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(54) Benævnelse: **METODE TIL HÅNDTERING AF EN MOBIL PLATFORM I EN TANK, DER INDEHOLDER IKKE-LEDENDE FARLIGE STOFFER**

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DESCRIPTION

TECHNICAL FIELD

[0001] Generally, this disclosure relates to devices and related methods for handling a mobile platform in a tank containing hazardous substances that may be non-conductive.

BACKGROUND

[0002] Otherwise routine tasks may become exceedingly difficult if the ambient conditions pose a potential hazard to humans and/or the machinery required to perform those tasks. One such task is inspecting the structural integrity of tanks used to contain flammable substances such as liquid or gaseous hydrocarbons. Tank inspections typically include measuring the wall thicknesses at multiple locations of the tank structure. An out-of-norm thickness indicates the presence of corrosion, or some other type of damage, which left unchecked could create leak paths for the resident fluids. Unfortunately, inspections of walls making up a bottom or floor of a tank must be conducted from the interior of the tank in order to accurately assess the condition of these walls.

[0003] A common approach to performing tank inspections is to use human work crews who enter the tank interior and scan the floors of tanks using magnetic and ultrasonic sensors. The tank must first be emptied of liquid contents and purged of all flammable substances to a sufficiently low concentration so that any sparks caused by equipment used by the work crews do not cause an explosion. The preliminary step of purging the tank is time consuming. Moreover, the tank must be decommissioned and taken out of service during the entire inspection process. Thus, manual tank inspections can be costly and disruptive to the ongoing operations of tank owners.

[0004] A recently developed method to inspect tanks proposed by PETROBOT utilizes a remotely operated inspection device that can scan the bottom of tanks. A flexible umbilical physically and operationally connects the inspection device to a control unit, which is positioned outside of the tank. An inert gas, such as nitrogen, is pumped via the umbilical into the inspection device before and while the inspection device is in the tank. The inert gas, which displaces the oxygen inside the inspection device, is believed to minimize the likelihood of a spark igniting the flammable substance. The umbilical is also used for bi-directional communication. Data collected by the inspection device can be transmitted via the umbilical to the external control unit. A human operator at the external control unit transmits control signals via the umbilical to steer the inspection device. In addition to gas and signals, electrical power is conveyed by the umbilical. This system may eliminate the need for human work crews inside the tank.

[0005] However, remotely operated inspection devices such as the PETROBOT device appear to be labor intensive to operate due to, for example, human control of steering during inspection operations. Moreover, the need for an opening to accommodate the umbilical during operation presumably exposes the outside environment to the hazardous materials inside the tank. Thus, the need remains to more efficiently and safely conduct inspections of tanks used to contain flammable material.

[0006] In some aspects, the present disclosure addresses these and other drawbacks of systems and methods for performing tank inspections in an environment having flammable or combustible substances. However, inspections of wall thicknesses of a tank containing a flammable substance is only illustrative of the general problem of performing tasks in an environment that may be harmful to humans and / or machinery. For example, toxic materials, while not necessarily flammable, may pose difficulties when conducting manufacturing or processing operations. Therefore, in further aspects, the present disclosure addresses the need to more efficiently and safely perform one or more tasks in a hazardous environment.

[0007] Some ambient conditions may include energetic substances that may also be non-conductive. The non-conductivity of an environment in which machinery is to be used may pose additional considerations in handing and operating such machinery. For example, the non-conductive environment may not allow an electrical charge that accumulates on machinery during operation to dissipate prior to retrieval. This accumulated electrical charge may cause a spark if the machinery is sufficiently close to a body with which it has a voltage differential. Such a spark may ignite an energetic substance, if present.

[0008] In aspects, the present disclosure addresses these and other drawbacks of systems and methods that utilize machinery in an environment having energetic substances that may be non-conductive. In some aspects, the present disclosure addresses such drawbacks by controlling electrical charge accumulation on such machinery. In some aspects, the present disclosure addresses such drawbacks by reducing an accumulated electrical charge on such machinery prior to or during retrieval.

[0009] Tanks are sometimes specifically designed to restrict access into an interior in which substances are stored in order to provide a sealed or isolated environment of such substances. For example, a tank may include a relatively small hatch, which is easily sealed, to allow personnel to access the tank interior. Personnel may encounter difficulties in reaching locations that are not in the immediate vicinity of that hatch.

[0010] In some aspects, the present disclosure addresses the drawbacks of systems and methods for deploying and retrieving equipment used in containers, such as tanks, that have limited access to interior locations in such containers. In some aspects, the present disclosure addresses the drawbacks of systems and methods for handling and retrieving machinery having an accumulated electrical charge due to use in containers that store non-conductive substances. US 6,104,970 discloses a crawler inspection vehicle with precise mapping capability. WO 2012/145745 discloses an underwater robotic venting and inspection system.

SUMMARY

[0011] The present disclosure, in part, relates to methods and related systems for handling a mobile platform in a tank containing non-conductive hazardous substances. By "non-conductive" or "electrically non-conductive," it is meant an electrical conductivity less than 1,000 picosiemens per meter (pS/m). By way of comparison, common drinking water is more than one thousand times as conductive as a substance defined as non-conductive in this disclosure.

[0012] According to one aspect, the present disclosure provides a method for retrieving a mobile platform from a tank as claimed in claim 1.

[0013] The above-recited example of features of the disclosure have been summarized rather broadly in order that the detailed description thereof that follows may be better understood, and in order that the contributions to the art may be appreciated. There are, of course, additional features of the disclosure that will be described hereinafter and which will form the subject of the claims appended hereto.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] For detailed understanding of the present disclosure, references should be made to the following detailed description of the disclosure, taken in conjunction with the accompanying drawings, in which like elements have been given like numerals and wherein:

FIG. 1 sectionally illustrates a tank that may be inspected by using a mobile platform according to the present disclosure;

FIG. 2 is a functional block diagram of one embodiment of a mobile platform in accordance with the present disclosure;

FIGS. 3A-C illustrate one embodiment of an enclosure for a mobile platform according to the present disclosure;

FIG. 4 is a functional block diagram of a control unit and certain related elements for a mobile platform according to one embodiment of the present disclosure;

FIGS. 5A-E illustrate embodiments of a marker detector that detects markers according to the present disclosure;

FIG. 6A is a flow chart depicting an illustrative method for controlling the mobile platform according to one embodiment of the present disclosure;

FIG. 6B illustrates a bottom wall of a tank having discontinuities detected by a mobile platform

in accordance with one embodiment of the present disclosure;

FIG. 7 schematically illustrates a propulsion system according to one embodiment of the present disclosure that uses a pressurized interior;

FIG. 8 isometrically illustrates a power supply according to one embodiment of the present disclosure;

FIGS. 9A-B schematically illustrate a task module adapted with sensors in accordance with one embodiment of the present disclosure;

FIG. 10 schematically illustrates a switch assembly in accordance with one embodiment of the present disclosure;

FIGS. 11A-B schematically illustrate retrieval modules in accordance with embodiments of the present disclosure;

FIGS. 11C-D schematically illustrate devices that may be used to facilitate deployment and / or retrieval of a mobile platform in accordance with embodiments of the present disclosure;

FIG. 12A-B isometrically illustrate another embodiment of a mobile platform in accordance with the present disclosure;

FIG. 13 is a functional block diagram of another control unit for a platform according to one embodiment of the present disclosure;

FIG. 14 illustrates a bottom wall of a tank along which the **FIG. 13** embodiment steers a mobile platform in accordance with one embodiment of the present disclosure;

FIG. 15 is a flow chart depicting an illustrative method for using the mobile platform to perform a task according to one embodiment of the present disclosure;

FIGS. 16A-B sectionally illustrate the deployment, release, and retrieval of a mobile platform during the performance of the FIG. 15 method according to embodiments of the present disclosure;

FIG. 17 is a partial sectional view of a tank having active markers according to embodiments of the present disclosure;

FIGS. 18A-B are flow charts illustrating alternate methods for steering mobile platforms according to the present disclosure;

FIG. 19 illustrates a system for retrieving a mobile platform using a primary and a secondary tether according to an embodiment of the present disclosure;

FIGS. 20A-B schematically illustrate an embodiment wherein a primary and a secondary tether are connected to a buoyant body according to the present disclosure.

FIG. 20C schematically illustrates an embodiment wherein a tether is stored and released from

a buoyant body according to the present disclosure;

FIG. 21 is a flow chart illustrating an embodiment of a retrieval method according to the present disclosure that uses the systems and devices of **FIG. 19** and **FIGS. 20 A-C**;

FIG. 22 illustrates a system for retrieving a mobile platform that reduces an electrical charge on the mobile platform according to an embodiment not according to the present invention;

FIG. 23 illustrates an electrical connection between an electrically conductive cable and an electrically conductive member on an enclosure of a mobile platform according to embodiments not according to the present invention;

FIG. 24 is a flow chart illustrating a retrieval method according to one embodiment not according to the present invention; that uses the **FIG. 22** system;

FIGS. 25A-B are flow charts illustrating alternate steps for making electrical connections when using the **FIG. 24** method;

FIG. 26 illustrates a charge accumulation control system for a mobile platform according to an embodiment not according to the present invention;

FIG. 27 is a flow chart illustrating a retrieval method according to one embodiment not according to the present invention that uses the system of **FIG. 26**;

FIG. 28 is a flow chart illustrating alternate steps for activating the charge accumulation control system according an embodiment not according to the present invention; and

FIG. 29 is a flow chart illustrating exemplary steps for controlling a charge accumulation on a mobile platform according an embodiment not according to the present invention.

DETAILED DESCRIPTION

[0015] The present disclosure provides devices, systems, and methods for performing tasks in a hazardous environment. For conciseness and clarity, the description below is principally directed to systems and related methods for inspecting a tank structure having an interior in which energetic materials such as hydrocarbon fluids are present. The present disclosure also provides devices, systems, and methods for handling mobile platforms used in a non-conductive, energetic substance. For conciseness and clarity, the description below is principally directed to systems and related methods for handling mobile platforms in a tank structure having an interior in which non-conductive, energetic substances, such as some classes of hydrocarbon liquids and gases, are present. However, it is emphasized that the present teachings can be readily applied to other industries and uses.

[0016] Referring initially to **Fig. 1**, a tank **10** may be used to store an energetic substance,

such as hydrocarbons, in the form of a liquid body **12** and a vapor **14.** The fluid-tight tank may include a domed top wall **16**, a generally planar bottom wall **18**, and a cylindrical vertical wall **20.** An interior **22** of the tank **10** may be accessed via a hatch **24.** In some tanks, pillars **26** may be used for structural support or other uses. Also, it is common for the tank **10** to also contain objects **27**, which may be intentionally placed such as sumps, piping, supports, etc. or foreign material such as debris, dropped tools, chains, wires, etc. The tank **10** may be a fixed above-ground tank or an underground tank. The tank **10** may also be positioned on a vehicle or vessel such as a barge, ship, land vehicle, etc. Moreover, the tank **10** may employ different configurations; *e.g.,* the top wall **16** may be flat and / or an interior floating roof may be used. As will be evident from the discussion below, systems and methods of the present disclosure can perform inspections of the tank **10**, and other similar structures irrespective of their usage, location, or design, with greater efficiency and safety than conventional tank inspection devices and methods.

[0017] Referring now to **Fig. 2**, there is shown, in functional block diagram format, a non-limiting embodiment of an intelligent mobile platform **100** for performing one or more tasks in the tank **10** of **Fig. 1.** The mobile platform **100** includes an enclosure **200**, a control unit **300**, a propulsion system **400**, and a power supply **500**. Optionally, a task module **600** may also be carried by the mobile platform **100.** As used herein, the term "carried by" means that the object is inside, attached to, or on the mobile platform **100.** Hereafter, these structures and on-board equipment will collectively be referred to as "subsystems." In some embodiments, the control unit **300** has bi-directional communication with one or more subsystems via a communication network **360.** In other embodiments, communication may be in one direction to one or more subsystems. In still other embodiments, no communication is provided to or from some of the subsystems. The power supply **500** supplies power to one or more systems via a power distribution network **362**, which may share circuitry with the communication network **360.** The mobile platform **100** may be considered "intelligent" because the control unit **300** is configured to control the subsystems of the mobile platform **100** by using only previously programmed instructions and information acquired "real time" or "near real time" via on-board sensing instruments. That is, the mobile platform **100** can acquire information relevant to an assigned task and make decisions in furtherance of the completion of that task without human intervention. Therefore, advantageously, the mobile platform **100** may not have and may not require any umbilical, physical or otherwise, to a location external to a tank through which power or command signals are received. The subsystems of the mobile platform **100** are discussed in greater detail below.

[0018] Generally, the mobile platform **200** is configured to be inherently safe. By "inherently safe," it is meant that the mobile platform **200** is designed such that at no time during operation in the tank **10 (Fig. 1)** will a spark from the mobile platform **200** come into contact with the energetic substance outside of the mobile platform **200.** An element of the "inherently safe" design is that the enclosure **200** incorporates structural features that prevent a spark, or a spark from an explosion of the energetic substance **12, 14,** or a spark from an explosion of another energetic substance similar to the energetic substance **12, 14**, occurring inside the enclosure **200** under normal operating and standard atmospheric conditions (*i.e.,* twenty

degrees Celsius (sixty-eight degrees Fahrenheit) and 1.01325 bar) from passing to an exterior of the enclosure **200.** Another energetic substance is considered to be "similar" to the energetic substance **12,14** if such other energetic substance has a Maximum Experimental Safe Gap (MESG) in the same class as the energetic substance **12, 14** (such class specified as: i. less than or equal to 0.45mm (17.72 mils), ii. greater than 0.45mm (17.72 mils) and less than or equal to 0.75mm (29.53 mils), or iii. greater than 0.75mm (29.53 mils)) and/or has a Minimum Igniting Current Ratio (MICR) in the same class as the energetic substance **12, 14** (such class specified as: i. less than or equal to 0.4, ii. greater than 0.4 and less than or equal to 0.8, or iii. greater than 0.8).

[0019] An "intrinsically safe" component is one that cannot create a spark when used as intended for the purpose for which the component was designed. A "non-intrinsically safe" or "spark-generating" component may generate a spark when operated as intended. The interior of the enclosure **200** houses all components of a device, assembly, or subassembly that are not intrinsically safe; *i.e.,* all "spark-generating" components. Thus, the enclosure **200** may be considered an "inherently safe" structure.

[0020] Generally, "spark-generating components" include mechanical structures that move fast enough to cause a spark and electrical components that operate at sufficiently high energy state to cause sparking. Generally, "non spark-generating components" include mechanical structures that do not move fast enough to cause a spark and electrical components that operate at sufficiently low energy state to preclude sparking. It should be noted that some subsystems may include spark-generating and non-spark-generating components. The mobile platform **100** is designed such that spark-generating components of such subsystems are positioned inside the enclosure **200.** The non-spark-generating components of such subsystems may be positioned internal or external to the enclosure **200.** By way of example, the propulsion system **400** has spark-generating components isolated inside the enclosure **200** and intrinsically safe external components external to the enclosure **200.**

[0021] As described below, the enclosure **200** uses construction techniques and materials that ensure that sparks from a spark-generating component, or sparks from explosions caused by such sparks, do not pass to the exterior of the enclosure **200** and ignite any ambient energetic material.

[0022] Referring to **Fig. 3A**, there is shown one enclosure **200** according to the present disclosure. While the enclosure **200** is shown as a single integral body, the enclosure **200** may have two or more separate and fully self-contained bodies. The enclosure **200** includes a shell **202** and a top lid **204.** The shell **202** is defined by a side wall **220** and a bottom **206**, which collectively define an interior **208.** The vertical wall **220** and bottom **206** may be formed as an integral body or an assembly of individual walls. The outer shell **200** may be formed as an elongated box. However, other shapes, and combination of shapes, such as spherical, frustoconical, or cylindrical may be used. Moreover, the enclosure **200** may incorporate planar, curvilinear, and /or asymmetric geometries. Suitable materials for the enclosure **200** include metals, alloys, polymers, glass, composites, and combinations thereof. Additionally, the

enclosure **200** may be liquid-tight so that the mobile platform **100 (Fig. 2)** can be partially or fully submerged in the liquid body **12 (Fig. 1)** inside the tank 10 **(Fig. 1).**

[0023] Referring to **Fig. 3B**, the walls **220** and internal structures of the enclosure **200** may use a range of thicknesses. The walls may be formed as plates, ribs, meshes, etc. Selected areas may be strengthened using reinforcement members such as steel rings (not shown). In some situations, it may be desirable that the enclosure **200** use features such as fillets and symmetric arrangements to manage or control stress concentrations in the enclosure **200**. For example, the interior **208** is symmetrically arranged in the longitudinal and transverse axes. Depending on the application, the symmetry may be along one, two, or three axes. For purposes of the present disclosure, the symmetry does not require identical features (*e.g.*, volumes or dimensions) on each side of an axis. Rather, the interior **208** may be considered symmetric if both sides of an axis cause a spark or related explosion to dissipate in generally the same manner (*e.g.*, rate of propagation / dissipation, direction of movement, etc.).

[0024] The enclosure **200** may also use structures that disrupt detonation paths such as interior baffles, orthogonal corners, and shields in front of relatively weak wall sections and / or portals or other passages leading to the exterior of the enclosure **200.** For example, a majority of corners of the shell **202** that define the interior **208** can have a ninety-degree angle. Other arrangements may have more than sixty percent or eighty percent of such corners having a ninety-degree angle. Additionally, one or more interior plates **222** may be positioned to divide the volume of the interior **208** to reduce the length of pathways that pressure waves can travel unobstructed across the interior **208.** These interior plates **222**, which may be referred to as baffles or blast shields, create circuitous paths that can dissipate shock waves.

[0025] Referring to **Figs. 3A-C**, in embodiments, the lid **204** may be removably affixed to a top surface **224** of the vertical wall **220** with a plurality of fastening elements **226.** The fastening elements **226** may be distributed continuously along a perimeter of the lid **204** to provide a nearly uniform compressive / clamping force that secures the lid **204** to the shell **202.** In some arrangements, the fastening elements **226** are spaced apart such that the interstitial length is at a defined maximum fraction of a length along which the fastening elements **226** are distributed. For example, if the defined maximum fraction is one-twentieth and the length of a perimeter along which the fastening elements **226** are distributed is one meter, then fastening elements **226** are distributed such that no fastening element **226** is more than five centimeters from one another fastening element **226.** In embodiments, the maximum defined fraction may be one-half, one-quarter, one-fifth, an eighth, or a tenth of a length along which the fasteners are distributed. A fastening element **226** may be any member that connects to the shell **202** and applies a compressive force that presses the lid **204** against the shell **202.** Fastening elements **226**, include screws, bolts, clamps, rivets, etc.

[0026] In one embodiment, the enclosure **200** incorporates one or more of the above described structural features, and / or other known structural features, to prevent permanent structural deformation upon encountering a specified pressure for a specified time in the interior **208** of the enclosure **200.** The specified pressure and duration may be based on the

anticipated use for the mobile platform **100** and selected to simulate a maximum stress imposed on the enclosure **200** should an explosion occur during operation. In some applications, a "permanent structural deformation" is a plastic deformation that forms a path between the interior **208** and an exterior of the enclosure **200.** The path, which may be caused by a loosening of joints or bursting of the enclosure **200**, may allow a spark to be communicated to the exterior of the enclosure **200.** In embodiments, the specified pressure and duration may be at least ten bars for at least ten seconds, a pressure of at least eight bars for at least eight seconds, a pressure of at least six bars for least six seconds, a pressure of three and one-half bars for at least ten seconds, or a pressure of at least four bars for at least four seconds.

[0027] In addition to pressure resistance, the enclosure **200** may incorporate further features to allow operations in particular types of tanks. Referring to **Fig. 1**, the mobile platform **100** may be sized for entry into and out of a tank **10** having openings and associated hatches **24** of different shapes and relatively limited sizes. The dimensions of openings and related reinforcement structures take into account fall protection, anchorage, hoisting, or personnel retrieval. Experienced engineers may size openings as appropriate for a particular application. Nevertheless, some standardized openings are used. For example, some parallelogram-shaped openings may have maximum dimensions of 36 inches (914.4 mm) by 72 inches (1,828.8 mm). Other parallelogram-shaped openings may have maximum dimensions of 36 inches (914.4 mm) by 36 inches (914.4 mm). Also, some circular openings may have a maximum diameter of 23.62 inches (600 mm), 24 inches (609.4 mm), or 36 inches (914.4 mm). Therefore, in embodiments, mobile platforms **100** of the present disclosure may be sized to pass through a parallelogram-opening having a width no larger than 36 inches (914.4 mm) and a length no larger than 72 inches (1,828.8 mm) or a width no larger than 36 inches (914.4 mm) and a length no larger than 36 inches (914.4 mm). In other embodiments, mobile platforms **100** of the present disclosure may be sized to pass through a circular opening no larger than 36 inches (914.4 mm) in diameter, a circular opening no larger than 24 inches (609.6 mm) in diameter, or a circular opening no larger than 600 mm (23.62 inches) in diameter.

[0028] Further, in embodiments, the overall weight of the mobile platform **200** may be maintained at or below a value that could impose difficulties during handling or damage the bottom wall **18** of the tank **10.** In embodiments, the overall weight of the mobile platform **100** may be below 10,000 pounds (4,536 kg). In other embodiments, the overall weight of the mobile platform **100** may be below 6,000 pounds (2,722 kg).

[0029] Thus, the construction of the enclosure **200** may be bounded by pressure resistance requirements, maximum size requirements, and maximum weight. Construction techniques for making enclosures resistant to rapid increases in pressure are known in the art; *e.g.,* U.S. Pat. 2,801,768, *Explosion-proof Enclosure;* U.S. 6,452,163, *Armored Detector Having Explosion Proof Enclosure;* U.S. Pat. 8,227,692, *Explosion-Proof Enclosure;* WO 2017003758, *Improved Explosive-Proof Thermal Imaging System;* and EP 2418926, *Sheet Metal Explosion-Proof, and Flame-Proof Enclosures.* Thus, for conciseness, details of such construction features will not

be discussed in further detail. It is emphasized that the above-described construction techniques are merely illustrative of known techniques for configuring the enclosure **200** to be inherently safe. Enclosures **200** encompassed by the present disclosure may incorporate some or all of the above-features or incorporate only other known construction techniques.

[0030] Additionally, the enclosure **200** may include two or more separate housing structures. These structures may have the same or similar features and house spark-generating components. For example, one or more additional separate enclosures may house lights and associated batteries to assist with camera images, sensors, tooling, etc. The additional enclosure(s) may be bolted onto the enclosure **200**, attached with a tether, towed separately in a wagon type of arrangement, or otherwise physically connected.

[0031] Referring to **Fig. 4**, there is shown one non-limiting embodiment of an intelligent control unit **300** that is programmed to control one or more functions of the mobile platform **100** (**Fig. 2**). The control unit **300** may include a processor module **302** and a navigation module **304.** While the control unit **300** may be discussed in the singular, it should be understood that the control unit **300** may be configured as a group of two or more discrete programmed processing devices that work independently or collectively. Moreover, these discrete processing devices may be either distributed throughout the enclosure **200**, in separate enclosures, or centralized in one location.

[0032] The processor module **302** may include pre-programmed algorithms **303** for controlling some or all of the mobile platform **100.** By way of example and not limitation, these algorithms **303** may be executed to issue control signals **308** for operating the propulsion system **400**, control signals **310** to manage the power supply **500**, and control signals **312** for operating one or more task modules **600.** For example, information **309** relating to the power supply **500** may be used to manage power distribution. As used herein, an algorithm means instructions stored in a memory module that can be accessed and implemented by a processor-based machine. The processor module **302** may use conventional micro-processors, memory modules that store one or more databases, **303 a,b** and other known components of information processing devices.

[0033] The navigation module **304** may be configured to acquire information that may be used to determine a position of the mobile platform 100 and / or a position relative to a feature associated with a tank **10 (Fig.** 1) and / or an orientation of the mobile platform **100.** For brevity, the term "position" is inclusive of an orientation *(e.g.,* heading, tilt, azimuth, etc.) and location (*i.e.,* a point relative to an external reference frame such as a Cartesian coordinate system or a polar coordinate system). A "relative" position is a position identified by referencing a previous position. In one embodiment, the navigation module **304** may include a marker detector liquid that generates signals in response to a detected feature associated with the tank **10 (Fig. 1).** The marker detector **306** may be passive or active as discussed in connection with **Figs. 5A-E** below. The feature may be either structural or added to the tank **10 (Fig. 1).** One non-limiting example of such a feature is a discontinuity found at the juncture of two or more steel plates from which a tank wall is formed; *e.g.*, the bottom wall **18** shown in **Fig. 1.**

The marker detector embodiments discussed herein below use different techniques to detect the discontinuity, which manifests itself as a change in a material property, composition, and / or dimension.

[0034] Referring to **Figs. 5A-E**, there are shown five non-limiting detector arrangements for detecting features such as discontinuities. **Fig. 5A** illustrates the mobile platform **100** during contact with a discontinuity **320** on an inner surface **322** of a tank **10 (Fig. 1).** The mobile platform **100** prior to encountering the discontinuity **320** is shown in dashed lines. The discontinuity **320** may include a weld seam **325** at a juncture of two overlapping plates **324**, **326.** The mobile platform **100** may have a marker detector **306 (Fig. 4)** that senses orientation, such as an inclinometer **328.** Other orientation sensing devices may include accelerometers and gyroscopes. During contact with the discontinuity **320**, the inclinometer **328** will sense a change in inclination and generate a responsive signal. The control unit **300 (Fig. 4)** can process the signal to determine if the detected signals are indicative of a juncture between two plates or some other discontinuity. The **Fig. 5A** arrangement may be considered a passive system because no energy is emitted to detect the discontinuity **320.**

[0035] In **Fig. 5B**, the mobile platform **100** includes a signal emitter **330** that emits an energy wave **332** that interacts with the discontinuity **320.** The returning waves **333** from the discontinuity **320** may be detected by the signal emitter **330**, in the case of a transducer, or a separate detecting device. Different discontinuities **320** may each uniquely affect the emitted signal. That is, a change in material thickness or material composition may affect the emitted signal differently from variations along a surface (*e.g.*, a protrusion, recess, cavity, etc.). The detected returning waves **333** can be processed to determine if the detected signals are indicative of a juncture between two plates or some other discontinuity. The **Fig. 5B** arrangement may be considered an active system because energy is emitted to detect the discontinuity **320.**

[0036] In **Fig. 5C**, the mobile platform **100** includes a tactile detector **335** that physically contacts the surface **322** and detects characteristics such as a change in inclination, clearance, or roughness that are indicative of the discontinuity **320.** In one embodiment, the tactile sensor **335** may "feel" the contour by using a ball wheel **336** pushed down by gravity, or using a biasing member, to trace the surface **322.** A sensor **337**, such as a Hall sensor, inside a supporting vertical tube **338** may sense the movement up and down of a supporting shaft **339.** Other tactile detectors **335** may measure a deflection, bend, or other deformation in a member (not shown) contacting the surface **322.**

[0037] In **Fig. 5D**, the mobile platform **100** includes an optical detector **340** that optically scans the surface **322** and detects visual characteristics that are indicative of the discontinuity **320.** In one embodiment, a light source **341**, which may be positioned in one or more external enclosures (not shown), emits light **343** that illuminates the surface **322.** The optical detector **340** can record the reflected light **347** for processing and analysis.

[0038] Fig. 5E illustrates another embodiment wherein the mobile platform **100** includes an

optical detector **340** that optically scans the surface **322** and detects visual characteristics that are indicative of discontinuities (not shown). In this embodiment, the optical detector **340** and the light source **341** are positioned on one or more vertical faces **345** of the mobile platform **100.** The vertical face **345** may be the front or the back of the mobile platform **100.** It should be appreciated that any of the other sensors and detectors discussed may also be mounted on one or more vertical faces **345** or faces other than vertical (not shown). That is, the present disclosure is not limited to only downwardly directed sensing devices. Additionally, while described as configured for detecting discontinuities, the above-described sensor arrangements may be used to locate, identify, and characterize other features such as pumps, equipment, pillars, etc., for general steering, obstacle avoidance, or other purposes.

