or freezer 102 for use via the opening 116. In some implementations, the storage cassettes 302 are manually removed from the cryogenic storage tank or freezer 102 when needed, and manually placed in the cryogenic storage tank or freezer 102 to store the specimens in the specimen container 300 at cryogenic temperatures.

In other implementations, the cryogenic storage system 100 includes a picker or elevator 120 to automatically remove selected ones of the stacks or racks of storage cassettes 302 from the cryogenic storage tank or freezer 102 when needed, and to automatically place the storage cassettes 302 with the specimen containers 300 in the cryogenic storage tank or freezer 102 to store the specimens in the specimen containers 300 at cryogenic temperatures. The storage and retrieval mechanism (*e.g.*, turntable, picker or elevator) of the cryogenic storage tank or freezer 102 can automatically replicate movements of a human, and hence is denominated as a robot or robotic system. Whether manually moved or automatically moved, it is typically important to minimize exposure of the specimens

to temperatures high than about negative 190°C (*e.g.*, ambient room temperature or about 23 °C).

Referring to Figures 15 to 19, the workstation 104 may include a platform 122 that facilitates a transfer of specimen containers, for example the specimen containers 300, into and out of the cryogenic storage tank or freezer 102. For example, the platform 122 may facilitate transfer of one or more of the specimen containers 300 from a vessel with a sealed interior compartment such as the specimen transporter 380, to a storage cassette, for example a storage cassette with an open interior compartment such as the storage cassette 302, or vice versa. According to one embodiment, the workstation 104, including the platform 122, may interface with a conventional commercially available cryogenic automated storage system (*e.g.*, the Bistore III Cryo -190°C System sold by Brooks Life Sciences)).

As shown in the illustrated embodiment, the platform 122 may include a front 124, a back 126, a work surface 128, and at least one well 130. The at least one well 130 may be recessed in the work surface 128, as shown. The at least one well 130 includes a bottom 132 and at least one sidewall 134 that extends upwardly from the bottom 132. The workstation 104 may include at least a first bucket 136 removably receivable by the at least one well 130 of the platform 122. The first bucket 136 may include a bottom 138, a top 140, at least one sidewall 142 extending from the bottom 138 to the top 140 with an opening 144 at the top 140. The opening 144 may be sized to receive at least partially therein at least one of a cassette or a carrier, for example the storage cassette 302 and/or the specimen transporter 380, that holds an array of specimen containers, for example the specimen containers 300, therein.

The first bucket 136 may include a handle 145 coupled to the least one sidewall 142. The handle 145 may be pivotally coupled such that the handle 145 pivots between a deployed position and an un-deployed position. The first bucket 136 may include at least one stop 147 that limits rotation of the handle 145 at the deployed position. The first bucket 136 may include at least one stop 149 that limits rotation of the handle 145 at the un-deployed position. Alternatively, the handle 145 may be fixed, for example monolithic with, the first bucket 136.

According to one embodiment shown in Figure 18, the workstation 104 may include the first bucket 136 and a second bucket 146 that are simultaneously, removably, receivable by the at least one well 130 of the platform 122. The first bucket 136 and the second bucket 146 may be identical, and may be able to receive both the storage cassette 302 and the specimen transporter 380 (one at a time each). Alternatively, the first bucket 136 and the second bucket 146 may have different structures, such that the first bucket 136 includes features that correspond to the storage cassette 302 and the second bucket 146 includes features that correspond to the specimen transporter 380. As shown in Figure 19, the first bucket 136 may be sized to receive multiple storage cassettes, such as one of the storage cassette 302 and one of the specimen transporter 380, simultaneously.

The workstation 104 may include at least one array of antennas 150 positioned beneath the bottom 132 of the at least one well 130. According to one embodiment, the bottom 132 of the at least one well 130 includes an enclosure 154 that receives a printed circuit board 152 that carries the at least one array of antennas 150. Alternatively, the at least one array of antennas 150 may be mounted beneath the at least one well 130 such that the at least one array of antennas 150 is accessible from the surrounding environment, and the bottom 132 of the well 132 may be devoid of the enclosure 154. Alternatively, the enclosure 154 may be attachable to the bottom 132 of the at least one well 130, rather than a part of the bottom 132 of the at least one well 130.

The workstation may include a reader, the reader including the at least one array of antennas 150, such that the reader may perform wireless interrogation of wireless transponders, e.g., passive radio frequency identification (RFID) transponders used to tag respective ones of the specimen containers 300 (shown in Figure 4). The reader may individually identify the specimen containers 300 via unique identifiers stored by the wireless transponders 308, and locates a respective position of the specimen containers 300 in an arrangement of the specimen containers 300.

The reader may include at least one antenna board positioned under a surface of the workstation 104, such as the bottom 132 of the well 130. The at least one antenna board may include at least one printed circuit board that carries a two-

dimensional array of spiral antennas, for example up to a nine-by-nine (9x9) array of spiral antennas (not shown).

As shown, the at least one array of antennas 150 can include a first two-dimensional array 156 of the antennas 150 and a second two-dimensional array 158 of the antennas 150. The antenna board may include a first printed circuit board that carries the first two-dimensional array 156 and a second printed circuit board that carries the second two-dimensional array 158. By virtue of the layout of the first and second arrays of antennas 156, 158 and the mechanical alignment features of the components of the workstation 104 (discussed in detail below), each of the spiral antennas in the first and second two dimensional arrays 156, 158 is positioned to align with a respective position in which a respective specimen container 300 may be located when the workstation 104 is used as described below. The reader may include at least one radio that causes transmission of interrogation signals via the antennas 150 and which decodes unique identifiers from response signals returned by the wireless transponders 308 in response to the interrogation signals.

Referring to Figure 20, the at least one array of antennas 150 (only one shown) may be positioned so as to be within a defined perpendicular distance 160 of a distal end, for example the wireless transponders 308 of the specimen container 300 (only one shown) when the storage cassette 302 or the carrier that supports the specimen container 300 is positioned in the first bucket 136, and the first bucket 136 is positioned within the at least one well 130. The workstation 104 may include a thickness of: the bottom 316 of the bulk container 312, the thermal shunt 332, any support features (such as the set offs 352), the thermally insulative material 342, or any combination thereof, so as to position the specimen container 300 longitudinally such that a bottom portion of the specimen container 300, for example the wireless transponder 308, is within the defined perpendicular distance 160 of a respective one of the antennas 150. According to one embodiment, the defined perpendicular distance 160 is less than 20 mm.

Referring to Figures 15 to 17, the work surface 128 may include a planar portion 162 and a peripheral wall 164 that extends upwardly from the planar portion 162 about at least a portion of a periphery 166 of the work surface 128. A portion of the peripheral wall 164, for example at the back 126 of the platform 122,

may include an angled face 168 that slopes downward from the back 126 of the platform 122 towards the front 124 of the platform 122. As shown in the illustrated embodiment, the work surface 128 may provide a path from the opening 116 to the at least one well 130. For example, the storage cassette 302 may exit the cryogenic storage tank or freezer 102 through the opening 116, then slide down the angled face 168, across the planar portion 162 to the at least one well 130, and then be positioned at least partially within the at least one well 130.

The work surface 128 may include a first opening 170. The first opening 170 may serve as an entrance into the at least one well 130. The work surface 128 may include a fixed planar portion 172 and a frame 174. The frame 174 may be selectively removable from the fixed planar portion 172 to expose an interior of the at least one well 130. The frame 174 may include one or more openings 176, for example a first opening 176a and a second opening 176b, that each provide access through the work surface 128 and into the at least one well 130.

As shown, the first bucket 136 and the second bucket 146 may be placed within the at least one well 130 via passage through the at least one opening 170 with the frame 174 removed from the fixed planar portion 172. With the first bucket 136 and the second bucket 146 in position in the at least one well 130, the frame 174 may be positioned adjacent the fixed planar portion 172 such that at least a portion of the first opening 170 is blocked, thereby preventing removal of the first bucket 136 and the second bucket 146 from the at least one well 130. Then a first vessel, for example the storage cassette 302, may be positioned within the first bucket 136 via passage through the first opening 176a, and a second vessel, for example the specimen transporter 380, may be positioned within the second bucket 146 via passage through the second opening 176b.

Referring to Figure 21, the work surface 128 may include the first opening 170 and a second opening 171. The first opening 170 and the second opening 171 may be formed in the fixed planar portion 172 of the work surface 128, and the work surface 128 may be devoid of the frame 174 (shown in Figure 17). The second opening 171 of the work surface 128 may be distinct from the first opening 170 of the work surface 128, as shown. The first opening 170 may be sized to closely receive an outer perimeter of the first bucket 136, and the second opening

171 may be sized to closely receive an outer perimeter of the second bucket 146. The first bucket 136, the second bucket 146, or both may include a spout 178, and the first opening 170, the second opening 171, or both may be shaped so as to correspond to the shape of the spout 178.

As shown, the first bucket 136 may be positioned within a first of the at least one wells 130 via passage through the first opening 170, and the second bucket 146 may be placed within a second of the at least one well 130 via passage through the second opening 171. The first bucket 136 may sit in the first opening 170 such that a top 180 of the first bucket 136 is flush with the work surface 128, and the second bucket 146 may sit in the second opening 171 with a top 182 of the second bucket 146 flush with the work surface 128.

The peripheral wall 164 may have a first opening 184, a second opening 186, or both, each positioned at the front 124 of the platform 122. Each of the first opening 184 and the second opening 186 may be sized to accommodate the handle 145 of a respective one of the first bucket 136 and the second bucket 146 when the respective one of the first bucket 136 and the second bucket 146 is received in the respective one of the at least one well 130 with the respective handles 145 each pivoted to the un-deployed position.

With the first bucket 136 and the second bucket 146 in position in respective ones of the at least one well 130, a first vessel, for example the storage cassette 302, may be positioned within the first bucket 136 via passage through the first opening 170, and a second vessel, for example the specimen transporter 380, may be positioned within the second bucket 146 via passage through the second opening 171.

Referring to Figures 22 to 34, the workstation 104 may include one or more alignment structures that facilitate positioning of the specimen containers 300 relative to the one or more array of antennas 150 such that the wireless transponders 308 of each of the specimen containers 300 are readable by a respective one of the antennas 150.

Referring to Figures 22 and 23 an outer (or top) surface 188 of the enclosure 154, and an outer (or bottom) facing surface 192 of the bottom 132 of the at least one well 130 may include corresponding alignment structures. The

alignment structures may be sized and shaped to prevent relative movement between the at least one well 130 and the first bucket 136 along at least one degree of freedom up to six degrees of freedom. For example, the bottom 132 and the outer facing surface 188 may include a projection 194 and corresponding recess 196, such as a T-shaped projection and recess.

Referring to Figures 24 to 29, the at least one well 130 may include an alignment structure that corresponds to an alignment structure of the first bucket 136, the second bucket 146, or both. As shown the bottom 132 of the well 130 may include a projection 460, for example in the form of a raised bump, and the bottom 138 of the first bucket 136 may include a corresponding recess 462 that receives the projection 460 and thereby aligns the at least one well 130 and the first bucket 136. If the at least one well 130 is already aligned with the at least one array of antennas 150, the recess 462 that receives the projection 460 will align the first bucket 136 and the at least one array of antennas 150. The projection 460 and the recess 462 may be positioned such that the projection 460 and the recess 462 align the storage cassette 302 with respect to the first bucket 136, and thereby aligns the storage cassette 302 (and any specimen containers within) with the at least one array of antennas 150.

As shown in Figures 24 and 25, the alignment structure may include a single projection 460 and a single, corresponding recess 462. The projection 460 and the recess 462 may form an “island” surrounded by a planar portion of the bottom 138 of the first bucket 136. As shown in Figures 26 and 27, the projection 460 and the recess 462 may form a “peninsula” extending inward from an edge of the bottom 138 with the remaining sides of the projection 460 and the recess 462 surrounded by a planar portion of the bottom 138 of the first bucket 136. As shown in Figures 28 and 29, the alignment structure may include a plurality of projections 460 and a corresponding plurality of recesses 462. The projections 460 and the recesses 462 may form a plurality of “islands,” for example such that the plurality of projections and recesses form a T-shape.

Referring to Figures 18 to 19 and 30 to 31, the first bucket 136, the second bucket 146, or both may include an alignment structure that corresponds to an alignment structure of the storage cassette 302, the specimen transporter 380, or

both. As shown, the at least one side wall 142 can be tapered and extend up from the bottom 138 such that an intersection of the at least one side wall 142 and the bottom 138 forms a shape that corresponds to a shape of the outer perimeter of the storage cassette 302, the specimen transporter 380, or both.

As shown in Figures 18 and 19, the alignment structure of the first bucket 136, the second bucket 146, or both may include a projection 198 that extends up from the bottom 138. The projection 198 cooperates with the intersection of the at least one side wall 142 and the bottom 138 to form the shape that corresponds to the shape of the outer perimeter of the storage cassette 302, the specimen transporter 380, or both. As shown in the illustrated embodiment, the storage cassette 302 and the specimen transporter 380 may be devoid of a recess that corresponds to the projection 198.

As shown in Figures 30 and 31, the alignment structure of the first bucket 136, the second bucket 146, or both may be devoid of the projection 198 (shown in Figures 18 and 19) that extends up from the bottom 138. Instead the first bucket 136 may be shaped to block movement of the storage cassette 302 in the direction lacking an abutment at the bottom 138. For example, the first bucket may include a tapered portion 199 that blocks movement of the storage cassette 302 in the direction lacking an abutment at the bottom 138.

Referring to Figures 32 to 34, the at least one well 130 may include a rail 220 as part of the alignment structure. The rail 220 may be positioned within the at least one well 130, as shown. The rail 220 may include at least one notch 222 that corresponds to a portion of the handle 145 of the first bucket 136. When the portion of the handle 145 is received in the notch 222 the first bucket 136, and any storage cassette contained therein, may be aligned with the array of antennas 150, for example aligned in a first direction L, a second direction A (perpendicular to the first direction L), and a third direction T (perpendicular to both the first direction L and the second direction A).

When the portion of the handle 145 is received in the notch 222, the first bucket 136 may be positioned with respect to the at least one well 130 such that the bottom 138 of the first bucket 136 contacts the bottom 132 of the at least one well 130 and there is no contact between the at least one side wall 142 of the first

bucket 136 and the at least one side wall 134 of the at least one well 130. Alternatively, the portion of the handle 145 may be received in the notch 222 such that there is no contact between the bottom 138 of the first bucket 136 and the bottom 132 of the at least one well 130, and there is no contact between the at least one side wall 142 of the first bucket 136 and the at least one side wall 134 of the at least one well 130.

Referring to Figures 32 and 33, the at least one sidewall 134 of the at least one well 130 may include an alignment structure, for example a notch 224 that corresponds in shape to a portion of the at least one sidewall 142, for example a spout 226. When the spout 226 is received in the notch 224 the first bucket 136, and any storage cassette contained therein, may be aligned with the array of antennas 150, for example aligned in the first direction L, the second direction A, and the third direction T.

When the spout 226 is received in the notch 224, the first bucket 136 may be positioned with respect to the at least one well 130 such that the bottom 138 of the first bucket 136 contacts the bottom 132 of the at least one well 130 and there is no additional contact between the at least one side wall 142 of the first bucket 136 and the at least one side wall 134 of the at least one well 130, besides the spout 226 and the notch 224. When the spout 226 is received in the notch 224, the first bucket 136 may be positioned with respect to the at least one well 130 such that the bottom 138 of the first bucket 136 contacts the bottom 132 of the at least one well 130 and a portion of the at least one side wall 142 of the first bucket 136, for example a portion opposite the spout 226 with respect to the first direction L, contacts a portion of the at least one side wall 134 of the at least one well 130, for example a portion opposite the notch 224 with respect to the first direction L. Other portions of the at least one side wall 142 and the at least one side wall 134 may be spaced apart by a gap 228.

The alignment structure may include a combination of any of the alignment structures described above. For example, the at least one well 130 may include the notch 224 and the projection 460, for example a T-shaped, “peninsula” projection, and the first bucket 136 may include the spout 226 and the recess 462, for example a T-shaped, “peninsula” recess.

Referring to Figures 37 to 39, the cryogenic storage system 100 may include a registration tray 700 that registers the wireless transponders 208, 308. During a registration process one or more of the wireless transponders 208, 308 (and the respective specimen holders 200, 300, 400 to which the wireless transponders 208, 308 are attached, may be associated with a patient and their biological specimen. The registration tray 700 includes a housing 702 and a printed circuit board assembly 704.

The housing 702 forms a registration recess 706 sized to receive one of the specimen containers 200, 300, 400. The housing 702 encloses the printed circuit board assembly 704 such that the printed circuit board assembly 704 is positioned to identify the wireless transponder 208, 308 of the specimen container 200, 300, 400 that is positioned within the registration recess 706.

The housing 702 may form one or more storage recesses 708 that each hold one of the specimen containers 200, 300, 400 after the specimen holder 200, 300, 400 has been registered. The storage recesses 708 are positioned relative to the printed circuit board assembly 704 so as to not interfere with the registration of the specimen container 200, 300, 400 positioned within the registration recess 706. This allows one or more than one of the specimen containers 200, 300, 400 to kept organized during registration and association with one patient.

The registration tray 700 may include an indicator 710 that visually displays information related to the registration process. For example, the indicator 710 may include a light ring, e.g. positioned around the periphery of the registration recess 706. The light ring may have multiple states which represent different stages of the registration process. The light ring may display a first color when a specimen container is positioned within the registration recess 706, but the specimen container is not yet registered and associated with a patient. The light ring may display a second color when a specimen container is positioned within the registration recess 706, and the specimen container has been registered and associated with a patient.

The registration tray 700 may include one or more depressions 712 formed in the housing 702 to hold portions of a specimen container prior to assembly, registration, or both of the specimen container. The registration tray 700

may be communicatively coupleable, for example via USB, to a processor that assists in the registration process.

Referring to Figures 40 to 46 a method of installing the cryogenic storage system 100 is described. As shown in Figure 40, the method of installing the cryogenic storage system 100 may include locating a base frame 800 adjacent to the cryogenic storage tank or freezer 102. The base frame 800 may include one or more feet 802 adjustable to level the base frame 800. The base frame 800 may be secured relative to the cryogenic storage tank or freezer 102, e.g. using connectors such as bolts, screws, rivets, etc. or other means such as welding.

For example, the cryogenic storage tank or freezer 102 may include a first bracket 805a mounted to an exterior surface of the cryogenic storage tank or freezer 102. The workstation 104, for example the base frame 800, may include a second bracket 805b. The cryogenic storage system 100 may include a connection pin 807 receivable by the first bracket 805a and the second bracket 805b to releasably secure the workstation 104 to the cryogenic storage tank or freezer 102. According to one embodiment, the first bracket 805a, the second bracket 805b, and the connection pin 807 when received within the first bracket 805a and the second bracket 805b are positioned such that the connection pin 807 is insertable and removable from the first bracket 805a and the second bracket 805b at any stage during the method of installing the cryogenic storage system 100.

The cryogenic storage system 100 may include multiple sets of the first bracket 805a, the second bracket 805b, and the connection pin 807. According to one embodiment, the cryogenic storage system 100 may include two each of the first bracket 805a, the second bracket 805b, and the connection pin 807. According to one embodiment, the cryogenic storage system 100 may include four each of the first bracket 805a, the second bracket 805b, and the connection pin 807.

Thus, the base frame 800 may be coupled to the cryogenic storage tank or freezer 102 and then the rest of the workstation 104 may be assembled as described below. Additionally, the workstation 104 may be assembled while remote from the cryogenic storage tank or freezer 102 and then the assembled workstation 104 may be secured to the cryogenic storage tank or freezer 102, for example via the first bracket 805a, the second bracket 805b, and the connection pin 807.

Additionally, a fully assembled workstation 104 may be removed from one cryogenic storage tank or freezer 102 and secured to another cryogenic storage tank or freezer 102.

As shown in Figure 41, the method may include coupling a console frame 804 to the base frame 800. The console frame 804 may include the wells 130. As shown in Figure 42, the method may include securing the platform 122 to the console frame 804 such that the first opening 176a and the second opening 176b each provide access through the work surface 128 and into the at least one well 130. The display 128 may be secured to the platform 122.

As shown in Figure 43, a base platform 806 may be coupled to the frame 800 such that an operator standing on the base platform 806 has access to the platform 122. The base platform 806 may include one or more feet 808 adjustable to level the base platform 806. As shown in Figure 44, the base platform 806 may include a floor 810 that supports the operator accessing the platform 122. One or more guide rails 812 may be secured to the base platform 806 to prevent an operator from falling off of the base platform 806. As shown in Figure 45, a step 814 may be coupled to the base platform 806. As shown in Figure 46, side skirts 816 may be coupled to the base platform 806 to enclose the feet 808.

Referring to Figures 1 to 40, at least one array of antennas 150 may be operable to read information from one or more wireless transponders physically associated with respective specimen containers 300, storage cassettes 302, and/or specimen transporters 380. As explained in detail herein, the at least one array of antennas 150 may include a two-dimensional array of antennas, and one or more transmitters, receivers, transceivers (collectively radios), operable to cause the antennas 150 to emit interrogation signals and to receive response signals in response to the interrogations signals.

The workstation 104 may include one or more dedicated user interface components (*e.g.*, touch screen display, speakers, microphones), or may employ a user interface component of the cryogenic storage system 100, for example a touch screen display 128.

Portions of the cryogenic storage system 100 may be of a conventional design. For example, the cryogenic storage tank or freezer and/or the picker or

elevator may take the form of a commercially available automated storage system (*e.g.*, the Bistore III Cryo -190°C System sold by Brooks Life Sciences).

Figure 47 shows a processor-based transfer system 122 of, or that interfaces with, the cryogenic storage system 100 of Figure 1. The processor-based transfer system 122 facilitates transfers, whether automated or manual, of the specimen containers 300 between the storage cassettes 302 and the specimen transporters 380. The storage cassettes 302 may be designed for long term storage in cryogenic refrigerators (*e.g.,* tanks or dewars), which are typically large and heavy fixtures. The specimen transporters 380 may be designed for temporary storage, in a format that is portable.

Examples of suitable storage cassettes 302, and of the specimen transporters 380, which can temporarily maintain cryogenic materials at cryogenic temperatures, as wells as the specimen containers 200 for use therewith, are described in U.S. patent application 62/900,281, filed September 13, 2019; U.S. patent application 62/880,786, filed July 31, 2019; U.S. patent application 62/879,160, filed July 26, 2019; U.S. patent application 62/741,986, filed October 5, 2018; and U.S. patent application 62/741,998, filed October 5, 2018.

The processor-based transfer system 122 includes one or more readers 400a-400e (five shown, collectively 400), a control subsystem 402, and a user interface system 404. The processor-based transfer system 122 optionally includes one or more robots, for example one or more co-robots 405 (only one shown) that interface with the picker or elevator 120 (Figure 1) of the cryogenic storage system 100.

The readers 400 may take any of a variety of forms. For example, the processor-based transfer system 122 includes one or more readers 400a-400d that wireless read information stored in the wireless transponders 208, 308 physically associated with the specimen containers 300 and/or the storage cassettes 302 and/or the specimen transporters 380. Such readers 400a-400d each include one more transmitters, receivers or transceivers, collectively and individually referred to herein as radios. Such readers 400 each include one or more antenna 401a-401d (only one antenna called out for each, to prevent clutter of drawing) communicatively coupled to the respective radios, and operable to emit wireless signals (*e.g.*,

interrogation signals) and/or to receive wireless signals (*e.g.*, response signals) returned from the wireless transponders 208, 308. The wireless signals are typically in the radio or microwave frequency bands of the electromagnetic spectrum.

Also for example, one or more readers 400e (*i.e.*, machine-readable symbol reader or scanner) may optically read information stored or encoded in one or more machine-readable symbols 210, 310 (*e.g.*, one-dimensional or barcode symbols, two-dimensional or area code symbols) carried by, printed on, or inscribed in the specimen containers 200, 300, the storage cassettes 302, and the specimen transporters 380.

The readers 400a-400e may each include one or more processors, for example, one or more of: one or more microcontrollers, one or more microprocessors, one or more central processing units, one or more digital signal processors (DSPs), one or more graphics processing units (GPUs), one or more application specific integrated circuits (ASICs), one or more field programmable gate arrays (FPGAs), and/or one or more programmable logic controllers (PLCs). The readers 400a-400e may each include one or more nontransitory storage media, for example, one or more nonvolatile storage media and/or one or more volatile storage media, for example one or more of: one or more read only memories (ROMs), one or more random access memories (RAMs), one or more FLASH memory, one or more magnetic disk drives, one or more optical disk drives, one or more solid state drives, one or more cache memories, and/or one or more registers of one or more processors.