[0039] It should be noted that the discontinuity **320** may be detected by measuring any number of material or structural features; *e.g.*, changes in wall thickness, material composition, roughness, density, color, etc. Numerous types of passive and active sensing devices may be used to detect discontinuities. Illustrative, but not exhaustive, sensing devices include: devices using reflections of electromagnetic waves such as LIDAR or other related laser-based sensor, a camera or other image sensor, a radar sensor; devices that use reflections of mechanical waves such as an ultrasonic sensor and a sonic sensor; devices that detect a change in orientation relative to the gravity vector such as inertial measurement unit (IMU), accelerometers, gyroscopes, and inclinometer; devices that detect variances in speed, voltage, current, and / or power usage within the propulsion system **400 (Fig. 2)** caused by traversing a discontinuity **320**; tactile devices configured to "feel" the discontinuity; and devices that detect changes in the transmission of magnetic fields such as a magnetic flux leakage sensor and an eddy current sensor.

[0040] Thus, it should be appreciated that the marker detector **306** may be an orientation sensor such as the inclinometer **328,** a signal emitter **330** that emits an energy wave **332,** a tactile detector **335** that contacts a surface **322,** and / or an optical detector **340** that optically scans a surface **322.** However, the marker detector **306** may be any device that is configured to detect the presence of an active and / or passive marker.

[0041] Figs. 6A, B illustrate a method by which the control unit **300** may intelligently traverse an interior of a tank **10** using the navigation module **304** that detects discontinuities **320**, which are shown in **Fig. 6B. Fig. 6B** is a top view of a tank bottom wall **18** that includes discontinuities **320** in the form of weld structures. Some discontinuities **320** follow a grid-like pattern, such as weld lines formed by intersecting perpendicular lines. Other discontinuities **320** do not conform to a particular order or geometric pattern, such as the weld lines next to the wall **20.**

[0042] Referring now to **Figs. 1, 2, 4** and **6A,** the control unit **300** may include one or more navigation algorithms that use the discontinuities **320** to steer the mobile unit **100** in accordance with the **Fig. 6A** method. Step **800** begins after the mobile platform **100** has been positioned in the tank **10.** The control unit **300** may initiate operations by executing a navigation algorithm that issues control signals **308** to the propulsion system **400.** The

propulsion system **400** may transmit information **313** to the control unit **300** that relates to system operations (*e.g.*, confirmation of commands, system status, operating set points, etc.). The navigation algorithm may move the mobile platform **100** randomly or according to a preset initial course.

[0043] At step **802,** the marker detector **306** passively or actively scans the interior of the tank **10** for discontinuities **320.** If the marker detector **306** is a component of the task module **600,** the control unit **312** may transmit control signals **312** to the control the task module **600** and the task module **600** may transmit information **311** representative of the detected discontinuities **320.** The discontinuities **320** may be structural or augmented and be present in any of the walls of the tank **10** or other structures of the tank, such as the pillars **26** or equipment (*e.g.*, sump). As signals are received, the control unit **300** may analyze these signals to determine if a discontinuity for steering the mobile platform **100** has been detected. At step **804**, if such a discontinuity has been found, the control unit **300** accesses a map, which is a digital database (*e.g.*, database **303a (Fig. 4)).** In some arrangements, data in the map database is referenced to estimate a position or orientation of the mobile platform **100.** In other arrangements, the control unit **300** creates the map or updates the map, if pre-existing, to record the position or relative position of the detected discontinuity and / or the position / relative position of the mobile platform **100.** In this instance, the relative position may include an element of the position such as a distance travelled from another feature, a heading taken from another feature, and / or an orientation relative to another feature.

[0044] At step **806**, the control unit **300** may set a course based on one or more detected markers, which may be passive markers such as discontinuities. The course may be in parallel with, perpendicular to, or another heading relative to the detected discontinuity or a feature identified by the detected discontinuities, such as a corner. While following the set course, the mobile platform **100** may perform one or more of the assigned tasks using the task module **600**, such as scanning the tank bottom wall **18** for corrosion or other forms of damage. Also, one or more databases (*e.g.*, **303b** (**Fig. 4**)) may be continually updated with the positions, relative positions, and /or orientations of the detected discontinuities. The control unit **300** may repeat steps **802** to **806** as desired. Optionally, the control unit **300** may utilize information in the map, *e.g.,* the location of previously detected discontinuities, along with the information relating to the currently detected discontinuity to determine a heading. A similar methodology may be used when detecting one or more active markers.

[0045] At step **808**, the control unit **300** may determine that one or more preset termination criteria have been met. The termination criteria may be based on completion of the assigned task(s). Termination criteria may also be based on a time duration (*e.g.*, a maximum of thirty-six hours in the tank **10**), battery life (*e.g.*, battery drained to ten percent of capacity), system health, operating condition, or another preset parameter. Upon determining that the termination criteria have been satisfied, the control unit **300** may initiate a power down of the mobile platform **100.** Optionally, at step **810**, the control unit **300** may instruct the mobile platform **100** to move to a predetermined retrieval location.

[0046] It should be appreciated the **Fig. 6A** method allows the mobile platform **100** to traverse the interior of the tank **10** without any "real time" or "near real time" human input. That is, human interaction with the mobile platform **100** may end after the mobile platform **100** is released inside the tank **10.** Thus, the mobile platform **100** may be considered intelligent in that information relating to the environment is autonomously collected and processed in order to methodically traverse the interior of the tank **10.** It should be understood that the described steps do not necessarily have to occur in the order described. For example, step **802** may occur before, simultaneously with, or after step **800.** It is also emphasized that the **Fig. 6A** method is only one of numerous control schemes that may be used to imbue the mobile platform **100** with intelligent control. Other control schemes are discussed in detail later.

[0047] Referring to **Fig. 7**, there is shown one non-limiting embodiment of a propulsion system **400** according to the present disclosure. The propulsion system **400** may be configured to provide the mobile platform **100** with multiple degrees of freedom of movement. That is, the mobile platform **100** can change positions in the tank **10 (Fig. 1)** by at least two or more of types of movement. These movements include linear movements such as surge (forward/backward), heave (up/down), and sway (left/right) and rotation movements about an axis such as pitch (lateral axis), yaw (normal axis), and roll (longitudinal axis). The propulsion system **400** may include an electrically powered internal rotary power device **402** and an external drive assembly **404.** The rotary power device **402** may include a suitable motor. A drive shaft **412** extends through the enclosure wall **220** via an opening **440** and physically connects the internal rotary power device **402** to the external drive assembly **404.** A seal **414** disposed in the enclosure wall **220** surrounds the drive shaft **412.** The seal **414** may independently provide adequate sealing protection against tank fluids leaking into the enclosure interior **208 (Fig. 3**). In some embodiments, a pressurizer **430** may release a pressurized gas that maintains or increases the pressure of the fluid in the enclosure **200 (Fig. 3)** to be the same as or greater than the pressure of the fluid outside the enclosure **200 (Fig. 3);** *i.e.*, a neutral to a positive pressure differential. It should be understood that other types of propulsion systems may also be used.

[0048] Mobile platforms **100** of the present disclosure are not limited to any particular type or number of external drive assemblies. A mobile platform **100** may utilize a single external drive **404** assembly or two or more external drive assemblies **404.** Also, the external drive assembly **404** may include gearing **405** for driving one or more impetus members such as wheels **450** as shown in **Fig. 7B** or tracks **442** as shown in **Fig. 5A.** Other arrangements may use propellers or impellers for impetus members. Thus, any structure that is capable of using the rotary power to provide the impetus for moving mobile platform **100** may be used. Herein, any structure or body configured for such use may be referred to as an impetus member. In some embodiments, the impetus member(s) may include magnetic elements or other device that enable the mobile platform **100** to climb vertical walls or hang from ceilings.

[0049] Mobile platforms **100** of the present disclosure are also not limited to the internal drive and external drive assembly configurations described above. **Fig. 7** depicts an impetus member having a dedicated internal rotary power device **402.** However, in variants, a

propulsion system **400** may include one internal rotary power device **402** that drives two or more external drive assemblies **404.** Thus, arrangements for the propulsion system **400** may or may not have a one-to-one correspondence between the internal rotary power devices **402**, and the external drive assemblies **404.**

[0050] Referring to **Fig. 8**, power for the subsystems of the mobile platform **100** may be supplied by the power supply **500.** The power supply **500** may include a battery bank **502** housed within a suitable casing **504.** In some embodiments, one power supply **500** energizes all of the subsystems. In other embodiments, two or more separate power supplies **500** may be used. Additionally, electronic and computer-implemented controls for power discharge may be performed by suitable processing circuitry (not shown). Generally, the power supply 500 supplies power at a level to fully energize all subsystems of the mobile platform **100** because the mobile platform **100** does not have an active line supplying power during operations. By "fully" energized, it is meant that that a subsystem is supplied with sufficient energy to execute all intended functions.

[0051] Referring to **Figs. 9A,B**, there is shown one embodiment of a task module **600** that may be carried by the mobile platform **100** to perform inspections of a tank wall **16, 18, 20 (Fig. 1).** The task module **600** may include one or more instruments that collect information from which the thicknesses of sections or segments of the walls making up the tank may be determined. In one embodiment, the task module **600** includes a transducer array **602** configured to direct acoustic signals through windows **232** out from the bottom **206** of the enclosure **200.** The windows **232** may be sealed with a material (not shown) such as a polymer that is conductive to acoustic energy. Thus, the windows **232** do not impair the liquid-tight nature of the enclosure **200.** In one arrangement, the transducer array **602** may include a plurality of sensors that emit signals into the tank wall **16, 18, 20 (Fig. 1)** and detect the reflections of these signals. Illustrative sensors include, but are not limited to, sonic sensors, ultrasonic sensors, magnetic field and flux detectors. The detected signals may be digitized using appropriate circuitry and transmitted to the control unit **300 (Fig. 2)** via a communication link **604.** The control unit **300 (Fig. 2)** can store the information in a suitable memory module for later retrieval. It should be noted that the transducer array **602** may also be used to identify discontinuities for navigation / guidance purposes. The task module **600** may be supported by a suitable base **230 (Fig. 3B, C)** fixed in the enclosure **200 (Fig. 3B,C).**

[0052] It should be understood that the task module **600** may also incorporate other devices for estimating the condition or state of one or more features of the tank **10.** The features may be one or more structures making up the tank **10** or an ambient condition in the tank **10.** Referring to Figs. **2** and **5A-E**, by way of non-limiting examples, the task module **600** may include an orientation sensor such as the inclinometer **328,** a signal emitter **330** that emits an energy wave **332,** a tactile detector **335** that contacts a surface **322,** and / or an optical detector **340** that optically scans a surface **322**. These instruments may provide information relating to the condition of the walls or of other structures of the tank **10** such as corrosion, damage, structural integrity, etc. The task module **600** may also incorporate devices for the retrieval of materials from the inside of the tank **10** or for the delivery of materials to the inside

of the tank **10.**

[0053] The mobile platform may optionally include other mechanisms to enable additional functions. Other examples of such devices are described in connection with **Figs. 10** and **11A-D** below.

[0054] Referring to **Fig. 10,** there is shown a switch assembly **250** for communicating with the mobile platform **100 (Fig. 2).** For example, the switch assembly **250** may be used to shift between power states, activate or de-activate sub-systems, initiate pre-programmed instructions, etc. The switch assembly **250** is a non-momentary type that does not require a passage to the interior **208** of the enclosure **200.** A "momentary switch" only engages while actuated. A "non-momentary switch" latches and remains in a set position. In one non-limiting embodiment, the switch assembly **250** may have a lever member **251** positioned on or near an outer surface of the enclosure **200.** The lever member **251** may have an external magnetic element **252,** or a magnetic material such as iron, and that is moveable between two positions, *e.g.*, an "off" position **254** and an "on" position **256** (shown in hidden lines). The movement may be a rotation and/ or a translation. Sealed inside the enclosure **200** is a sensor **258** that can detect a magnetic field such as a Hall effect type sensor or a reed switch. Shifting the switch assembly **250** from the "off" position **254** to the "on" position **256** causes the sensor **258** to transmit a signal **260** to the control unit **300 (Fig. 2)).** Other non-momentary switches may utilize pressure activation or a command signal (*e.g.*, acoustic wave).

[0055] Referring to **Figs. 1, 2,** and **10,** in one non-limiting method of operation, the switch assembly **250** is moved to the "on" position while the mobile platform **100** is outside of the tank **10 (Fig. 1).** The signal **260** received by the control unit **300** from the switch assembly **250** commands the control unit **300** to shift from a no-power, low-power or sleep mode to a higher power consuming mode, such as a "start of operation" mode. The "start of operation" mode may begin with a system check, the successful conclusion of which may be indicated by an audio, visual, mechanical (*e.g.*, shock, vibration, impact, pressure, physical movement, etc.), or electromagnetic (EM) signal. Next, the control unit **300** may start a preset duration for a quiet mode of, say thirty minutes. In the quiet mode, the control unit **300** remains functionally dormant while the mobile platform **100** is being positioned in the tank **10.** At the end of the quiet mode, the control unit **300** may enter a period where quiescence is monitored. For example, an on-board motion sensor, such as an accelerometer, may be used to detect whether or not the mobile platform **100** is moving. If the mobile platform **100** has been determined to be motionless for a preset duration, *e.g.*, thirty minutes, then the control unit **300** may commence operation, which may be the highest power consuming mode. It is emphasized that the described switch assembly and method for commencing operations is only one of various devices and methods that may be used to bring the mobile platform **100 (Fig. 2)** to operational readiness.

[0056] Referring now to **Fig. 11A,** there is shown one example beyond the scope of the claims of a retrieval module **700** that may be used to retrieve the mobile platform **100** from the tank **10** at the conclusion of operations. As noted previously, the mobile platform **100** may be fully

submerged, perhaps by several feet, within a liquid contained in the tank **10 (Fig. 1).** The retrieval module **700** may release a buoy that can float at or below the liquid surface to facilitate location and retrieval. In one embodiment, the retrieval module **700** includes a buoyant body **702** having an inner compartment **704** in which a tether **706** is stored. The body **702**, while shown as cylindrical, can be of any shape or size. The body **702** may be formed of one or more materials that enable the body **702** to be buoyant in the surrounding liquid. Optionally, the body **702** may be inflatable with a gas. For example, the body **702** may be formed as an expandable bag or bladder that can increase in volume using pressurized gas. A handle **708** or other suitable projection such as an eyelet may be fixed to an outer surface of the body **702**. The body **702** may also include one or more magnetic elements **710** disposed on a lower portion and in close proximity to the outer surface of the enclosure **200.** In embodiments, a magnetic steel may also be suitable. Sealed inside the enclosure **200** may be one or more electro-magnets **712.** The electro-magnets **712** may be electrically connected to the control unit **300 (Fig. 2)** and the power supply **500 (Fig. 2)** via one or more lines **214.** The magnetic elements **710**, the electromagnets **712**, and the control unit **300** form a latch assembly **715** that uses a magnetic force for selectively releasing the buoyant body **702.**

[0057] During operation, the latch assembly **715** is in a locked position wherein the electro-magnets **712** are kept energized so that a magnetic connection is maintained with the magnetic elements **710.** Thus, the buoyant body **702** is fixed to the enclosure **200.** At the appropriate time, the control unit **300** shifts the latch assembly **715** to the released position wherein electro-magnets **712** are de-energized by terminating electrical power, which eliminates the magnetic connection. The buoyant body **702** then floats to or near the surface of the liquid in the tank **10 (Fig. 1).** The tether **706** connects the body **702** to the mobile platform **100.** Thus, the mobile platform **100** may be retrieved by pulling on the tether **706** or using the tether **706** as a guide to physically locate the submerged mobile platform **100.** When the tether **706** is used as a retrieval carrier, then the tether **706** may use materials and construction that provide suitable loading capacity to support the mobile platform **100.**

[0058] Referring now to **Fig. 11B**, there is shown in schematic form another non-limiting embodiment of a retrieval module **700** that may be used to retrieve the mobile platform **100** from the tank **10** at the conclusion of operations. In this embodiment, the retrieval module **700** includes a buoyant body **702,** a handle or other similar manipulation member **708,** and one or more electromagnetically actuated latches **724.** The latches **724** may positively engage a lip **730** of the buoyant body **702** and thereby fix the body **702** against the enclosure **200.** The latches **724** may be shifted between a locked and unlocked position using electromagnetic type actuators **726.** In the illustrated embodiment, the latches **724** slide away from the lip **730** in the direction shown by arrows **728** when the electromagnetic actuators **726** are energized. Other modes of movement or shifting may be used; *e.g.*, rotational, pivoting, etc. Optionally, a switch assembly **250** may be fixed to one of the latches **724.** The switch assembly **250** may be similar to that shown in **Fig. 10.** In one arrangement, when the latches **724** are in the closed position as shown, the switch assembly **250** is in "on" position. When the latches **724** are slid to the open position to release the buoyant body **702**, the switch assembly **250** shifts to the "off" position, shown in hidden lines. It should be noted that a latch assembly having one or more

latches and electromagnetic actuators may also be used in the **Fig. 11A** embodiment.

[0059] The retrieval module **700** of **Fig. 11B** uses a two-stage external tether **736** that includes a relatively light first stage tether **738** and a relatively stronger second stage tether **740.** The first stage tether **738** may be connected by a flexible member **742**, such as a wire, to the body **702.** The material of the first stage tether **738** is selected to be light enough as to not impair the buoyancy of the body **702** but be strong enough to support the weight of the second stage tether **740** as the second stage tether **740** is unwound and retrieved. The material of the second stage tether **740** is selected to be strong enough to support the weight of the mobile platform **100** during retrieval. The second stage tether **740** may also be referred to as a retrieval carrier. Thus, each tether **738, 740** may have different loading capacities (*e.g.*, tension loading). As a consequence, whereas a polymer cable may be suitable the first stage tether **738,** a metal cable may be more appropriate for the second stage tether **740.** However, any material-type may be used for either stage tether **738, 740** as long as their respective loading requirements are satisfied.

[0060] The **Fig. 11B** also integrates the shutdown of the mobile platform **100** into the operation of the retrieval module **700.** Sealed inside the enclosure **200** may be one or more electro-magnets **726.** The electro-magnets **726** may be electrically connected to the control unit **300** and the power supply **500** via one or more lines **214.** While the mobile platform **100** is operating, the electro-magnets **726** maintain the latches **724** in the locked position. Thus, the buoyant body **720** is fixed to the enclosure **200.** At the appropriate time, electro-magnets **726** may be de-energized by terminating electrical power, which eliminates the magnetic connection. The buoyant body **702** then floats toward the surface of the liquid in the tank **10 (Fig. 1).** At the same time, the latches **724** move to the unlocked position, the switch assembly **250** shifts to the "off" position, which shuts down the mobile platform **100.** Thereafter, the mobile platform **100** may be retrieved by first pulling on the first stage tether **738** to retrieve the second stage tether **740** and then pulling up the submerged mobile platform **100** using the second stage tether **740.** It should be noted that a switch assembly **250** may also be integrated with the retrieval module of the **Fig. 11A** embodiment.

[0061] Referring now to **Figs. 11C-D**, there are shown devices that may be used to facilitate deployment and / or retrieval of a mobile platform **100. Fig. 11C** schematically illustrates a deployment assembly **760** that includes a dock **762** connected to a carrier **764.** The mobile platform **100** may connect to the dock **762** using a mechanical and / or magnetic coupling **763.** Optionally, the deployment assembly **760** may include a signal emitting beacon **766** that emits a wave **768**, such as an electro-magnetic or acoustical wave. The carrier **764** may be a passive physical line, such as a cable, wire or rope. By "passive," it is meant that the carrier **764** does not convey signals, pressurized fluids, or power. The carrier **764** has sufficient tensile strength to convey the deployment assembly **760** and mobile platform **100** into the tank **10.** In one mode of use, the deployment assembly **760** and mobile platform **100** may be lowered into a tank **10** together. Thereafter, the mobile platform **100** decouples from the dock **762** and moves freely, as shown in hidden lines. The deployment assembly **760** may be extracted from or remain in the tank **10** during operations. If the deployment assembly **760** remains in the tank

10 during operations, the carrier **764** may provide a physical, passive connection between the dock **762** and an object (not shown) inside or outside of the tank **10.** Upon completion of operations, the mobile platform **100** may return and re-connect to the dock **762** for retrieval or be retrieved in another manner. In some embodiments, the carrier **764** may be used without the dock **762** to deploy and / or retrieve the mobile platform **100.** That is, the carrier **764** may be configured to function as a deployment carrier and / or a retrieval carrier.

[0062] If present, the beacon **766** may emit a signal that the mobile platform **100** may use for navigation or other purposes. It should be understood that the beacon **766** is merely representative of any number of devices that may be carried by the dock **762.** For instance, a control unit (not shown) may be carried by the dock **762** and communicate with the mobile platform **100.**

[0063] Fig. 11D schematically illustrates a passive carrier **780** that remains connected to the mobile platform **100** during operations in the tank **10.** The passive carrier **780** may be a rope, wire, cable, or other tension-bearing member that may be used to move or simply locate the mobile platform **100.** As noted above, a passive carrier does not communicate any power, signals, or materials (*e.g.*, pressurized gas) to or from the mobile platform **100.** Rather, the carrier **780** may provide a physical, passive connection to an object inside or outside of the tank **10.** Thus, the carrier **780** may act as a deployment and / or retrieval mechanism or a line that allows the mobile platform **100** to be located.

[0064] Referring now to **Figs. 12A-B**, there is shown another embodiment of an intelligent mobile platform **100** according to the present disclosure. Similar to the embodiment of **Fig. 2**, the mobile platform **100** includes an enclosure **200**, a control unit **300**, a propulsion system **400**, a power supply **500**, and a task module **600.** The lid **204** of the enclosure **200** is shown only in **Fig. 12B** to better illustrate the interior **208** in **Fig. 12A.** The details and variants of the enclosure **200**, propulsion system **400**, power supply **500**, and the task module **600** have been described in detail above. The **Fig. 12A** embodiment includes a non-momentary switch **250** as described in connection with **Fig. 10** and a retrieval module **700** as described in connection with **Fig. 11A-B**. An eyelet **240** may be fixed to the lid **204.** The eyelet **240** may be any loop, hook, or other body to which a lifting / handling device can be releasably connected. The control unit **300** of the **Figs. 12A-B** embodiment is discussed below.

[0065] Referring to **Fig. 13**, the control unit **300** of the **Figs. 12A-B** mobile platform includes a navigation module **304** having two or more distinct types of sensing instruments. The first sensing instrument is a marker detector **306** that detects discontinuities as described previously in connection with **Figs. 4-5E.** The second sensing instrument may be a dynamic sensor **380** that estimates one or more navigation parameters. As used herein, a navigation parameter characterizes an absolute and / or a relative position of the mobile platform **100** in a desired coordinate system (*e.g.*, x/y space, polar coordinate defined space) and / or orientation (*e.g.*, direction faced, inclination, etc.). For example, the dynamic sensor **380** may estimate a parameter such as a distance travelled, a degree of rotation, acceleration, tilt, and / or relative changes in the direction of movement. While referred to in the singular, it should be

understood that the dynamic sensor **380** may comprise a suite of two or more discrete and different sensors, each of which provide different information. Suitable dynamic sensors include, but are not limited to, odometers, RPM sensors, inclinometers, gyroscopes, and accelerometers. Still other dynamic sensors may sense operating parameters of motors, transmissions, and motor controllers (not shown). The information from a dynamic sensor **380** may be used to steer in a desired direction, reduce errant motion of the mobile platform **100 (Figs. 12A-B**), steer past obstacles, and / or identify locations of interest (*e.g.*, a retrieval point).

[0066] Some of the uses for the information provided by the dynamic sensor **380** may be illustrated with reference to **Fig. 14**, which shows a portion of a tank bottom wall **18** formed of steel plates, an obstacle such as a pillar **26**, and a retrieval point **382.** Referring to **Figs. 12A-B** and **13**, during operation, the mobile platform **100** may follow a path having a leg **384.** The mobile platform **100** may have started on the leg **384** upon the marker detector **306** detecting a discontinuity **320.** Thereafter, the dynamic sensor **380** may provide information that can be used to issue steering instructions to steer the mobile platform **100** along the leg **384.** Thus, for instance, the dynamic sensor **380** can detect if the mobile unit **100** has drifted to the left or right from a desired heading and quantify the amount of variance from the desired heading. Corrective steering commands can be issued based on this information.

[0067] During operation, the mobile platform **100** may encounter a number of obstacles. One common obstacle is a pillar **26.** Other obstacles include sumps, walls, bracing structures, debris, joints, etc. As noted previously, some are known whereas others have entered the tank **10** unintentionally. The mobile platform **100** may be programmed to handle such obstructions using a variety of techniques. For instance, upon encountering the obstacle **26**, the steering algorithm may direct the mobile platform **100** to incrementally change direction to maneuver around the obstacle **26** until the mobile platform **100** has returned to a heading of the prior leg **384.** Thereafter, the mobile platform **100** begins the next leg **386.**

[0068] The return to the heading of the prior leg **384** is enabled by the information provided by the dynamic sensor **380**. For instance, the dynamic sensor **380** can determine the degree of rotation and the distance travelled during the maneuvering. Additionally, when preset criteria are met, such as the conclusion of the task, the dynamic sensor **380** can provide information for steering the mobile platform **100** to the retrieval point **382.** For instance, the dynamic sensor **380** can determine the degree of rotation required to head toward the retrieval point **382** and the distance travelled while heading to the retrieval point **382.**

[0069] It should be understood that the mobile platform **100** does not necessarily carry all the above-described features and components within a single enclosure. Rather, in some embodiments, the above-described components may be dispersed into two or more separate enclosures that may be physically attached to one another. For instance, in some embodiments, an enclosure having only a power supply **500**, a propulsion system **400**, and task module **600** are in one mobile enclosure, and the remainder of the components, such as the control unit **300**, are in a separate enclosure.

[0070] An illustrative mode of use of the mobile platform of **Figs. 12A-B** will be discussed with reference to **Figs. 15** and **16A, B. Fig. 15** is a flow chart that identifies the several steps by which the mobile platform **100** is used to perform one or more functions in a tank **10. Fig. 16A** schematically illustrates the mobile platform **100** during insertion into a tank **10** and during operation and **Fig. 16B** schematically illustrates the mobile platform **100** ready for retrieval after operation. While not always the case, the tank **10** is shown filled with liquid **12**, such as a hydrocarbon, at a level that fully submerges the mobile platform **100.** Above the liquid body **12** is a gaseous body **14**, which may also be a hydrocarbon. Other substances, such as dirt and debris, may also be in the tank **10.**

[0071] At step **850**, the mobile platform **100** is activated while outside of the tank **10**, such as by using the switch **250**, to enter a pre-operation mode. At this time, the control unit 300 may initiate one or more diagnostic sweeps and provide an indication to a work crew that on-board systems are functional. Thereafter, the control unit **300** may enter a quiet mode while the work crew inserts the mobile platform **100** into the tank via the hatch **24** at step **852.** The mobile platform **100**, shown in hidden lines in **Fig. 16A,** may be lowered into the tank using a suitable deployment carrier **50** and bracing structure (not shown). The deployment carrier may be anon-rigid carrier such as tether, which may comprise a rope, cable, chain, etc. In other embodiments, the deployment carrier may be rigid, such as a pipe, pole, or tube. At step **854**, after the mobile platform **100** rests on the tank bottom wall **18**, the deployment carrier **50** is decoupled and retrieved and the hatch **24** may be closed.