In some implementations, the processor-based transfer system 122 includes: a mapping or box reader 400a and associated antenna(s) 401a, a signal specimen container reader 400b and associated antenna(s) 401b, a cassette identification reader 400c and associated antenna(s) 401c, and a bulk reader 400d and associated antenna 401d. The mapping or box reader 400a may include a two-dimensional array of antennas 401a and allows the scanning of a two-dimensional array of positions, which can be used to query or audit the contents of the storage cassette 302, and/or the specimen transporter 830.

The antenna array 150 may, for example, be formed or carried on one side of the printed circuit board 152, while various electrical or electronic

components (*e.g.*, inductors, resistors, capacitors) may be carried on the other side if the printed circuit board, thereby providing a substantially flat planner surface that faces the specimen containers during use, and minimizing a distance therebetween (*e.g.*, less than or equal to 2 mm). The signal specimen container reader 400b may be fixed or more preferably handheld, and is operable to read information from the wireless transponders 208, 308 of individual specimen containers 200, 300 for example when the specimen container 200, 300 is removed from one of the storage cassettes, 202, 302.

The antenna(s) 401c of the cassette identification reader 400c are positioned to read cassette identifiers from wireless transponders 208, 308 physically associated with (*e.g.*, attached or fix to or on) the carrier or storage cassettes, 202, 302, for example when the storage cassettes 202, 302, are positioned at one or more stations. The bulk reader 400d may, for example be a handheld, and is operable to read information from respective wireless transponders 208, 308 of all of the specimen containers 200, 300 held by one of the storage cassettes, 202, 302, respectively.

The control subsystem 402 may include one or more processors 406, for example, one or more of: one or more microcontrollers, one or more microprocessors, one or more central processing units, one or more digital signal processors (DSPs), one or more graphics processing units (GPUs), one or more application specific integrated circuits (ASICs), one or more field programmable gate arrays (FPGAs), and/or one or more programmable logic controllers (PLCs). The control subsystem 402 may include one or more nontransitory storage media, for example, one or more nonvolatile storage media and/or one or more volatile storage media, for example a system memory 408 that includes one or more of: one or more read only memories (ROMs) 410, one or more random access memories (RAMs) 412, one or more FLASH memory, one or more magnetic disk 414 and associated drives 416, one or more optical disk drives 418 and associated drives 420, one or more solid state drives 422, one or more cache memories, and/or one or more registers of one or more processors 406. The control subsystem 402 may include one or more communications channels 424 (*e.g.*, buses) that communicatively couple the processor(s) with the storage media. The control subsystem 402 may

include one or more communications ports, for example one or more wired communications ports 426, wireless communications ports 428 (*e.g.*, Wi-Fi and/or Bluetooth radios and associated antennas 430; infrared transceivers) that provide for communications between the control subsystem 402 and external devices (*e.g.*, dedicated control system of conventional cryogenic refrigerator system with, or without picker or elevator 120).

The processor(s) 406 of the control subsystem 402 are operable to execute logic, for example to execute one or more algorithms stored as process-executable instructions by the one or more nontransitory storage media. Suitable algorithms are set out herein. Process-executable instructions may, for example, include a basic input/output operating system (BIOS) 432, for example stored in ROM 410. Process-executable instructions may, for example, include an operating system (OS) 434, for example stored in RAM 412 during execution. Process-executable instructions may, for example, include one or more application programs 436, which provide the logic to collect user information, map transfers between storage and carrier cassettes, verify that the specimen containers are at the correct positions in the carrier or storage cassettes, and establish evidence of a chain-of-custody for the same, the applications program(s) stored, for example, in RAM 412 during operation.

Process-executable instructions may include one or more other programs or modules 438, for example to provide for communications with external devices and/or to control operation of co-robot(s) 405, and which may be stored, for example, in RAM 412 during execution. One or more data structures 440 may store information, for example information that identifies specific users, identifies specific clinicians, identifies specific patients, identifies specific procedures, identifies specific specimen containers and associates the specific specimen containers with specific patients, and that maps specimen containers to respective storage cassettes and/or carrier cassettes. The data structures 440 may take a variety of forms including databases, data sets, records and fields, tables, linked lists, trees, binary trees, etc. The data structures 440 may be stored, for example, in RAM 412 during execution.

The processor(s) 406 of the control subsystem 402 are communicatively coupled operable (*e.g.*, wired, optical, wireless or radio) to receive

information from the readers 400a-400e, and optionally to control operation of one or more of the readers 400a-400e. The processor(s) 406 of the control subsystem 402 are also operable to receive user input from, and provide user out to, one or more user interface devices of the user interface system 404, to allow a human user to interact with the processor-based transfer system 122.

The user interface system 404 may, for example, include one or more of: one or more display screens, one or more touch-sensitive display screens 442, one or more speakers 444, one or more microphones 446, one or more keyboards 448, one or more pointer devices 450 (*e.g.*, computer mouse, trackpad, trackball), one or more haptic interfaces. The user interfaces 406 are communicatively coupled (*e.g.*, wired, optical, wireless or radio) with the processor(s) via one or more peripheral interfaces 452a, 452b to provide user input to the processor(s) 406 and to receive output from the processor(s) 406 to be presented to a user. In particular, the processor(s) 406 may execute processor-executable instructions that cause the processor(s) to cause devices to present a user interface (*e.g.*, a graphical user interface), for instance via a touch screen display 442. Various user interface elements are illustrated and described herein.

In at least some implementations, the cryogenic storage system 100 may be designed to operate with existing lab equipment, for example with conventional specimen containers (*e.g.*, FluidX™ 24-Format tubes, FluidX™ 48-Format tubes FluidX™ 96- Format tubes available from Brooks Life Sciences) or with plates or racks (*e.g.*, 5 ¼ inch by 5 ¼ inch plates or wells, Vision Plate™ 96 Well plate, Vision Plate™ 24 Well plate, 10x10 Cryo Rack rack, 14x14 Cryo Rack rack available from Brooks Life Sciences). Designing the cryogenic storage system 100 to operate with existing lab equipment places a number of constraints on the structure as well as the operation. For example, a two-dimensional array of antennas must be designed to successfully interrogate RFID transponders array in the various available formats. This can place limits on the size (*e.g.*, coil size) of the antennas used to interrogate and received response signals from RFID transponders.

Smaller antennas typically reduce the range, which may require higher transmit power to compensate for the loss of range. This may be particularly true

where the antennas of the wireless transponders are subject to extremely cold temperatures, for instance when the wireless transponders are immersed in a liquid nitrogen bath, while antennas of a reader are at room temperature. Also, relatively close spacing dictated by conventional equipment formats can increase the amount of cross-talk during interrogation, where an interrogation signal from one antenna excites and elicits response signals from more than one wireless transponder. Cross-talk may also increase with increasing transmit power, for instance where antenna size must be small, for instance to accommodate a spacing dictated by conventional spatial formats. The user of existing wireless transponders and readers (*e.g.*, RFID interrogators or RFID readers) can also require specific accommodations to be made in structure and/or operation. For example, RFID readers typically employ automatic gain control.

The cryogenic storage system 100 comprise: a plurality of antennas spatially arrayed in a two-dimensional array of antennas, the two-dimensional array of antennas having a set of dimensions or orders (*e.g.*, 2x2, 3x3, 5x5, 4x6, 7x7, 9x9, 8x12). One or more radios are communicatively coupled to drive the antennas to emit interrogation signals to interrogate the wireless transponders and to receive response signals from any of the wireless transponders in a range of one or more of the antennas. There may for example be a single radio which is multiplexed to the various antennas. Alternatively, there may be one radio per antenna. Alternatively, the antennas may be grouped into sets, for instance four sets, and one radio per set, multiplexed to the antennas of the respective sets.

In some instances the radios are transmitters, in some the radios are receivers, and in yet other instances the radios are transceivers. A processor-based control system is communicatively coupled to the radio(s). The processor-based control system determines, based on response signals received in response to a given interrogation, whether at least one of the wireless transponders is located at an expected position of one of the storage or the transfer cassettes. In response to a determination that the at least one of the wireless transponders is not located at the expected position of one of the storage or the transfer cassettes the processor-based control system causes a signal indicative of an occurrence of an unexpected condition to be provided. To cause a signal indicative of an occurrence of an

unexpected condition to be provided, the processor-based control system may cause a visual prompt to be presented and/or cause a signal to be provided to a robot that causes the robot to make a movement.

For each response signal received in response to a given interrogation, the processor-based control system may determine which response signal was returned from one of the wireless transponders that is closest wireless transponder to the antenna that emitted the respective interrogation signal to which the wireless transponders are responding. For example, for each response signal received in response to a given interrogation, at least one of the processor-based control system or the at least one radio may normalize a respective received signal strength indicator (RSSI) value that indicates a received signal strength of the response signal to account for any automatic gain adjustment introduced by the at least one radio.

For instance, for each interrogation, the processor-based control system determines which of the respective normalized RSSI values for the response signals received in response to a given interrogation has the largest absolute value. To determine which of the respective normalized RSSI values for the response signals received in response to a given interrogation has the largest absolute value for each interrogation, the processor-based control system may compare the respective normalized RSSI values for the received response signals to one another.

To determine which response signal was returned from one of the wireless transponders that is closest wireless transponder to the antenna that emitted the respective interrogation signal to which the wireless transponders are responding, the processor-based control system may further compare a respective read rate to one another for each of the wireless transponders that respond, the respective read rate representative of a total number of times the respective wireless transponder is read per a unit of time. To determine which response signal was returned from one of the wireless transponders that is closest wireless transponder to the antenna that emitted the respective interrogation signal to which the wireless transponders are responding, the processor-based control system may additionally or alternatively further compare a respective response time to one another for each of the wireless transponders that respond, the respective response time

representative of an amount of time the respective wireless transponder takes to initially respond to the interrogation.

Before the processor-based control system determines whether at least one of the wireless transponders is located at an expected position of one of the storage or the transfer cassettes, the processor-based control system may further cause a prompt to be presented which indicates a position of one of the storage or the transfer cassettes from which to transfer one of the specimen containers along with the wireless transponder associated therewith and a position of the other of the storage or the transfer cassettes to which to transfer the specimen container, the expected position being the position of the other of the storage or the transfer cassettes to which the specimen container is to be transferred.

The processor-based control system may further determine, based on response signals received in response to one or more interrogations, whether there are any specimen containers marked by respective ones of the wireless transponders in an unexpected position in one of the storage or the transfer cassettes, and in response to a determination that there is at least one specimen container marked by respective one of the wireless transponders in an unexpected position in one of the storage or the transfer cassettes, cause a signal indicative of an occurrence of an unexpected condition to be provided.

The processor-based control system may further determine, based on response signals received in response to one or more interrogations, whether there are any specimen containers marked by respective ones of the wireless transponders that are missing from the one of the storage or the transfer cassettes, and in response to a determination that there is at least one specimen containers marked that is missing from the one of the storage or the transfer cassettes, cause a signal indicative of an occurrence of an unexpected condition to be provided. To cause a signal indicative of an occurrence of an unexpected condition to be provided, the processor-based control system may cause a presentation of a signal to be provided that is indicative of the occurrence of the unexpected condition and indicative of at least one of an incorrect location and a correct location for the specimen container in the at least one of the storage or the transfer cassettes.

Additionally, speed is typically important to commercial operation. To increase speed, antennas may be grouped into a plurality of sets, the sets which are operated in parallel with one another. For example, a two-dimensional array of antennas 96 antennas, arranged as a 8 x 12 array, may be grouped to four sets denominated A, B, C D, and corresponding to four quadrants of the two-dimensional array (*e.g.*, sets A, B, C D arranged clockwise starting with A in an upper left quadrant). The position in each quadrant may be represented by a pair of integers representing a row and column. In operation, a first antenna 1,1 of a first set A, a first antenna 1,1 of a second set B, a first antenna 1,1 of a third set C, and a first antenna 1,1 of a fourth set D, may be operated to concurrently transmit respective interrogation signals (*e.g.*, carrier waves) during a first interrogation cycle.

The other antennas of the first set A, second set B, third set C, and fourth set D may be monitored for response signals as part of the first interrogation cycle. Subsequently, a second antenna 1,2 of the first set A, a second antenna 1,2 of the second set B, the second antenna 1,2 of a third set C, and the second antenna 1,2 of the fourth set D, may be operated to concurrently transmit respective interrogation signals (*e.g.*, carrier waves) during a second interrogation cycle. The other antennas of the first set A, second set B, third set C, and fourth set D may be monitored for response signals as part of the second interrogation cycle.

Subsequent interrogation cycles may cycle through the remaining antennas of the sets, operating one of the antennas from each set to transmit interrogations currently with one another. In some implementations, operation may result in there being a fixed distance between the transmitting antennas of any two sets. For instance, during any given interrogation cycle the transmitting antenna in one set may be in the same relative position within its own set as the relative position of the other transmitting antennas in the other sets. This is similar to the operation described above, where the row/column pair of the transmitting antenna of each set match one another during each interrogation cycle.

Alternatively, operation may result in there being a maximum achievable distance between the concurrently transmitting antennas during any given interrogation cycle. For instance, a first antenna 1,1 of a first set A, a sixth antenna 1,6 of a second set B, a nineteenth antenna 4,1 of a third set C, and a

twenty-fourth antenna 4,6 of a fourth set D, may be operated to concurrently transmit respective interrogation signals (*e.g.*, carrier waves) in a first interrogation cycle. Thus, during the first interrogation cycle antennas at the opposite four corners of the two-dimensional array concurrently transmit interrogation signals. During subsequent interrogation cycles, the antennas in each set A, B, C, D may be stepped through in an order that matches one another, for example transmitting interrogation signals from antennas successively along a row, then successively from a next row, etc.

While four sets are described, any number of sets of antennas may be employed. While two patterns of antenna activation are described, other patterns may be employed. Also, while generally described as employing all antennas to monitor for a response signal except the antenna that most recently emitted the interrogation signal, other approaches may be employed. For example, all antennas may be monitored, including the antenna that most recently emitted the interrogation signal. In such implementations, delay will typically be employed to allow resonance in the transmitting antenna to decay sufficiently as to allow detection of a response signal. Alternatively, only a select one or select ones of the antennas may be employed to monitor for response signals. For instance, in some implementation, only the antenna that most recently transmitted the interrogation signal is monitored for a receipt of a response signal, typically after a delay time.

Figures 48 and 49 show a method 500 of operation to transfer specimen containers 200, 300 from the storage cassette 302, which can be stored in a cryogenic freezer 102, to the specimen transporter 380, for example a portable thermally insulated cryogenic carrier, according to at least one illustrated implementation. The method 500 may be performed when the storage cassette 302 and the specimen transporter 380 are each located in the at least one well 130 of the workstation.

The method 500 starts at 502. For example, the method may start in response to a powering on of the processor-based transfer system 122 or a component thereof, in response to detection of the storage cassette 302 and/or the specimen transporter 380 at a reader, receipt of a user input, or a call from a calling routine or program.

At 503, the processor-based transfer system 122 receives, verifies and stores user identification information. The user identification information may take a variety of forms, for example a user identifier, a password or passphrase, and/or biometric data (*e.g.*, digital fingerprint, digital iris scan, facial features).

At 504, the processor-based transfer system 122 receives identification information. The identification information may, for example, be received as user input via a user interface, or as an electronic transfer of information from another system, for instance from a clinical procedure management processor-based system. The identification information may, for example, include a patient name, unique patient identifier, patient data of birth, procedure type or unique procedure identifier, specimen container identifier, and/or specimen identifier.

At 506, the processor-based transfer system 122 determines which of the storage cassettes 302 that holds the one or more specimen containers 200, 250, 300, 1100 to be retrieved. For example, one or more of the specimen containers 200, 250, 300, 1100 may hold biological specimens or tissue to be used in a given procedure on a given patient. The processor-based transfer system may, for example, query a data structure using the identification information.

At 508, the processor-based transfer system 122 determines one or more positions of the identified specimen containers 200, 250, 300, 1100 in the storage cassette 302. The processor-based transfer system may, for example, query a data structure using the identification information.

At 510, the processor-based transfer system 122 determines position(s) of the specimen transporter 380 to hold specimen container(s) 200, 250, 300, 1100 transferred from the storage cassette 302. The processor-based transfer system may, for example, query a data structure using the identification information.

At 512, the processor-based transfer system 122 causes a presentation of queries to confirm conditions of carrier environment. Queries may be presented visually or aurally via a user interface. Queries may include a request that the user confirm that the specimen transporter 380 is ready, that there is adequate fluid (*e.g.*, liquid nitrogen) in the specimen transporter 380, and that the fluid is adequately cold (*e.g.*, at or below approximate 190° C).

At 514, the processor-based transfer system 122 receives information indicative of condition(s) of an environment of the specimen transporter 380. The information may, for example, be received via a user interface.

Optionally at 516, the processor-based transfer system 122 verifies that one or more conditions meet one or more thresholds. For example, a user may enter a fluid level and/or a temperature of the fluid, which can be compared to a threshold level and/or threshold temperature.

At 518, the processor-based transfer system 122 sends one or more commands to cause transfer of the specimen containers 200, 250, 300, 1100 from select position of the storage cassette 302 to select position(s) of the specimen transporter 380. In the case of manual transfers, the commands may be presented to a user as prompts via the user interface. In the case of automated transfers, the commands can be in the form of a motion plan for execution by a robot or other mechanical conveyance.

At 520, the processor-based transfer system 122 receives a confirmation of transfer. Confirmation may be received from a user via a user interface. Alternatively, confirmation may come from a processor-based system, for example a robot, indicating that a series of operations have been completed.

At 522, the processor-based transfer system 122 interrogates the specimen transporter 380. For example, a reader may sequentially interrogate each position in the specimen transporter 380, determining which positions have a wireless transponder tagged specimen container, and even the identity of each specimen container at each position that has a specimen container. Such may, for example, be implemented via an RFID reader or interrogator, with a two-dimensional array of antennas which are arranged to be in registration with respective positions of the specimen transporter 380.

At 524, the processor-based transfer system 122 determines whether the transferred specimen container(s) are in correct the position(s) in the specimen transporter 380. The processor-based transfer system 122 can query a data structure to determine, for each position of the specimen transporter 380that is supposed to have a specimen container, the identity of the specimen container that is supposed to be at that position. The processor-based transfer system 122

compares the actual mapping, as determined via interrogation, with the intended mapping, to verify that each specimen container is in the correct position, to identify specimen containers in incorrect positions, to identify missing specimen containers and/or specimen containers that should not be in the specimen transporter 380, as described below.

If it is determined at 524 that the transferred specimen container(s) are not in correct position(s) in the specimen transporter 380, then the processor-based transfer system 122 attempts to determine what specific errors have occurred. For example, at 526 the processor-based transfer system 122 determines whether the transferred specimen container(s) are present in the specimen transporter 380. If it is determined at 526 that the transferred specimen container(s) are not present in the specimen transporter 380, then at 528 the processor-based transfer system 122 causes a user interface to present a prompt to transfer the specimen container from the storage cassette 302 to the specimen transporter 380, identifying the specific positions in the storage cassette 302 and the specimen transporter 380, and control returns to 520 to await receipt of a confirmation that the transfer has been completed.

Alternatively, the processor-based transfer system 122 provides instructions to a robot to implement the transfer of the specimen container(s) 200, 250, 300, 1100. If it is determined at 526 that the transferred specimen container(s) is (are) present in the specimen transporter 380, then at 530 the processor-based system 122 causes the user interface to present a notification or prompt to move the specimen container(s) to the correct position(s) in the specimen transporter 380, including an identification of the position from which the specimen container should be moved from and the position to which the specimen container should be moved. Control then returns to await receipt of a confirmation that the transfer has been completed at 520.

If it is determined at 524 that the transferred specimen container(s) are in correct position(s) in the specimen transporter 380, then optionally at 532 the processor-based transfer system 122 determines whether there are any incorrect specimen container(s) present in the specimen transporter 380. If it is determined at 532 that there are incorrect specimen container(s) present in the specimen

transporter 380, then at 534 the processor-based transfer system 122 causes the user interface to present a notification that there are incorrect specimen container(s) in the specimen transporter 380, identifying incorrect position(s). Control then returns to await receipt of a confirmation that the transfer has been completed at 520. If it is determined at 532 that there are not incorrect specimen container(s) present in the specimen transporter 380, then control passes to 536.

At 536, the processor-based transfer system 122 updates a data structure to reflect transfer. The data structure can, for example take the form of a database, table, tree structure or linked list.

At 538, the processor-based transfer system 122 stores evidence of chain-of-custody, preferably in a tamper proof or tamper evident form. The evidence of chain-of-title may, for example be stored in a block-chain form.

The method 500 terminates at 540, for example until invoked again.

Figures 50 and 51 show a method 600 of operation to transfer specimen containers 200, 250, 300, 1100 from the specimen transporter 380, for example a portable thermally insulated cryogenic carrier, to the storage cassette 302 for storage in a cryogenic freezer 102, according to at least one illustrated implementation. The method 500 may be performed when the storage cassette 302 and the specimen transporter 380 are each located in the at least one well 130 of the workstation.

The method 600 starts at 602. For example, the method may start in response to a powering on of the processor-based transfer system 122 or a component thereof, in response to detection of the storage cassette 302 and/or the specimen transporter 380 at a reader, receipt of a user input, or a call from a calling routine or program.

At 603, the processor-based transfer system 122 receives, verifies and stores user identification information. The user identification information may take a variety of forms, for example a user identifier, a password or passphrase, and/or biometric data (*e.g.*, digital fingerprint, digital iris scan, facial features).

At 604, the processor-based transfer system 122 receives identification information. The identification information may, for example, be received as user input via a user interface, or as an electronic transfer of information from another

system, for instance from a clinical procedure management processor-based system. The identification information may, for example, include a patient name, unique patient identifier, patient data of birth, procedure type or unique procedure identifier, specimen container identifier, and/or specimen identifier.

At 606, the processor-based transfer system 122 determines which specimen transporter 380 holds the one or more specimen containers 200, 250, 300, 1100 to be stored in the cryogenic storage tank or freezer 102. For example, one or more specimen containers may hold biological specimens or tissue collected from a given procedure on a given patient. The processor-based transfer system 122 may, for example, query a data structure using the identification information.

At 608, the processor-based transfer system 122 determines one or more positions of the identified specimen containers in the specimen transporter 380. The processor-based transfer system 122 may, for example, query a data structure using the identification information.

At 610, the processor-based transfer system 122 determines position(s) of storage cassette to hold specimen container(s) transferred from the specimen transporter 380. The processor-based transfer system 122 may, for example, query a data structure using the identification information.

At 612, the processor-based transfer system 122 sends one or more commands to cause transfer of specimen containers from select position of the specimen transporter 380 to select position(s) of the storage cassette 302. In the case of manual transfers, the commands may be presented to a user as prompts via the user interface. In the case of automated transfers, the commands can be in the form of a motion plan for execution by a robot or other mechanical conveyance.

At 614, the processor-based transfer system 122 receives a confirmation of transfer. Confirmation may be received from a user via a user interface. Alternatively, confirmation may come from a processor-based system, for example a robot, indicating that a series of operations have been completed.

Optionally at 616, the processor-based transfer system 122 interrogates the storage cassette 302. For example, a reader may sequentially interrogate each position in the storage cassette 302, determining which positions have a wireless transponder tagged specimen container, and even the identity of

each specimen container at each position that has a specimen container. Such may, for example, be implemented via an RFID reader or interrogator, with a two-dimensional array of antennas which are arranged to be in registration with respective positions of the storage cassette 302.

Optionally at 618, the processor-based transfer system 122 determines whether the transferred specimen container(s) are in correct the position(s) in the storage cassette 302. The processor-based transfer system 122 can query a data structure to determine, for each position of the storage cassette 302 that is supposed to have a specimen container, the identity of the specimen container that is supposed to be at that position. The processor-based transfer system 122 compares the actual mapping, as determined via interrogation, with the intended mapping, to verify that each specimen container is in the correct position, to identify specimen containers in incorrect positions, to identify missing specimen containers and/or specimen containers that should not be in the storage cassette 302, as described below.

If it is determined at 618 that the transferred specimen container(s) are not in correct position(s) in storage cassette 302, then at 620 the processor-based transfer system 122 determines whether the transferred specimen container(s) are present in storage cassette 302. If it is determined at 620 that the transferred specimen container(s) are not present in storage cassette 302, then at 622 the processor-based transfer system 122 causes a user interface to present a prompt to transfer the specimen container from the specimen transporter 380to the storage cassette 302, identifying the specific positions in the specimen transporter 380 and the storage cassettes 302. Alternatively, the processor-based transfer system 122 provides instructions to a robot to implement the transfer of the specimen container(s). Control then returns to await receipt of a confirmation that the transfer has been completed at 614. If it is determined at 620 that the transferred specimen container(s) is (are) present in the storage cassette 302, then at 624 the processor-based system 122 causes the user interface to present a notification or prompt to move the specimen container(s) to the correct position(s) in the storage cassette 302, including an identification of the position from which the specimen container should be moved from and the position to which the specimen container should be

moved. Control then returns to await receipt of a confirmation that the transfer has been completed at 614.

If it is determined at 618 that the transferred specimen container(s) are in correct position(s) in the storage cassette 302, then optionally at 626 the processor-based transfer system 122 determines whether there are incorrect specimen container(s) present in the storage cassette 302. If it is determined at 620 that there are incorrect specimen container(s) present in the storage cassette 302, then at 628 the processor-based transfer system 122 causes the user interface to present a notification that there are incorrect specimen container(s) in the storage cassette 302, identifying incorrect position(s). Control then returns to await receipt of a confirmation that the transfer has been completed at 614. If it is determined at 620 that there are not incorrect specimen container(s) present in the storage cassette 302, then control passes to 630.

At 630, the processor-based transfer system 122 updates a data structure to reflect transfer. The data structure can, for example take the form of a database, table, tree structure or linked list.

At 632, the processor-based transfer system 122 stores evidence of chain-of-custody, preferably in a tamper proof or tamper evident form. The evidence of chain-of-title may, for example be stored in a block-chain form.

The method 600 terminates at 634, for example until invoked again.

The various implementations and embodiments described above can be combined to provide further implementations and embodiments. All of the commonly assigned US patent application publications, US patent applications, foreign patents, and foreign patent applications referred to in this specification and/or listed in the Application Data Sheet, including but not limited U.S. patent application no. 62/900,281, filed September 13, 2019; U.S. patent application no. 62/880,786, filed July 31, 2019; U.S. patent application no. 62/879,160, filed July 26, 2019; U.S. patent application no. 62/741,986, filed October 5, 2018; U.S. patent application no. 62/741,998, filed October 5, 2018; U.S. patent application no. 62/927,566, filed October 29, 2019; and U.S. patent application no. 63/082,789, filed September 24, 2020 are each incorporated herein by reference, in their entirety. These and other changes can be made to the embodiments in light of the above-detailed description.

In general, in the following claims, the terms used should not be construed to limit the claims to the specific implementations and embodiments disclosed in the specification and the claims, but should be construed to include all possible implementations and embodiments along with the full scope of equivalents to which such claims are entitled. Accordingly, the claims are not limited by the disclosure.

CLAIMS

1. A system for handling cryogenic frozen specimens, the system comprising:

a workstation comprising:

a platform having a front, a back, a work surface and at least one well, the at least one well recessed in the work surface and having a bottom and at least one sidewall that extends upwardly from the bottom of the at least one well;

at least a first bucket removably receivable by the at least one well of the platform, the first bucket having a bottom, a top, at least one sidewall extending from the bottom of the first bucket to the top of the first bucket with an opening at the top of the first bucket, the opening at the top of the first bucket sized to receive a least partially therein at least one of a cassette or a carrier that holds an array of specimen containers therein; and

at least one array of antennas positioned beneath the bottom of the at least one well and spaced to be within a defined perpendicular distance of a distal end of the specimen containers when the cassette or the carrier that holds the specimen containers is positioned in the first bucket.

2. The system of claim 1 wherein the work surface includes a planar portion.

3. The system of claim 2 wherein the work surface includes a peripheral wall that extends upwardly from the planar portion about at least a portion of a periphery of the work surface.

4. The system of claim 2 wherein a portion of the peripheral wall at the back of the platform has an angled face the slopes downward from the back of the platform towards the front of the platform.

5. The system of claim 1 wherein the work surface defines a first opening and a second opening therethrough, the second opening of the work

surface distinct from the first opening of the work surface, the first opening of the work surface sized to removably receive the first bucket therein and the second opening of the work surface sized to removably receive a second bucket therein.

6. The system of claim 5 wherein the first bucket sits in the first opening with a top of the first bucket flush with the work surface when the first bucket is received in the first well via the first opening of the work surface, and the second opening of the work surface sized to removably receive a second bucket therein, and the second bucket sits in the second opening with a top of the second bucket flush with the work surface when the second bucket is received in the first well via the second opening of the work surface.

7. The system of claim 6 wherein the work surface includes a peripheral wall that extends upwardly from the planar portion about at least a portion of a periphery of the work surface, the peripheral wall having a first opening and a second opening each positioned at a front of the platform, each of the first and second openings of the peripheral wall sized to accommodate a handle of a respective one of the first and the second buckets when the first and the second buckets are received in the first well via the first and the second openings of the work surface with the respective handles each pivoted to an un-deployed position.

8. The system of any of claims 5 through 7 wherein the work surface includes a fixed planar portion and a frame, the frame selectively removable from the fixed planar portion to expose an interior of the at least one well.

9. The system of claim 8 wherein the first opening of the work surface and the second opening of the work surface are each formed in the frame.

10. The system of claim 5 wherein the first opening of the work surface is sized to closely receive an outer perimeter of the first bucket and the second opening of the work surface is sized to closely receive an outer perimeter of the second bucket.

11. The system of claim 1 wherein the first bucket has a spout.

12. The system of claim 11 wherein the first bucket has a handle pivotally coupled to the least one sidewall to pivot between a deployed position and an un-deployed position.

13. The system of claim 12 wherein the first bucket has at least one stop that limits rotation of the handle at the deployed position.

14. The system of claim 1, further comprising:

the cassette or the carrier, wherein the cassette or the carrier is sized to hold a two-dimensional array of specimen containers.

15. The system of claim 14 wherein the cassette or the carrier comprises:

a first bulk container having a top, a bottom, and at least one side wall, the bottom having an inner facing surface and an outer facing surface, the at least one side wall having an inner facing surface and an outer facing surface, the inner facing surface of the bottom and the inner facing surface of the at least one side wall delineating an interior compartment of the first bulk container having an interior compartment profile, the first bulk container having an opening at the top thereof;

a first thermal shunt, the first thermal shunt comprising a substrate comprising a metal and having a first major face and a second major face, the second major face opposed from the first major face across a thickness of the substrate, the substrate having an array of a plurality of through holes that extend through the thickness of the substrate, each of the through holes of the substrate shaped and sized to receive at least a portion of a respective vial of a first number of vials therethrough, the substrate closely receivable in the interior compartment of the first bulk container; and

a first spacer closely receivable in the interior compartment of the first bulk container, the first spacer having an array of a plurality of through holes that extend therethrough, each of the through holes of the first spacer shaped and sized to receive at least a portion of a respective vial of the first number of vials therethrough, and

wherein, when the first spacer and the first thermal shunt are stacked in the interior compartment of the first bulk container, each of the through holes of the first spacer is axially aligned with a respective one of the through holes of the first thermal shunt.

16. The system of claim 15 wherein the first bulk container has a number of set offs that extend upwardly from the bottom in an interior of the first bulk container and the first thermal shunt are supported by the set offs to set the first thermal shunt off from the bottom of the first bulk container.

17. The system of claim 15 wherein the substrate of the thermal shunt is a heat sink in the form of a block of non-ferrous metal.

18. The system of claim 15 wherein the substrate of the thermal shunt is a heat sink in the form of a block of aluminum.

19. The system of claim 15 wherein the substrate of the thermal shunt is a heat sink in the form of a block of non-ferrous metal impregnated polymer.

20. The system of claim 15 wherein the through holes of the spacer and the thermal shunt are each circular.

21. The system of claim 15 wherein the through holes of the spacer and the thermal shunt are square with rounded corners.

22. The system of claim 15 wherein the first bulk container is part of the cassette and the first bulk container includes at least a first aperture in a first side and at least a second aperture in a second side, the second side opposed to the first side across a lateral dimension of the first bulk container.

23. The system of claim 15 wherein the first bulk container is part of the cassette, and the cassette further comprises:

a handle that is removably coupleable to the first bulk container.

24. The system of claim 15 wherein the first bulk container is part of the carrier, and the carrier further comprises:

a cover coupleable to the first bulk container to seal the opening in the top of the first bulk container while the spacer and the thermal shunt are stacked in the interior compartment of the first bulk container.

25. The system of claim 15 wherein the first bulk container is part of the carrier, and the carrier further comprises:

a handle that is pivotally coupled to the first bulk container.

26. The system of claim 15 wherein the at least one side wall of the first bulk container is a thermally insulated side wall.

27. The system of claim 15 wherein a combination of any of a thickness of the bottom of the first bulk container, the thermal shunt, any support features, and the spacer positions the vials longitudinally to space a bottom of the vials within a defined distance of an exterior surface of the bottom.

28. The system of claim 15 wherein a combination of any of a thickness of the bottom of the first bulk container, the thermal shunt, any support features, and the spacer positions the vials longitudinally to space a bottom of the vials within a distance of less than 20 mm or more preferably less than 15 mm of an exterior surface of the bottom.

29. The system of claim 15 wherein a combination of any of a thickness of the bottom of the first bulk container, the thermal shunt, any support features, and the spacer positions the vials longitudinally to space a bottom of the vials within the defined perpendicular distance of the antenna array.

30. The system of claim 15 wherein a combination of any of a thickness of the bottom of the first bulk container, the thermal shunt, any support features, and the spacer positions the vials longitudinally to space a bottom of the vials within a distance of less than 20 mm or more preferably less than 15 mm of the antenna array.

31. The system of claim 15 wherein a combination of any of: the at least one well, the first bucket, and the cassette or the carrier positions the specimen

containers to longitudinally to space a bottom of the specimen containers within the defined perpendicular distance of the antenna array.

32. The system of claim 15 wherein a combination of any of: the at least one well, the first bucket, and the cassette or the carrier positions the specimen containers to longitudinally space a bottom of the specimen containers within the defined perpendicular distance of less than 20 mm or more preferably less than 15 mm of the antenna array.

33. The system of any of claims 1 through 7 or 10 through 32, further comprising:

a cryogenic storage dewar having an interior and an opening via which specimen containers are transferred into and out of the interior of the cryogenic storage dewar, wherein a portion of the platform is located immediately adjacent the cryogenic storage dewar.

34. The system of claim 33, further comprising:

an elevator positioned and operable to place cassettes into the interior of the dewar and to retrieve cassettes from the interior of the dewar, the elevator including at least one port, wherein a rear portion of the platform is located immediately adjacent the at least one port of the elevator with no open gap therebetween.

35. The system of claim 34 wherein the at least one well of the platform is spaced from the at least one port of the elevator along a first axis that extends perpendicularly from the at least one port and laterally with respect thereto along a second axis that is orthogonal to the first axis.

36. The system of claim 33 wherein the workstation and the cryogenic storage dewar include corresponding fasteners that releasably secure the workstation and the cryogenic storage dewar.

37. The system of claim 36, wherein the corresponding fasteners include a first bracket of the workstation, a second bracket of the cryogenic storage

dewar and a connection pin receivable within both the first bracket and the second bracket to releasably secure the workstation and the cryogenic storage dewar.