[0072] At step **856**, the mobile platform **100** may execute a "countdown" phase during which the mobile platform **100** monitors one or more inputs, such as time and / or movement, to determine whether to enter a full operational mode.

[0073] Upon deciding to enter full operational mode, the control unit **300** may energize the necessary subsystems and begin execution of the pre-assigned task(s). It should be noted that the mobile platform **100** has not required a communication link with operators, human or otherwise, that are outside of the tank **10.** Therefore, all decisions to be made during operations may be done by the control unit **300** using pre-programmed instructions and by obtaining relevant information, *i.e.*, intelligently. However, in some variants, human or machines positioned external to the tank may interact with the mobile platform **100.** For example, striking the wall of the tank **10** may be used to impart an acoustic command signal to the mobile platform **100** *(e.g.,* "turn on," "turn off," "return to retrieval location," "switch operating modes," "transmit a signal," etc.).

[0074] Steering the mobile platform **100**, at step **858**, may include locating one or more discontinuities using the marker detector **306**, as described in reference to **Figs. 4-6A**, and estimating one or more navigation parameters using dynamic sensors as described in connection with **Figs. 13-14.** The control unit **300** processes this information to traverse the tank interior **22** using a predetermined methodology. It should be noted that the mobile platform **100** has no active physical connection after deployment as shown in **Fig. 16A,B.**

Specifically, no energy (e.g., electricity), data signals, or materials such as pressurized gases are communicated to the mobile platform **100** via a wire, cord, cable, pole, tube, pipe, or any other rigid or non-rigid conveyance carrier from a location external to the tank **10.** Thus, as used herein, an "active" line or carrier is one that communicates or transmits power, materials, or data signals while the mobile platform **100** is in the tank **10.** As noted above, the mobile platform **100** may have a passive carrier as discussed in connection with **Figs. 11C-D**. A "passive" line or carrier is one that does not communicate or transmit power, materials, or data signals while the mobile platform **100** is in the tank **10.**

[0075] Step **860**, which may be implemented for operations involving tank inspections, may be performed concurrently with step **858.** Using the sensing device as described in connection with **Fig. 13**, the mobile platform **100** scans one or more walls of the tank **10** using an inspection module such as the task module **600** shown in **Fig. 9A-B**. The task module **600** and the control unit **300** can collect, organize, and process the information required to generate a database of the wall thicknesses for the scanned areas of the tank **10.** The database may include the thicknesses of all sections of the tank bottom wall **18** or thicknesses of just the locations / sections that are "out of norm" *(i.e.,* different from a specified value or range). The walls inspected typically include the tank bottom wall **18.** It should be noted that for inspections, the sensing device used to inspect the walls of the tank **10**, such as ultrasonic sensors, may also be used as a marker detector **306.**

[0076] In one non-limiting method, the mobile platform **100** performs the scanning activity by first locating the edges, or sides, that define a perimeter of a plate. For instance, the mobile platform **100** may first locate a corner of the plate by tracing an edge until another edge is found, which identifies the corner. Tracing may be performed any number of ways including following a reversing path *(e.g.,* zigzag) along a detected edge. Next, the mobile platform **100** may steer parallel to one of the edges of that corner to locate the opposite corner. Locating the other corner then establishes the position of two parallel edges and one perpendicular edge of the plate. The mobile platform **100** may move incrementally along the parallel edges to locate the remaining corners of the plate. Thereafter, the mobile platform **100** may initiate a wall thickness scan of that plate. Once complete, the process can be repeated for another plate. In another non-limiting method, the mobile platform **100** may first identify the edges of all the plates making up the tank bottom wall **18** of the tank **10.** Afterwards, the mobile platform **100** can scan each of the plates. It should be noted that the multiple degrees of freedom along which the propulsion system **100** may move the mobile platform **100** enables efficient execution of the above task, as well as other tasks.

[0077] At step **862**, the mobile platform **100** begins the termination of operations. The termination may be triggered using any number of conditions. These conditions may be related to quality and / or quantity of information obtained during inspections, completion of assigned tasks, remaining power levels, operational considerations such as possible malfunctions, etc. One illustrative termination sequence may include navigating to a predetermined retrieval location. This location is below the hatch **24.** Alternatively, in an example beyond the scope of the claims if the mobile platform **100** has magnetic type external drive units, the mobile

platform **100** may drive to a location proximate to the hatch **24.** The magnetic type external drive units (not shown) will enable the mobile platform **100** hang effectively upside-down from the top wall **16.** Still other sequences may include simply remaining in place and transmitting a signal that identifies the location of the mobile platform **100.** The mobile platform **100** may be retrieved by hooking or otherwise connecting the mobile platform **100** to a suitable carrier, *e.g.,* the deployment carrier **50.** Thus, the deployment carrier **50** may be also be used to retrieve the mobile platform **100.** The mobile platform **100** may also be retrieved by using a separate retrieval mobile platform (*e.g.*, deployment assembly **760** of **Fig. 11C**) that can connect, to the mobile platform **100.**

[0078] Step **864** may be used for a mobile platform that includes a retrieval module **700**, such as that shown in **Figs. 11A-B**. After moving to a retrieval location or staying in place, the mobile platform **100** releases the buoyant body **702.** The buoyant body **702** floats to the surface of the liquid body or to a depth below the surface. Optionally, the buoyant body **702** may emit a signal, fluoresce, and / or be illuminated. Finally, the mobile platform **100** may power down all subsystems, except any device on the buoyant body **702** that emits a signal. At step **866**, the work crew can extract the mobile platform **100** by connecting a retrieval carrier, such as a cable or pole, to the buoyant body **702** or other part of the mobile platform **100.** Alternatively, the mobile platform **100** may be retrieved by using a released tether as discussed in connection with **Figs. 11A, B.**

[0079] The total "power down" or shut down of the mobile platform **100** at step **864** may be initiated by the control unit **300.** Alternatively, a retrieval module **700** as shown in **Fig. 11B** may be used to simultaneously release the retrieval body **702** and shut down the mobile platform **100.** By "power down" or "shut down," it is meant that the mobile platform **100** is in a state where no power is communicated to any sub-system and that no sub-system is consuming power or that no sub-system is consuming power at a level that could potentially generate a spark.

[0080] In some embodiments, one or more elements or components of the mobile platform **100** may remain in the tank **10** after retrieval. For example, the mobile platform **100** may deposit an object that functions as an active or passive marker to identify a retrieval point. The object left behind may also be a spent task module, a remnant of a deployment or retrieval carrier, or other component that does not require retrieval.

[0081] Among the many advantages of the teachings of the present disclosure, at least the following should be noted. One is that human presence was not required either inside or outside the tank **10** in order to operate the mobile platform **100.** Another advantage is that the mobile platform **100** performed the inspection while the tank **10** contained liquids. Thus, the tanks themselves can continue to be used as normal without service disruptions. Still another advantage is that the tank **10** is sealed by the hatch **24** during operation, which prevents the energetic substance **14** from escaping into the surrounding environment. Thus, a spark occurring external to the tank **10**, *e.g.,* near the hatch **24**, cannot ignite the energetic substance **12, 14** inside the tank **10.**

[0082] Referring to **Figs. 16A** and **B**, it should be appreciated that embodiments of the present disclosure that use ultrasonic sensing devices will operate with better resolution because the mobile platform **100** is submerged such that a liquid body extends between the mobile platform **100** and one or more surfaces of the tank **10.** The liquid body between the ultrasonic sensors and a wall of the tank provides a highly efficient wave transmitting medium through which acoustic energy can be transmitted. Notably, such a liquid body or layer is not present when inspections are performed by human personnel in air. Additionally, the ability of the mobile platform **100** to operate while fully submerged can also enable additional activities. For example, the mobile platform **100** may utilize acoustic receivers to detect sounds associated with leaking fluid. For acoustic detection, the mobile platform **100** may enter a semi-quiet mode wherein movement is halted and any subsystems that generate noise are shut down. In this semi-quiet mode, the acoustic receivers monitor the surrounding liquid body for acoustic signals caused by fluid leaking out of the tank **10.**

[0083] It should be appreciated that embodiments of the present disclosure that use the previously-described combinations of size and weight restrictions may facilitate the handling and deployment of the mobile platform **100** while also reducing the risk of damage to the tank in which a task is performed.

[0084] While step **860** of the **Fig. 15** method pertained to scanning walls of the tank **10** to determine thicknesses, it should be understood that the **Fig. 15** method may also be used to execute tasks related and unrelated to inspections. For example, other inspection methods such as visual scans can be performed. For example, cameras may be used to collect visual images of the tank walls such as the sides **20** and / or bottom **18.**

[0085] The above-described systems and related methods used discontinuities associated with the tank **10** (**Fig. 1**) as navigation markers, or simply 'markers,' to control movement. The welds and plate overlaps representing these discontinuities were formed while mating of steel panels and thus may be considered structural elements of the tank **10.** Thus, the above-described embodiments may be considered to intelligently traverse an interior of a tank **10** using structural markers. However, other embodiments of the present disclosure may utilize other types of markers.

[0086] Referring now to **Fig. 17**, there are shown several types of markers that may be used to control the movement of the mobile platform **100** in the tank **10.** By interacting with these markers, the control unit **300 (Fig. 2)** acquires an awareness of the location and /or orientation of the mobile platform **100** relative to a given location in the tank **10.**

[0087] A structural marker such as a discontinuity may be considered a passive marker. By passive, it is meant that the marker is inert and does not originate a signal detected by the mobile platform **100.** Another type of marker is energy emitting objects **902a,b,c,d** or 'active markers,' that emit a magnetic, electromagnetic, acoustic, and / or optical signal. Active markers may be positioned inside and / or outside of the tank **10.** For example, **Fig. 17** depicts

internal active markers **902a,b** and external active markers **902c,d.** Active markers may be utilized in a variety of methodologies. For example, a central internal active marker can be using by the mobile platform **100** as a homing beacon to identify a particular location in the tank **10.** Two or more spaced apart active markers may be used by the mobile platform **100** to locate itself and / or a direction within the tank **10.**

[0088] In some embodiments, a marker is not rigidly fixed to the tank **10.** For example, a marker **910** may float in a liquid body **12.** The marker **910** may float at the surface or be submerged at a selected depth below the surface. Optionally, a tether **912** may connect the marker **910** to the tank **10.** The marker **910** may be active; *e.g.*, transmit an energy signal such as an acoustic wave. The marker **910** may also be passive; *e.g.*, hang at a depth low enough as to allow contact with the mobile platform **100.**

[0089] Figs. 18A-B are flow charts of various guidance and navigation methodologies that may use the above-described markers.

[0090] Referring to **Figs. 12A-B, 13**, **17** and **Fig. 18A**, the control unit **300** processes signals from active markers in order to generate command signals to operate the mobile platform **100.** For example, at step **1100**, the marker detector **306** may detect distinct signals emitted by a plurality of internal and / or external markers **902 a-d.** At step **1102**, the control unit **300** may process the signals to estimate a current position of mobile platform **100**. Optionally, the control unit **300** may also use pre-programmed information such as the dimensions of the tank **10**, relative locations of the active markers **902 a-d**, as well as navigation parameters such as real-time information pertaining to orientation and direction of movement obtained by dynamic sensors **380.** At step **1104**, the control unit **300** issues a command signal to a subsystem such as a propulsion system **400** or the task module **600.**

[0091] Referring still to **Figs. 12A-B, 13,** and **17**, in the **Fig. 18A** and **Fig. 18B** methods, the control unit **300** may have one or more memory modules **390**, **392.** The memory module **390** stores information collected during operation. This information may be dynamically updated and include information such as position of markers and current position / heading /orientation of the mobile platform **100.** The memory module **390** may also store measured data indicative of the thickness of walls **16, 18, 20** of the tank **10.** The memory module **392** may include preprogrammed data that may be accessed while the mobile platform **100** is operating. The preprogrammed data may be a digital representation (or map) of a discontinuity pattern of one or more walls of the tank **10.** The discontinuity may be the weld / overlap pattern of one or more walls **26, 18,20** of the tank **10.** This information may have been obtained during a previous operation in the tank. At step **1200**, the marker detector **306** may detect the discontinuity and generate responsive signals. At step **1202**, the control unit **300** may process the marker detector signals along with the information in the stored map to estimate a current position and / or orientation of mobile platform **100.** At step **1204**, the control unit **300** issues a command signal to a subsystem such as a propulsion system **400** or a task module **600.**

[0092] Other navigation and guidance schemes may define a point and a line, such as an

edge leading to a tank wall or by any two points. A mobile platform **100** using such a scheme may have a control unit **300** programmed to estimate distances travelled using "dead reckoning" (*e.g.*, by counting wheel revolutions). Suitable sensors in the propulsion system **400** may be used to sense when progress has been impeded by an obstacle (*e.g.*, power variance) and / or travel reasonably straight without external references (*e.g.*, RPM sensors on wheels, drive shaft, rotor, or other rotating element of the propulsion system). Optionally, an internal navigation unit may be used to supplement navigation. The control unit **300** may be programmed to generate a "map" and proceed methodically through the tank **10** by referencing the map and performing the dead reckoning. The map, and any information gathered such as wall thickness data, may be correlated with the actual layout of the tank using common pattern mapping techniques.

[0093] Still another navigation method may not use sense / detect markers or use inertial navigation units. Instead, the mobile platform **100** may be programmed to traverse the tank **10** and take pre-assigned actions when encountering obstacles (*e.g.*, turn until travel is unimpeded). Any information gathered, such as wall thickness data, may be correlated with the actual layout of the tank using common pattern mapping techniques.

[0094] The methodologies discussed above are not mutually exclusive. That is, portions of each of the described methods may be blended or separate methodologies may be used concurrently. Some navigating methods involve generating a 'map' while performing one or more assigned functions. Other methods involve using a previously generated map in order to navigate to one or more predetermined locations.

[0095] From the above, it should be appreciated that what has been disclosed includes, in part, an apparatus for performing a selected task in a tank at least partially filled with an energetic substance. The apparatus may include an inherently safe mobile platform that comprises at least one control unit, at least one marker detector, at least one propulsion system, at least one power supply, and at least one inherently safe enclosure.

[0096] The at least one inherently safe enclosure is configured to prevent a spark occurring inside the at least one inherently safe enclosure from passing to an exterior of the at least one inherently safe enclosure, the spark being capable of igniting the energetic substance. All spark-generating components of the mobile platform are positioned inside the at least one inherently safe enclosure.

[0097] The at least one marker detector is configured to detect at least one marker associated with the tank. The at least one control unit is configured to generate at least one control signal based on the at least one detected marker. The propulsion system moves the mobile platform in response to the at least one generated control signal. The propulsion system has a rotary power device positioned inside the at least one inherently safe enclosure that supplies power to a drive assembly positioned outside the at least one inherently safe enclosure. The power supply energizes at least the at least one marker detector, the at least one control unit, and the at least one rotary power device. No active physical carrier connects the mobile platform to an

object exterior of the tank while the mobile platform is in the tank.

[0098] Variants of the mobile platform may include arrangements wherein: the at least one inherently safe enclosure is configured to not exhibit plastic deformation that forms a path allowing a spark occurring inside the at least one inherently safe enclosure from passing to an exterior of the at least one inherently safe enclosure after an interior of the at least one inherently safe enclosure is subjected to at least three and one-half bar for at least ten seconds; the mobile platform is configured to have at least two different degrees of freedom in the tank and to move along the at least two different degrees of freedom using the propulsion system; the mobile platform weighs less than 10,000 pounds (4,536 kg); the at least one control unit is programmed to determine a heading for the mobile platform based on the at least one detected marker, the heading being used to generate the at least one control signal; there are no physical carriers connecting the mobile platform to an object outside the tank; and / or the at least one power supply supplies sufficient power to fully energize at least the at least one control unit, the at least one marker detector, and the at least one propulsion system. Also, in variants, the apparatus may include a passive carrier connected to the mobile platform while the mobile platform moves in the tank.

[0099] In certain applications, the energetic substance is a liquid that contacts the mobile platform and an interior surface of the tank to form a wave transmitting medium. In such applications, the mobile platform is configured to transmit a wave and detect a reflection of the transmitted wave. The mobile platform can store information representative of the detected reflection in a memory module.

[0100] Further, while the above-described embodiments of the mobile platform **100** do not use a physical umbilical to receive power and / or communicate data, it is within the scope of the present disclosure that a mobile platform **100** may incorporate a carrier. The carrier may be a signal conveying media, *e.g.*, a conducting cable or simply a cable that may effectively "leash" the mobile platform **100** to another object.

[0101] Referring to **Fig. 1**, it should be noted that structures for storing energetic substances (**12, 14**), such as the tank **10**, may be constructed in a manner that can hinder the deployment into and retrieval out of an interior **22** of the tank **10.** For example, access to the interior **22** may only be available through the hatch **24**, which is positioned on the top wall **16.** In many instances, access to objects in the interior **22** is limited to the zone or area in the immediate vicinity of the hatch **24.** Limitations in the ability to detect the presence of an object, to identify the object, and / or manually reach and contact the object generally define such a zone or area. For instance, objects located immediately adjacent to the vertical wall **20** may be undetectable to personnel and not physically accessible without expending considerable effort and employing relatively complex lifting and handling equipment. Moreover, the interior **22** may contain energetic substances (**12, 14**), which may be non-conductive, that may require additional restrictions to the retrieval activity. As noted above, some classes of hydrocarbon liquids and gases are non-conductive. However, the teachings of the present disclosure may be readily applied to environments wherein energetic and / or non-conductive substances are

not present. Certain teachings of the present disclosure are directed to facilitating retrieval of mobile platforms deployed in such environments.

[0102] Exemplary retrieval devices and related methods have already been discussed in connection with **Figs. 11A-D**, **15**, and **16B**. Referring now to **Fig. 19**, there is schematically illustrated another non-limiting embodiment of the retrieval module **700** configured and implemented to simplify locating and retrieving the mobile platform **100** from inside the tank **10.**

[0103] For simplicity, the mobile platform **100** to be retrieved may be configured to include an enclosure **200**, a control unit **300**, a propulsion system **400**, and a power supply **500.** These components and sub-systems have been already discussed above and will not be described in further detail. It is emphasized that the configuration of these components and sub-systems are not limited to any particular previously described embodiment. For example, the enclosure **200** need not be inherently safe. Moreover, two or more enclosures may form the enclosure **200**, with each of these separate enclosures acting as housing structures for different components. Further, optionally, the mobile platform **100** may be used in conjunction with a carrier **1002**, which may be a passive or active carrier. Such carriers have already been described and will not be described in further detail.

[0104] The mobile platform includes a retrieval module **700** disposed at least partially on the enclosure **200.** That is, the parts making up the retrieval module **700** may be internal and / or external to the enclosure **200.** Also, some parts may be embedded in a wall or body of the enclosure **200.** The retrieval module includes a buoyant body **702**, a primary tether **1100**, and a secondary tether **1102.** The buoyant body **702** is similar to that previously described. The primary tether **1100** may be the same as the tether **738** of **Fig. 11B.**

[0105] In one arrangement, the primary tether **1100** and the secondary tether **1102** are directly connected to one another, the primary tether **1100** directly connects to the buoyant body **702**, and the secondary tether **1102** directly connects to the enclosure **200.** An example of this configuration is illustrated in **Fig. 11B**, wherein the primary tether **1100** is formed by the first stage tether **738** and the flexible member **742** and the secondary tether **1102** is formed by the second stage tether **740.** It should be noted that in this arrangement while the first stage tether **738** and **742** is shown as attached to the enclosure **200**, the attachment is not one through which a force, such as tension, is intended to be transmitted during retrieval of the mobile platform **100.** Thus, as used herein, the term "connection" refers to a functional engagement wherein there is a communication of force *(e.g.,* tension) or signals (*i.e.*, power or data) between two or more locations as opposed to merely holding one body stationary relative to another body.

[0106] In the **Fig. 11B** arrangement, the primary tether **1100** is indirectly connected to the enclosure **200** via the secondary tether **1102** and the secondary tether **1102** is indirectly connected to the buoyant body **702** via the primary tether **1100.** By "indirect" connection, it is meant that physical engagement occurs through an intervening and functionally distinct device or component.

[0107] Referring now to **Fig. 20A**, in another arrangement, the primary tether **1100** and the secondary tether are both directly connected to the buoyant body **702** and to the enclosure **200.** It should be noted that the direct connection may include one or more elements specifically configured to form a connection, such as a chain, cable, or buckle. For instance, a portion of the secondary tether **1102** may be used to connect the primary tether **1100** to the buoyant body **702.** A cavity, reel, or spool (not shown) inside or outside the buoyant body **702** may be used to store a length of the secondary tether **1102.**

[0108] In the Fig. **20A** arrangement, the primary tether **1100** is configured to release the secondary tether **1102** by severing in some manner. For instance, the connection between the primary tether **1100** and the enclosure **200** can be broken by using a suitable breaking force or by transmitting a signal. **Fig. 20A** shows the retrieval module **700** after the buoyant body **702** has been released and rises toward a surface **1116** of the non-conductive, liquid energetic substance **12.** The primary tether **1100** connects the buoyant body **702** to the enclosure **200**, while the secondary tether **1102** is not under tension at a magnitude occurring during the retrieval of the mobile platform **100. Fig. 20B** shows the retrieval module **700** of **Fig. 20A** after the primary tether **1100** has been disconnected from the enclosure **200** and the buoyant body **702** has been extracted from the non-conductive, liquid energetic substance **12.** In alternate embodiments, the primary tether **1100** could decouple from only the buoyant member **702** or decouple from both the enclosure **200** and the buoyant member **702.** The primary tether **1100** may also sever at an intermediate location thereby releasing the buoyant member **702** from the enclosure **200** while having a severed portion connected to both. Now, the secondary tether **1102** can act as a load bearing retrieval member for pulling up the mobile platform **200** toward the surface **1116** of the non-conductive, liquid energetic substance **12.**

[0109] Referring to **Fig. 20C**, there is shown another arrangement wherein the primary tether **1100** is housed within the buoyant body **702**. When activated, the buoyant body **702** rises toward a surface **1116** of the non-conductive, liquid energetic substance **12.** As the buoyant body **702** rises, the primary tether **1100** unspools, falls, or otherwise exits the buoyant body **702.**

[0110] While illustrated as single, unitary bodies, it should be understood that the buoyant body **702**, the primary tether **1100**, and the secondary tether **1102**, may be formed of two or more separate portions, sections, or segments.

[0111] Fig. 21 illustrates a non-limiting embodiment of a retrieval method **1200** according to the present disclosure. Referring to **Figs. 19 and 20A,B,** the method **1200** may be of particular use when the tank **10** is at least partially filled with a non-conductive, energetic substance **12, 14.** At step **1202,** the mobile platform **100** may be configured as shown in **Fig. 19.** However, the method **1200** may be used to retrieve other devices not described in the present disclosure. At step **1204,** personnel predetermines the buoyant body retrieval zone **1104** within the tank **10.** It should be noted that the hatch **24** permits relatively easy access to certain interior areas of the tank **100** directly below the hatch **24.** However, because the hatch **24** is

much smaller than the top **20,** limits access to areas closer to the vertical wall **20.** Thus, the buoyant body retrieval zone **1104** may be based on the limitation in lifting, handling, and access associated with performing retrievals through the hatch **24.**

[0112] At step **1206**, the mobile platform **100** is lowered into the tank **10** using a deployment carrier **50 (Fig. 16A).** Other embodiments may use the deployment carriers **764** or **780 (Figs. 11C, 11D,** respectively). At step **1208**, the enclosure **200** is submerged in the non-conductive, liquid energetic substance **12.** If two or more separate enclosures are present, then only one of those separate enclosure needs be submerged. Moreover, the enclosure **200** does not have be fully submerged; *i.e.*, a partially submerged state may be suitable in certain instances. At step **1209**, the mobile platform **100** may be moved by the propulsion system **400** to perform one or more tasks in the tank **10.**

[0113] At step **1210**, which may be at or near the conclusion of operations, the buoyant body **702** is released from the enclosure **200.** It should be noted that the buoyant body **702** and the primary tether **1100** are still connected to the enclosure **200** by the secondary tether **1102.** The step **1212**, positioning of the released buoyant body **702** occurs within the buoyant body retrieval zone **1106** by using the at least one primary tether **1100.** At step **1214**, retrieving the primary tether **1100** is performed by using the buoyant body **702.** For example, a retrieval member **1110** may be inserted into the tank **10** through the hatch **24** to capture the buoyant body **702.** The retrieval member **1110** may be a pole, hook, lasso, net, rod or other elongated member. At step **1216**, the primary tether **1100** may be used to release the secondary tether **1102.** For instance, the primary tether **1100** may be used to transmit a force or signal to the secondary tether **1102.** Suitable forces or signals may be tension, torsion, vibration, etc. At step **1218**, the secondary tether **1102** is used to retrieve the mobile platform **100** from inside the tank **10** to outside the tank **10.** The retrieval member **1110** may be inserted through the hatch **24** to retrieve the buoyant body **702**, the primary tether **1100**, and /or the secondary tether **1102.** It should be noted that other devices such as the primary tether **1100** and / or additional cables, wires, or other retrieval members may be used in conjunction with the secondary tether **1102** to retrieve the mobile platform **100.**

[0114] In embodiments, the primary tether **1102** may be configured to position the buoyant body **702** in the buoyant body retrieval zone **1104** by estimating a height of the non-conductive, liquid energetic substance **12** above the mobile platform **100** inside the tank **10** and selecting a length of the primary tether **1100** based, at least in part, on the estimated height of the non-conductive, liquid energetic substance **12** above the mobile platform **100** inside the tank **10**. In some methods, the length of the primary tether **1100** is also selected using, at least in part, a distance between a retrieval location **1112** of the mobile platform **100** and a wall **20** of the tank **10.** In other methods, the length of the primary tether **1110** is less than the square root of the sum of the square of the estimated height of the non-conductive, liquid energetic substance **12** above the mobile platform **100** inside the tank **10** and the square of a distance from the retrieval location **1112** of the mobile platform **100** to a farthest point **1114** on the wall **20** of the tank **10** at a level of the retrieval location **1112.**

[0115] As discussed previously in connection with **Fig. 19**, the primary tether **1100** is used to release the secondary tether **1102.** In one arrangement, the primary tether **1100** is configured to release the secondary tether **1102** in response to an applied predetermined releasing force. The releasing force may be selected to actuate a lever, break a frangible element, overcome frictional force, overcome a pre-tension in an object, bend, twist, or otherwise deform an object, overcome stored tension or spring force, or otherwise decouple the secondary tether **1102** from a suitable retaining mechanism. During retrieval, applying a force that is at least as great as the predetermined releasing force to the primary tether **1100** releases the secondary tether **1102.** In one non-limiting method, the predetermined releasing force is greater than a net buoyancy of the buoyant body **702** in the non-conductive, liquid energetic substance **12** and less than a net downward force of the mobile platform **100** in the non-conductive, liquid energetic substance **12.**

[0116] Additional variants of the method **1200** include sizing the secondary tether to be at least long enough to traverse a distance between the mobile platform **100** and a location proximate to a top wall **16** of the tank **100** and selecting a combined length of the primary tether **1100** and the secondary tether **1102** is at least long enough to traverse a distance between the mobile platform **100** and a location proximate to a top wall **16** of the tank **100.** One skilled in the art would understand that what is "proximate" will depend on a position of the buoyant body **702** that is close enough for personnel to reach and retrieve the buoyant body **702** or primary tether **1100** from the hatch **24.**

[0117] In some applications, the secondary tether **1102** is used to pull the mobile platform **100** either partially or fully out of the tank **10.** For example, the secondary tether **1102** may be used to pull up and support the mobile platform **100** at a surface **1116** of the non-conductive, liquid energetic substance **12.** Alternatively, the secondary tether **1102** may be used to lift the mobile platform **100** out of the non-conductive, liquid energetic substance **12.** In situations such as when a floating roof is present, the length of the primary tether **1100** may be selected to maintain a predetermined gap between the buoyant body **702** and a top wall **16** of the tank **10.**

[0118] Referring to **Figs. 1 and 2**, in certain situations, it may be desirable to reduce a voltage differential between the mobile platform **100** and the tank **10** and/or other surrounding electrically conductive structures before completing retrieval of the mobile platform **100.** Such a voltage differential may arise from an accumulation of electrical charge on the mobile platform **100** due to relative motion between the mobile platform **100** and contact with an adjacent surface and / or the operation of consumers of electrical energy onboard the mobile platform **100.** The adjacent surface may be a surface defining a wall **16, 18, 20** of a tank **10,** a pillar **26** of a tank **10,** and / or the non-conductive, liquid energetic substance **12.** Exemplary electrical power consumers include, but are not limited to, the control unit **300,** the marker detector **306 (Fig. 4),** the dynamic sensor **380 (Fig. 13),** the propulsion system **400,** and the task module **600 (Fig. 2).** The type and number of electrical power consumers will depend on the particular configuration of the mobile platform **100.** For simplicity, the term "on" will be used herein to describe an electrical charge accumulation "on" and "in" the mobile platform **100.**

[0119] Further, while partially or completely submerged in the non-conductive, liquid energetic substance **12,** the mobile platform **100** may be electrically isolated from the tank **10** by the non-conductive, liquid energetic substance **12** and possibly other non-conductive material. Such other non-conductive material may include paint, coatings, rust, and /or sludge. Electrical isolation may also occur if the mobile platform **100** is partially or completely immersed in a non-conductive, gaseous energetic substance **14** inside the tank **10.** When encountering such electrical isolation, the rate of electrical charge dissipation from the mobile platform **100** may be lower than the rate of electrical charge accumulation, which may cause a relevant amount of electrical charge accumulation on the mobile platform **100.**

[0120] Referring now to **Fig. 22,** there is shown a non-limiting embodiment of a retrieval system **1001** for retrieving a mobile platform **100** from a tank **10** at least partially filled with a non-conductive, energetic substance **12, 14.** As described below, the retrieval system **1001** may be used to reduce and/or minimize this charge accumulation before or during the retrieval of the mobile platform **100** from inside the tank **(10)** to outside the tank **(10).**

[0121] The mobile platform **100** to be retrieved may be configured to include an enclosure **200,** a control unit **300,** a propulsion system **400,** and a power supply **500.** These components and sub-systems have been already discussed above and will not be described in further detail. A generic electrical power consumer is shown with numeral **1330,** which is representative of any device that consumes electrical power, including but not limited to, the control unit **300,** the marker detector **306 (Fig. 4),** the dynamic sensor **380 (Fig. 13),** the propulsion system **400,** the task module **600 (Fig. 2),** and / or any device not described in the present specification that consumes electrical power. As noted previously, the configuration of these components and sub-systems are not limited to any previously described embodiment, *e.g.*, the enclosure **200** need not be inherently safe and the mobile platform **100** may be used in conjunction with a carrier (not shown), which may be a passive or active carrier. Also, two or more enclosures may form the enclosure **200**, with each of these separate enclosures acting as housing structures for different components. Moreover, other mobile platforms may include additional components or fewer components.

[0122] The mobile platform **100** also includes a retrieval module **700** disposed at least partially on the enclosure **200.** That is, the parts making up the retrieval module **700** may be internal and / or external to the enclosure **200.** Also, some parts may be embedded in a wall or body of the enclosure **200.** In one arrangement, the retrieval module **700** may include a buoyant body **702**, a tether **1100**, and an electrically conductive member **1300.** The retrieval system 1001 further includes a voltage differential neutralizing body **1302** and an electrically conductive cable **1304.**

[0123] In one embodiment, the tether **1100** connects the buoyant body **702** to the enclosure **200**, the tether having at least a portion that is not conductive. Because the tether **1100** electrically isolates the buoyant body **702** from the enclosure 200, proximity or contact with the buoyant body **702**, or the tether **1100** near the buoyant body **702**, will not form an electrical connection between the buoyant body **702** and the enclosure **200.** That is, at least a portion or

section of the tether **1100** is sufficiently not conductive to prevent a transmission of electrical energy between the buoyant body **702** and the enclosure **200.** The buoyant body **702** is similar to that previously described. In configurations where the tether **1100** is fully submerged in the non-conductive, liquid energetic substance **12,** the tether **1100** may not need to have a portion that is not conductive.

[0124] The electrically conductive member **1300** may be an object, body, plate, coating, or structure that is electrically connected to one or more regions on the enclosure **200.** The electrical connection is sufficient to transfer some, substantially all, or all of the electrical charge accumulated in and / or on the enclosure **200** to any electrically conductive object in electrical communication with the electrically conductive member **1300**, assuming the appropriate voltage differential exists. The voltage differential neutralizing body **1302** may be an object, device, body, plate, coating, or structure into which an electrical charge can be discharged. In some arrangements, the tank **10** or ground **30** can act as the voltage differential neutralizing body **1302.** The electrically conductive cable **1304** may be a conventional cable configured to transmit electrical energy between a neutralizing body end **1306** and a mobile platform end **1308.** In embodiments, the electrically conductive cable **1304** may include an insulating outer sheath (not shown).

[0125] Referring now to **Fig. 23**, there is shown a conveyance device **1310** for conveying the mobile platform end **1308** of the electrically conductive cable **1304** to the electrically conductive member **1300** on the enclosure **200** of the mobile platform **100.** The conveyance device **1310** may be a harness, ring, sleeve or other suitable sliding member that can slide along the tether **1100.** The conveyance device **1310** has sufficient mass to pull the mobile platform end **1308** downward to the electrically conductive member **1300.** The mobile platform end **1308** may include a suitable connector **1314** that electrically connects to the electrically conductive member **1300.** There may be a direct physical connection between the connector **1314** and the electrically conductive member **1300** or an indirect connection that allows electrical communication. The electrically conductive member **1300** is shown as electrically connected to one localized region of the enclosure **200.** However, in embodiments, the electrically conductive member **1300** may be in electrical communication with two or more discrete regions of the enclosure **200** at which electrical charges may accumulate. Referring to **Fig. 22**, the neutralizing body end **1306** of the electrically conductive cable **1304** may include a suitable connector **1316** that electrically connects to the voltage differential neutralizing body **1302.** Likewise, the connection may be a direct physical connection or an indirect connection.

[0126] While illustrated as single, unitary bodies, it should be understood that the described devices, including, but not limited to the buoyant body **702**, and the tether **1100**, the electrically conductive member **1300**, may be formed of two or more separate portions, sections, or segments. Further, as discussed previously, components of the mobile platform **100**, such as the enclosure **200**, may be formed of two or more separate enclosures.

[0127] Additionally, some variants of the retrieval module **700** of **Figs. 11A, B** and **19** include a primary tether **1100** that is constructed to be buoyant in the liquid energetic material **12.** For

example, the primary tether **1100** may include one or more materials that make the primary tether **1100** positively buoyant in the liquid energetic material **12.** Alternatively or additionally, the primary tether **1100** may include buoyant bodies distributed along the length of the primary tether **1100.** In such variants, the buoyant body **702** is considered integral with the primary tether **1100.**

[0128] Fig. 24 illustrates a non-limiting embodiment of a retrieval method **1400** not according to the present invention that employs the retrieval system **1001** of **Figs. 22** and **23.** The method **1400** may be of particular use when the tank **10** is at least partially filled with a non-conductive, energetic substance **12, 14.** At step **1402,** the mobile platform **100** to be retrieved may be configured as shown in **Fig. 22.** However, the method **1400** may be used to retrieve other mobile devices not described in the present disclosure.

[0129] At step **1404,** the mobile platform **100** is lowered into the tank **10** using a deployment carrier **50 (Fig. 16A).** Other embodiments may use the deployment carriers **764** or **780 (Figs. 11C, 11D,** respectively) or other suitable systems for lowering the mobile platform **100** into the tank **10.** At step **1406**, the enclosure **200** is submerged in the non-conductive, liquid energetic substance **12.** If two or more separate enclosures are present, then only one of those separate enclosure needs be submerged. Moreover, the enclosure **200** does not have to be fully submerged; *i.e.,* a partially submerged state may be suitable in certain instances. It should be noted after step **1406**, some components used in conjunction with the mobile platform **100**, such as an active or passive carrier (not shown) may not be submerged. At step **1408**, the mobile platform **100** is moved using the propulsion system **400.** The movement may be in connection with performing an assigned task or some other function. At step **1410,** which may be at or near the conclusion of completing the assigned task(s) and / or function(s), the buoyant body **702** is released to convey the tether **1100** toward a surface **1116** of the non-conductive, liquid energetic substance **12.**

[0130] At step **1412,** the electrically conductive cable **1304** is conveyed to the electrically conductive member **1300** of the mobile platform **100** using the tether **1100.** At step **1414,** the neutralizing body end **1306** of the electrically conductive cable **1304** is connected to the voltage differential neutralizing body **1302** in a "spark inhibiting ambient condition." As used herein, a spark inhibiting condition is a condition wherein ambient conditions in which the connection is being made are sufficiently deficient in oxygen and / or an energetic substance to preclude a spark from igniting an energetic substance, if such an energetic substance is present.

[0131] At step **1416,** the mobile platform end **1308** of the electrically conductive cable **1304** is connected electrically to the electrically conductive member **1300** of the mobile platform **100** while the electrically conductive member **1300** is below the surface **1116** of the non-conductive, liquid energetic substance **12.** A fully submerged condition is considered a "spark inhibiting ambient condition" due to a suitable deficiency of oxygen.

[0132] In conjunction with the execution of steps **1412, 1414,** and **1416,** the connector **1314**

may be conveyed to the mobile platform **100** using the tether **1100** and connected electrically to the electrically conductive member **1300.** Depending on the system used, an exemplary method may involve retrieving the buoyant body **702** with a retrieval member **1110,** attaching an electrically conductive mobile platform end **1308** of the electrically conductive cable **1304** to the tether **1100,** and sliding the electrically conductive mobile platform end **1308** along the tether **1100** to the mobile platform **100.** Thereafter, the electrically conductive mobile platform end **1308** is connected electrically to the electrically conductive member **1300.**

[0133] At step **1418,** the mobile platform **100** is retrieved from inside to outside of the tank **10.**

[0134] In variants, personnel may first estimate when a voltage differential between the mobile platform **100** and the tank **10** is below a predetermined value and thereafter retrieve the mobile platform **100** from inside to outside of the tank **10.** The predetermined value may be a voltage differential that cannot generate a spark capable of igniting one or more energetic substances in or around the tank **10.** The estimation may be based on measurements, theoretical calculations or modeling, and / or historical information.

[0135] Figs. 25A,B are flow charts depicting other sequences for electrical connection of the electrically conductive cable **1304** to the voltage differential neutralizing body **1302** and the electrically conductive member **1200.**

[0136] In **Fig. 25A,** the steps **1414** and **1416** are be performed in reverse order. That is, step **1416,** wherein the mobile platform end **1308** of the electrically conductive cable **1304** is connected electrically to the electrically conductive member **1300,** can be performed before step **1414,** wherein the neutralizing body end **1306** of the electrically conductive cable **1304** is connected to the voltage differential neutralizing body **1302.**

[0137] In the **Fig. 25B** method, the initial step is step **1414,** wherein the neutralizing body end **1306** of the electrically conductive cable **1304** is connected to the voltage differential neutralizing body **1302.** Next, step **1412** is taken, in which the electrically conductive cable **1304** is conveyed to the electrically conductive member **1300** of the mobile platform **100** using the tether **1100.** Thereafter, step **1416** is taken, in which the mobile platform end **1308** of the electrically conductive cable **1304** is connected electrically to the electrically conductive member **1300.** Finally, at step **1418,** the mobile platform **100** is retrieved from inside to outside of the tank **10.**

[0138] As discussed previously in connection with the embodiment of **Fig. 22,** when the mobile platform **100** is operated in an environment that creates electrical isolation, the rate of electrical charge dissipation from the mobile platform **100** may be lower than the rate of electrical charge accumulation, which may cause a relevant amount of electrical charge accumulation on the mobile platform **100. Figs. 10** and **26** illustrate non-limiting embodiments of a mobile platform **100** that uses a charge accumulation control system (CACS) to reduce and/or minimize this charge accumulation or the rate of increase of this charge accumulation prior to and during retrieval of the mobile platform **100.**

[0139] In the **Fig. 10** embodiment, a switch assembly **250** for communicating with the mobile platform **100** is described as configured to shift between power states, activate or de-activate sub-systems, initiate pre-programmed instructions, etc. Near or at the end of operations, the switch assembly **250** shifts to the "off" position, which shuts down the mobile platform **100.** The shutdown of the mobile platform **100** effectively stops the relative motion between the non-conductive, liquid energetic substance **12** and the at least a portion of the mobile platform **100** contacting the non-conductive, liquid energetic substance **12** while the mobile platform **100** is inside the tank **10** and prevents any such relative motion later while the mobile platform **100** is inside the tank **10** and also terminates the supplied power and prevents a reengagement of the supplied power later while the mobile platform **100** is inside the tank **10.**

[0140] Fig. 26 illustrates another CACS **1003** for controlling a charge accumulation between a mobile platform **100** and a tank **10** at least partially filled with a non-conductive, energetic substance **12, 14.** The mobile platform **100** may be configured to include an enclosure **200,** a control unit **300,** a propulsion system **400,** and a power supply **500.** These components and sub-systems have been already discussed above and will not be described in further detail. A generic electrical power consumer is shown with numeral **1330,** which is representative of any device that consumes electrical power, including but not limited to, the control unit **300,** the marker detector **306 (Fig. 4),** the dynamic sensor **380 (Fig. 13),** the propulsion system **400,** the task module **600 (Fig. 2),** and / or any device not described in the present specification that consumes electrical power.

[0141] The mobile platform **100** also includes a retrieval module **700** that has a tether **1010** connected to a buoyant body **702.** The tether **1010** may be any of the tethers described in this disclosure or any other connecting cable, line, rope, or wire. The configuration of these components and sub-systems are not limited to any previously described embodiment, *e.g.*, the enclosure **200** need not be inherently safe and the mobile platform **100** may be used in conjunction with a carrier (not shown), which may be a passive or active carrier. Also, two or more enclosures may form the enclosure 2**00**, with each of these separate enclosures acting as housing structures for different components. Moreover, other mobile platforms may include additional components or fewer components. As discussed previously, components of the mobile platform **100** may be formed of two or more separate structures. Thus, while illustrated as single, discrete components, it should be understood that the enclosure **200,** control unit **300,** and power supply **500,** buoyant body **702** may be formed of two or more separate portions, structures, sections, modules, or segments.

[0142] To control charge accumulation, the mobile platform **100** may include the CACS **1003,** which may be operationally integrated into the mobile platform **100.** By operationally integrated, it is meant that the CACS **1003** can, either cooperatively with the control unit **300** or independently, control the operation of sub-systems that initiate movement of the mobile platform **100,** such as the propulsion system **400,** and / or the delivery or the utilization of electrical power by sub-systems, such as the power supply **500** and control unit **300,** respectively. The CACS **1003** may be a component or module of the control unit **300** or a

structurally and functionally separate device.

[0143] In an embodiment, the CACS **1003** may be configured to control an accumulation of electrical charge on the mobile platform **100.** Control may be exerted to reduce a rate of increase in the charge accumulation or reduce a total amount of accumulated charge. The CACS **1003** may include a microprocessor programmed with suitable algorithms, application, or programs and circuitry to transmit control signals based on processed data, which may be pre-programmed and / or acquired during operation. The data may relate to operational data such the time duration of operation, amount of power consumed, time spent moving, data acquired, estimated time to completion of a task, etc. The data may also be acquired using sensors such as voltmeters. Based on pre-programmed criteria, the CACS **1003** transmits control signals to the sub-systems controlling movement of the mobile platform **100** and / or one or more electrical power consumers onboard the mobile platform **100.** As used herein, the term "control signals" includes energy waves (*e.g.*, electrical signals, magnetic signals, optical waves, etc.) as well as physical movement (*e.g.*, translation, rotation, etc.)

[0144] In response to the control signals from the CACS **1003,** the sub-system that receives the control signal(s), or "receiving sub-system," shifts to an operating state that uses less power. By operating at a lower energy state, the rate of increase of charge accumulation on the mobile platform **100** may be either arrested, reduced, or reversed. The control signals may also cause the receiving sub-system to not return to an operating state that requires a higher power consumption. For example, the control signals may instruct the receiving sub-system to not return to the prior operating state or to an operating state that requires electrical power exceeding a predetermined limit. As noted in connection with the embodiment of **Fig. 10,** the control signal may physically reconfigure an electrical circuit to prevent signal / power transfer while the mobile platform **100** is in the tank **10.**

[0145] The CACS **1003** may also be configured to provide an indication that charge accumulation control is occurring or will occur after a predetermined time period; *i.e.,* provide an indication of an activation state of the CACS **1003.** In one arrangement, the CACS **1003** releases the buoyant body **702** to provide an indication of the activation state. Personnel and / or machinery can detect the presence of the buoyant body **702** visually or by another method such as monitoring for audio signals, light signals, vibrations, etc. In the embodiment of **Fig. 10,** actuation of the switch assembly **250** shifts the entire mobile platform **100** to a non-operating state while simultaneously releasing the buoyant body **702.** Thus, the presence of the buoyant body **702** at or toward a surface **1116** of the non-conductive, liquid energetic substance **12** indicates to personnel and / or machinery that the mobile platform **100** is in a non-operating state. The position at or toward the surface **1116** of the buoyant body **702** and attached tether **1010** is shown in hidden lines. In variants, the buoyant body **702** may be released before charge accumulation control occurs. In such instances, presence of the buoyant body **702** indicates that charge accumulation control will occur after expiration of a predetermined time delay (*e.g.*, ten minutes, thirty minutes, an hour, etc.) or other measurable parameter (*e.g.*, quiescence). In other variants, the buoyant body **702** may be released after charge accumulation control has been initiated. In these instances, presence of the buoyant

body **702** indicates that charge accumulation control is presently occurring.

[0146] Thus, by detecting the presence of the released buoyant body **702** inside the tank **10,** personnel may estimate a magnitude of the electrical charge accumulation on the mobile platform **100** and retrieve the mobile platform after the estimated magnitude of the electrical charge accumulation is below a predetermined value. Depending on the situation, the presence of the released buoyant body **702** may indicate that the magnitude of the electrical charge accumulation is below the predetermined value or that the magnitude of the electrical charge accumulation will be below the predetermined value after expiration of a predetermined time duration after the presence of the released buoyant body **702** has been detected. The predetermined value may be a voltage differential that cannot generate a spark capable of igniting one or more energetic substances in or around the tank **10.** The estimation may be based on measurements, laboratory testing, field tests, theoretical calculations or modeling, and / or historical information.

[0147] Referring to **Fig. 26,** in some embodiments, the CACS **1003** may also include an electrical charge dissipater **1500** and an actuator **1502.** The electrical charge dissipater **1500** is configured to discharge an electrical charge accumulated on the mobile platform **100** to a voltage differential neutralizing body **1504.** The electrical charge dissipater **1500** is shown as electrically connected to one localized region of the enclosure **200.** However, in embodiments, the electrical charge dissipater **1500** may be in electrical communication with two or more discrete regions of the enclosure **200** at which electrical charges may accumulate. The voltage differential neutralizing body **1504** may be the tank **10,** the non-conductive, liquid energetic substance **12,** and / or an object **1506** positioned inside the tank **10.** When activated by the CACS **1003,** the actuator **1502** extends, drops, exposes or otherwise electrically engages the electrical charge dissipater **1500** with the voltage differential neutralizing body **1504.** This electrical connection may reduce the electrical charge accumulation on the mobile platform **100** and thereby reduce a voltage differential between the mobile platform **100** and the voltage differential neutralizing body **1504.**

[0148] Fig. 27 illustrates a flow chart of one non-limiting embodiment of a retrieval method **1600** not according to the present invention that employs the CACS **1003.** At step **1602**, the mobile platform **100** to be retrieved may be configured as shown in **Fig. 27.** However, the method **1600** may be used to retrieve other mobile devices not described in the present disclosure.

[0149] At step **1604,** the mobile platform **100** is lowered into the tank **10** using a deployment carrier **50 (Fig. 16A).** Other embodiments may use the deployment carriers **764** or **780 (Figs. 11C, 11D,** respectively) or other suitable system for lowering the mobile platform 100 into the tank 10. At step 1606, the enclosure **200** is submerged in the non-conductive, liquid energetic substance **12.** If two or more separate enclosures are present, then only one of those separate enclosure needs be submerged. Moreover, the enclosure **200** does not have be fully submerged; *i.e.*, a partially submerged state may be suitable in certain instances. It should be understood that the enclosure **200** need not be completely submerged in the non-conductive,

liquid energetic substance **12**; *i.e.*, "submerged" does not mean that the entire enclosure **200** is immersed in the non-conductive, liquid energetic substance **12.** It should be noted after step **1606,** some components used in conjunction with the mobile platform **100,** such as an active or passive carrier (not shown) may not be submerged. At step **1608,** the mobile platform **100** is used to perform one or more tasks in the tank **10.** At step **1610,** an activation state of the CACS **1003** is indicated by releasing the buoyant body **702** toward a surface **1116** of the non-conductive, liquid energetic substance **12.** At step **1612,** the CACS **1003** controls the accumulation of electrical charges on the mobile platform. At step **1614,** the mobile platform **100** is retrieved from inside to outside of the tank **10.**

[0150] Fig. 28 depicts a method that reverses the steps of charge accumulation control and indication of such control activity. Specifically, the charge accumulation control step **1612** occurs before the step **1610** of releasing the buoyant body **702.** As noted previously, the two steps can also occur simultaneously.

[0151] Fig. 29 is a flow chart depicting details of steps that may be performed during the charge accumulation control step **1612.** The steps **1616, 1618, 1620** are intended to reduce a rate of increase of electrical charge accumulation, maintain a level of accumulated electrical charges, or reduce the amount of accumulated electrical charges. Steps **1616** and **1618** may be considered "passive" in that performance of these steps controls sources contributing to electrical charge accumulation, but not the electrical charge accumulated on the mobile platform **100.** Step **1620** may be considered "active" in that performance of this step changes the magnitude of the accumulated electrical charge on the mobile platform **100.** These steps may be taken independently or together in any combination. At step **1616,** control signals or some form of actuation reduce or stop motion that contributes to electrical charge accumulation. At step **1618,** control signals or some form of actuation reduce or stop power usage that contributes to electrical charge accumulation. For both of steps **1616** and **1618,** a return to the prior magnitude of motion or power usage is prevented unless acted upon by an input that is external to the mobile platform **100.** That is, an actor, whether human or machine, that is external to the mobile platform **100** must take an action, *e.g.*, transmission of a signal or manipulation of some form of switch or other actuator, to allow a return to the prior magnitude of motion or power usage. At step **1620,** the electrical charge dissipater **1500** is actuated to discharge some or all of the accumulated electrical charge on the mobile platform **100** into a voltage differential neutralizing body **1504.**

[0152] Other systems and related methods may use an active carrier in conjunction with a mobile platform and may not use an inherently safe enclosure and incorporate one or more features described in connection with **FIGS. 2-29.**

[0153] By "conductive" or "electrically conductive," it is meant an electrical conductivity greater than 100 microsiemens per meter.

[0154] By "electrically isolating" two objects, it is meant that the electrical resistance between the two objects exceeds 1 mega ohm.

[0155] By "charge accumulation" or "electrical charge accumulation," it is meant the exchange of electrons between two objects resulting in either a positive or negative voltage differential increasing between the two objects.

[0156] By "charge dissipation," it is meant the exchange of electrons between two objects resulting in either a positive or negative voltage differential decreasing between the two objects.

[0157] By "not conductive" or "not electrically," it is meant an electrical conductivity less than or equal to 100 microsiemens per meter.

[0158] An "energetic substance" is any material that is considered to be at risk of igniting or burning. In certain applications, an energetic substance has one or more of the following properties: (i) an Autoignition Temperature (AIT) of 700°C or less, (ii) a flashpoint of 150°C or less, (iii) a Minimum Ignition Energy (MIE) of 1.5 mJ or less, and / or (iv) a Minimum Ignition Current Ratio (MICR) of 1.5 or less.

[0159] An AIT is the minimum temperature required to initiate or cause self-sustained combustion of a material independently of the heating or heated element. A flashpoint is the minimum temperature at which a liquid gives off vapor in sufficient concentration to form an ignitible mixture with air near the surface of the liquid at standard atmospheric conditions. A MIE is the minimum energy required from a capacitive spark discharge to ignite the most easily ignitible mixture of a gas or vapor. A MICR is the ratio of the minimum current required from an inductive spark discharge to ignite the most easily ignitible mixture of a gas or vapor, divided by the minimum current required from an inductive spark discharge to ignite methane under the same test conditions. A MESG is the maximum gap of the joint between the two parts of the interior chamber of a test apparatus that, when the internal gas mixture is ignited and under standard atmospheric conditions, prevents ignition of the external gas mixture by flame propagating through a 25 mm (984 mils) long joint, for all concentrations of the tested gas or vapor in air.

[0160] Energetic substances can be dust, particulates, slurries, solids, liquids, vapors, gases, and combinations thereof. Examples of energetic substances include, but are not limited to, coal dust, hydrocarbon liquids, fuel oils, and gasoline.

[0161] "Burning" is the chemical reaction that takes place when an energetic substance is ignited. Burning encompasses combustions, explosions, detonations, and deflagrations. "Ignite," "ignited," and "igniting" mean applying energy of a sufficient quantity to an energetic substance to start the chemical reaction. A "spark" is a thermal event having at least enough energy to ignite an energetic substance. The term "thermal event" includes sparks and sparks caused by explosions. A "combustible" material is a material that undergoes a chemical change that produces heat and light when ignited. A "flammable" material is a gas, liquid or solid that ignites and continues to burn in air if ignited.

[0162] It is emphasized that the present teachings can be readily applied to a variety of industries and uses beyond tank inspections, whether above ground or underground. Thus, the described systems and methods are only illustrative of how the advancements of the present disclosure may be implemented. For example, mobile platforms according to the present disclosure may be used in connection with storage units and containers carried by barges, tankers, railroad cars, or ships.

[0163] The foregoing description is directed to particular embodiments of the present disclosure for the purpose of illustration and explanation. It will be apparent, however, to one skilled in the art that many modifications and changes to the embodiment set forth above are possible without departing from the scope of the disclosure. Thus, it is intended that the following claims be interpreted to embrace all such modifications and changes.

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- US6104970A **[0010]**
- WO2012145745A **[0010]**
- US2801768A **[0029]**
- US6452163B **[0029]**
- US8227692B **[0029]**
- WO2017003758A **[0029]**
- EP2418926A **[0029]**

Patentkrav

1. Fremgangsmåde til at hente en mobil platform (100) fra en tank (10) med en luge (24), og som er mindst delvist fyldt med et ikke-ledende, energisk stof (12, 14), hvor fremgangsmåden er **kendetegnet ved**:

- at udforme den mobile platform (100) til at indbefatte mindst:

- en indkapsling (200),

- mindst en kontrolenhed (300), placeret inden i indkapslingen (200),

- mindst et fremdriftssystem (400), placeret mindst delvist inden i indkapslingen (200),

- mindst en strømforsyning (500), placeret indeni indkapslingen (200), og

- mindst et hentningssystem (700), placeret mindst delvist på indkapslingen (200), og omfattende mindst:

- mindst et flydende legeme (702),

- mindst en primær fortøjning (1100), forbundet til mindst et flydende legeme (702) og til indkapslingen (200);

- mindst en sekundær fortøjning (1102), forbundet til mindst et flydende legeme (702) og til indkapslingen (200);

- en forudbestemmelse af et modtagelsesområde (1104) for det flydende legeme indeni tanken (10), hvor modtagelsesområdet (1104) for det flydende legeme er under lugen (24);

- at sænke den mobile platform (100) ned i tanken (10) ved anvendelse af et isætningsbæreorgan (50, 764, 780);

- nedsænkning af indkapslingen (200) i et ikke-ledende, flydende, energisk stof (12);

- flytning af den mobile platform (100) ved hjælp af mindst et fremdriftssystem (400) med henblik på at udføre mindst en opgave i tanken (10);

- frigørelse af det mindst ene flydende legeme (702) og den mindst ene primære fortøjning (1100) fra indkapslingen (200);

- anbringelse af det frigjorte mindst ene flydende legeme (702) indenfor modtagelsesområdet (1104) til det flydende legeme ved hjælp af den mindst ene primære fortøjning (1100);

- adgang til det mindst ene flydende legeme (702) gennem lugen (24);

- hentning af den mindst ene primære fortøjning (1100) ved hjælp af det mindst ene flydende legeme (702);

- anvendelse af den mindst ene primære fortøjning (1100) til at frigøre den mindst ene sekundære fortøjning (1102); og

- indsættelse af et hentningslegeme (1110) gennem lugen (24), der skal hente mindst en af: (i) det mindst ene flydende legeme (702), (ii) den mindst ene primære fortøjning (1100) og (iii) den mindst ene sekundære fortøjning (1102).