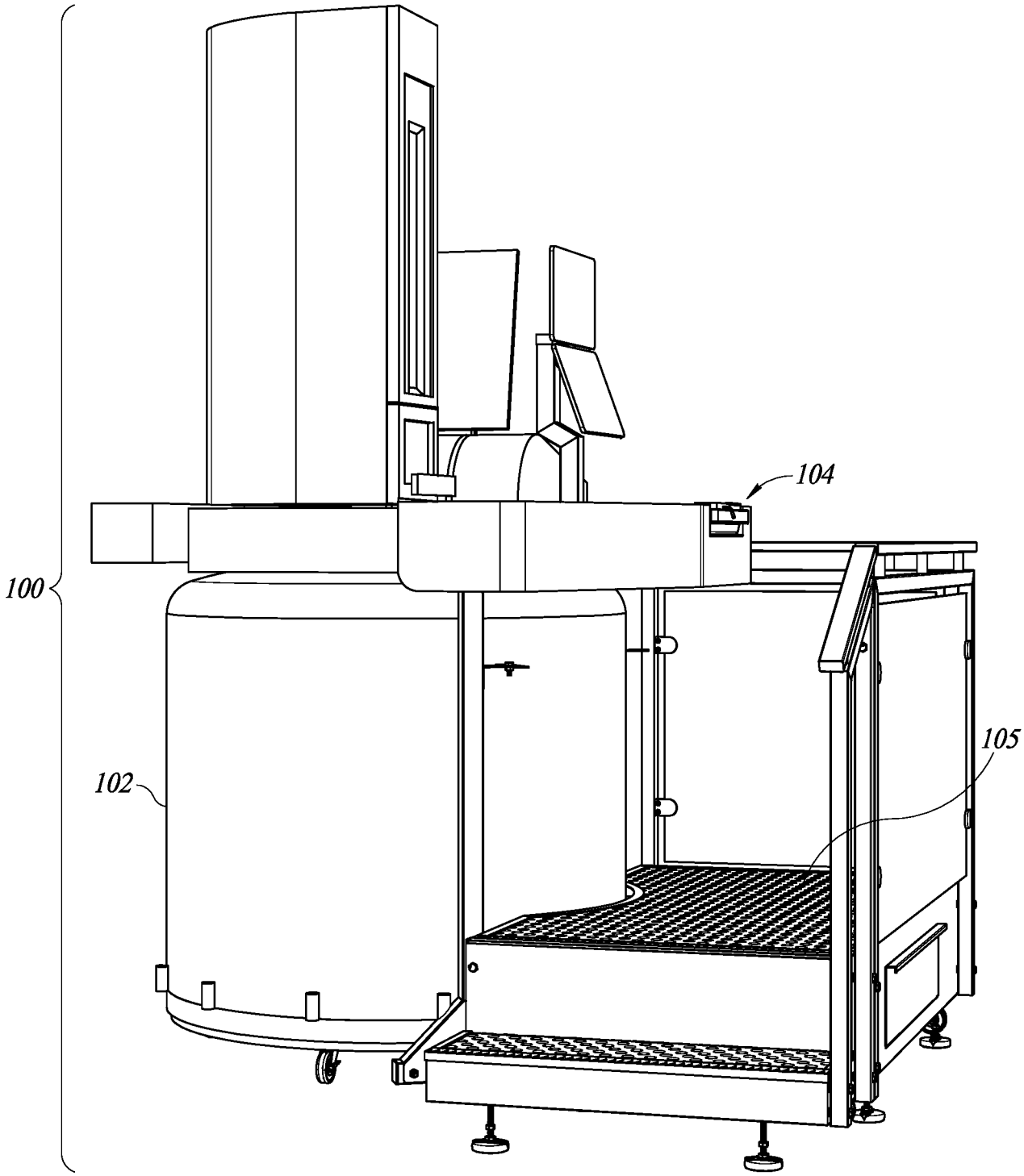


FIG. 1

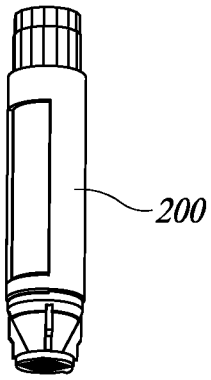


FIG. 2

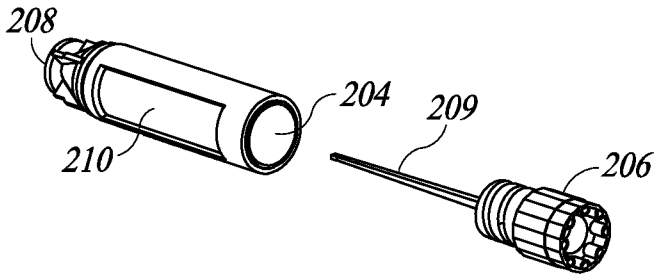


FIG. 3

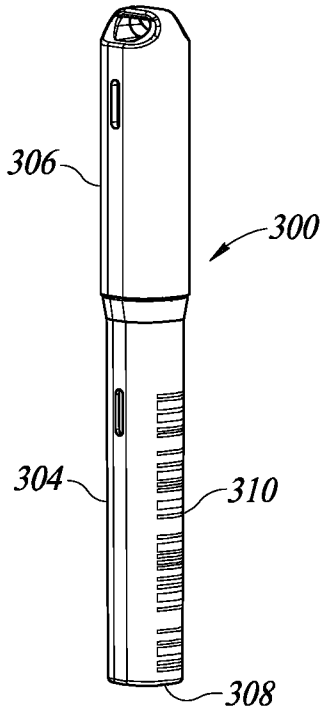


FIG. 4

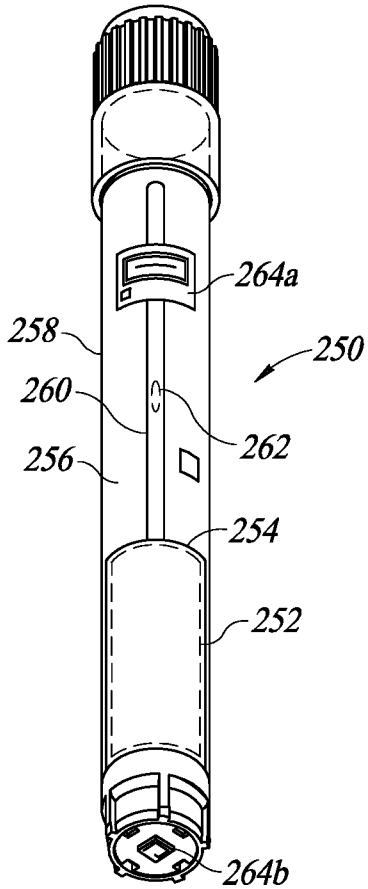


FIG. 5

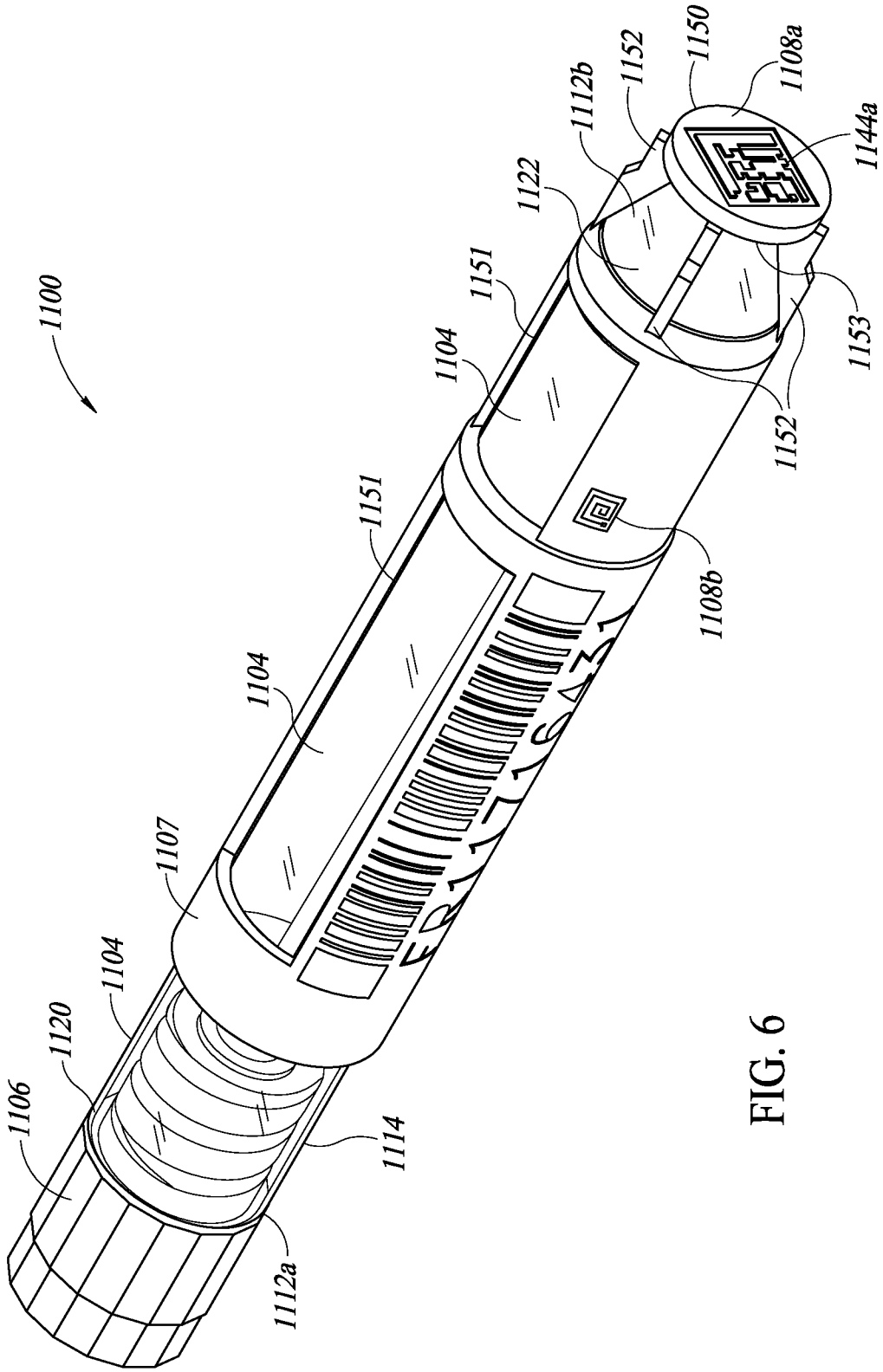

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FIG. 6

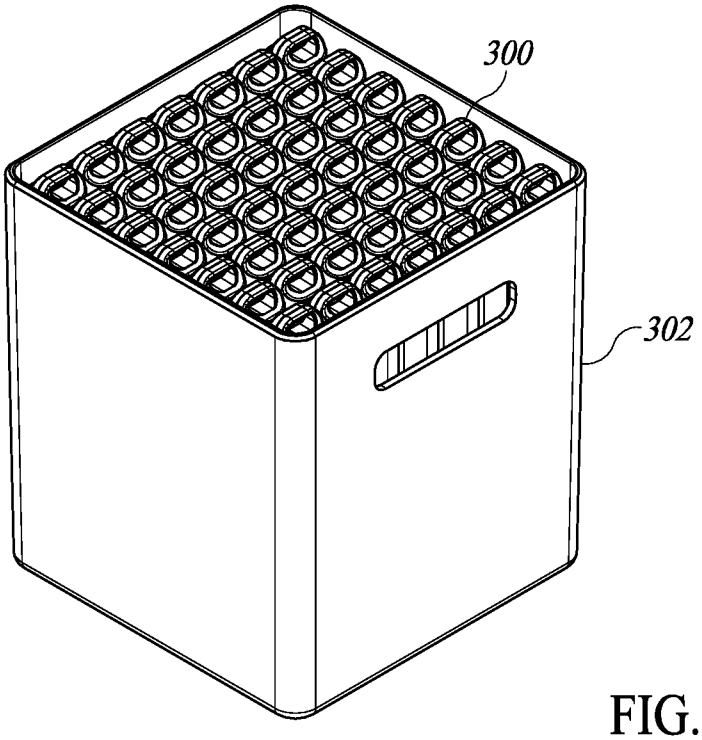


FIG. 7

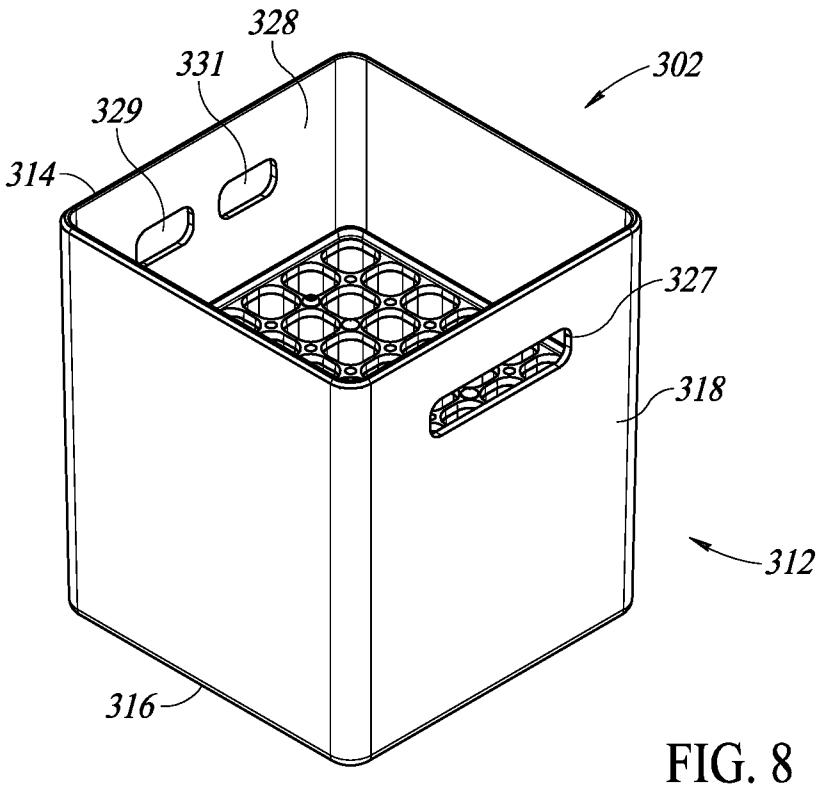


FIG. 8

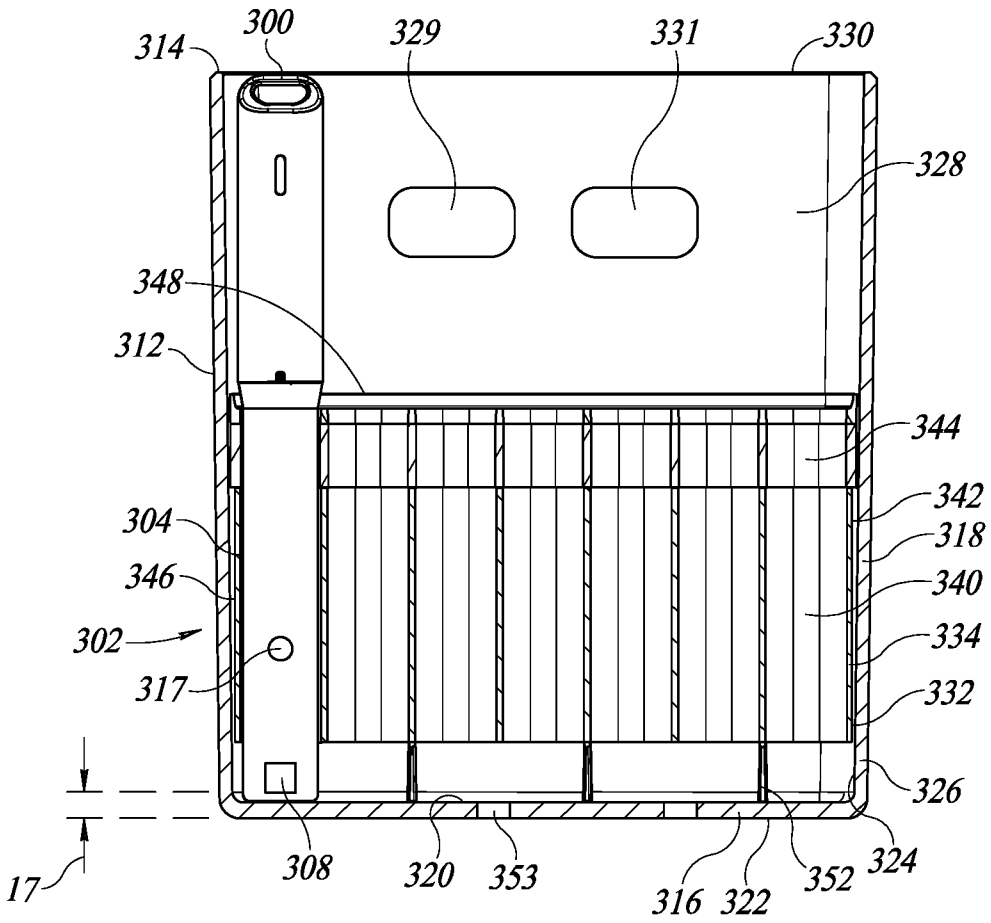

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FIG. 9

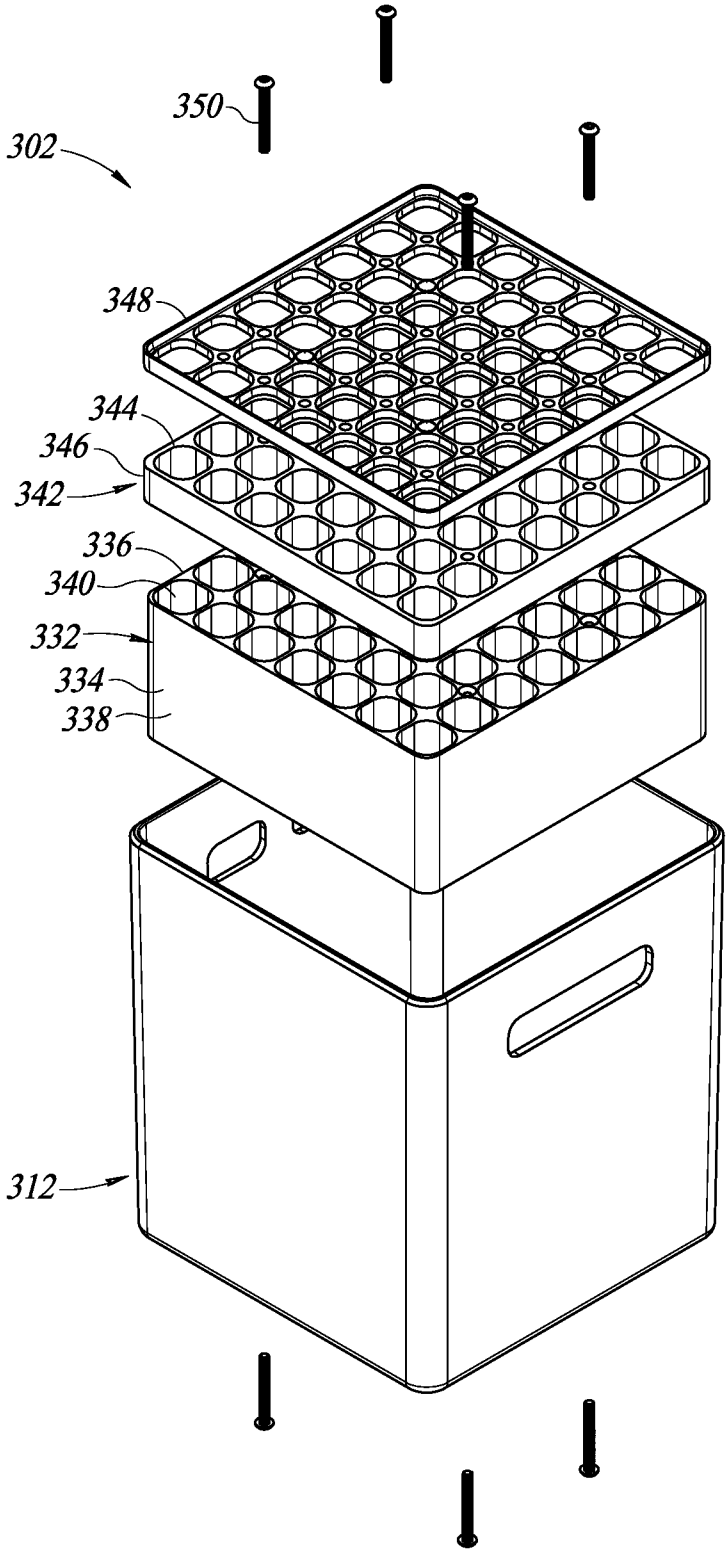


FIG. 10

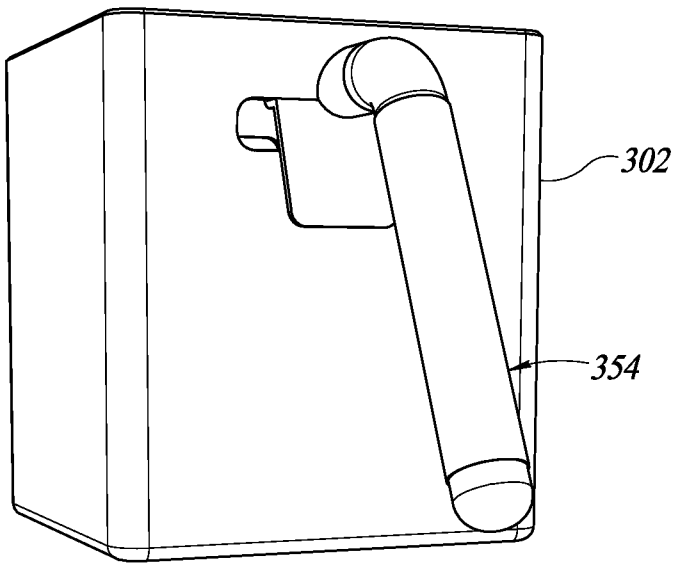


FIG. 11

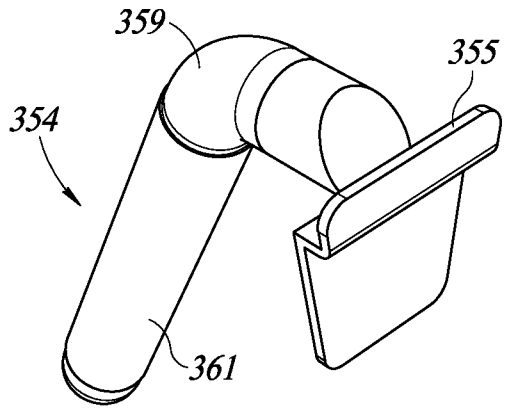


FIG. 12

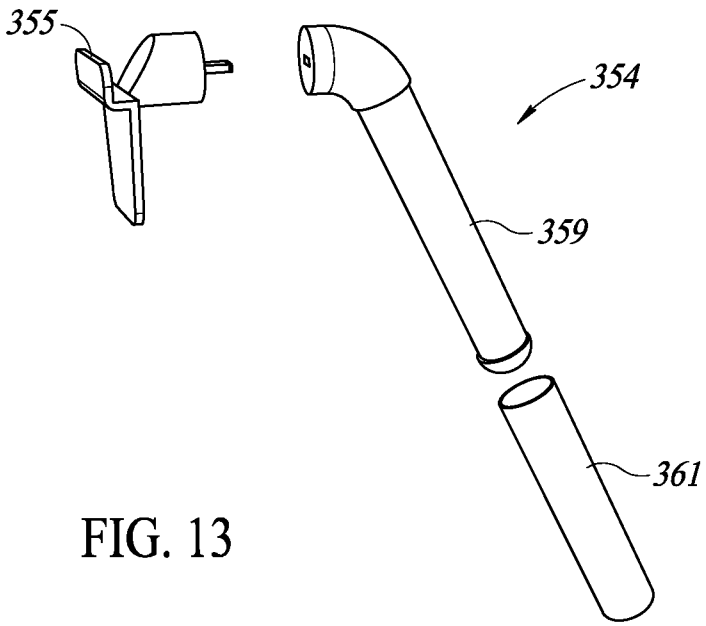


FIG. 13

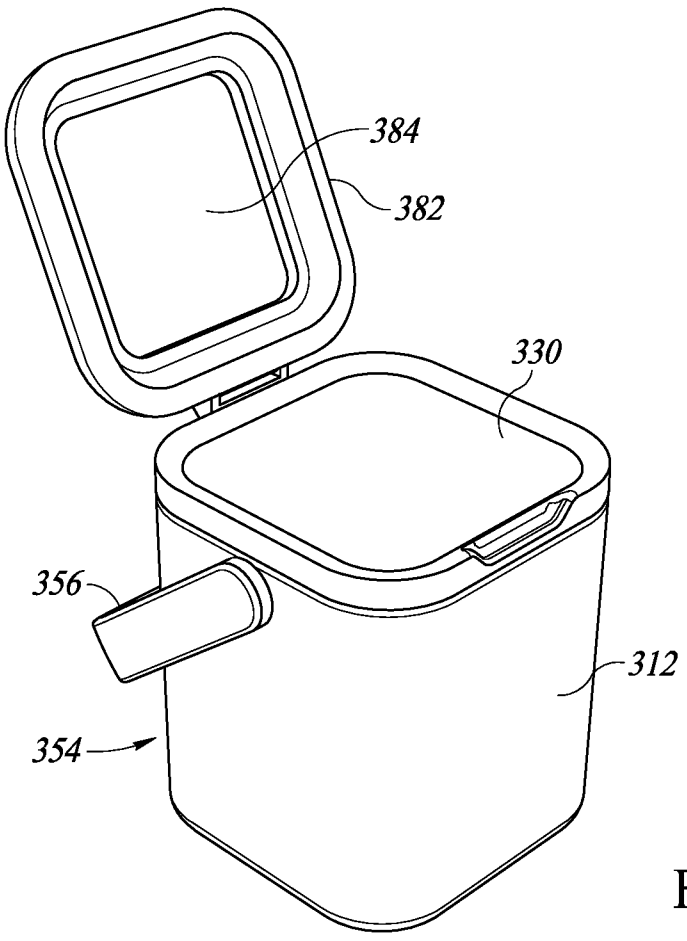