2. Fremgangsmåden ifølge krav 1, som endvidere er **kendetegnet ved**:

- en estimering af en højde på det ikke-ledende, flydende, energiske stof (12) over den mobile platform (100) indeni tanken (10); og

- valg af en længde for den mindst ene primære fortøjning (1100), baseret på mindst den estimerede højde på det ikke-ledende, flydende, energiske stof (12) over den mobile platform (100) indeni tanken (10), med henblik på at anbringe det mindst ene flydende legeme (702) indenfor modtagelsesområdet (1104) til det flydende legeme.

3. Fremgangsmåden ifølge krav 2, hvor længden af den mindst ene primære fortøjning (1100) også vælges ved hjælp af mindst en afstand mellem en hentningsplacering (1112) for den mobile platform (100) og en væg (20) i tanken (10).

4. Fremgangsmåden ifølge krav 1, som endvidere er **kendetegnet ved**:

- udformning af den mindst ene primære fortøjning (1100), så den frigør den mindst ene sekundære fortøjning (1102) som reaktion på en påført, forudbestemt frigørelseskraft; og

- påføring af en kraft, der er mindst lige så stor som den forudbestemte frigørelseskraft, på den mindst ene primære fortøjning (1100) med henblik på at frigøre den mindst ene sekundære fortøjning (1102).

5. Fremgangsmåden ifølge krav 4, endvidere **kendetegnet ved**, at den forudbestemte frigørelseskraft er større end det flydende legemes (702) totale opdrift i det ikke-ledende, flydende, energiske stof (12) og mindre end den mobile platforms (100) totale nedadgående kraft i det ikke-ledende, flydende, energiske stof (12).

6. Fremgangsmåden ifølge krav 1, endvidere **kendetegnet ved**, at den mindst ene sekundære fortøjning (1102) mindst er lang nok til at kunne nå over en afstand mellem den mobile platform (100) og en placering tæt på tankens (100) øverste væg (16).

7. Fremgangsmåden ifølge krav 1, endvidere **kendetegnet ved**, at den sammenlagte længde af den mindst ene primære fortøjning (1100) og den mindst ene sekundære fortøjning (1102) mindst er lang nok til at kunne nå over en afstand mellem den mobile platform (100) og en placering tæt på tankens (100) øverste væg (16).

8. Fremgangsmåden ifølge krav 1, endvidere **kendetegnet ved**, at den mindst ene sekundære fortøjning (1102) anvendes til at trække den mobile platform (100).

9. Fremgangsmåden ifølge krav 1, endvidere **kendetegnet ved**, at længden af den mindst ene primære fortøjning (1100) er valgt med henblik på at fastholde et

forudbestemt mellemrum mellem det flydende legeme (702) og tankens (10) øverste væg (16).

10. Fremgangsmåden ifølge krav 1, endvidere **kendetegnet ved**, at den mindst ene primære fortøjning (1100) omfatter en pluralitet af primære fortøjningssegmenter.

11. Fremgangsmåden ifølge krav 1, endvidere **kendetegnet ved**, at den mindst ene sekundære fortøjning (1102) omfatter en pluralitet af sekundære fortøjningssegmenter.

12. Fremgangsmåden ifølge krav 1, endvidere **kendetegnet ved**, at den mindst ene primære fortøjning (1100) forbinder den mindst ene sekundære fortøjning (1102) til indkapslingen (200).

13. Fremgangsmåden ifølge krav 1, endvidere **kendetegnet ved**, at den mindst ene sekundære fortøjning (1102) forbinder den mindst ene primære fortøjning (1100) til indkapslingen (200).

14. Fremgangsmåden ifølge krav 1, endvidere **kendetegnet ved**, at indkapslingen (200) omfatter en pluralitet af separate indkapslinger, og at mindst en indkapsling (200) ud af pluraliteten af separate indkapslinger er nedsænket i det ikke-ledende, flydende, energiske stof (12).

DRAWINGS

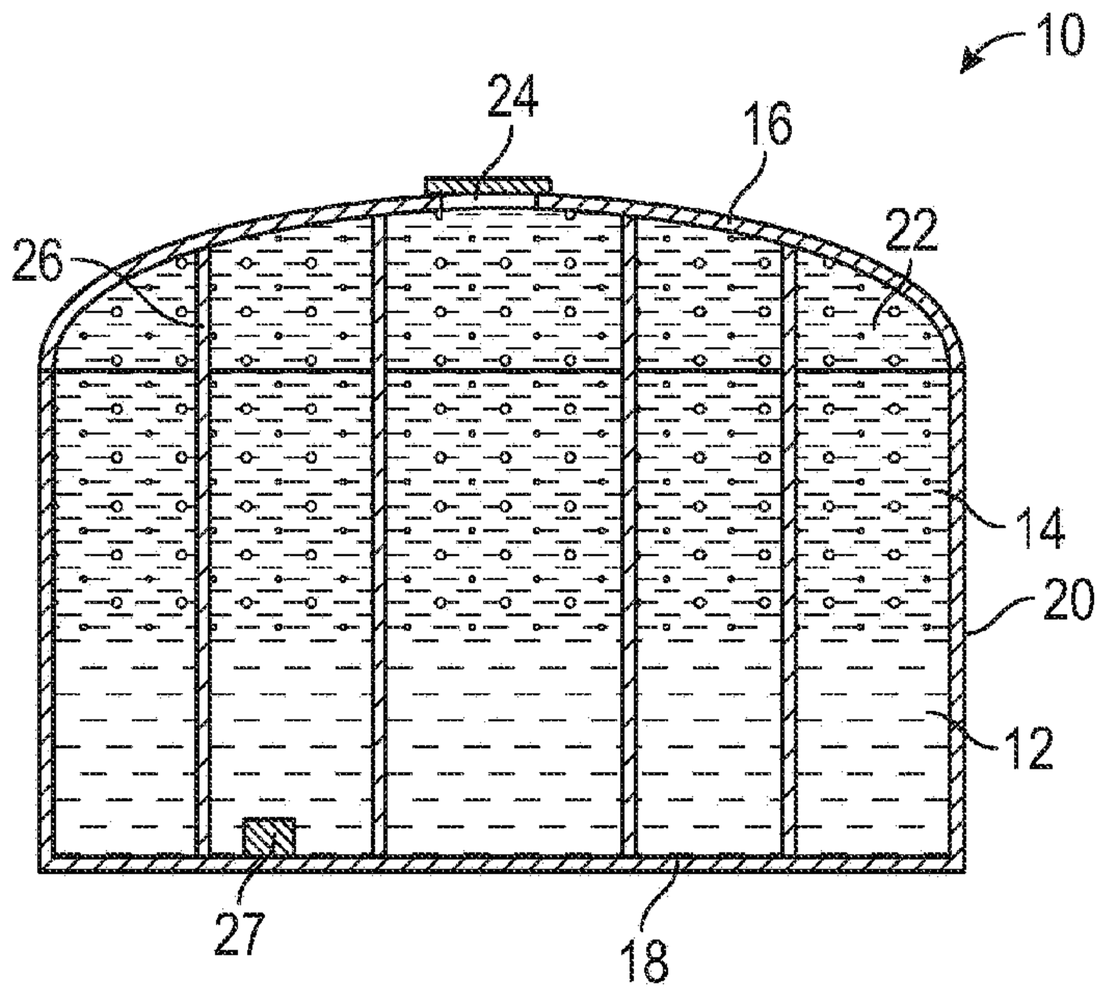


FIG. 1

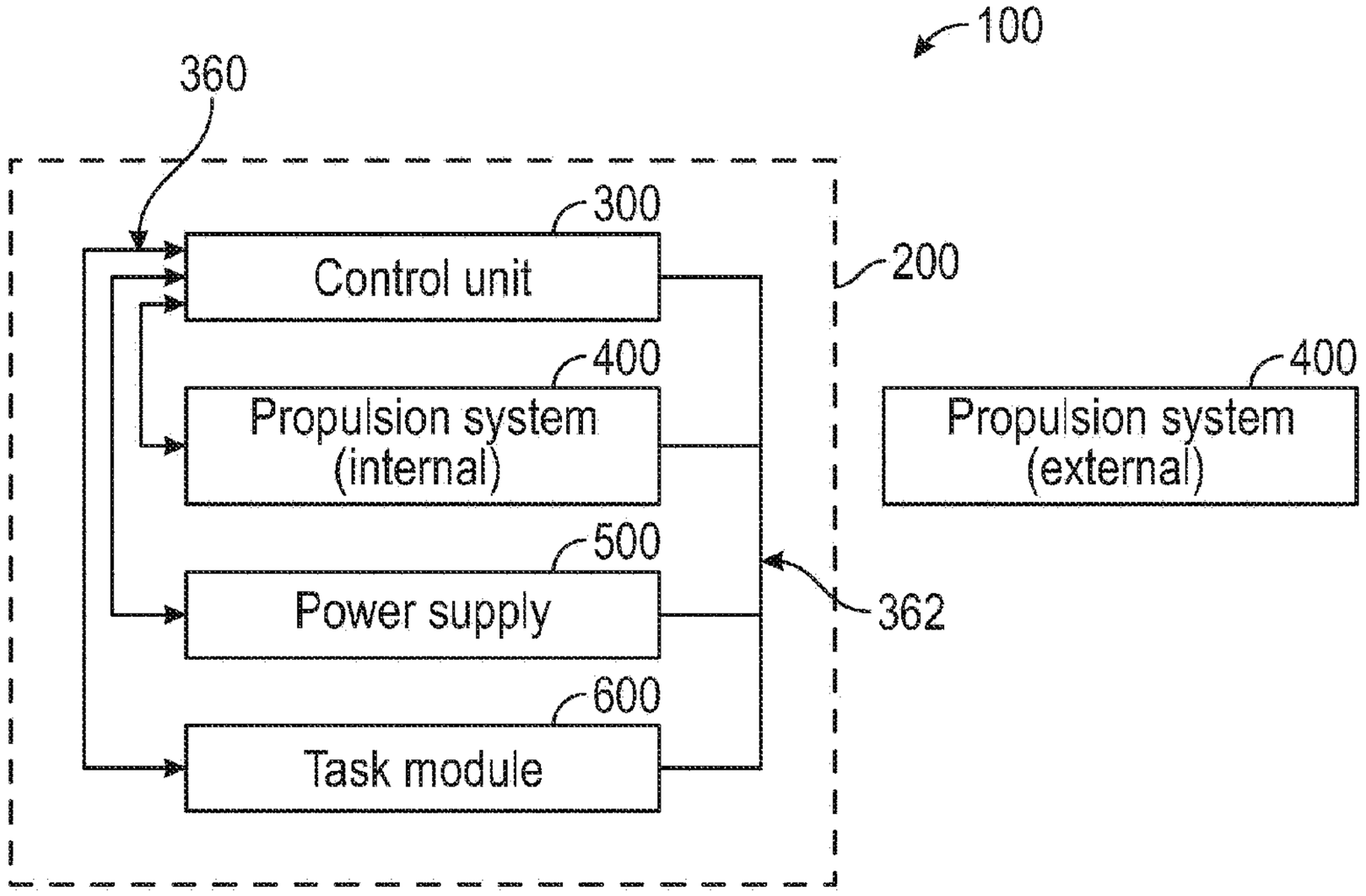


FIG. 2

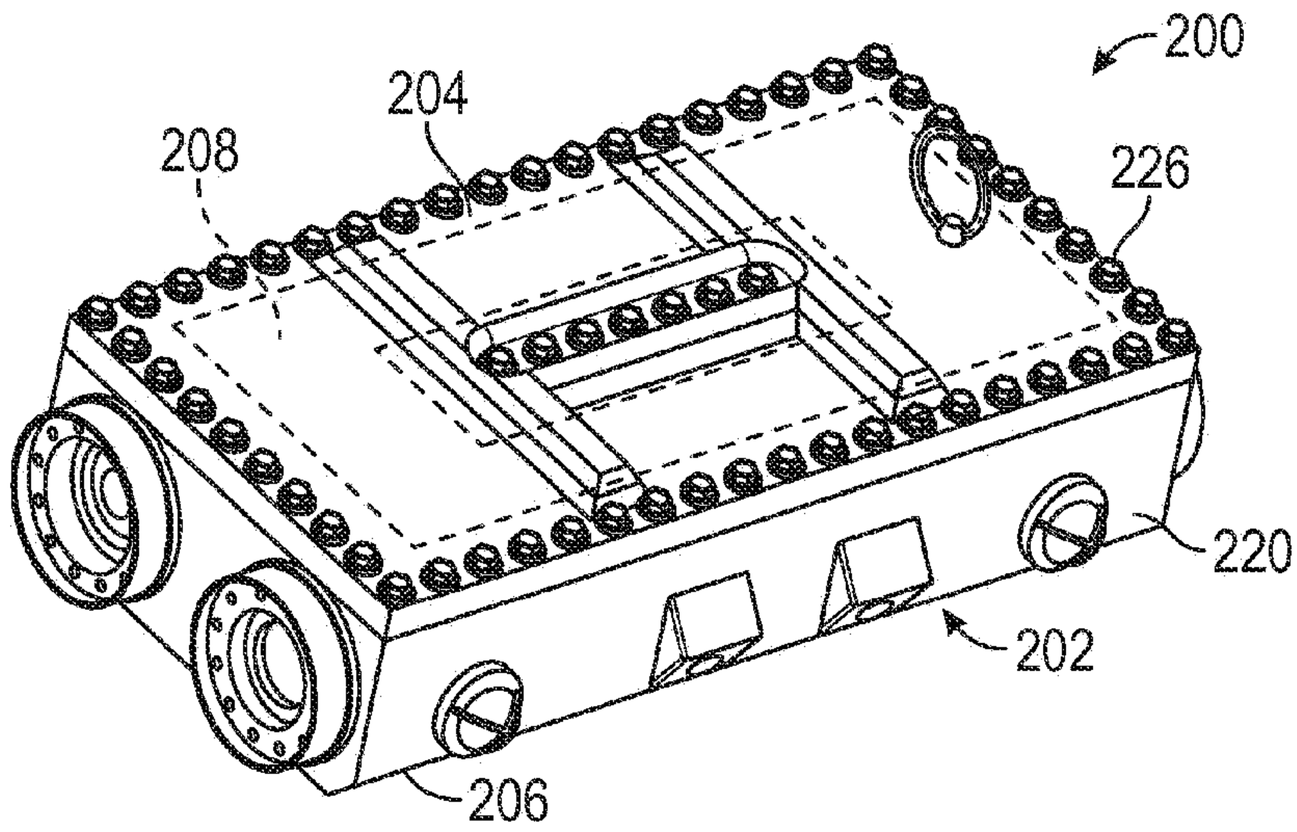


FIG. 3A

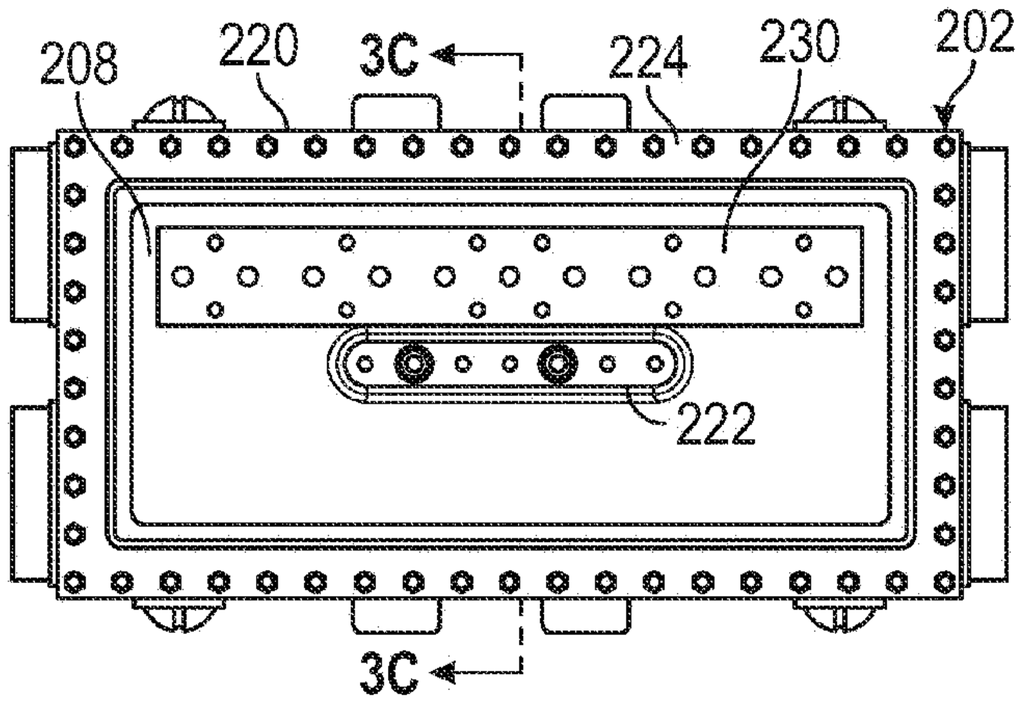


FIG. 3B

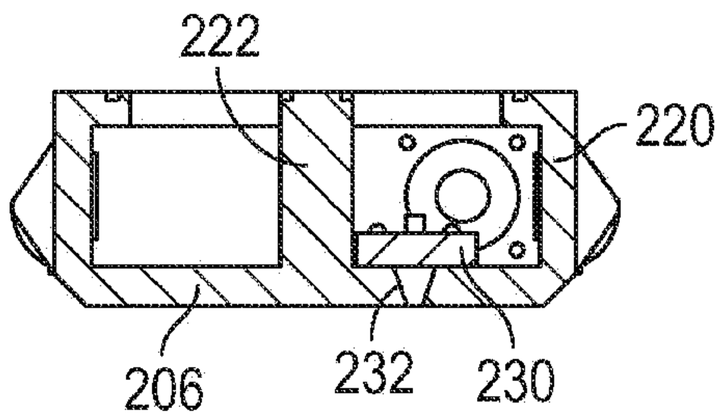


FIG. 3C

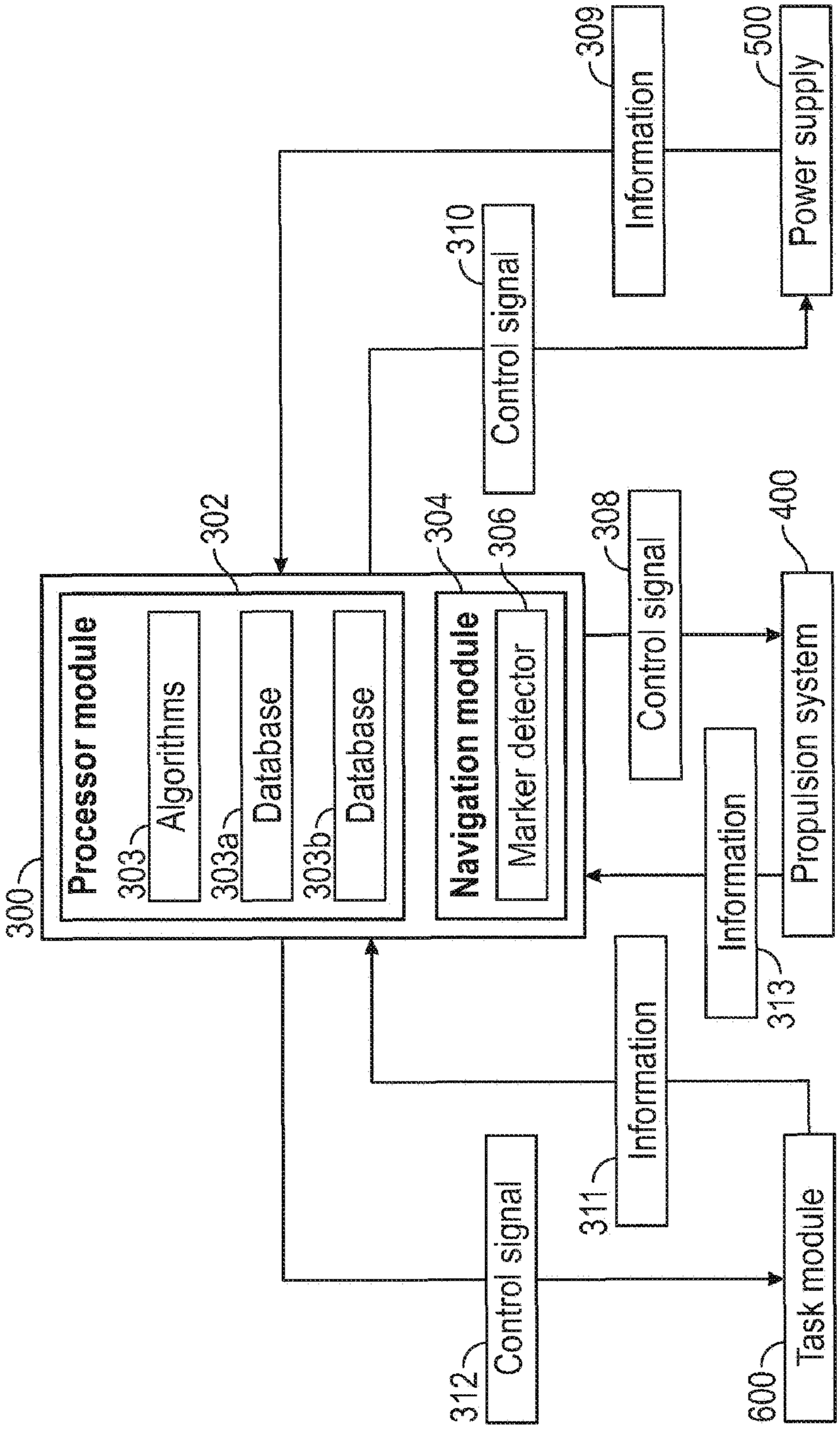

300
Processor module
303
Algorithms
303a
Database
303b
Database
302
304
Navigation module
306
Marker detector
308
Control signal
400
Propulsion system
313
Information
309
Information
500
Power supply
310
Control signal
311
Information
312
Control signal
600
Task module