FIG. 14

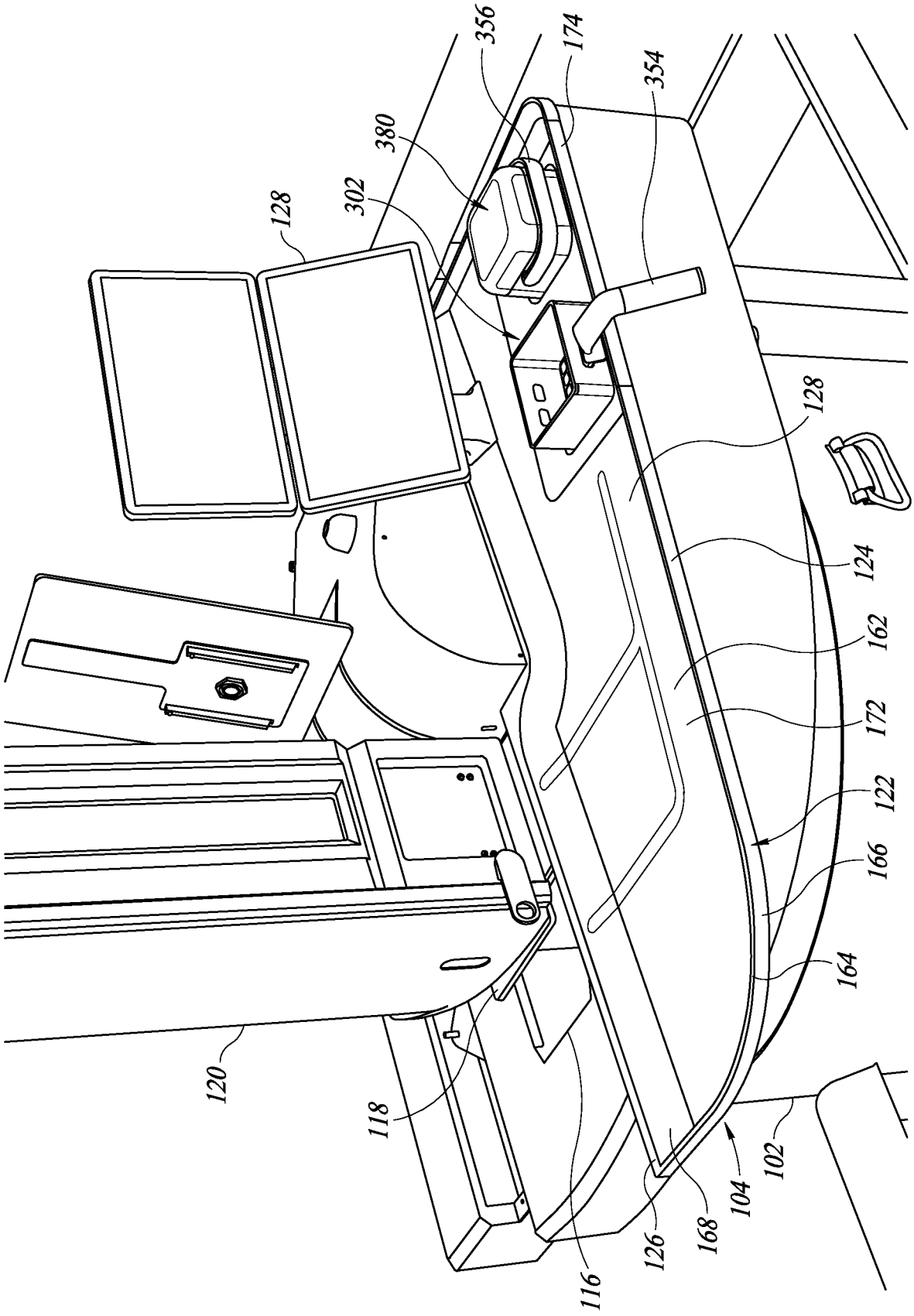

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FIG. 15

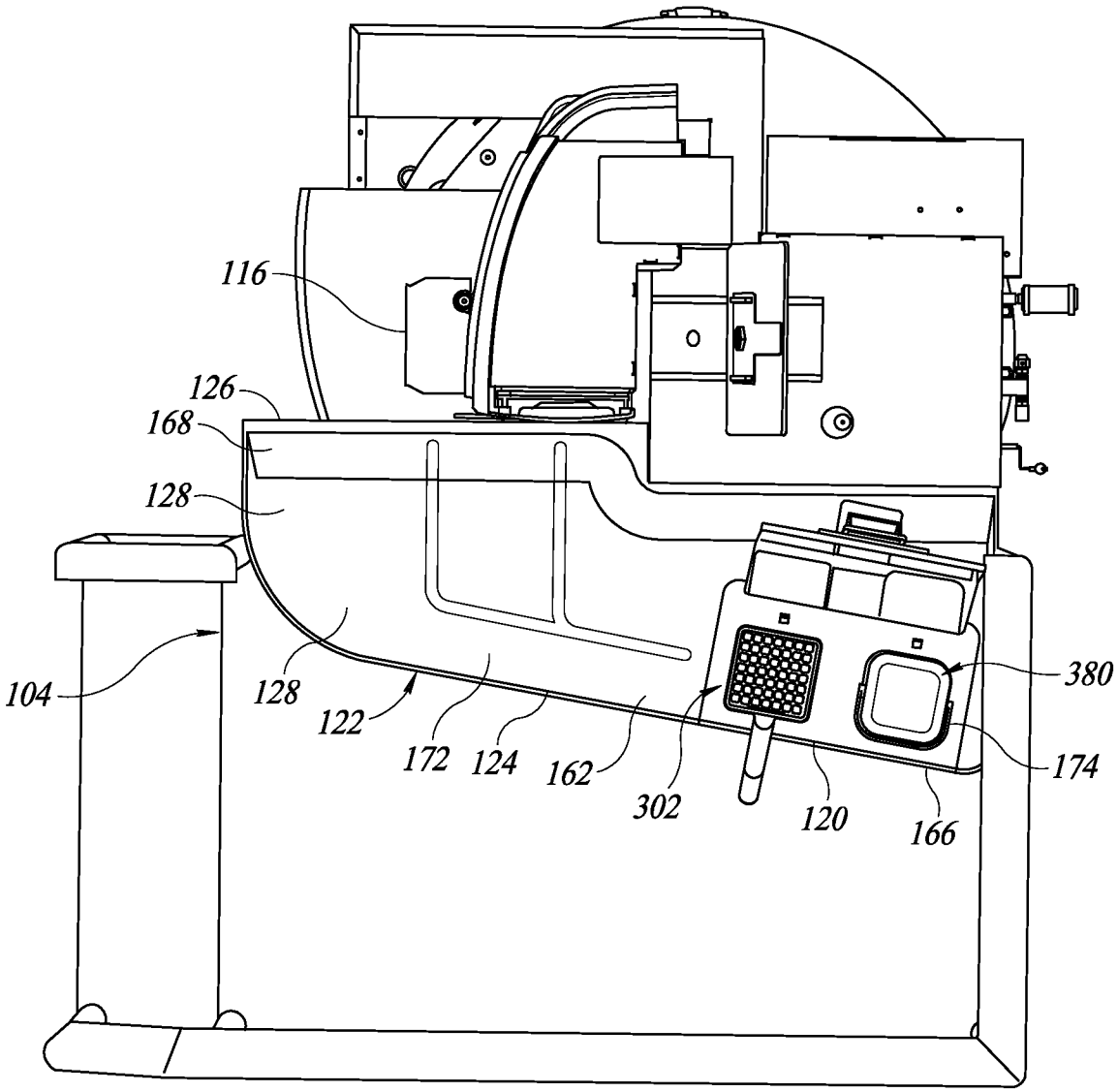


FIG. 16

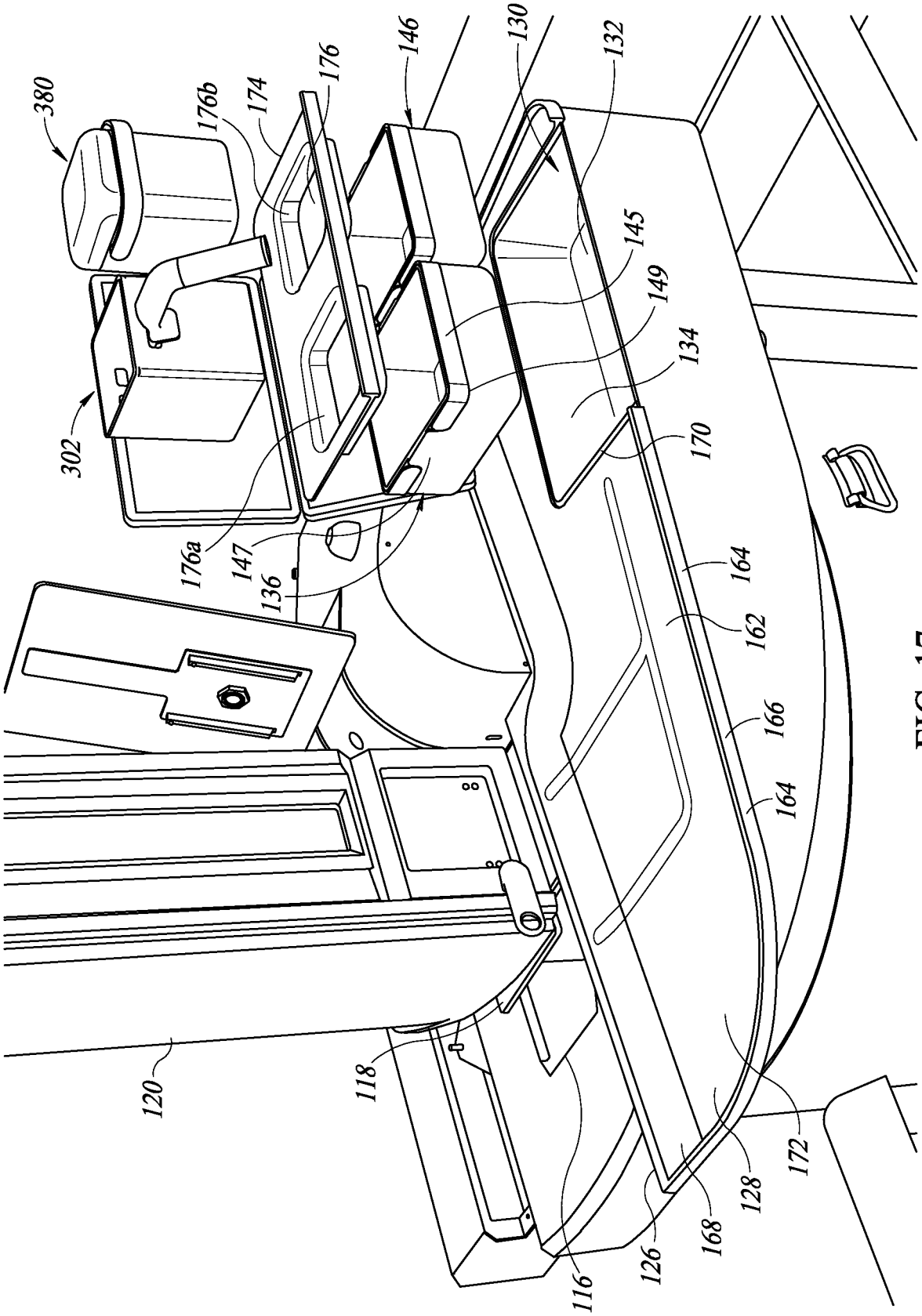

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FIG. 17

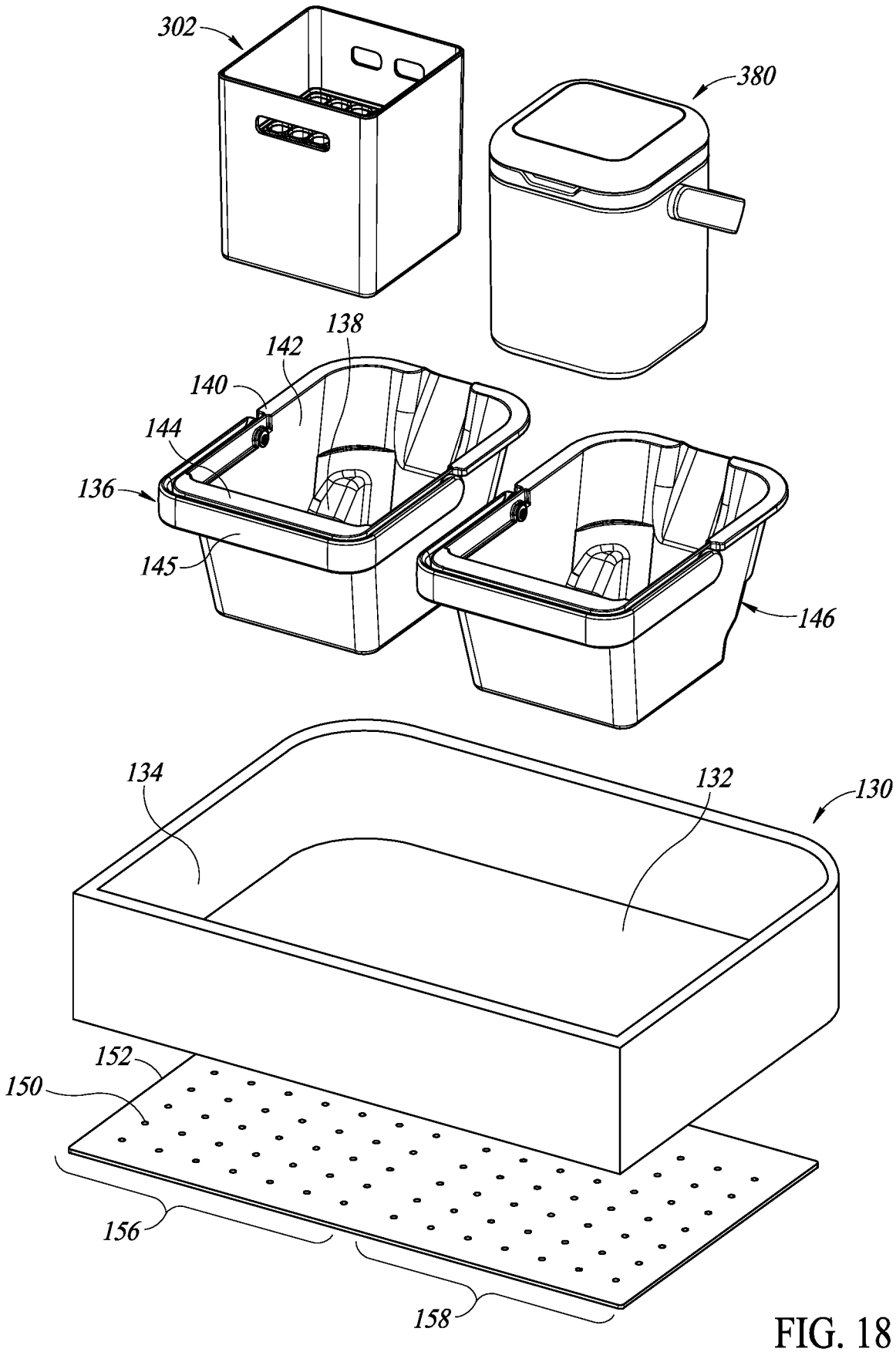


FIG. 18

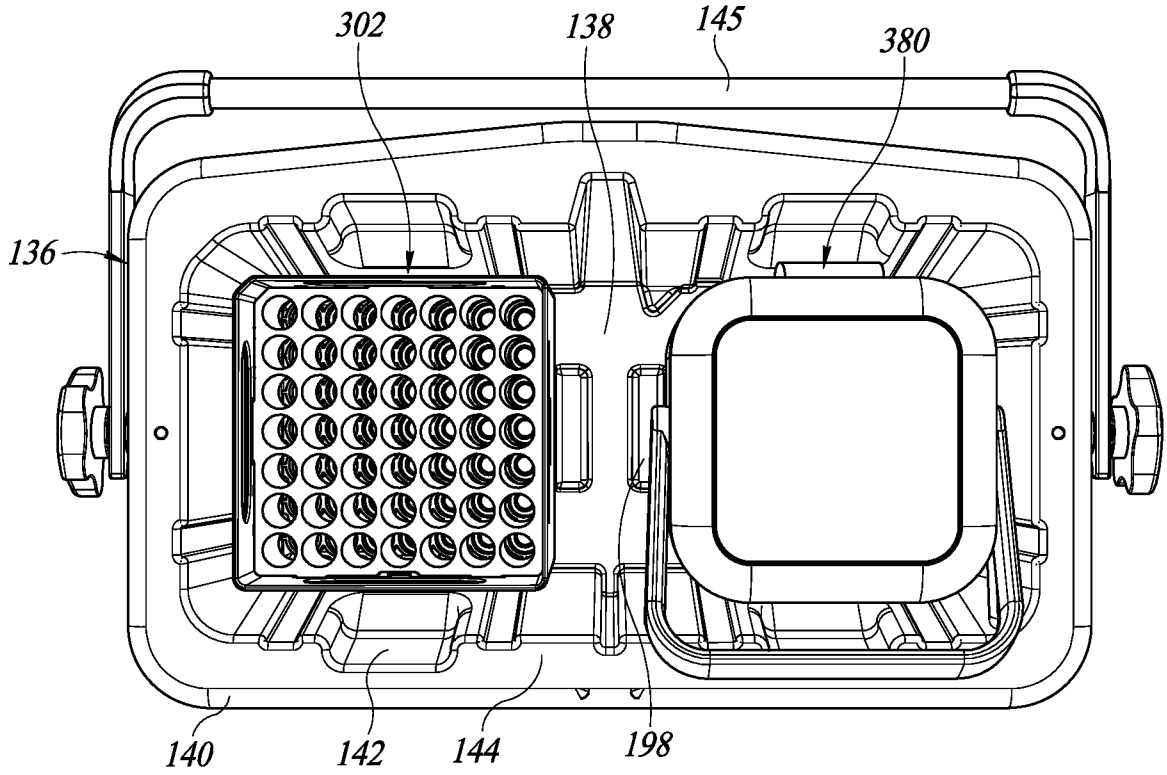

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FIG. 19

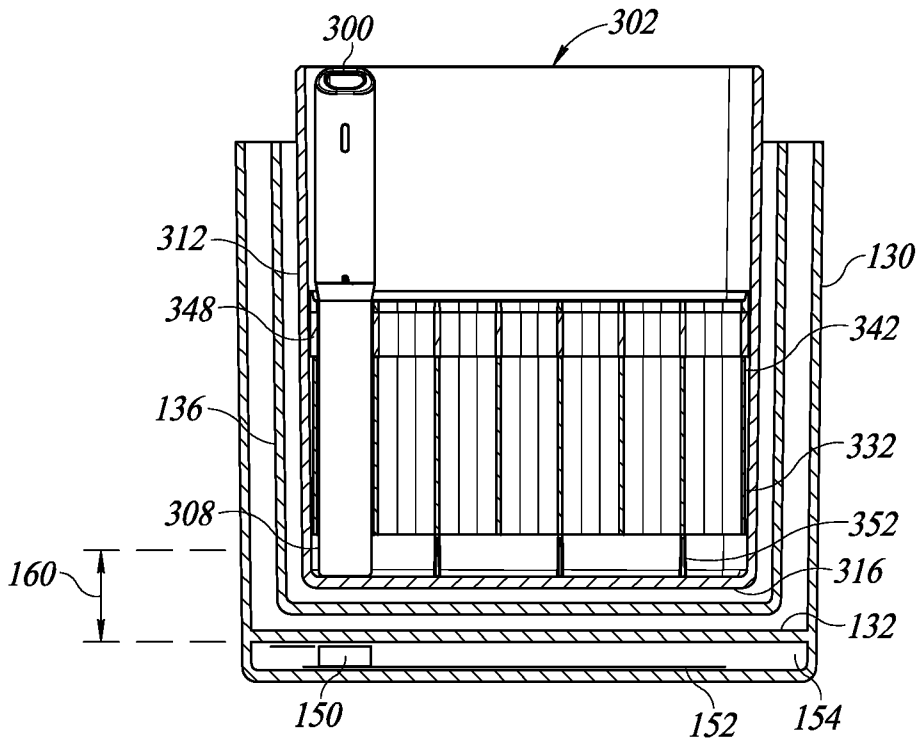

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FIG. 20

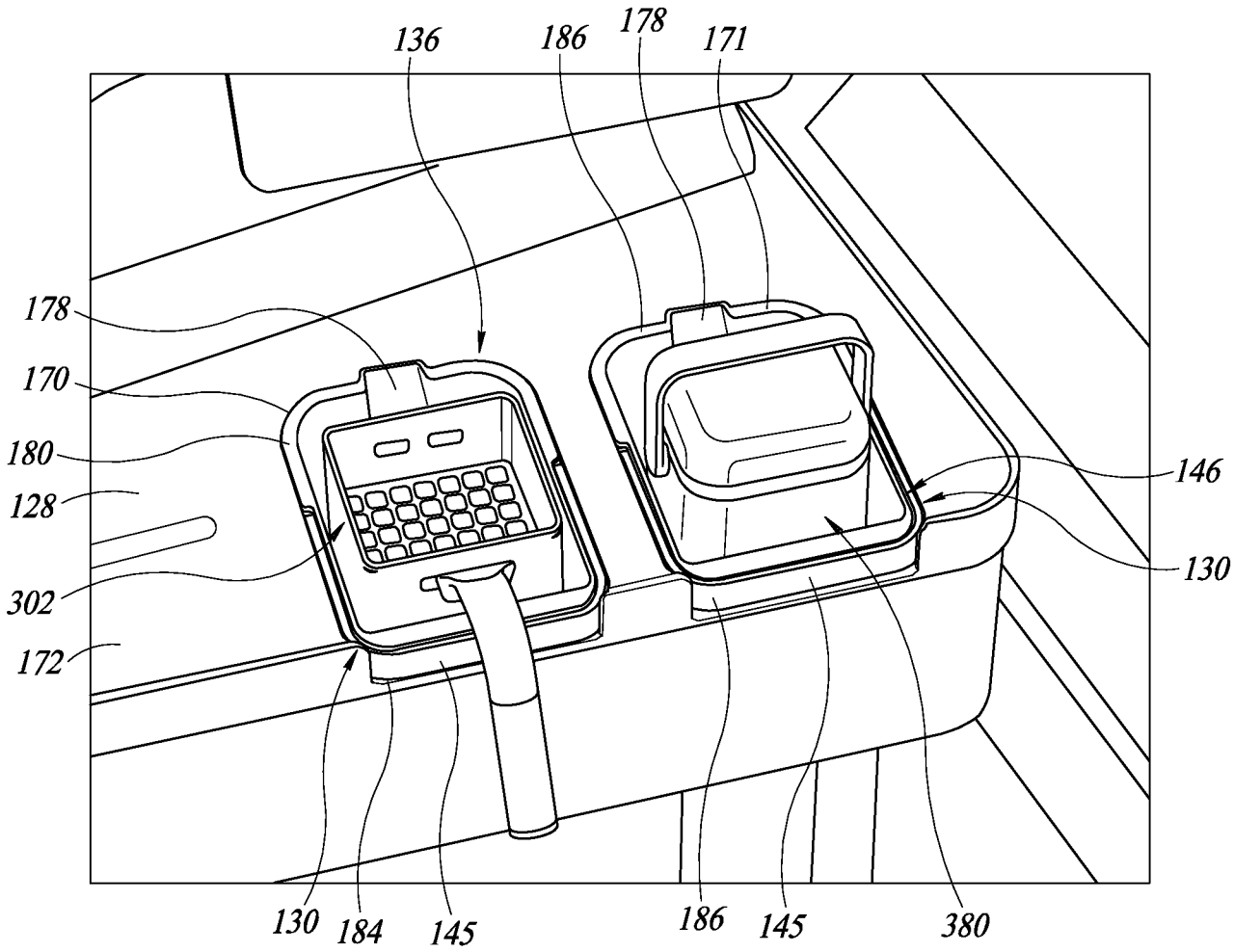

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FIG. 21

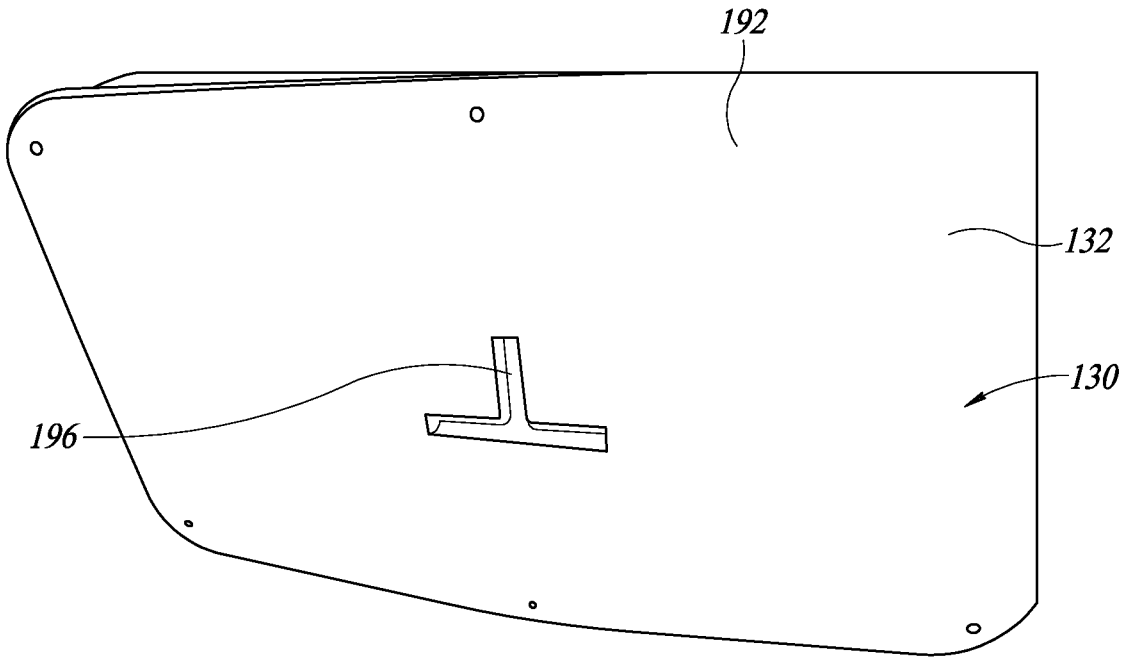


FIG. 22

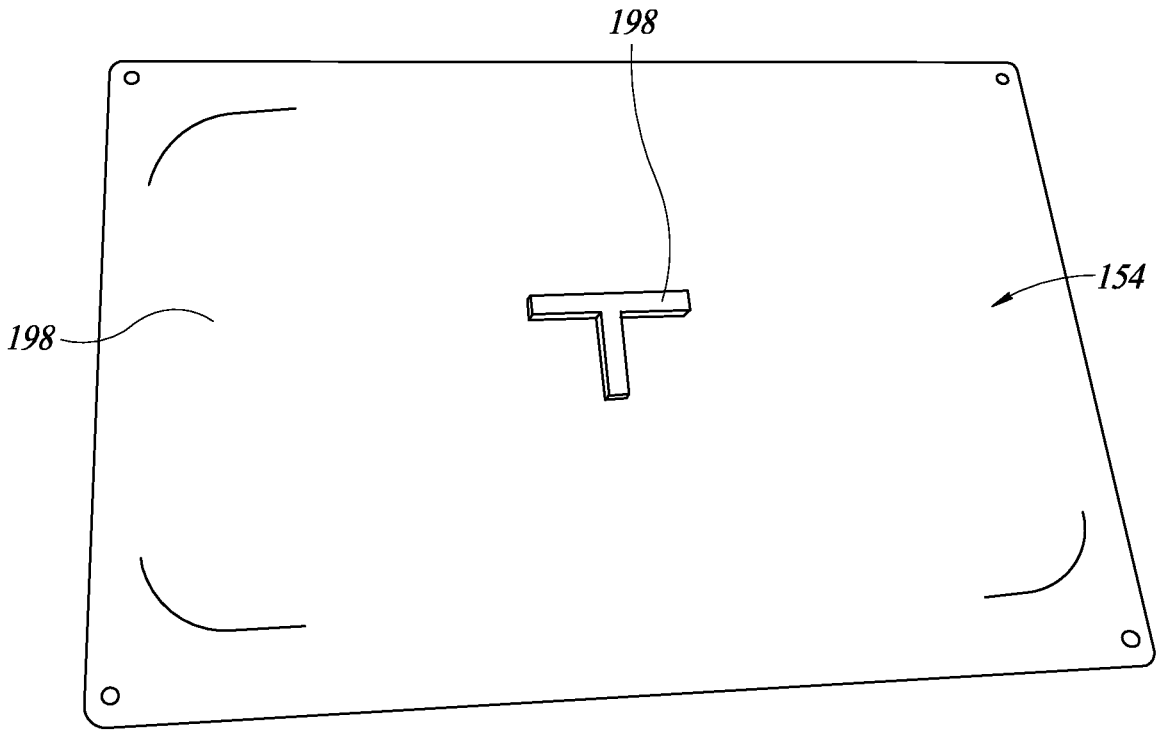


FIG. 23

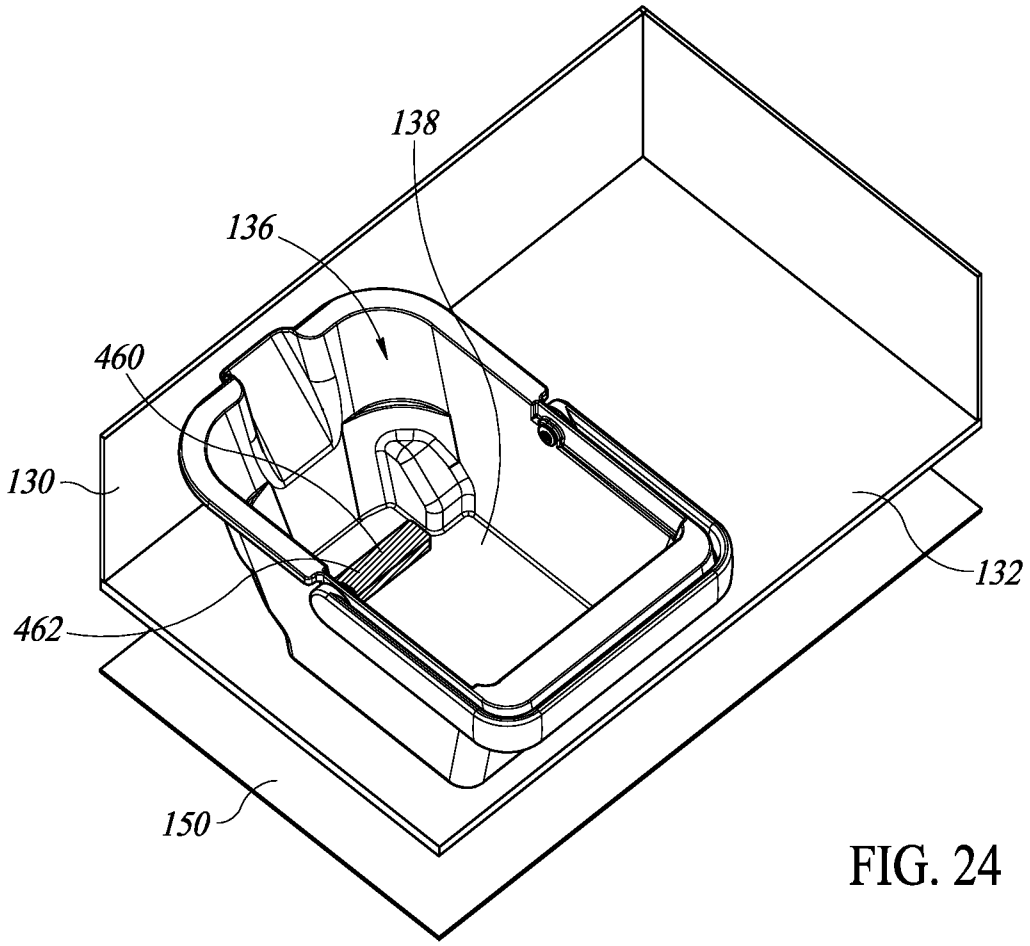


FIG. 24