FIG. 4

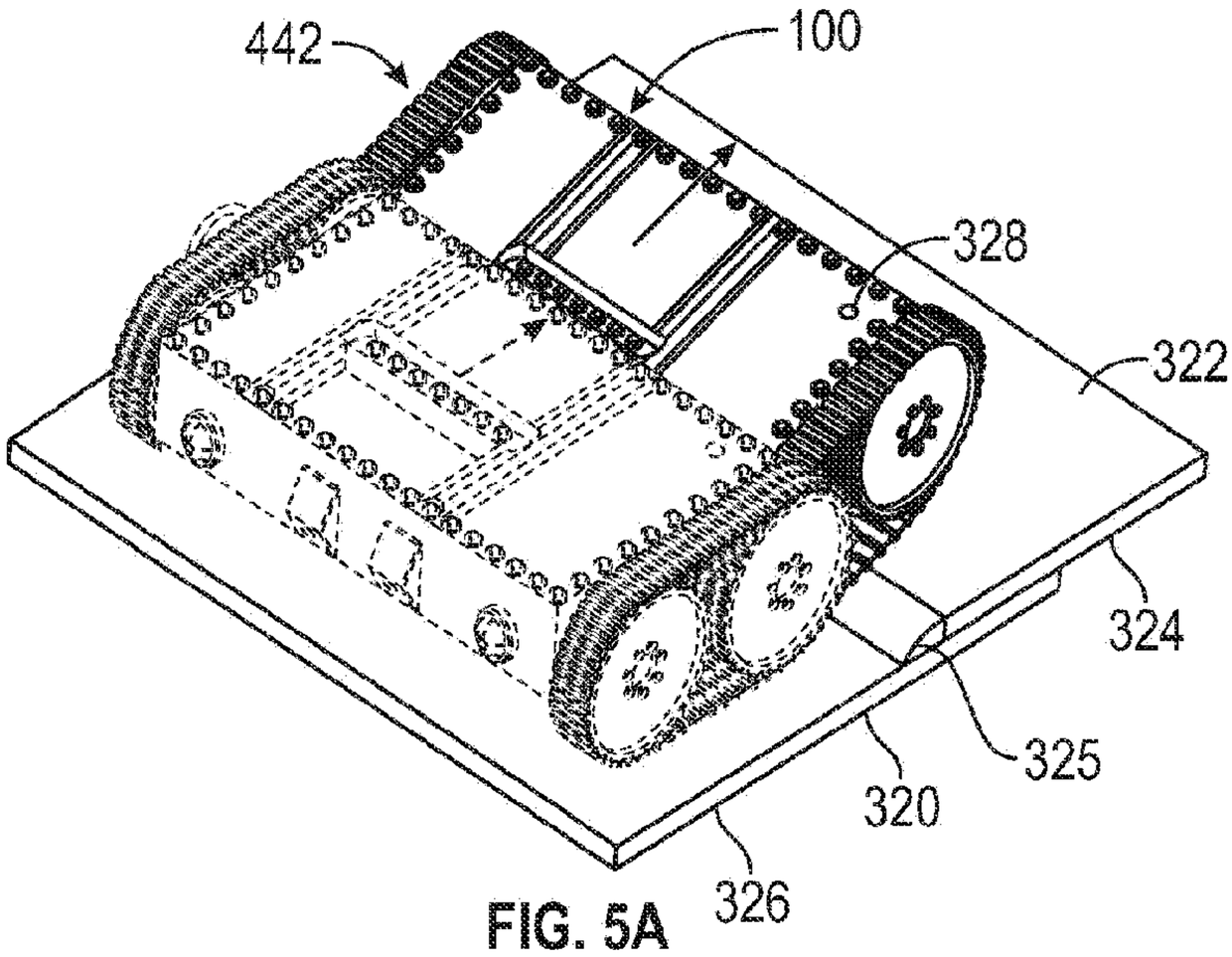


FIG. 5A

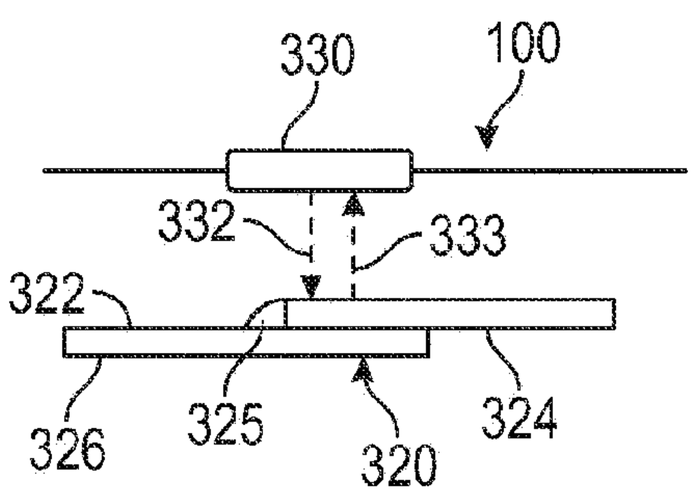


FIG. 5B

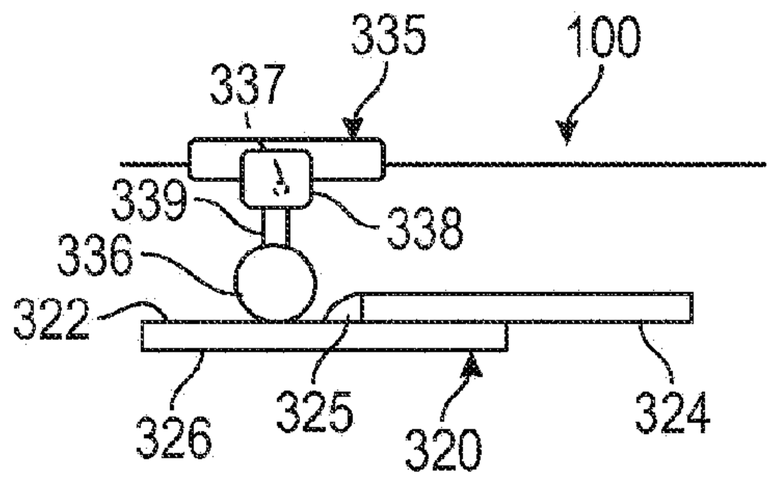


FIG. 5C

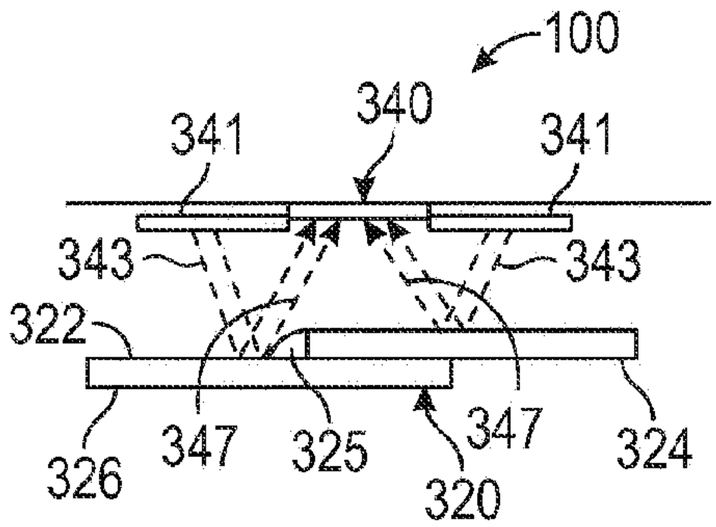


FIG. 5D

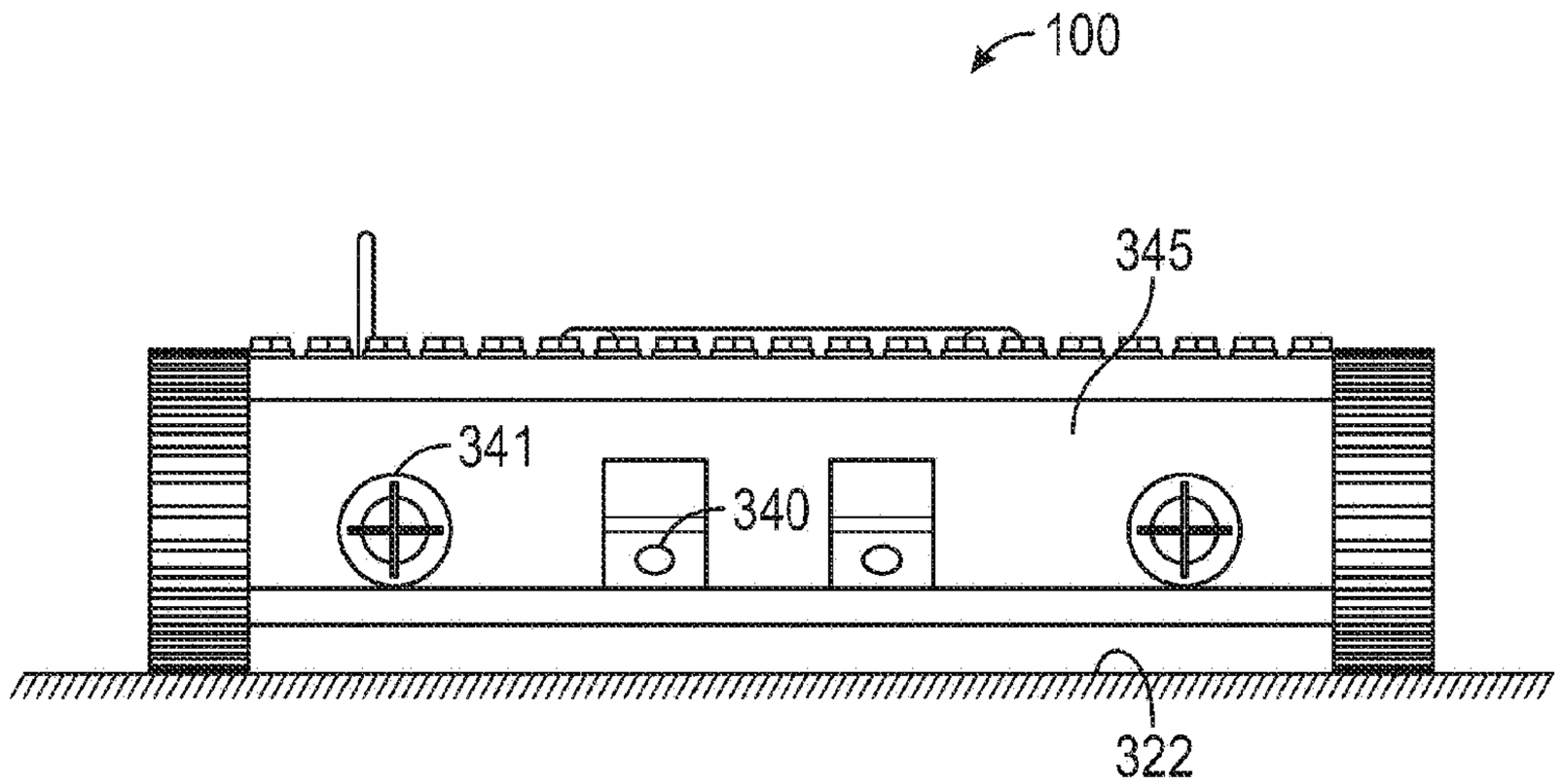


FIG. 5E

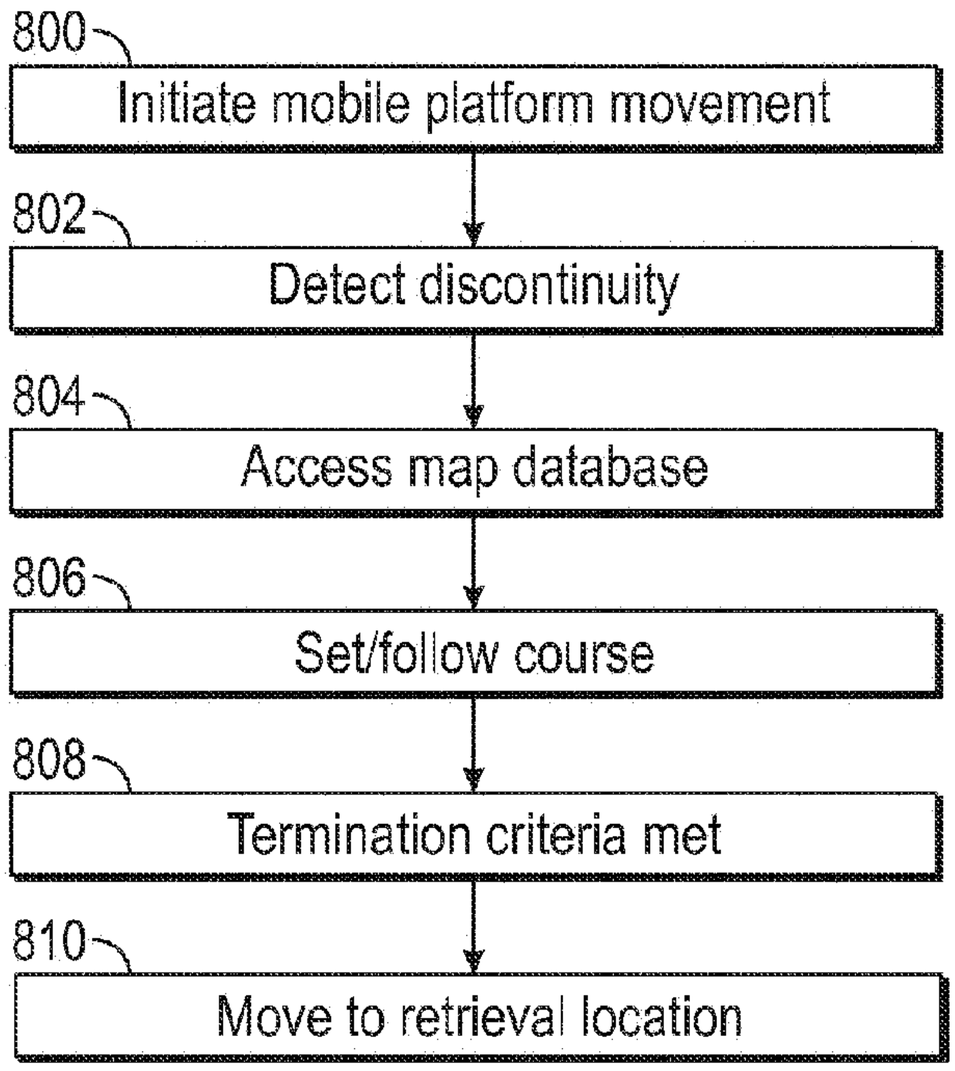

800
Initiate mobile platform movement
802
Detect discontinuity
804
Access map database
806
Set/follow course
808
Termination criteria met
810
Move to retrieval location

FIG. 6A

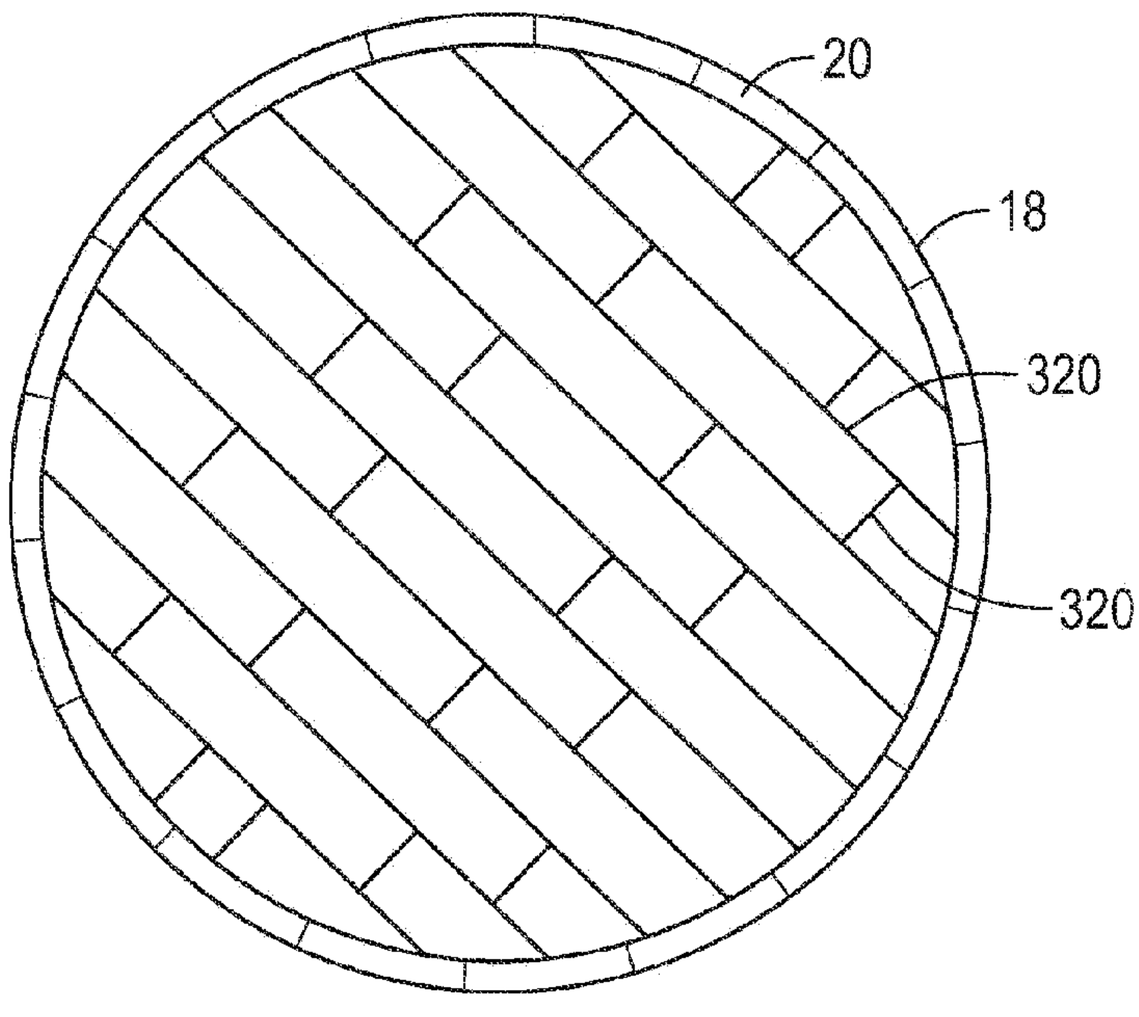

20
18
320
320

FIG. 6B

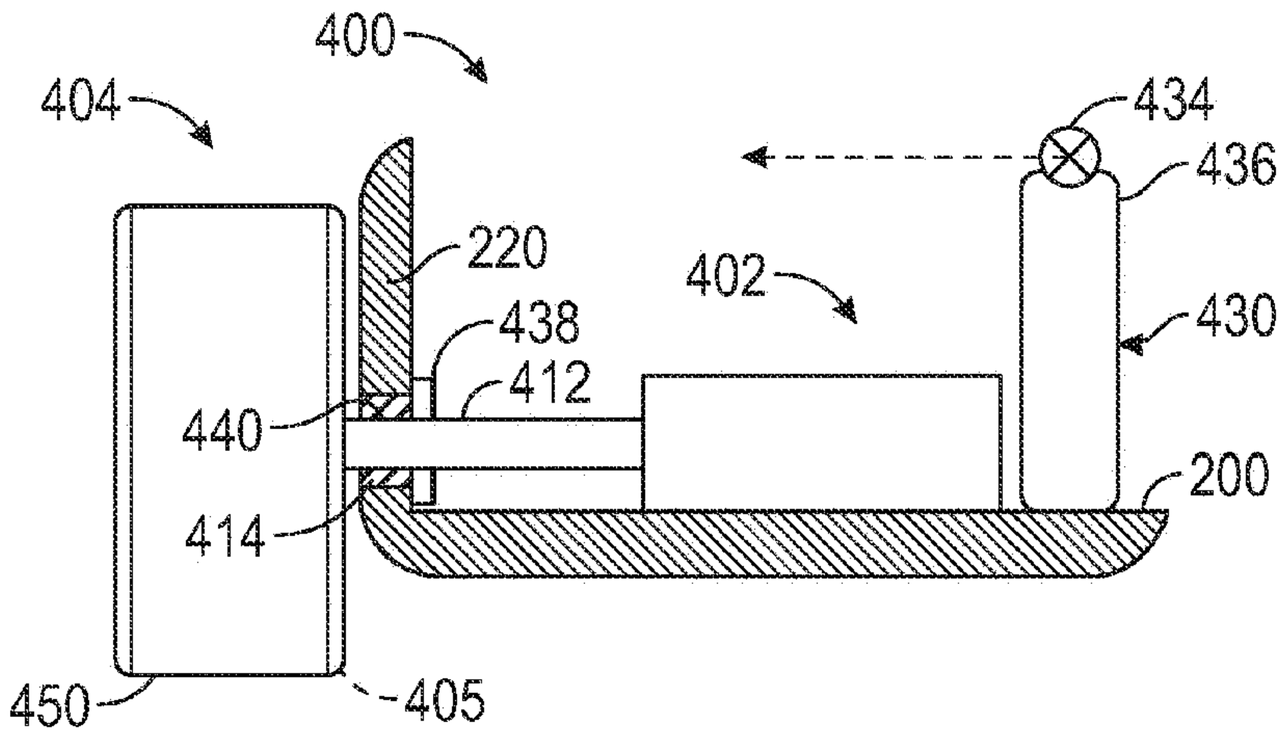

400
404
434
436
220
402
438
430
412
440
200
414
450
405

FIG. 7

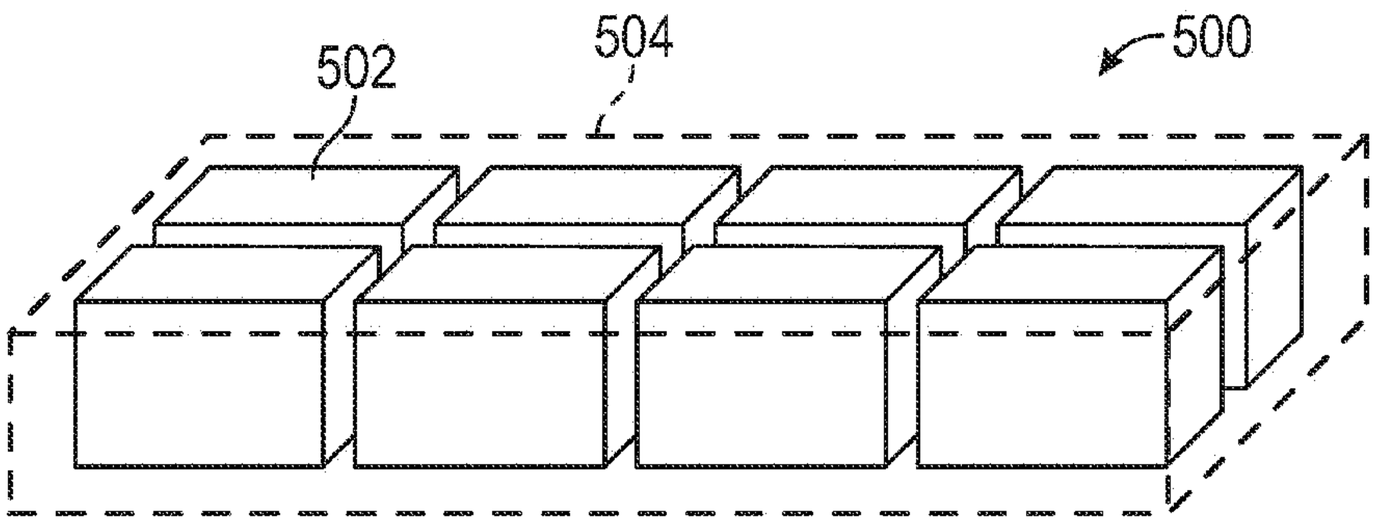

502
504
500

FIG. 8

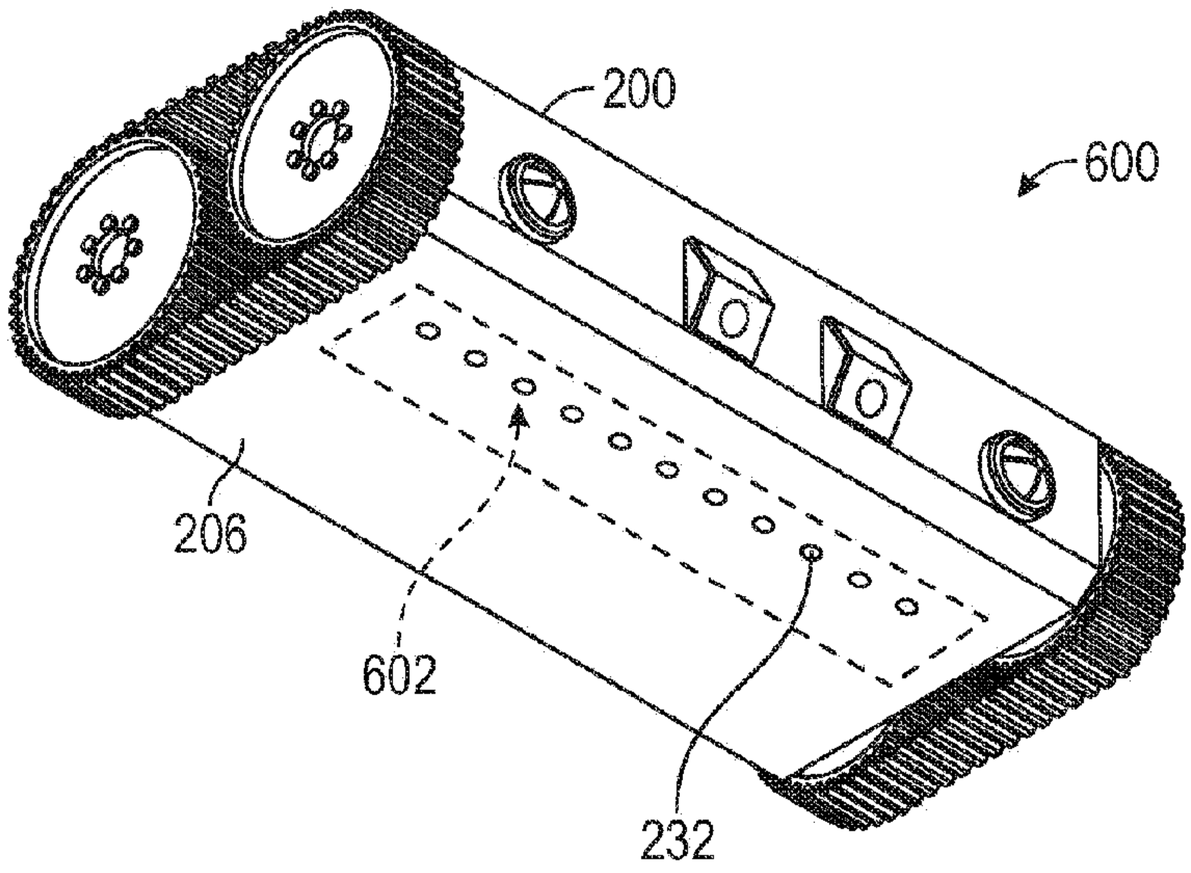


FIG. 9A

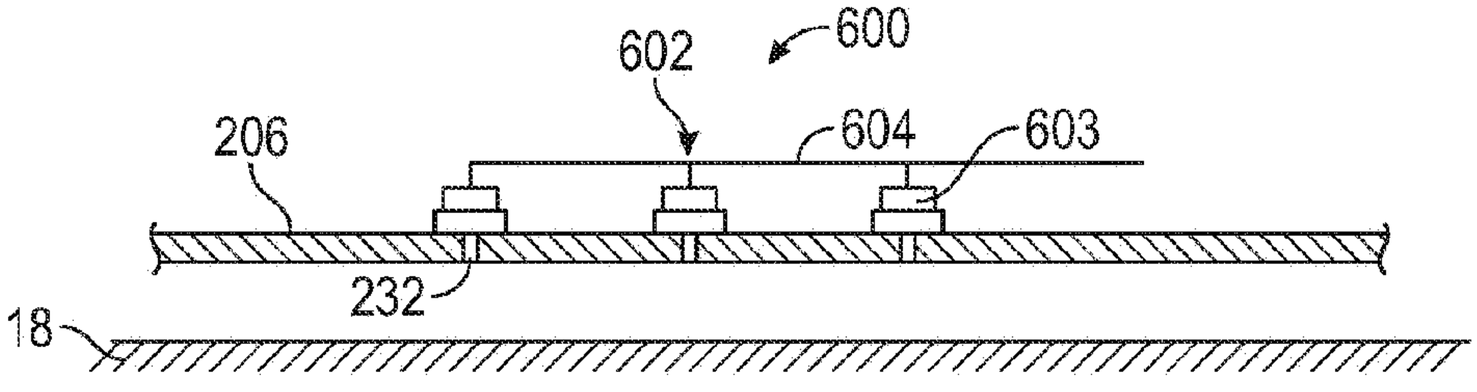


FIG. 9B

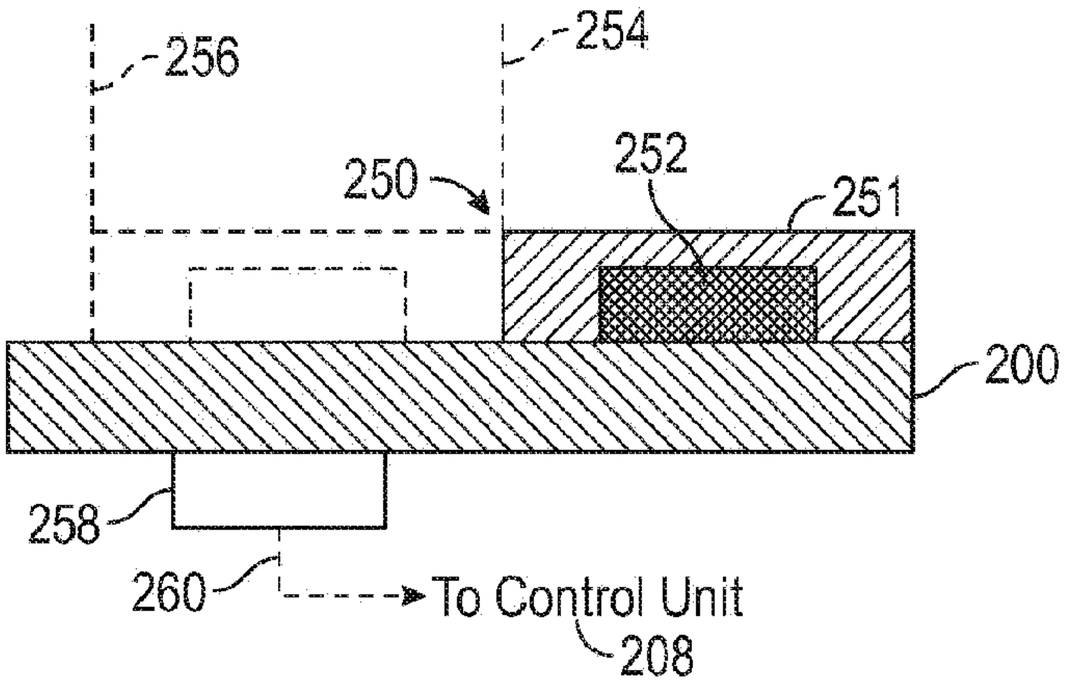


FIG. 10

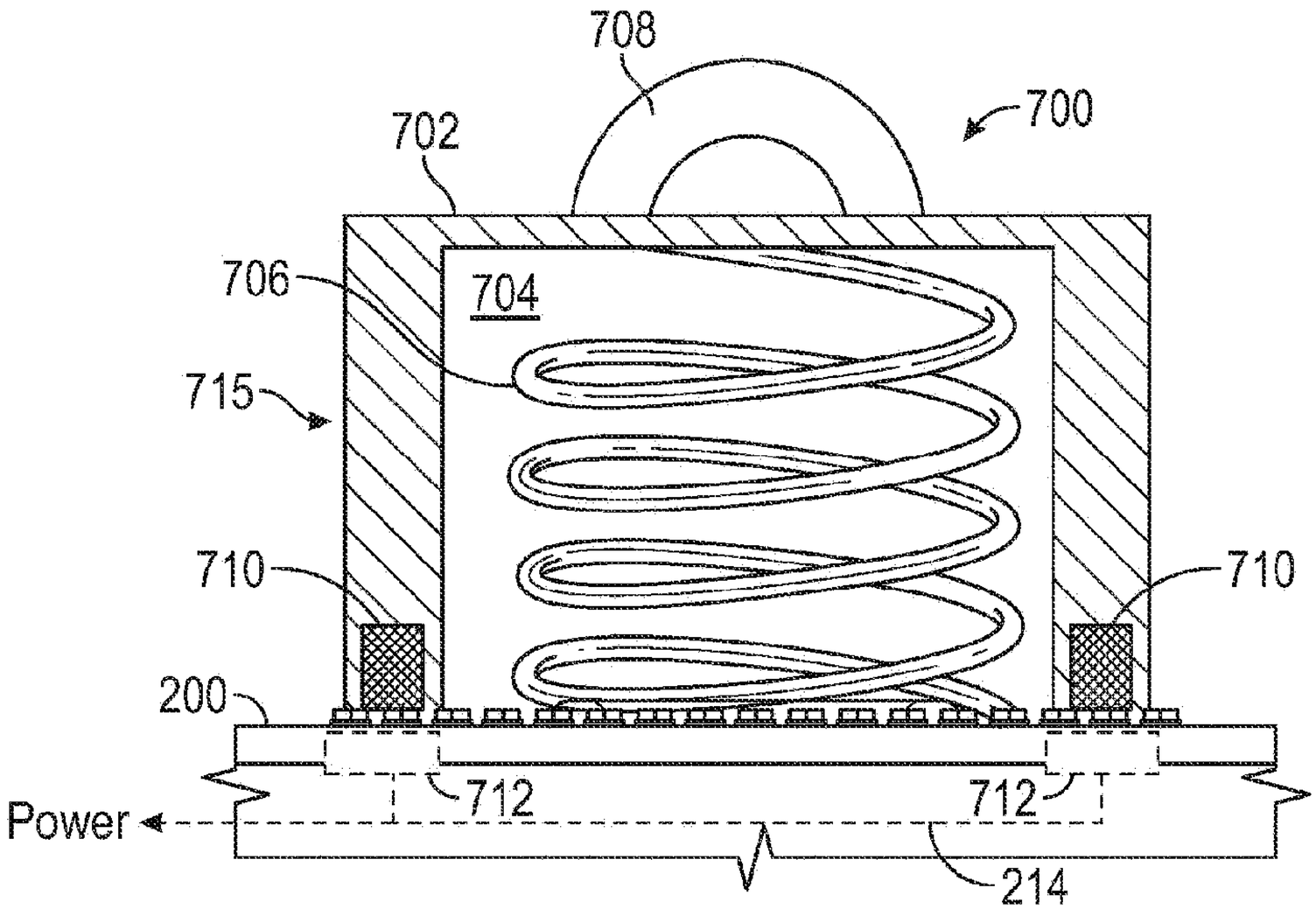


FIG. 11A

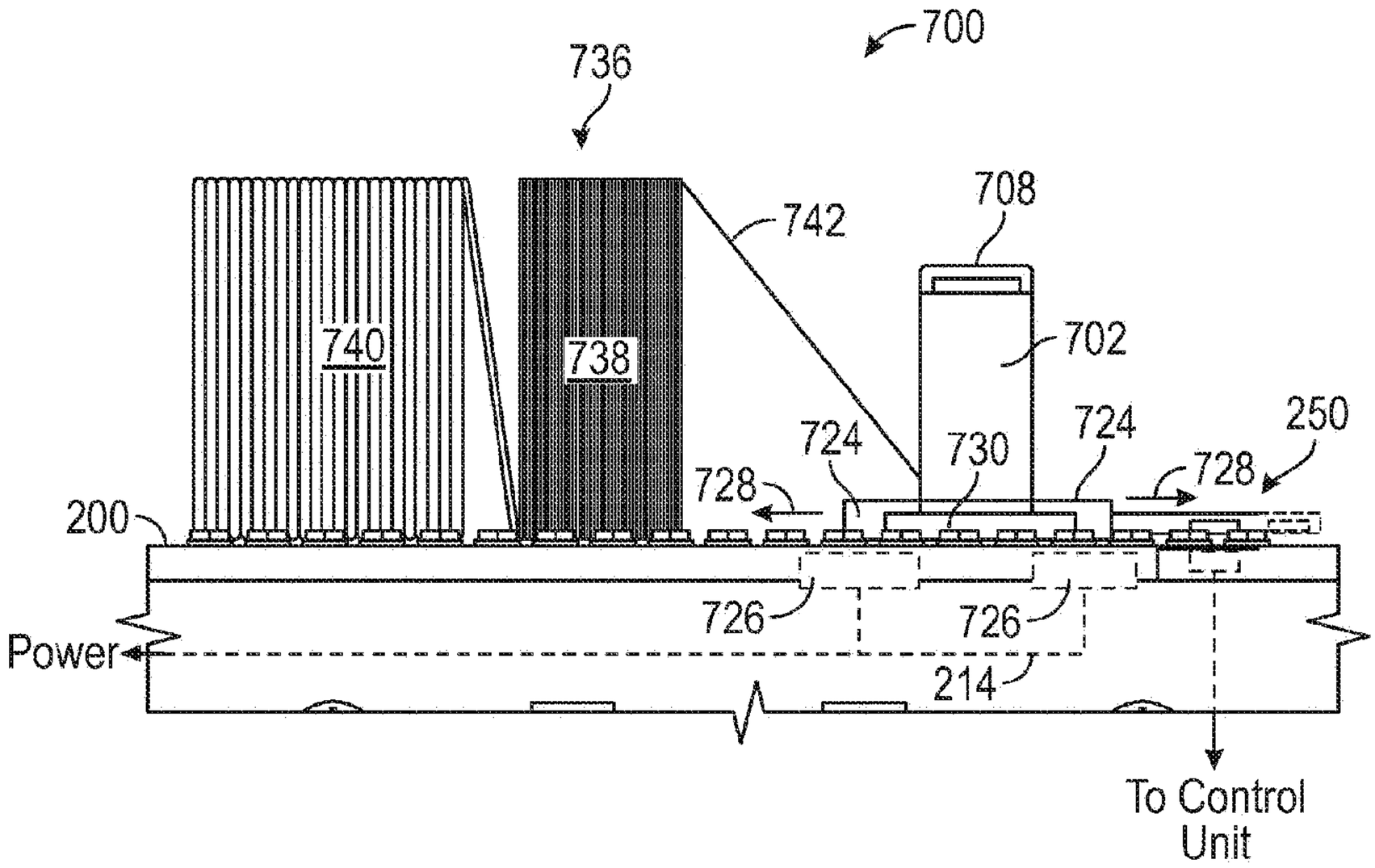


FIG. 11B

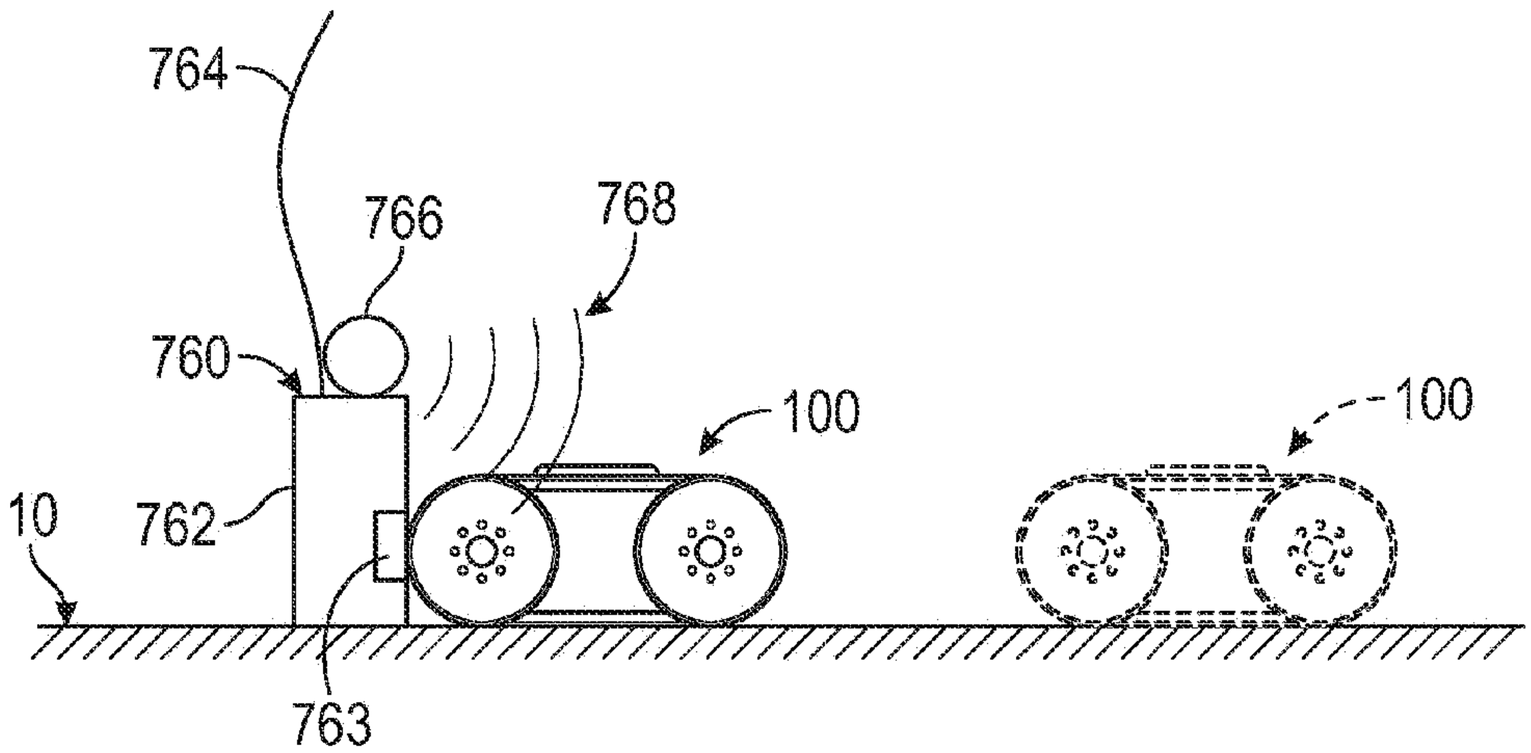


FIG. 11C

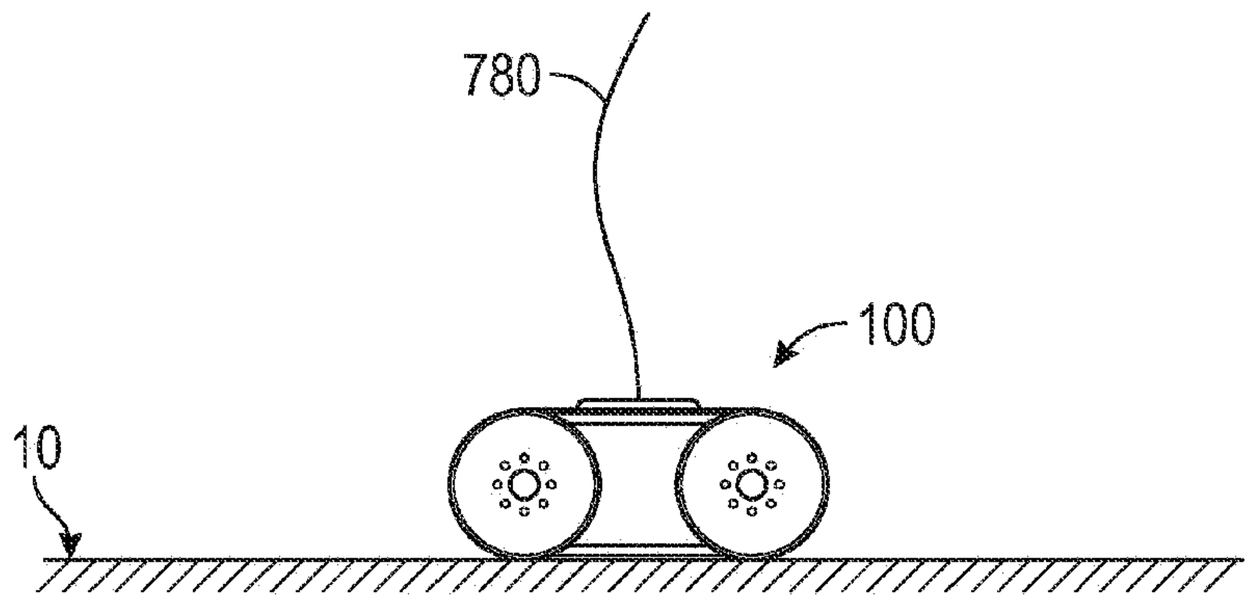


FIG. 11D

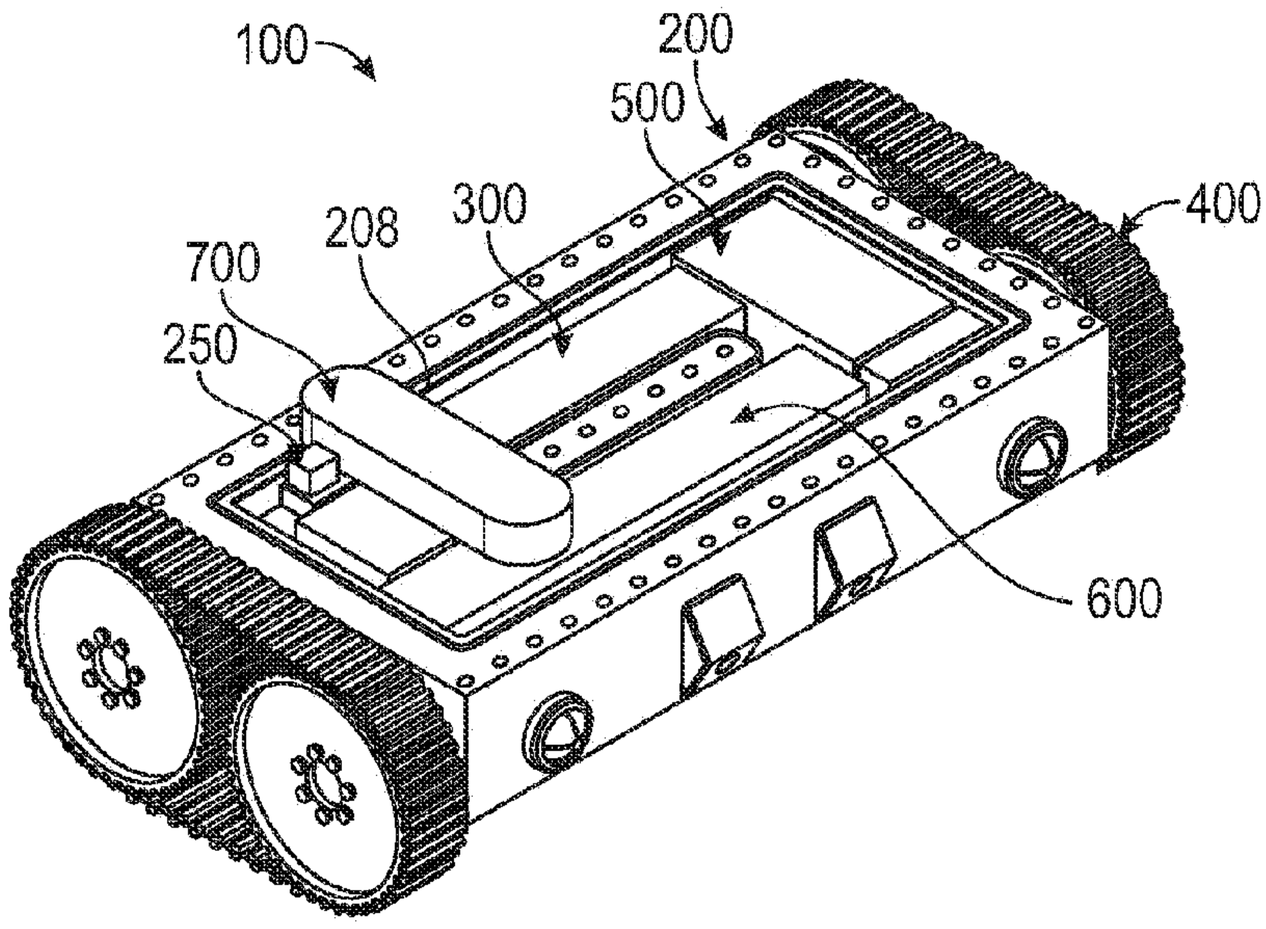


FIG. 12A

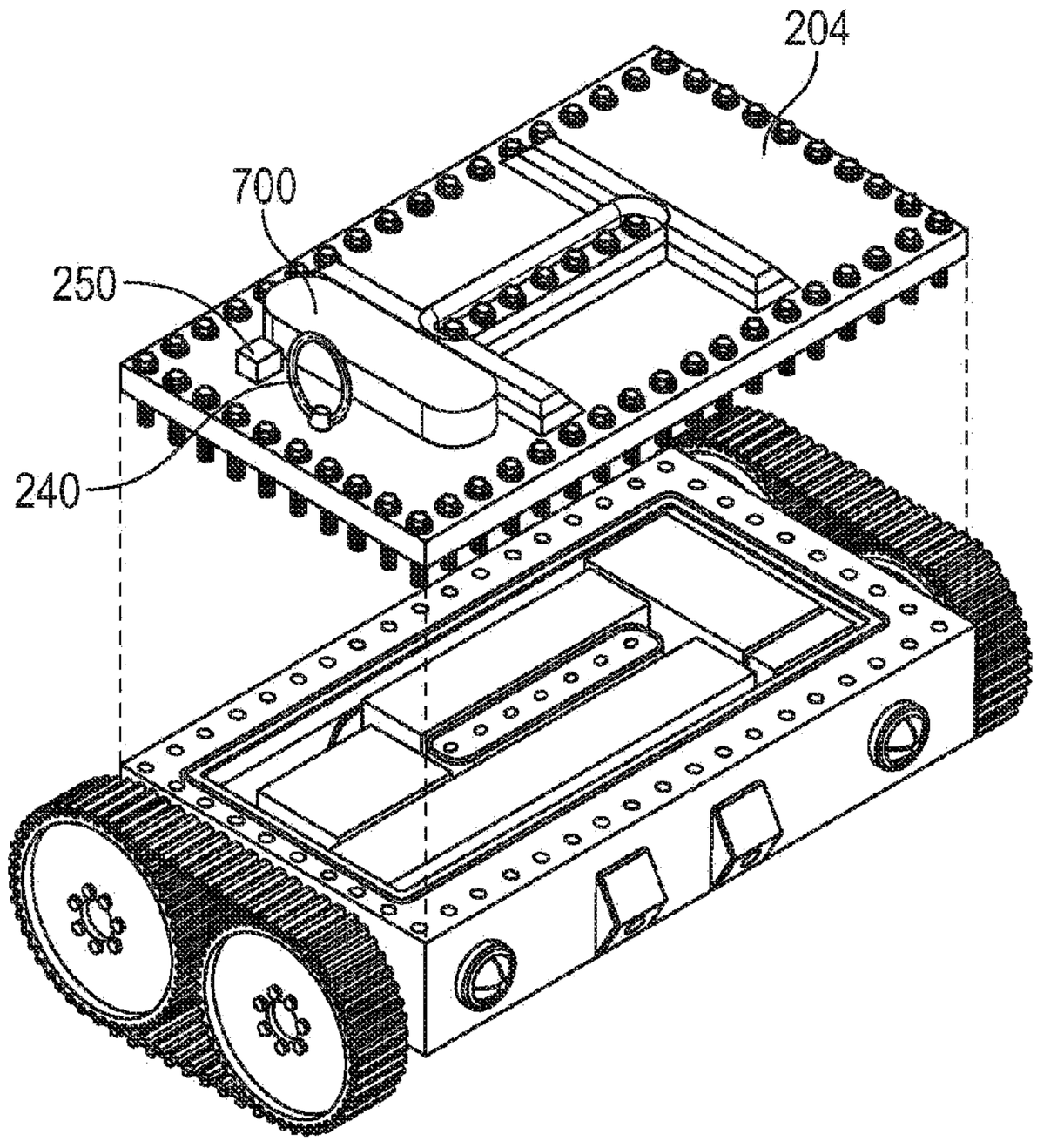


FIG. 12B

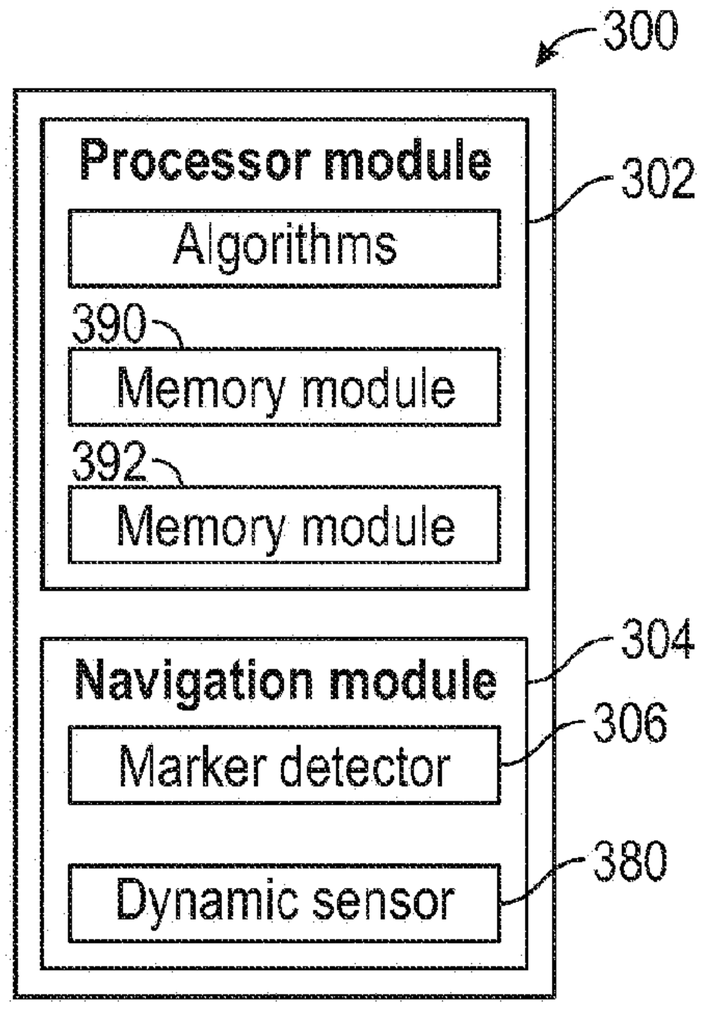

300
Processor module
302
Algorithms
390
Memory module
392
Memory module
304
Navigation module
306
Marker detector
380
Dynamic sensor

FIG. 13

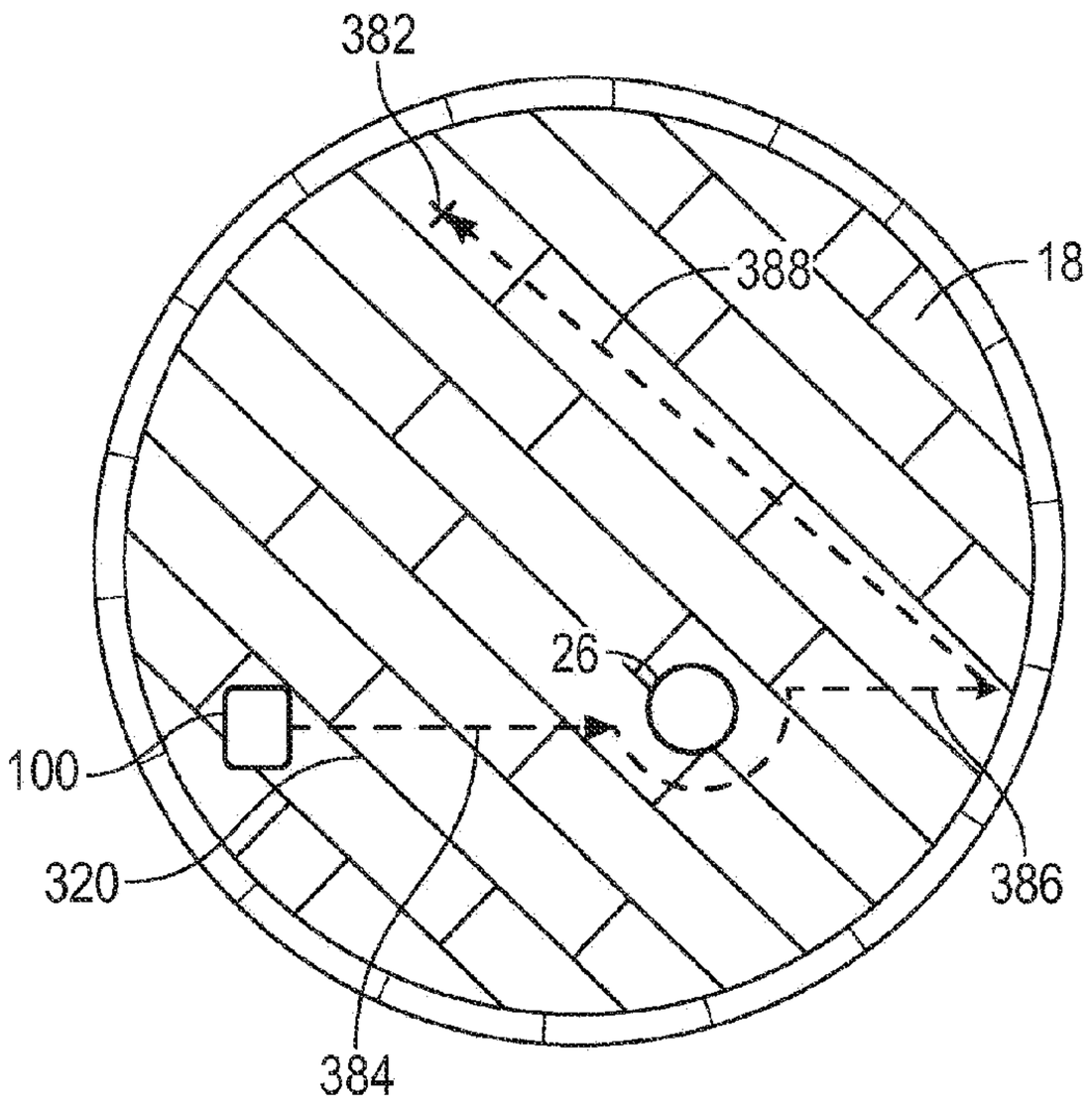

382
388
18
26
100
320
386
384

FIG. 14

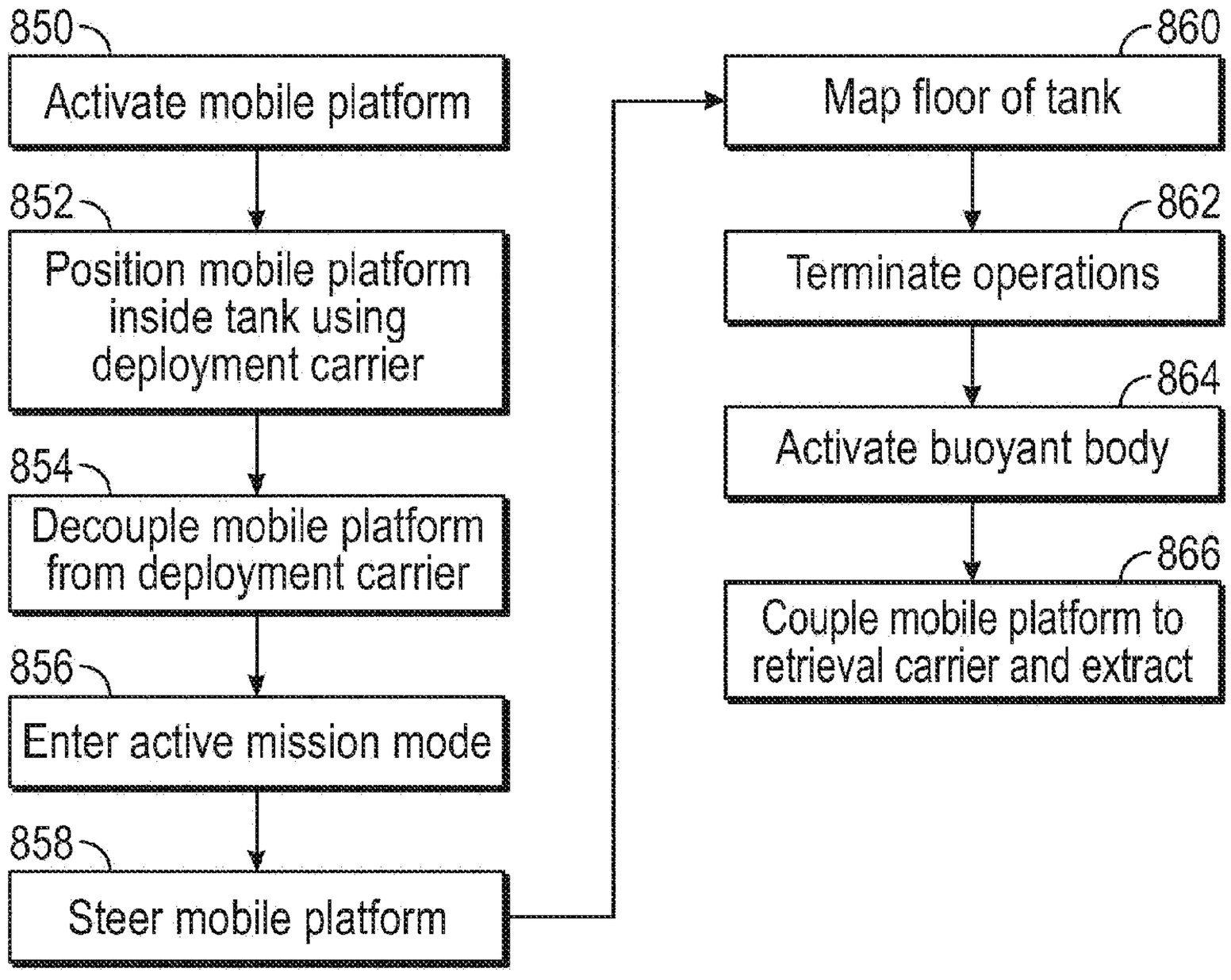

850
Activate mobile platform
852
Position mobile platform inside tank using deployment carrier
854
Decouple mobile platform from deployment carrier
856
Enter active mission mode
858
Steer mobile platform
860
Map floor of tank
862
Terminate operations
864
Activate buoyant body
866
Couple mobile platform to retrieval carrier and extract