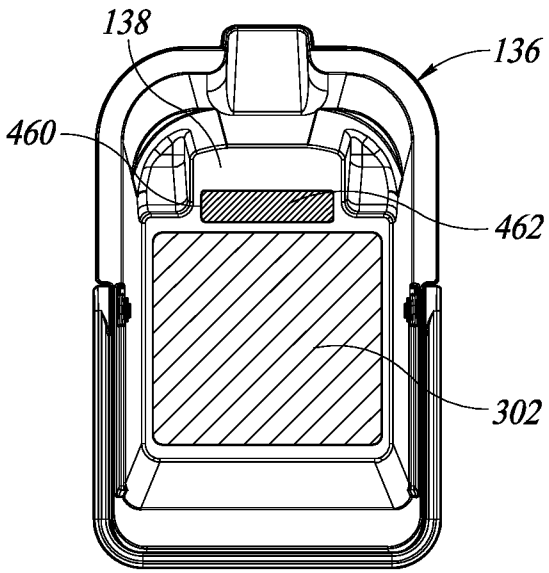


FIG. 25

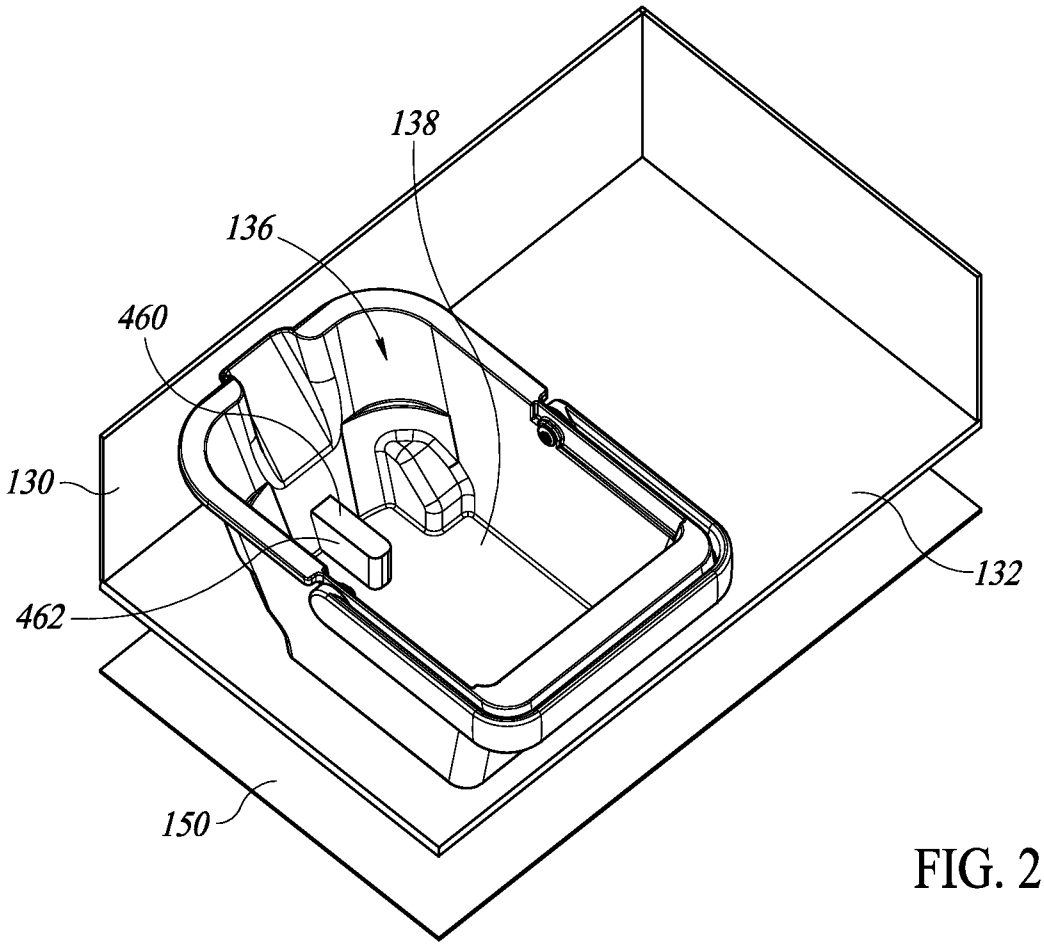


FIG. 26

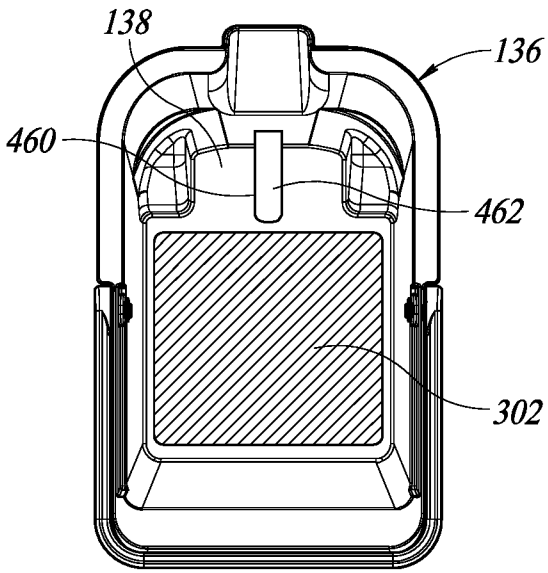


FIG. 27

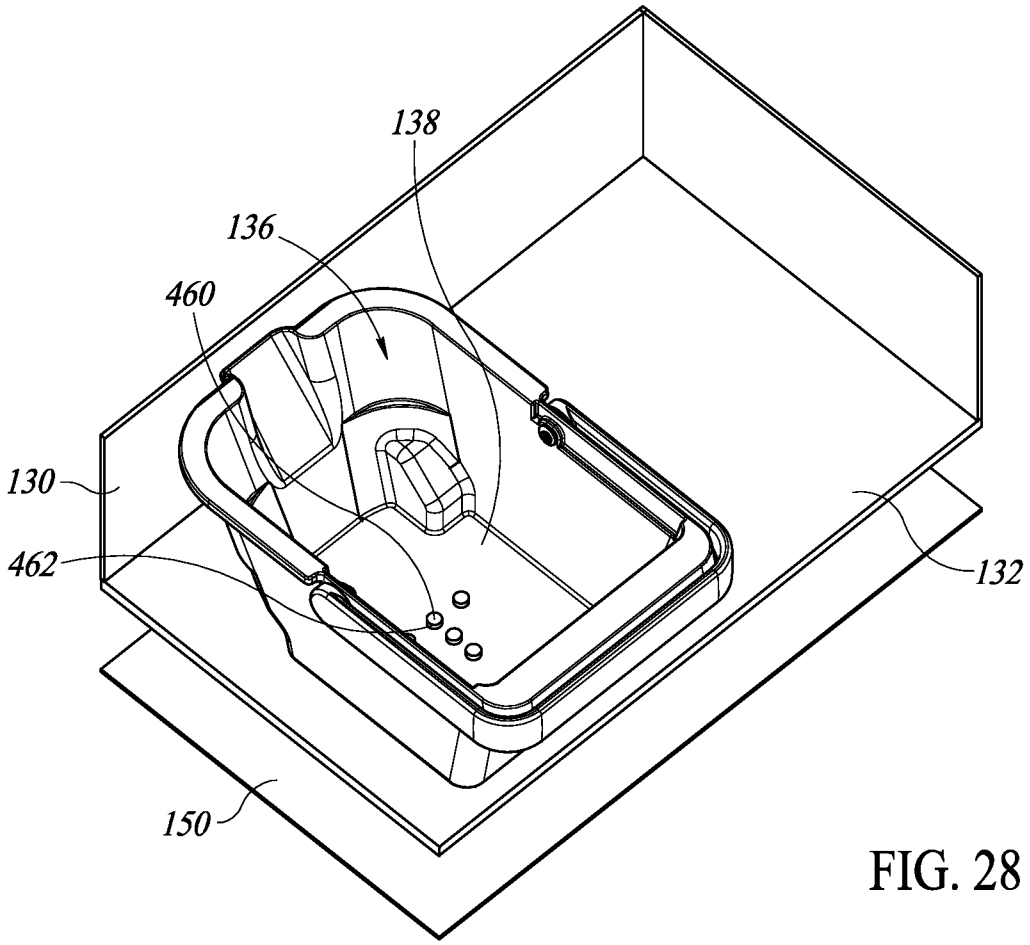


FIG. 28

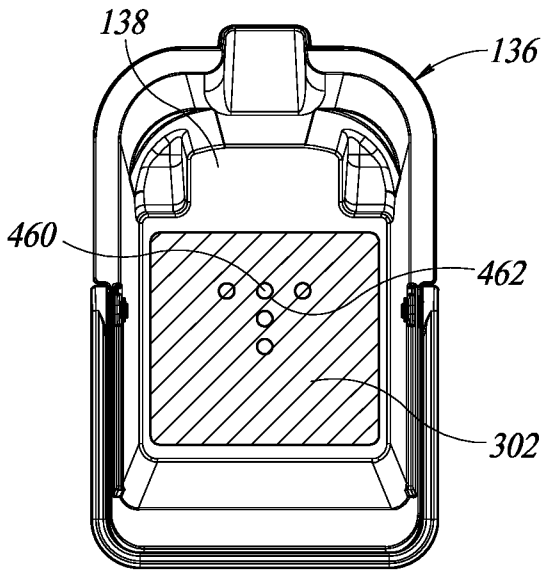


FIG. 29

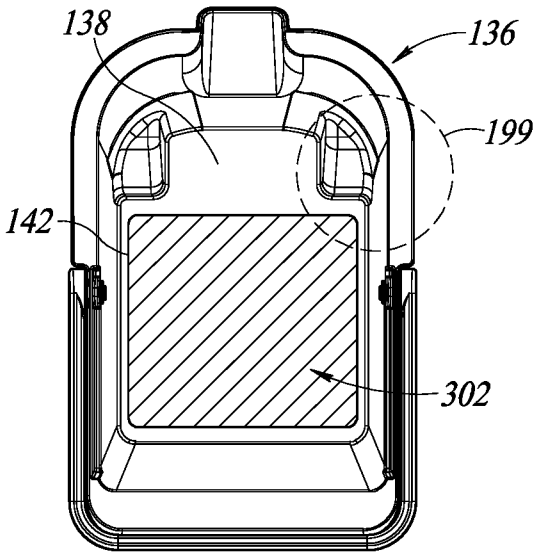


FIG. 30

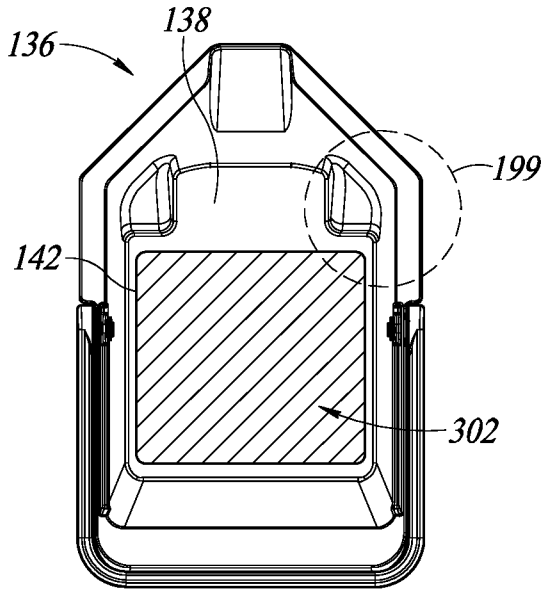


FIG. 31

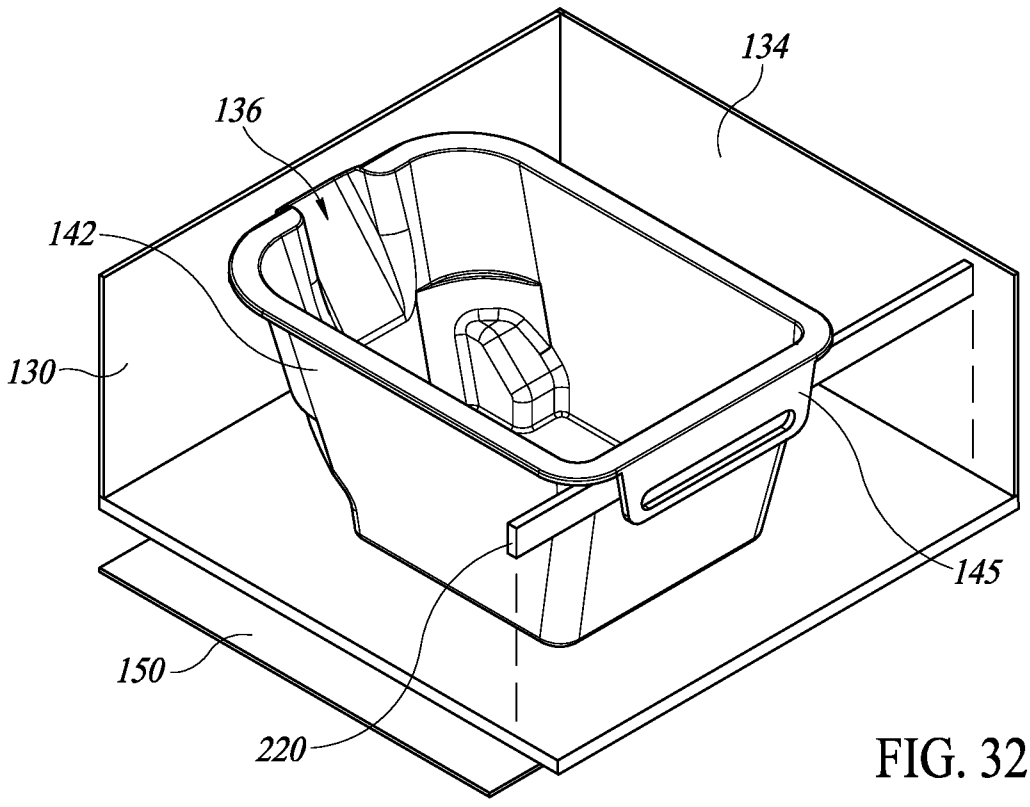


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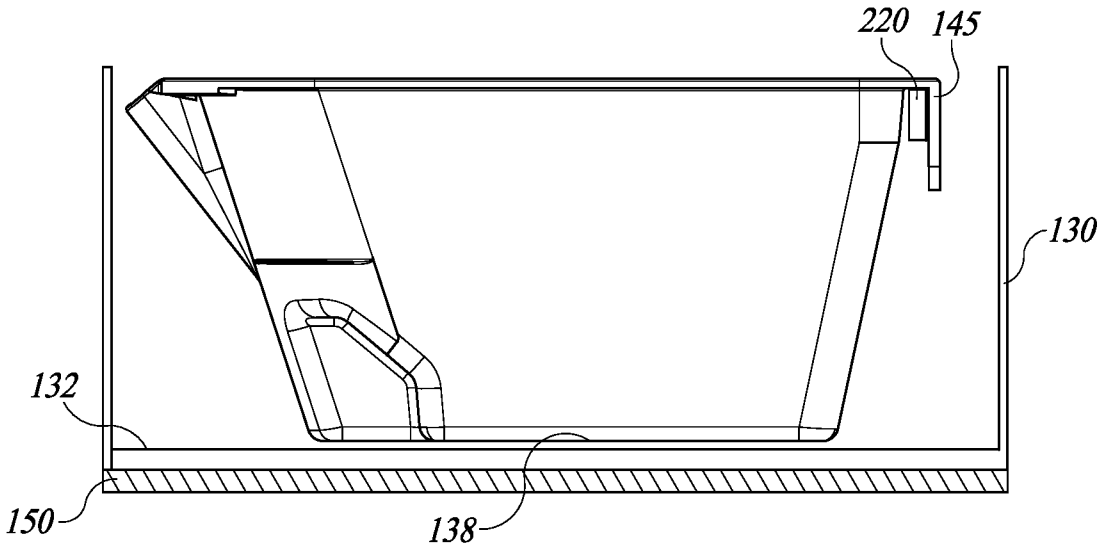


FIG. 33

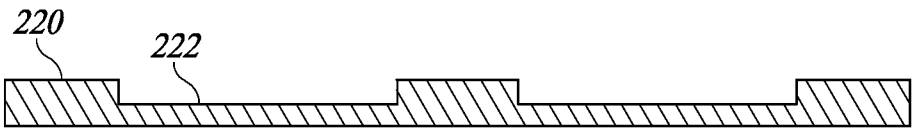


FIG. 34

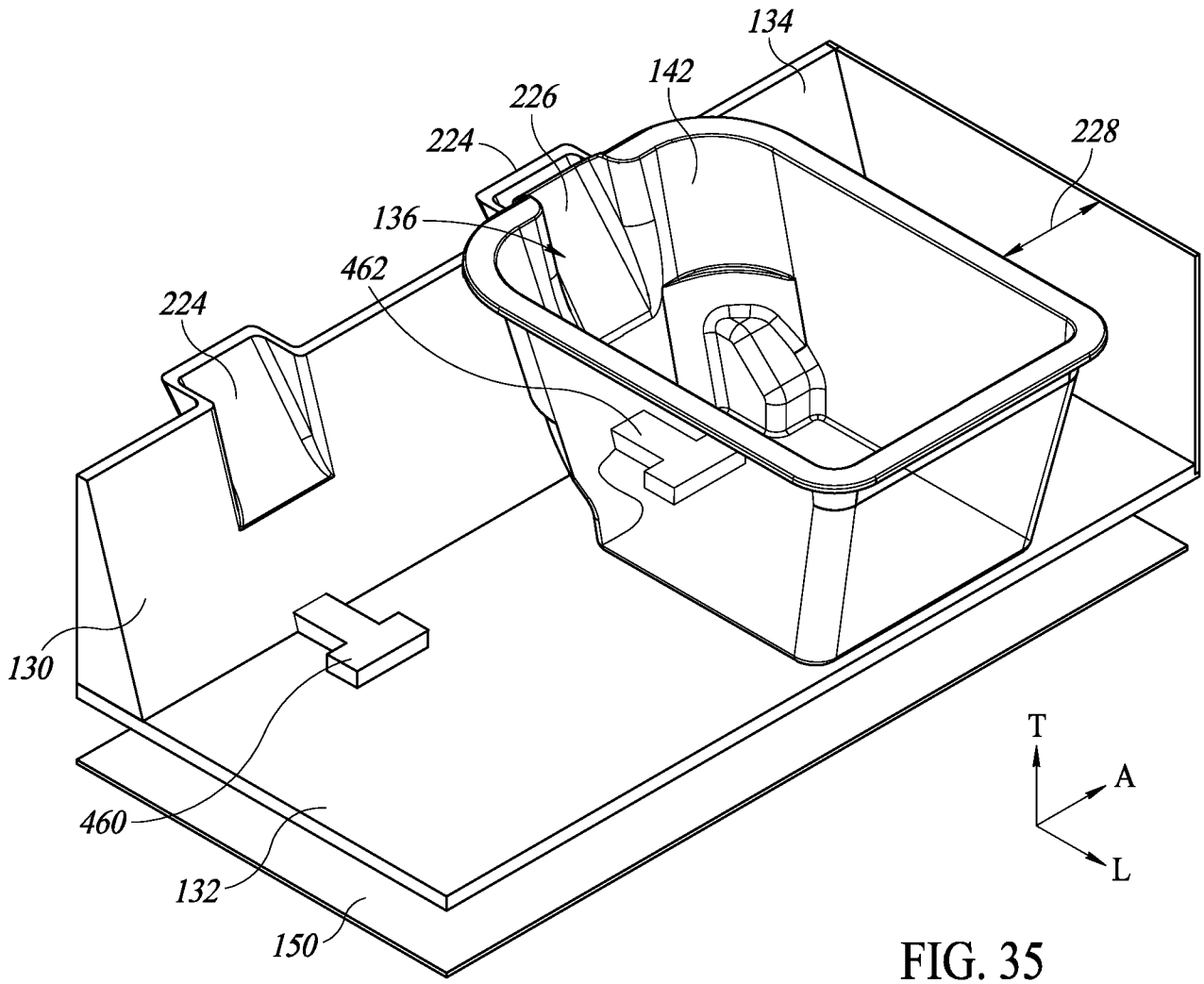

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FIG. 35

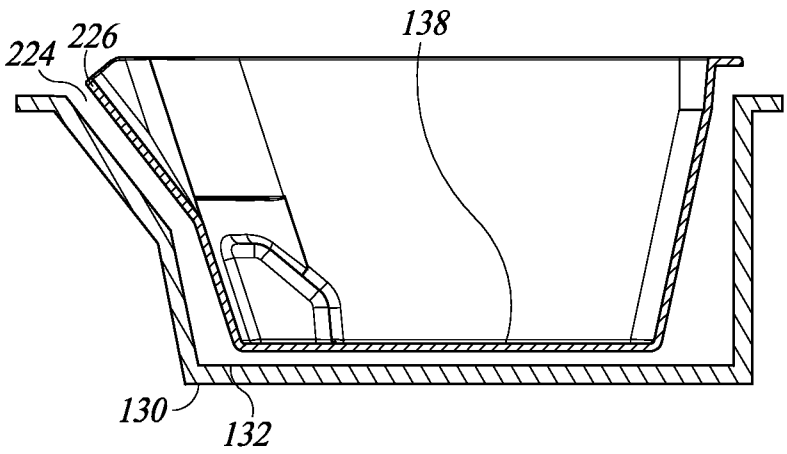

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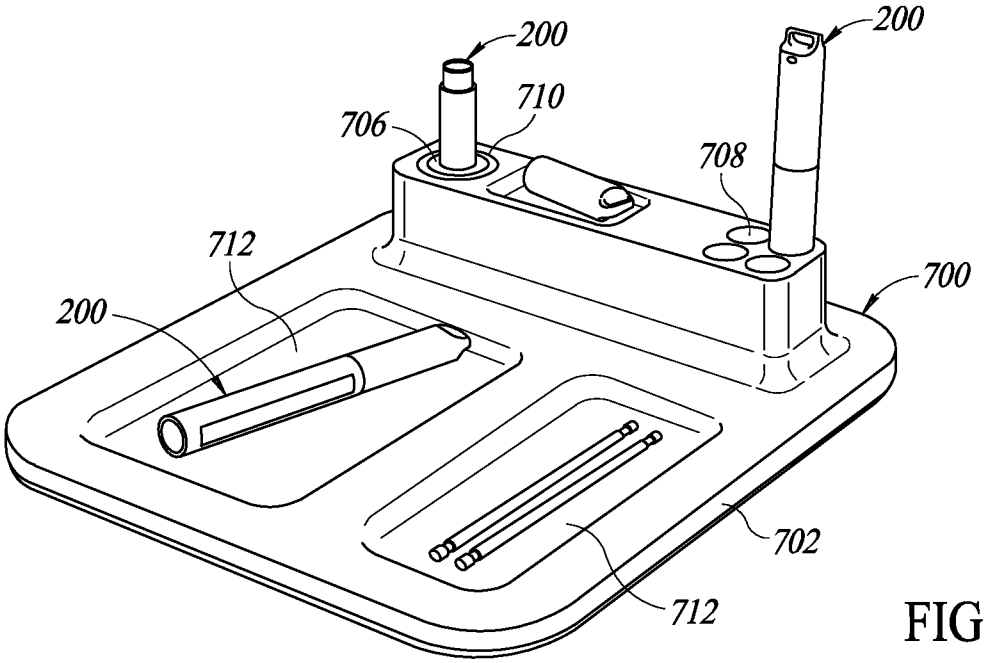

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FIG. 37

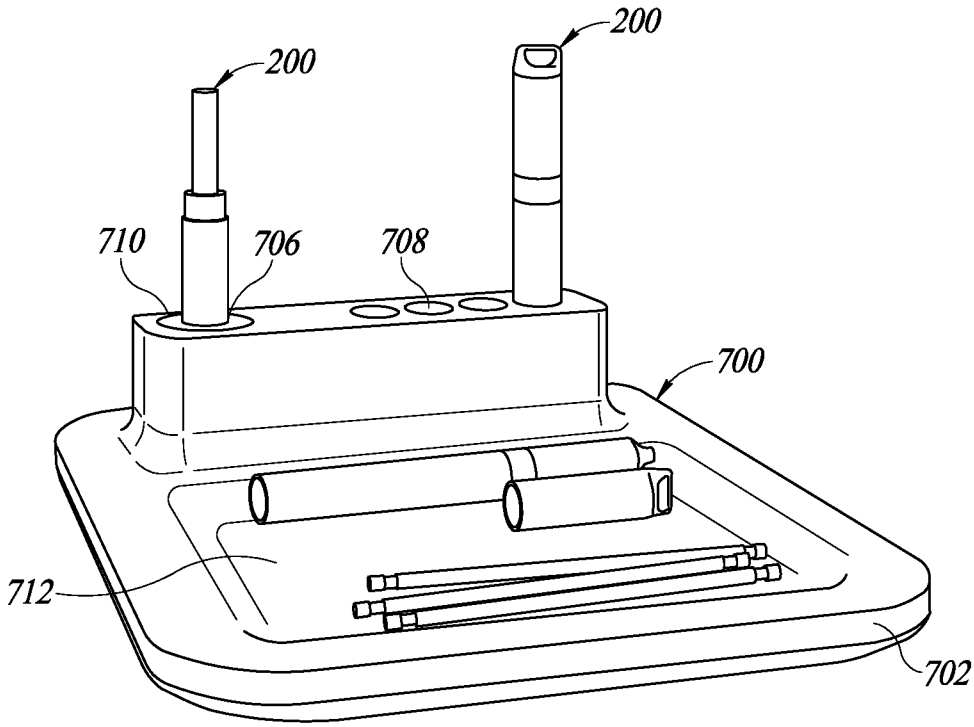

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FIG. 38

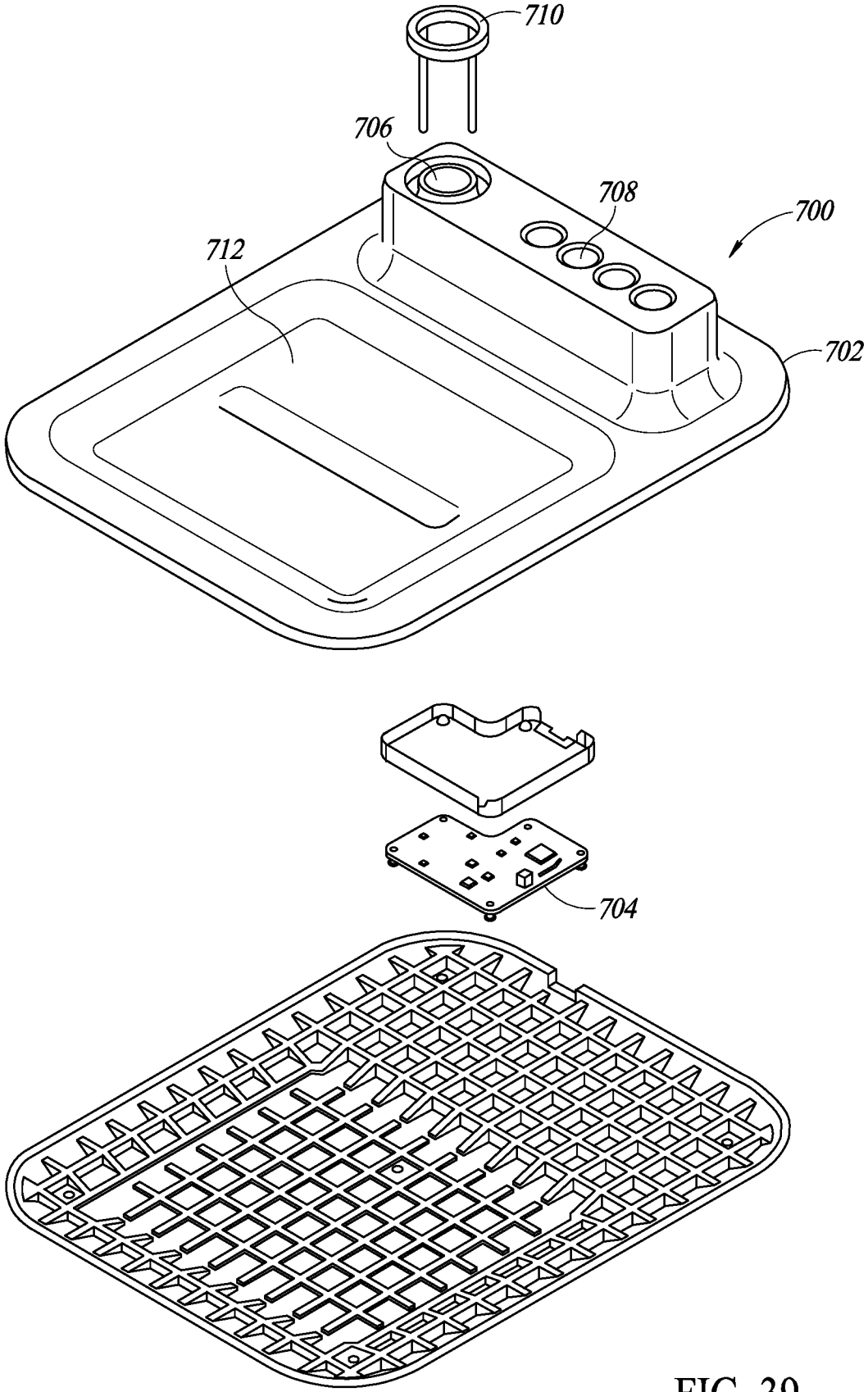


FIG. 39

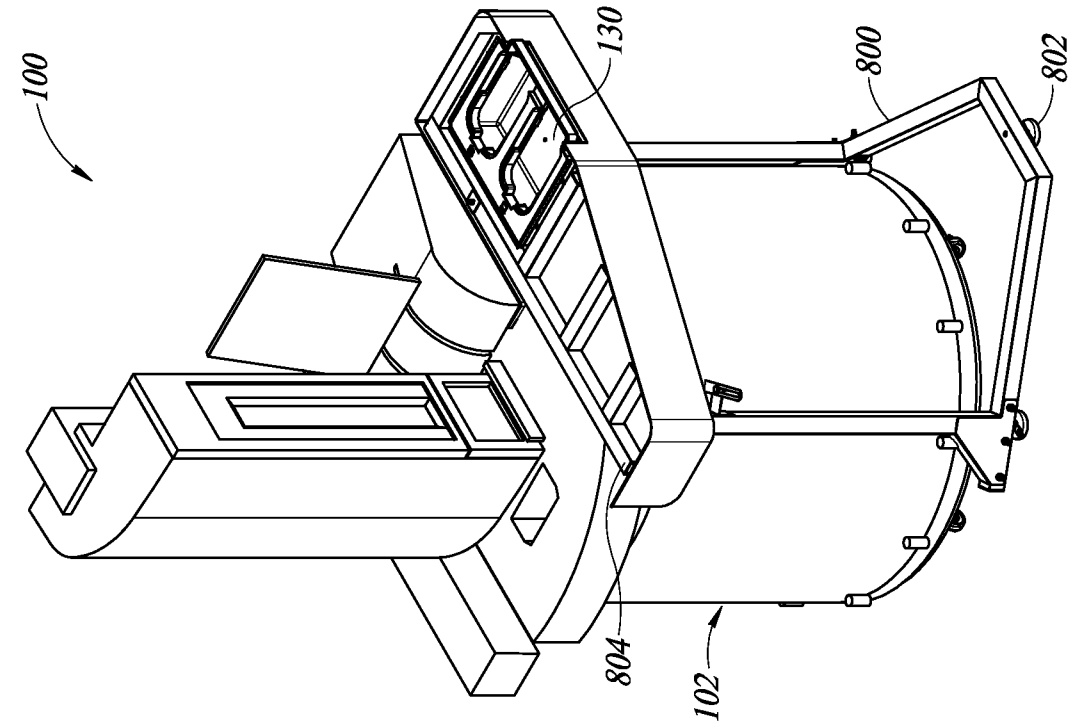


FIG. 41

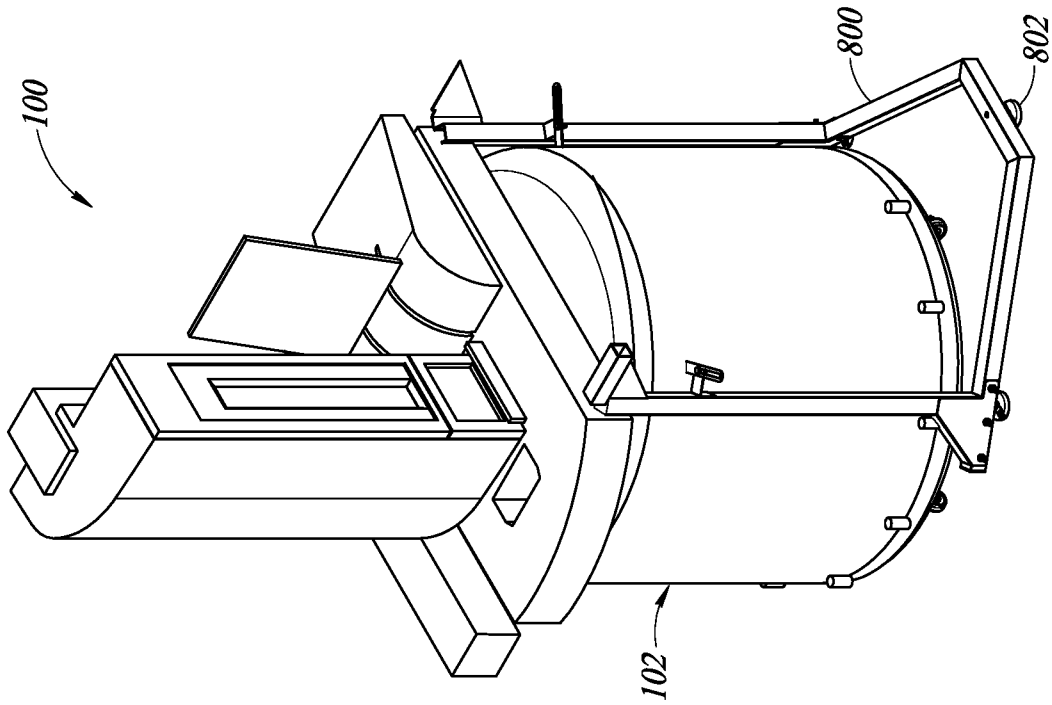


FIG. 40

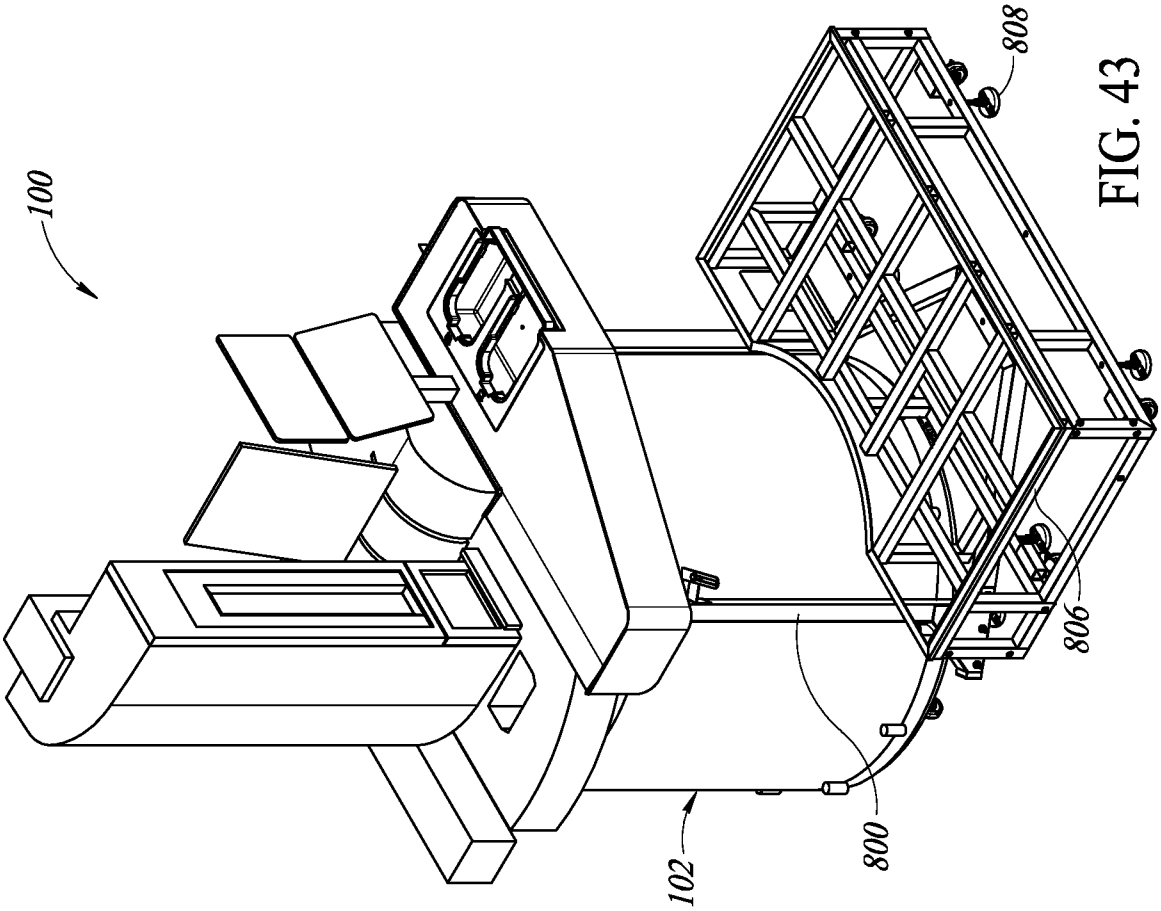


FIG. 43

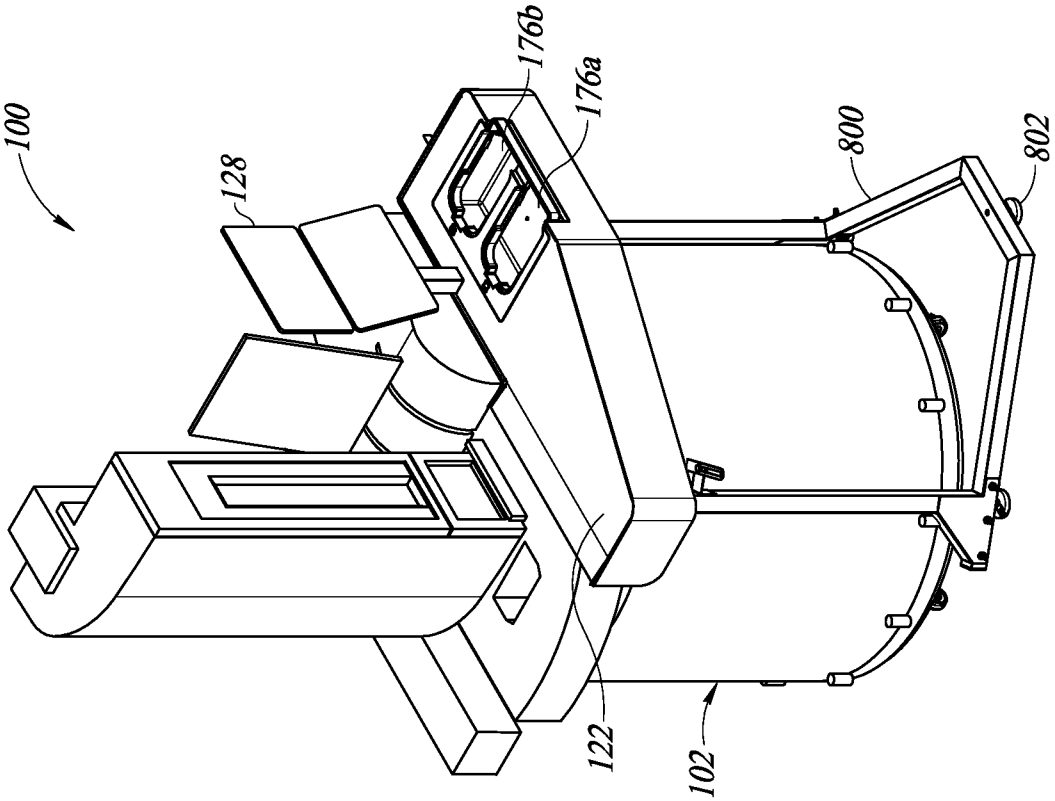


FIG. 42

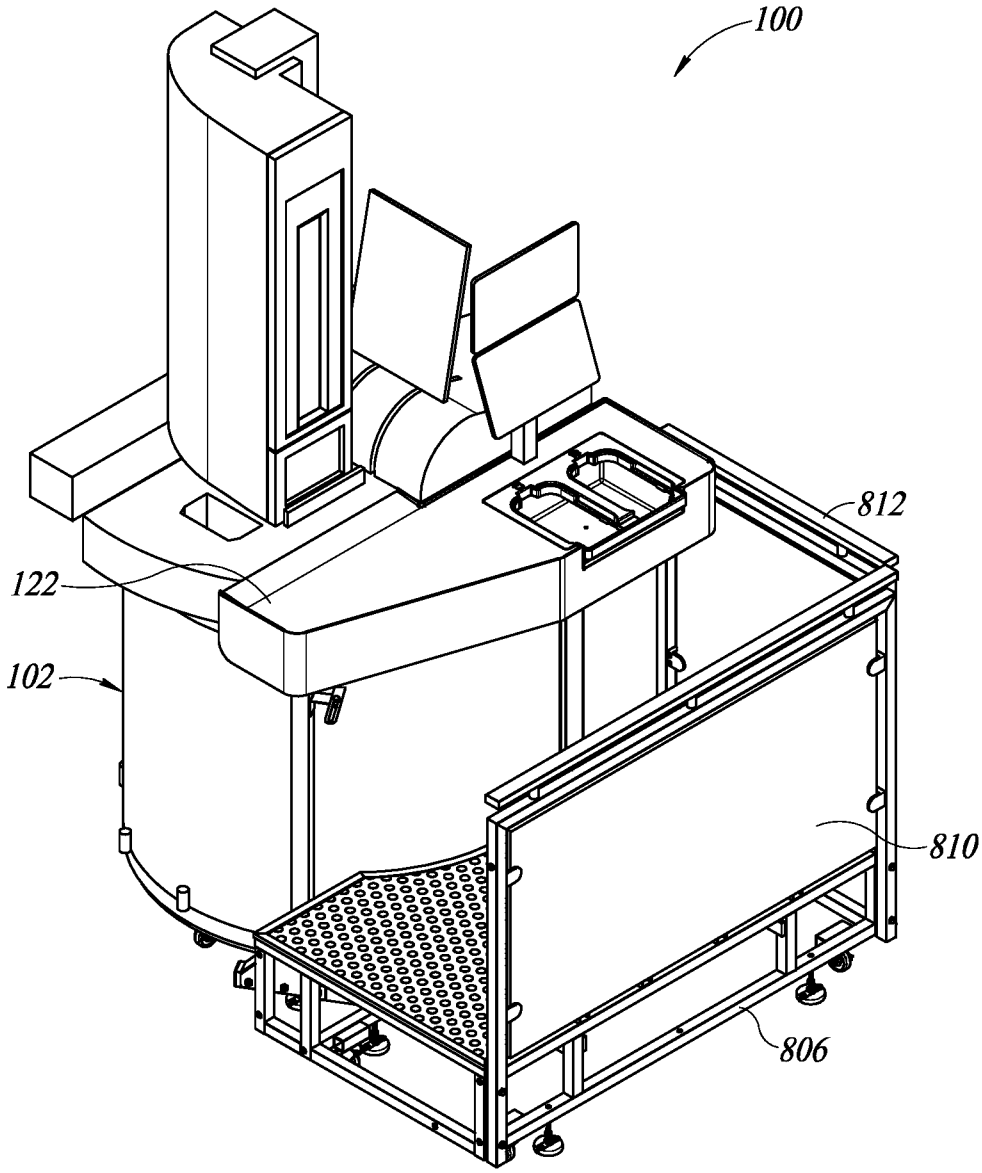


FIG. 44

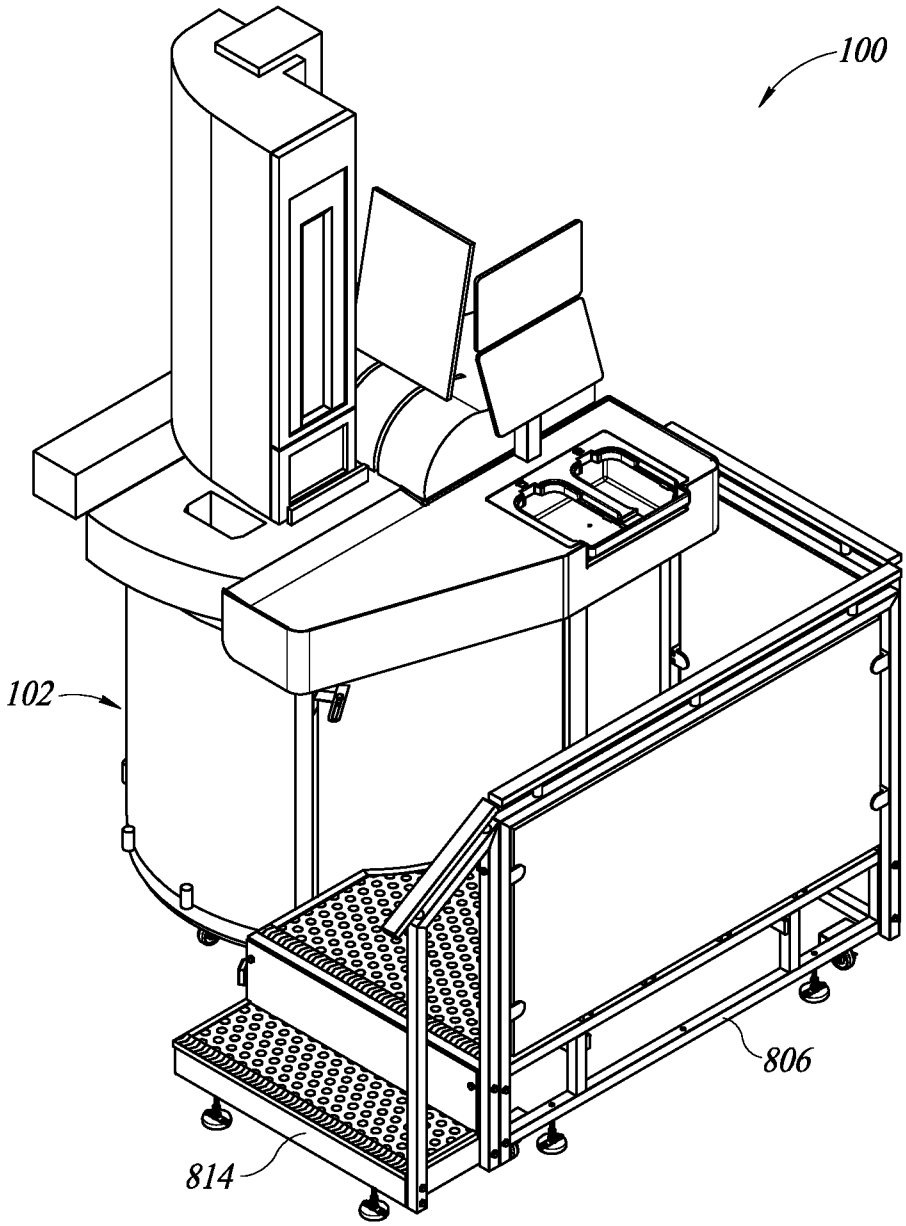


FIG. 45

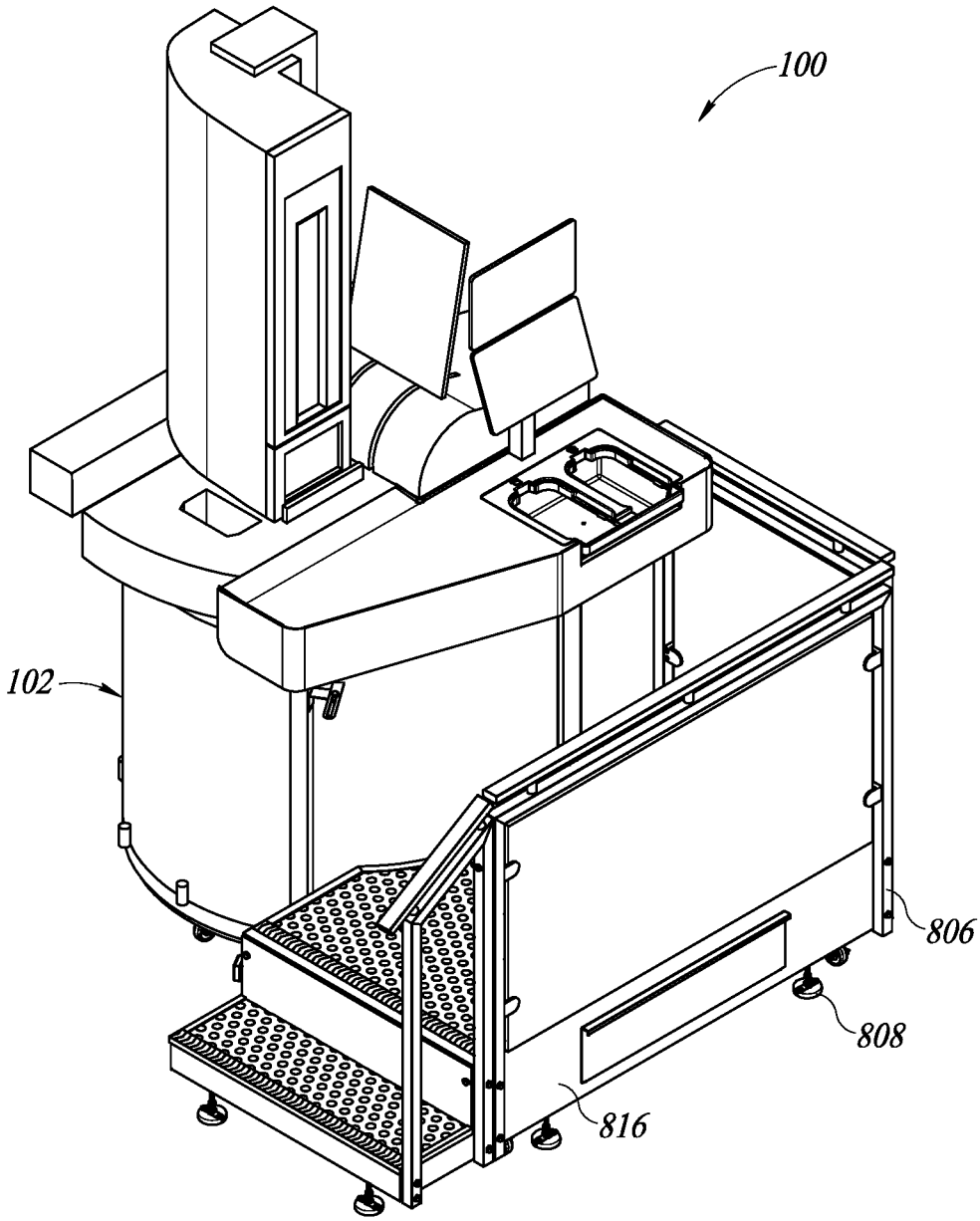


FIG. 46

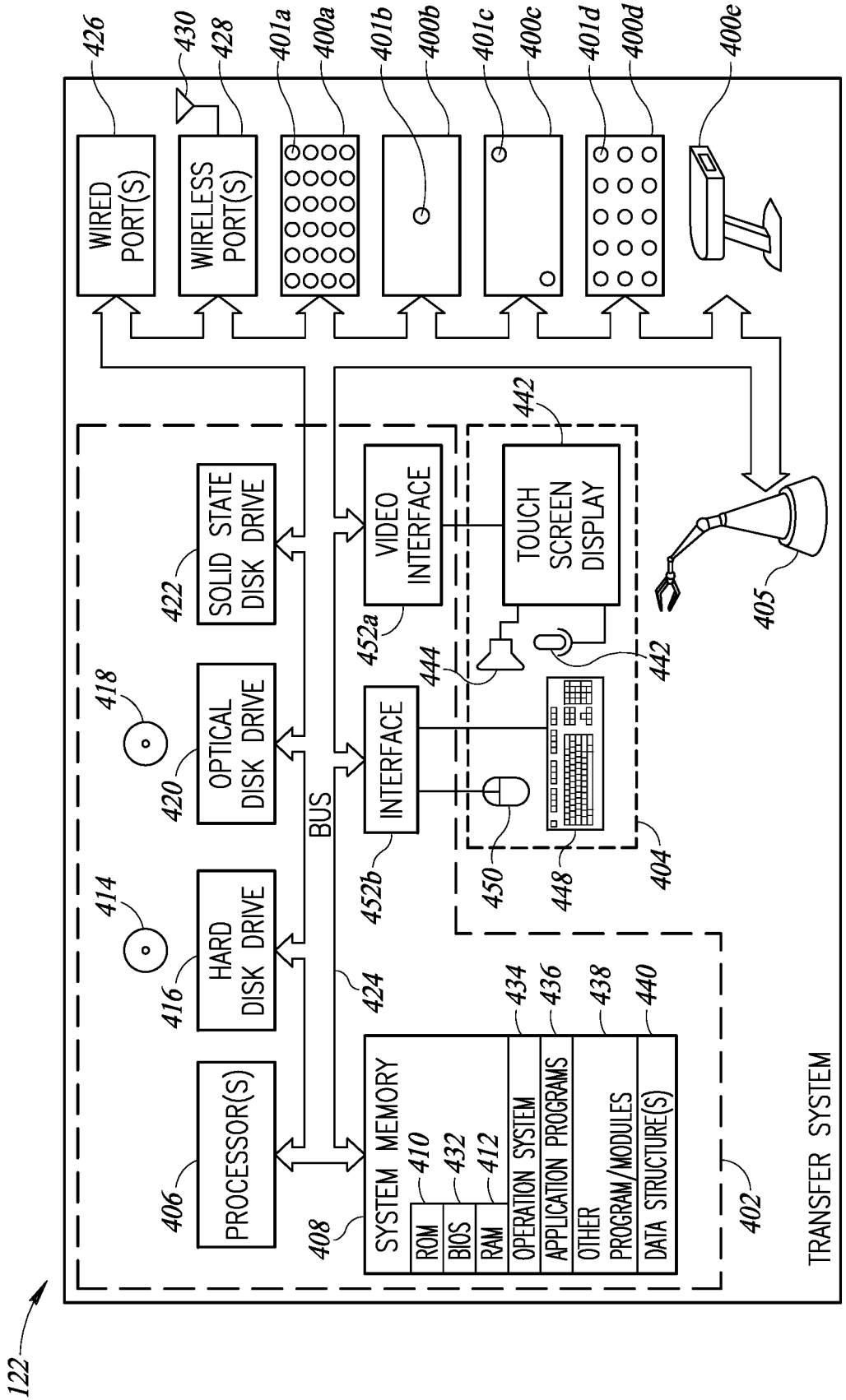

122
TRANSFER SYSTEM
402
408
SYSTEM MEMORY
410
ROM
432
BIOS
412
RAM
434
OPERATION SYSTEM
436
APPLICATION PROGRAMS
438
OTHER PROGRAM/MODULES
440
DATA STRUCTURE(S)
406
PROCESSOR(S)
414
416
HARD DISK DRIVE
418
420
OPTICAL DISK DRIVE
422
SOLID STATE DISK DRIVE
424
BUS
452b
INTERFACE
452a
VIDEO INTERFACE
442
TOUCH SCREEN DISPLAY
444
450
448
404
405
426
WIRED PORT(S)
430
428
WIRELESS PORT(S)
401a
400a
401b
400b
401c
400c
401d
400d
400e

FIG. 47

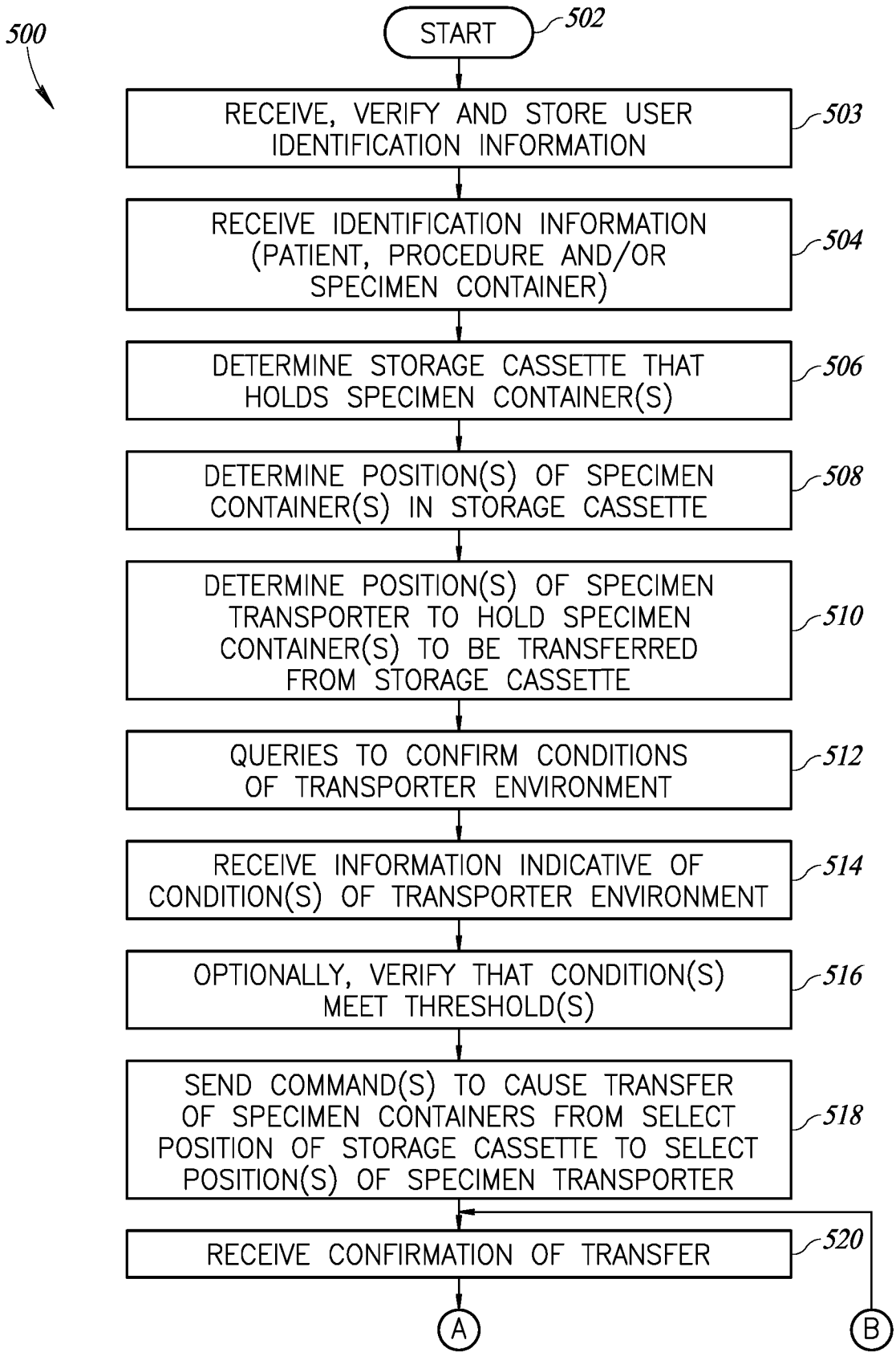

500
START
502
RECEIVE, VERIFY AND STORE USER IDENTIFICATION INFORMATION
503
RECEIVE IDENTIFICATION INFORMATION (PATIENT, PROCEDURE AND/OR SPECIMEN CONTAINER)
504
DETERMINE STORAGE CASSETTE THAT HOLDS SPECIMEN CONTAINER(S)
506
DETERMINE POSITION(S) OF SPECIMEN CONTAINER(S) IN STORAGE CASSETTE
508
DETERMINE POSITION(S) OF SPECIMEN TRANSPORTER TO HOLD SPECIMEN CONTAINER(S) TO BE TRANSFERRED FROM STORAGE CASSETTE
510
QUERIES TO CONFIRM CONDITIONS OF TRANSPORTER ENVIRONMENT
512
RECEIVE INFORMATION INDICATIVE OF CONDITION(S) OF TRANSPORTER ENVIRONMENT
514
OPTIONALLY, VERIFY THAT CONDITION(S) MEET THRESHOLD(S)
516
SEND COMMAND(S) TO CAUSE TRANSFER OF SPECIMEN CONTAINERS FROM SELECT POSITION OF STORAGE CASSETTE TO SELECT POSITION(S) OF SPECIMEN TRANSPORTER
518
RECEIVE CONFIRMATION OF TRANSFER
520
A
B

FIG. 48

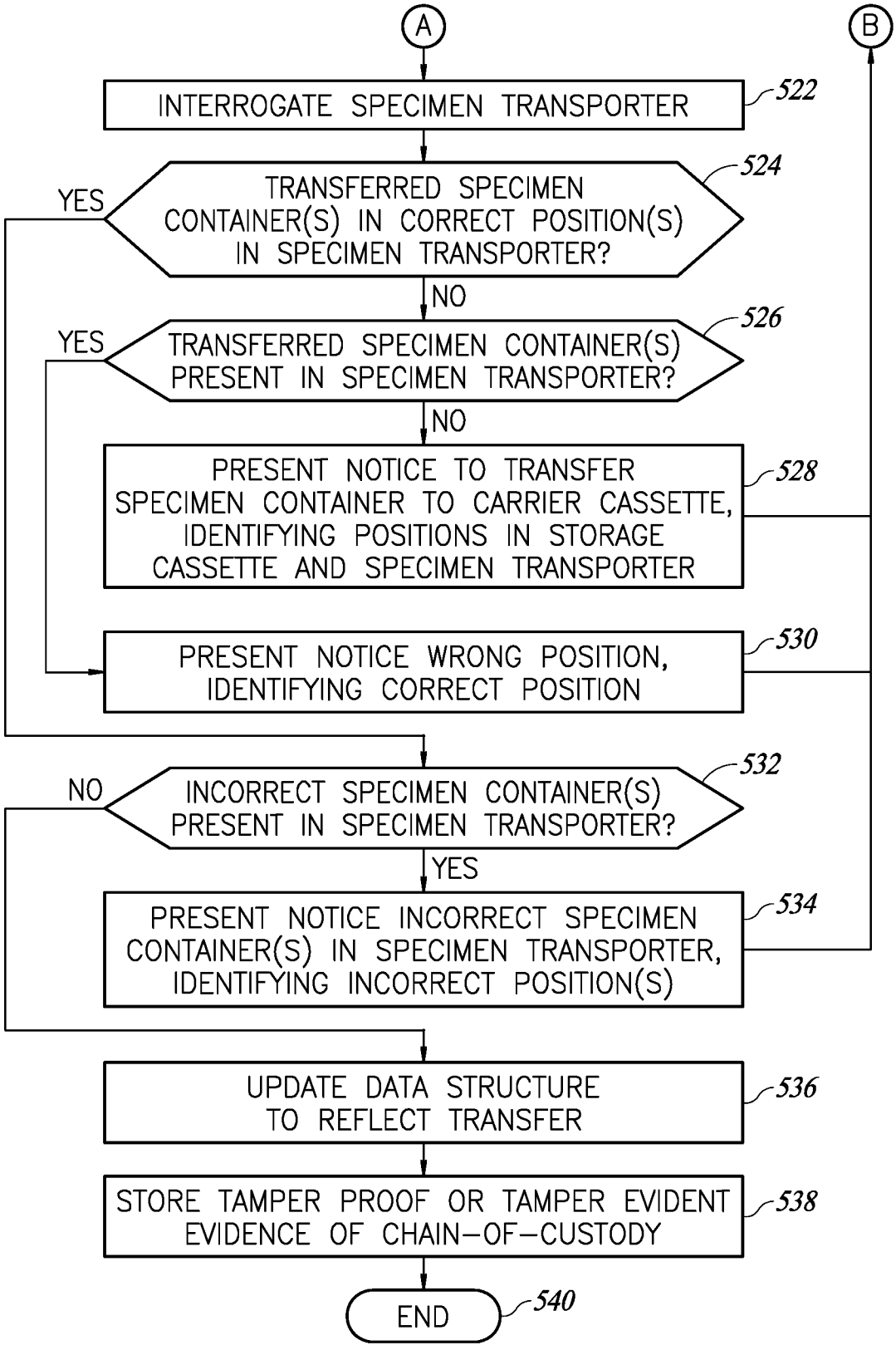

A
B
INTERROGATE SPECIMEN TRANSPORTER
522
TRANSFERRED SPECIMEN CONTAINER(S) IN CORRECT POSITION(S) IN SPECIMEN TRANSPORTER?
524
YES
NO
TRANSFERRED SPECIMEN CONTAINER(S) PRESENT IN SPECIMEN TRANSPORTER?
526
YES
NO
PRESENT NOTICE TO TRANSFER SPECIMEN CONTAINER TO CARRIER CASSETTE, IDENTIFYING POSITIONS IN STORAGE CASSETTE AND SPECIMEN TRANSPORTER
528
PRESENT NOTICE WRONG POSITION, IDENTIFYING CORRECT POSITION
530
INCORRECT SPECIMEN CONTAINER(S) PRESENT IN SPECIMEN TRANSPORTER?
532
NO
YES
PRESENT NOTICE INCORRECT SPECIMEN CONTAINER(S) IN SPECIMEN TRANSPORTER, IDENTIFYING INCORRECT POSITION(S)
534
UPDATE DATA STRUCTURE TO REFLECT TRANSFER
536
STORE TAMPER PROOF OR TAMPER EVIDENT EVIDENCE OF CHAIN-OF-CUSTODY
538
END
540

FIG. 49

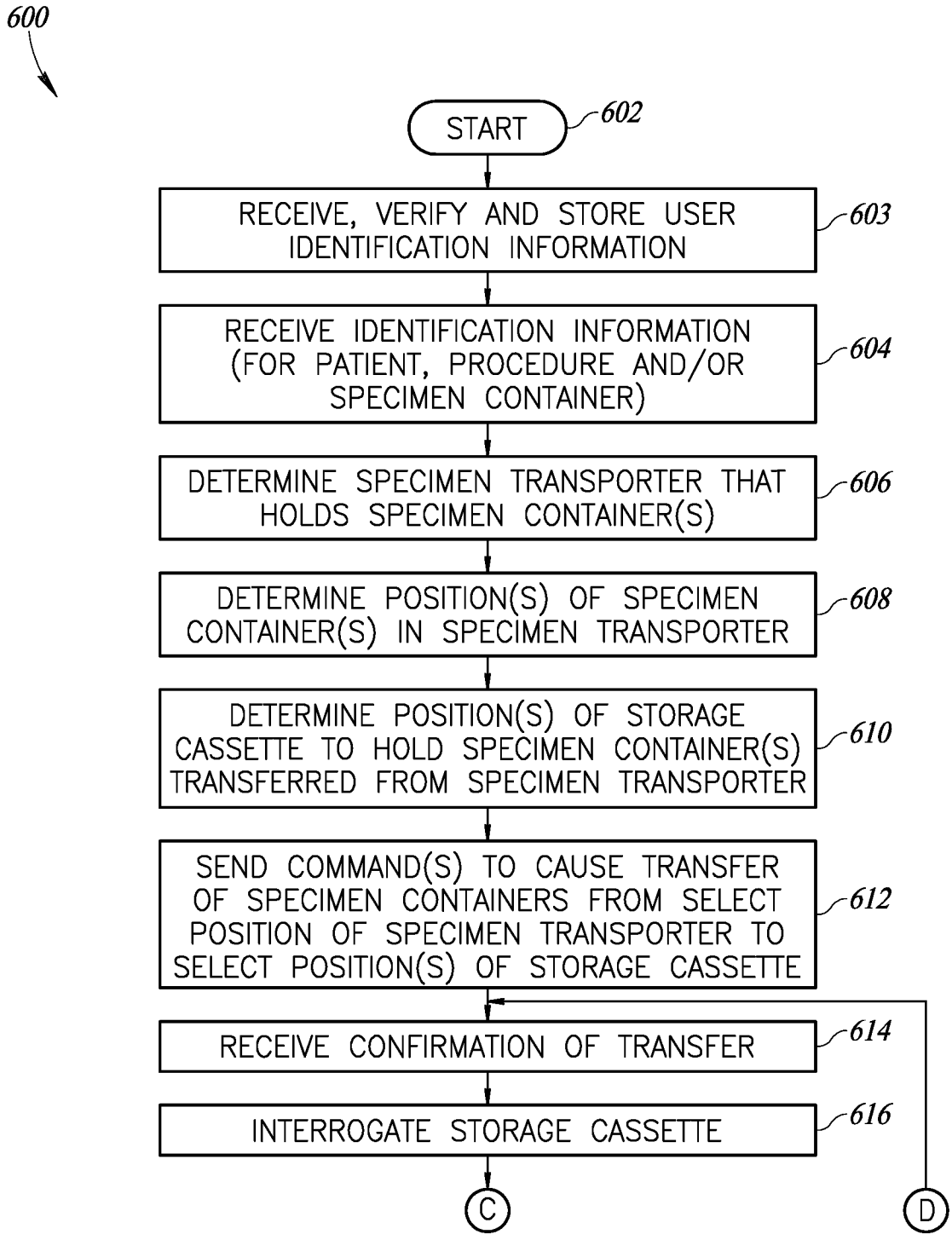

600
START
602
RECEIVE, VERIFY AND STORE USER IDENTIFICATION INFORMATION
603
RECEIVE IDENTIFICATION INFORMATION (FOR PATIENT, PROCEDURE AND/OR SPECIMEN CONTAINER)
604
DETERMINE SPECIMEN TRANSPORTER THAT HOLDS SPECIMEN CONTAINER(S)
606
DETERMINE POSITION(S) OF SPECIMEN CONTAINER(S) IN SPECIMEN TRANSPORTER
608
DETERMINE POSITION(S) OF STORAGE CASSETTE TO HOLD SPECIMEN CONTAINER(S) TRANSFERRED FROM SPECIMEN TRANSPORTER
610
SEND COMMAND(S) TO CAUSE TRANSFER OF SPECIMEN CONTAINERS FROM SELECT POSITION OF SPECIMEN TRANSPORTER TO SELECT POSITION(S) OF STORAGE CASSETTE
612
RECEIVE CONFIRMATION OF TRANSFER
614
INTERROGATE STORAGE CASSETTE
616
C
D

FIG. 50

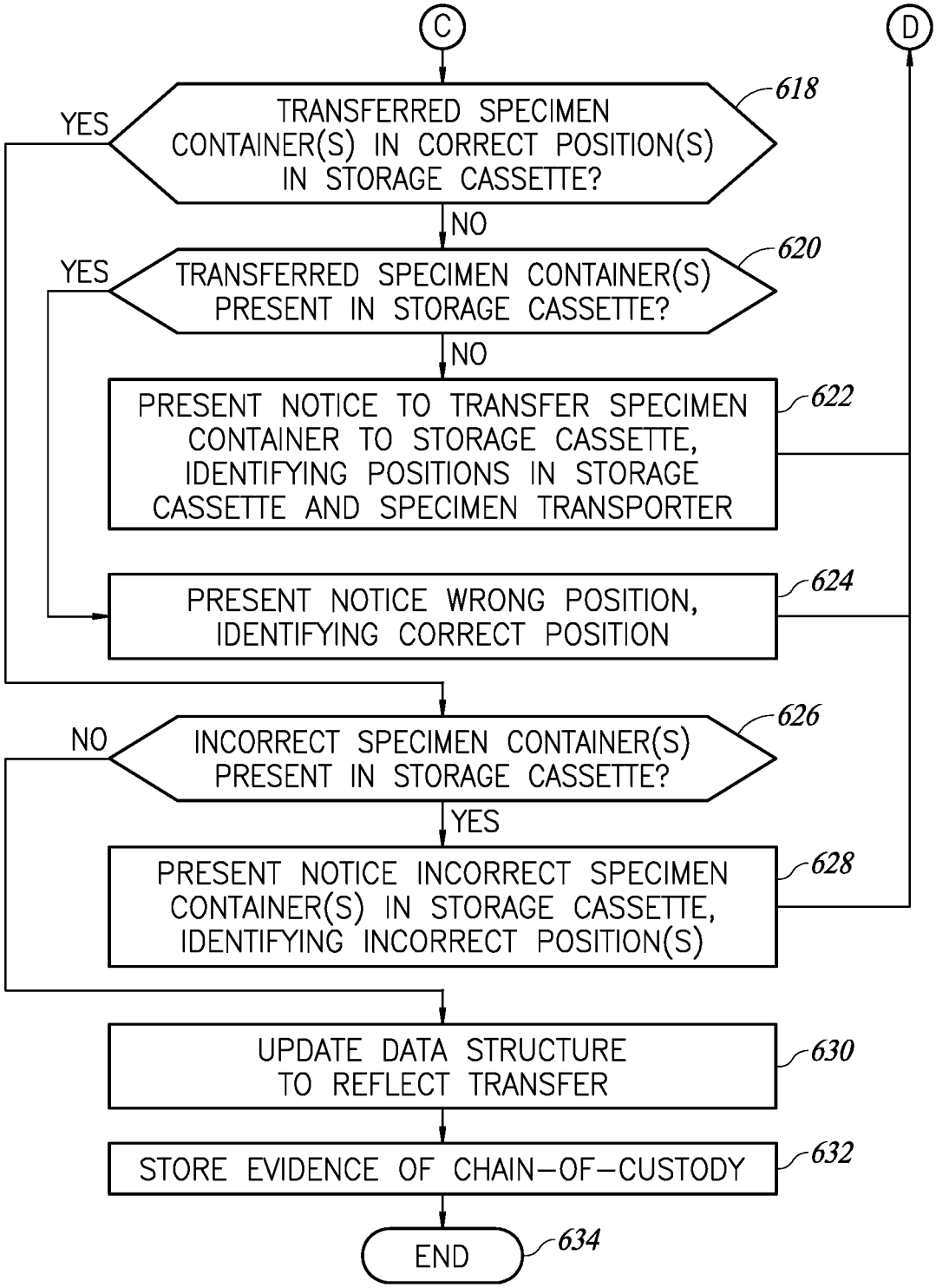

C
D
TRANSFERRED SPECIMEN CONTAINER(S) IN CORRECT POSITION(S) IN STORAGE CASSETTE?
618
YES
NO
TRANSFERRED SPECIMEN CONTAINER(S) PRESENT IN STORAGE CASSETTE?
620
YES
NO
PRESENT NOTICE TO TRANSFER SPECIMEN CONTAINER TO STORAGE CASSETTE, IDENTIFYING POSITIONS IN STORAGE CASSETTE AND SPECIMEN TRANSPORTER
622
PRESENT NOTICE WRONG POSITION, IDENTIFYING CORRECT POSITION
624
INCORRECT SPECIMEN CONTAINER(S) PRESENT IN STORAGE CASSETTE?
626
NO
YES
PRESENT NOTICE INCORRECT SPECIMEN CONTAINER(S) IN STORAGE CASSETTE, IDENTIFYING INCORRECT POSITION(S)
628
UPDATE DATA STRUCTURE TO REFLECT TRANSFER
630
STORE EVIDENCE OF CHAIN-OF-CUSTODY
632
END
634

FIG. 51

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2021/051803

A. CLASSIFICATION OF SUBJECT MATTER

G01N 35/10(2006.01)i; **G01N 35/00**(2006.01)i; **A01N 1/02**(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

G01N 35/10(2006.01); A01N 1/02(2006.01); A61B 10/00(2006.01); F25B 13/00(2006.01); F25B 29/00(2006.01); F25D 29/00(2006.01); G01N 1/28(2006.01); G01N 1/42(2006.01); G01N 35/00(2006.01)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS(KIPO internal) & Keywords: cryogenic, workstation, platform, bucket

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2019-0293344 A1 (BROOKS AUTOMATION, INC.) 26 September 2019 (2019-09-26) abstract; claim 1; paragraph [0014]	1-37
A	US 2019-0162639 A1 (COOPERSURGICAL, INC.) 30 May 2019 (2019-05-30) claims 1-27	1-37
A	WO 92-16800 A1 (CRYO-CELL INTERNATIONAL, INC.) 01 October 1992 (1992-10-01) the entire document	1-37
A	WO 2015-109315 A2 (BROOKS AUTOMATION, INC.) 23 July 2015 (2015-07-23) the entire document	1-37
A	CN 107624751 A (SHANGHAI PROPER ENERGY CELL BIOLOGICAL CRYOGENIC LTD.) 26 January 2018 (2018-01-26) the entire document	1-37

☐ Further documents are listed in the continuation of Box C. ☑ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"D" document cited by the applicant in the international application
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
12 January 2022	**12 January 2022**

Name and mailing address of the ISA/KR	Authorized officer
Korean Intellectual Property Office **189 Cheongsa-ro, Seo-gu, Daejeon** **35208, Republic of Korea**	**HAN, Inho**
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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/US2021/051803

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CN 107624751 A	26 January 2018	None	