FIG. 15

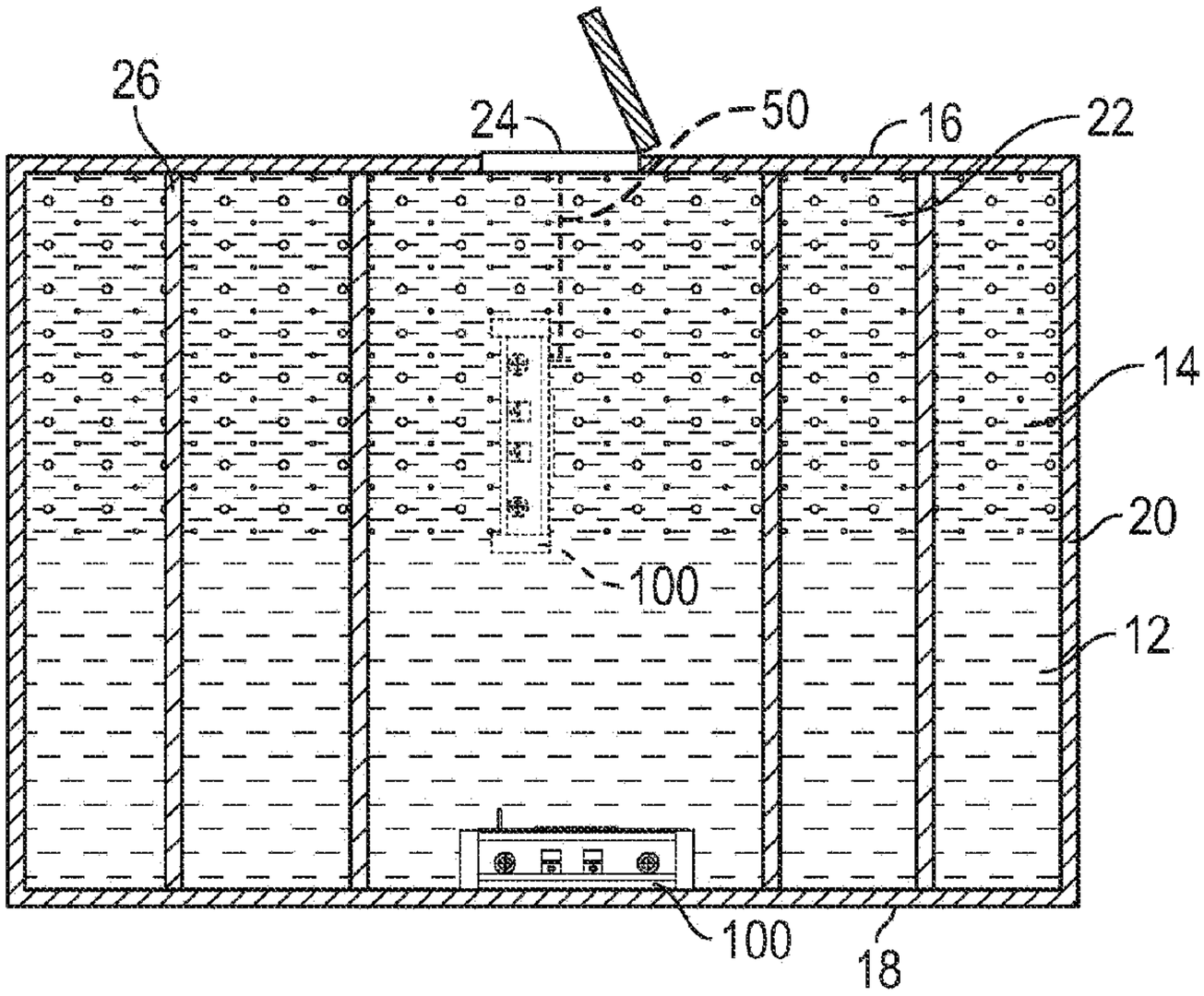


FIG. 16A

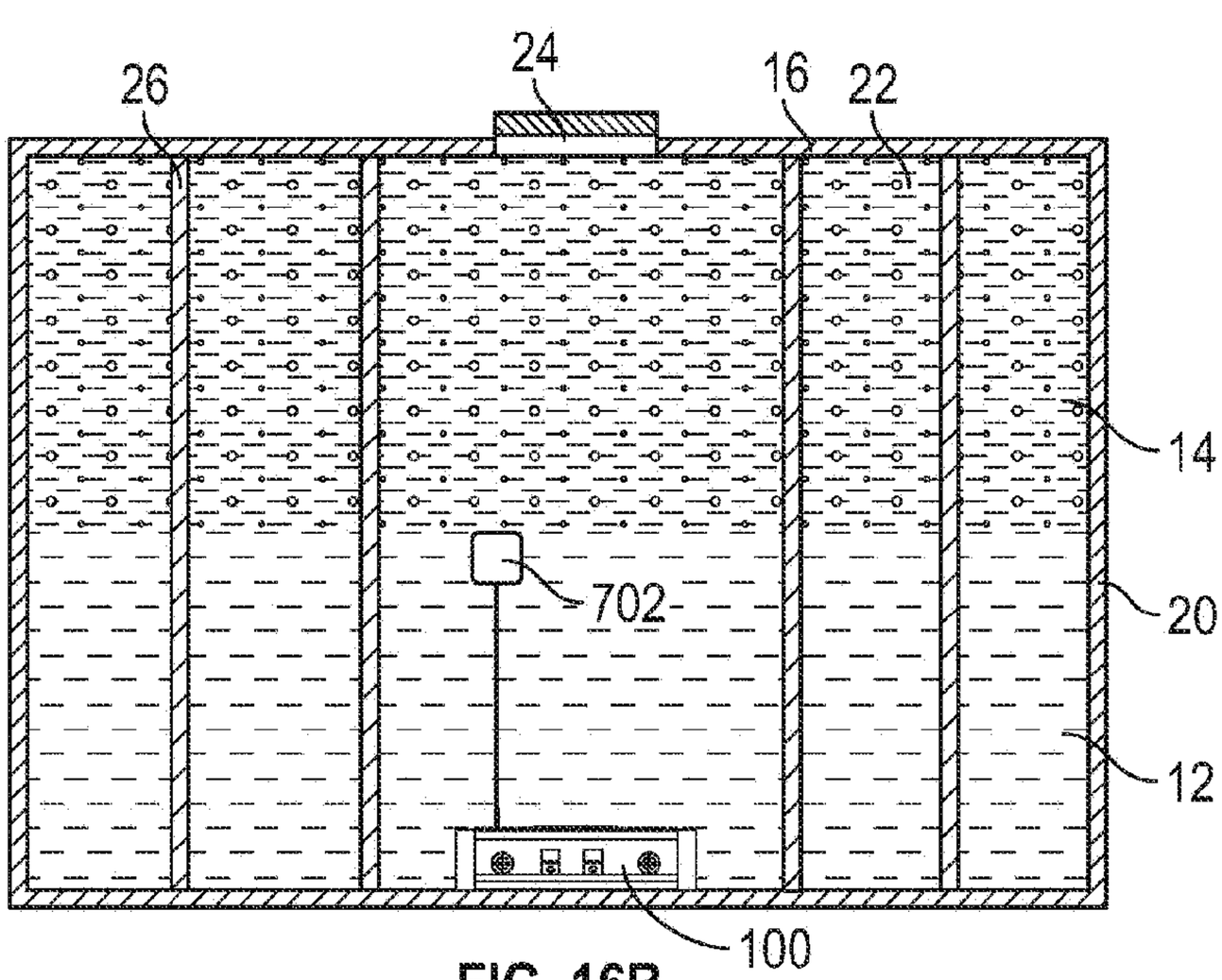


FIG. 16B

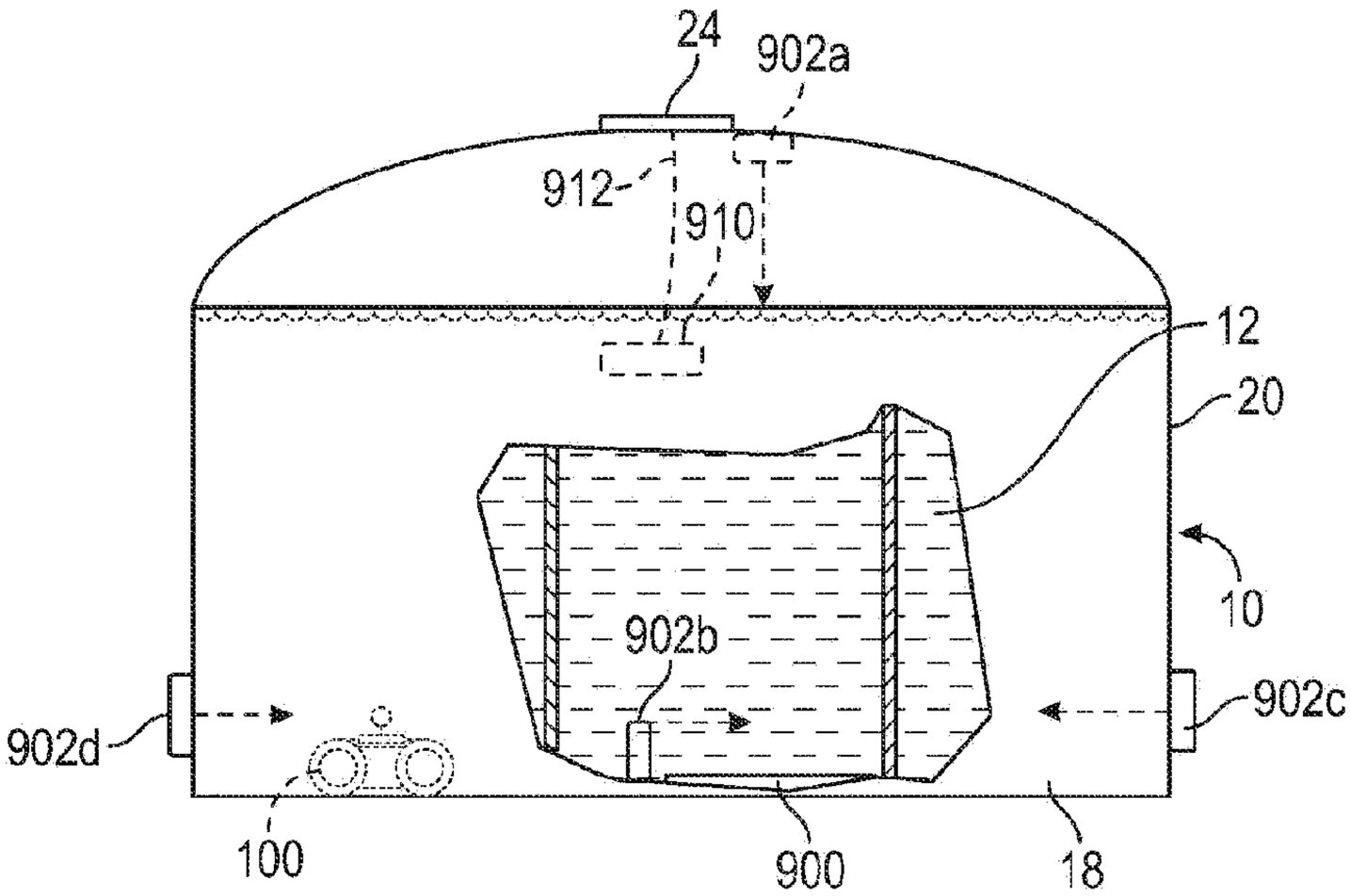


FIG. 17

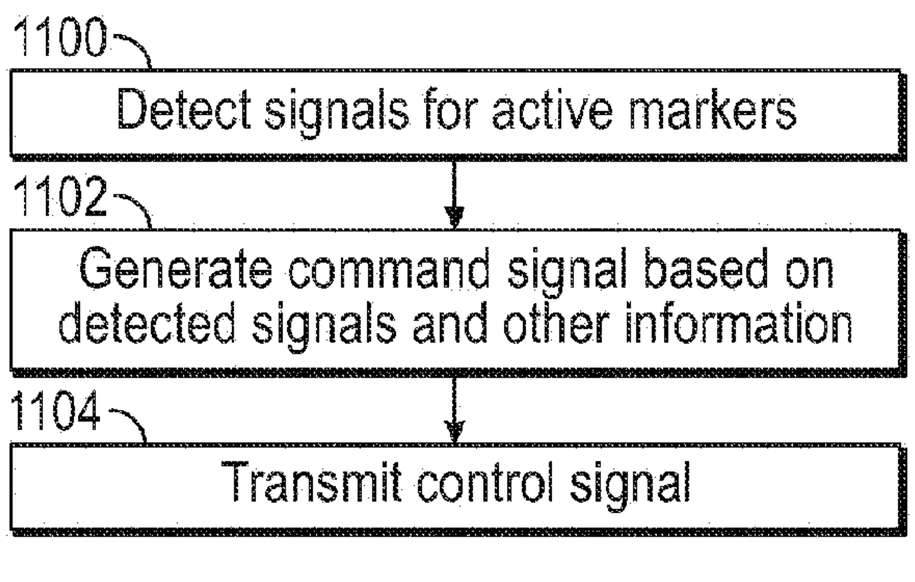


FIG. 18A

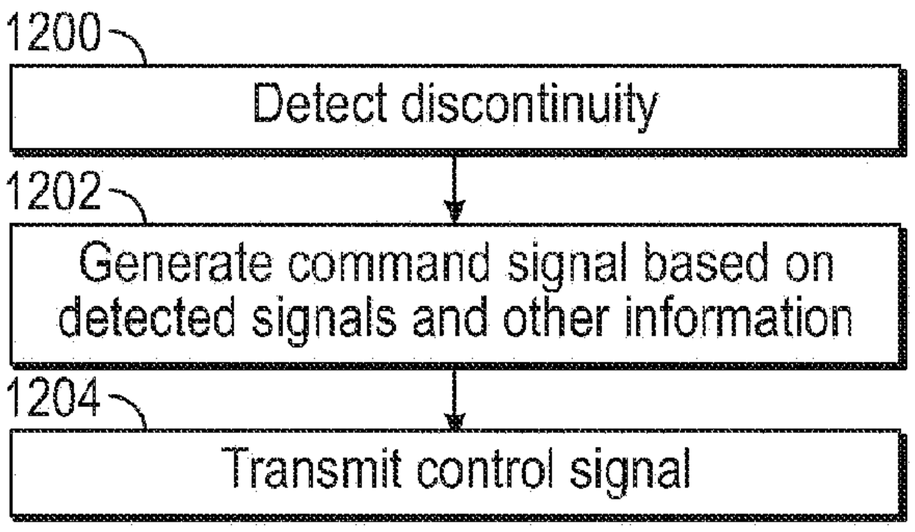


FIG. 18B

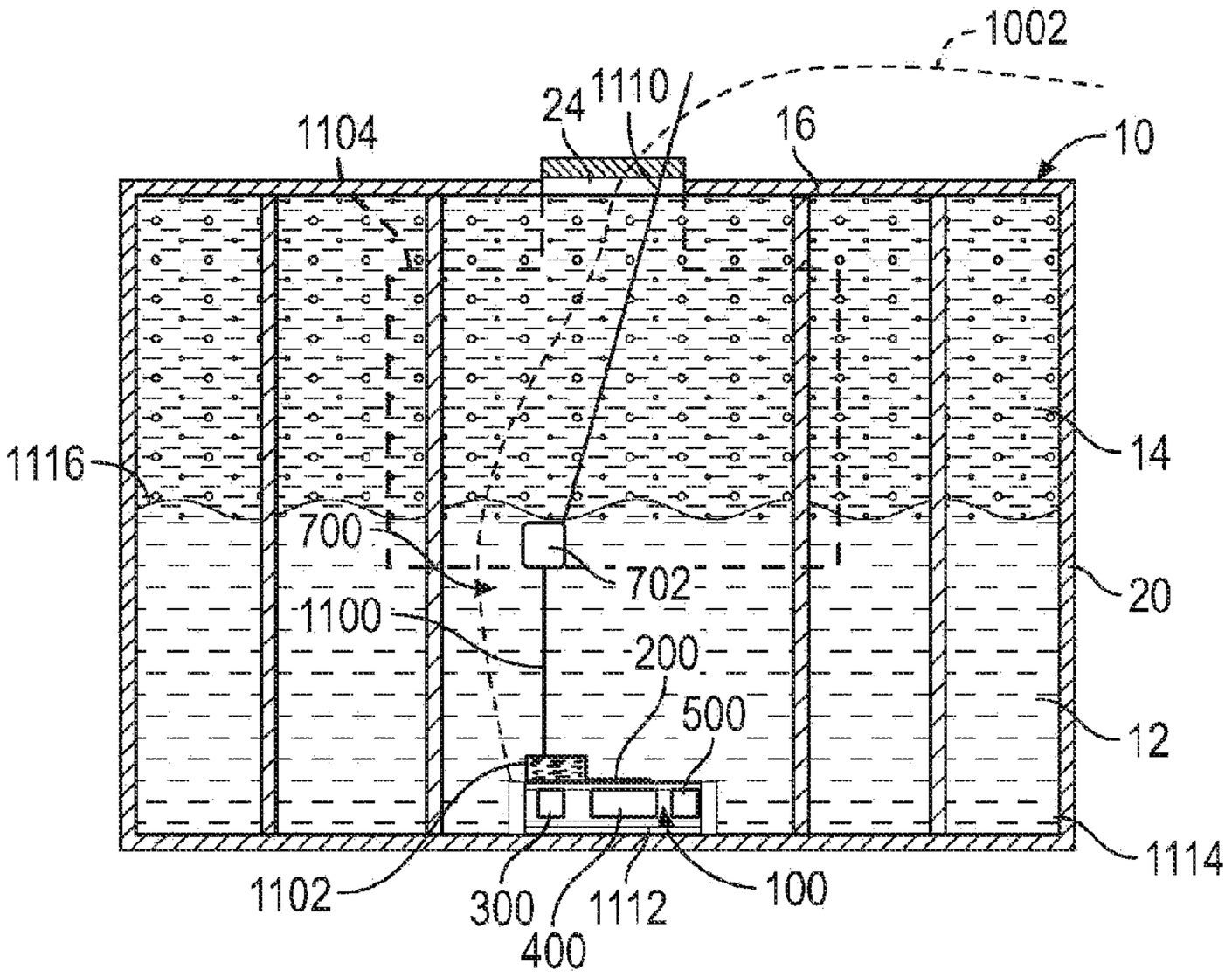


FIG. 19

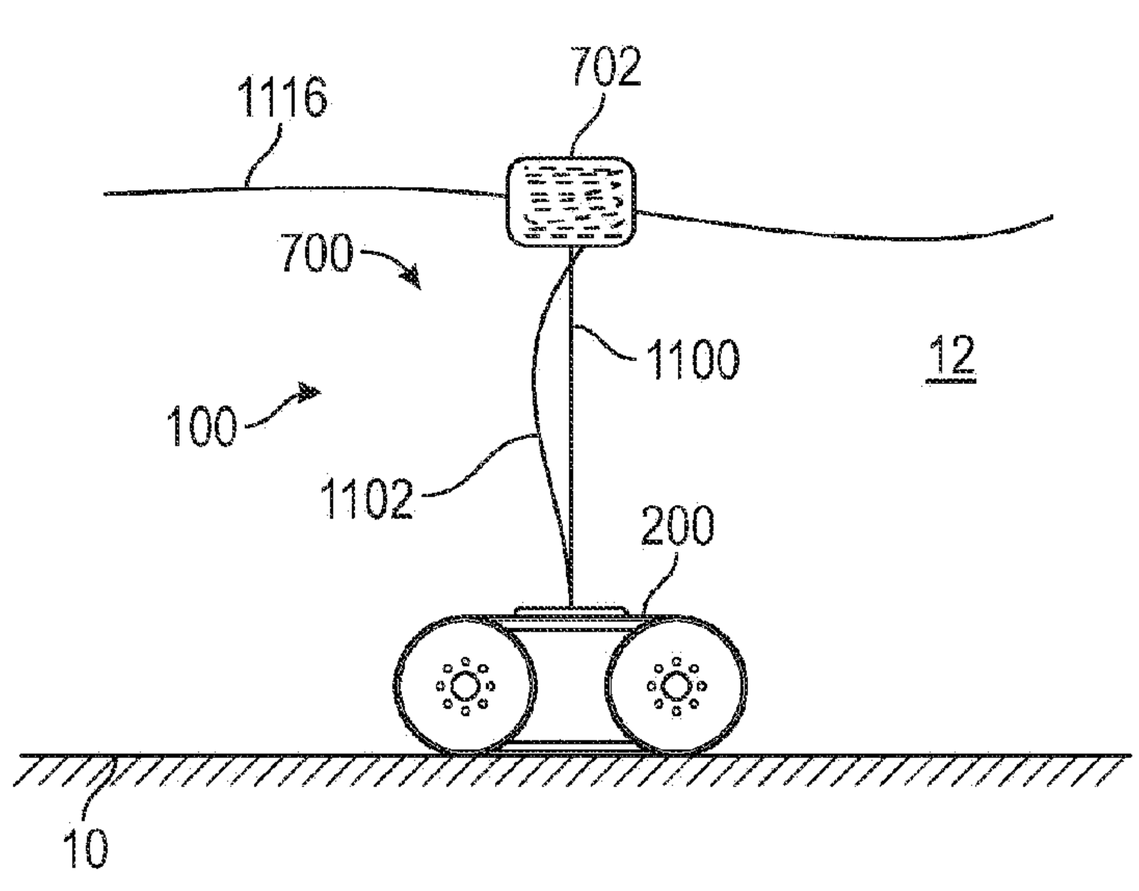


FIG. 20A

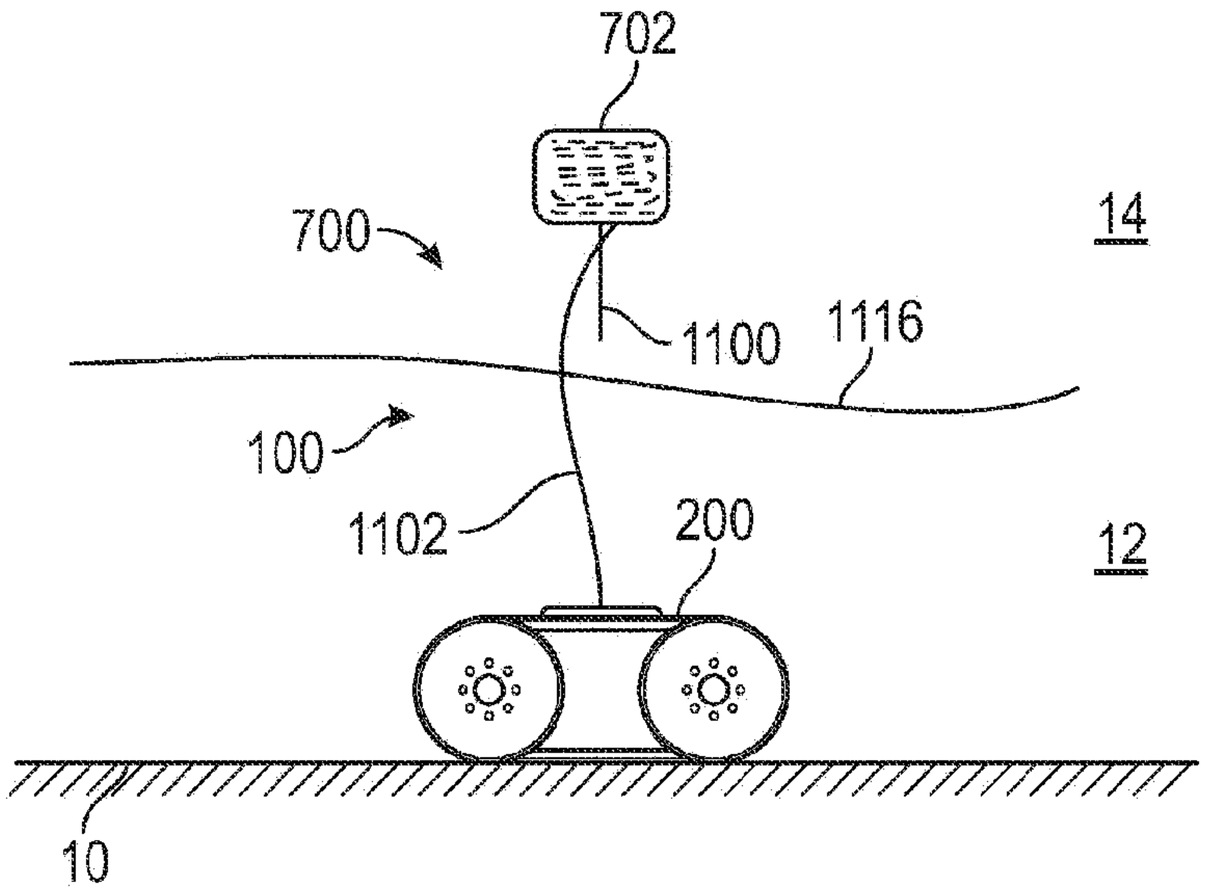


FIG. 20B

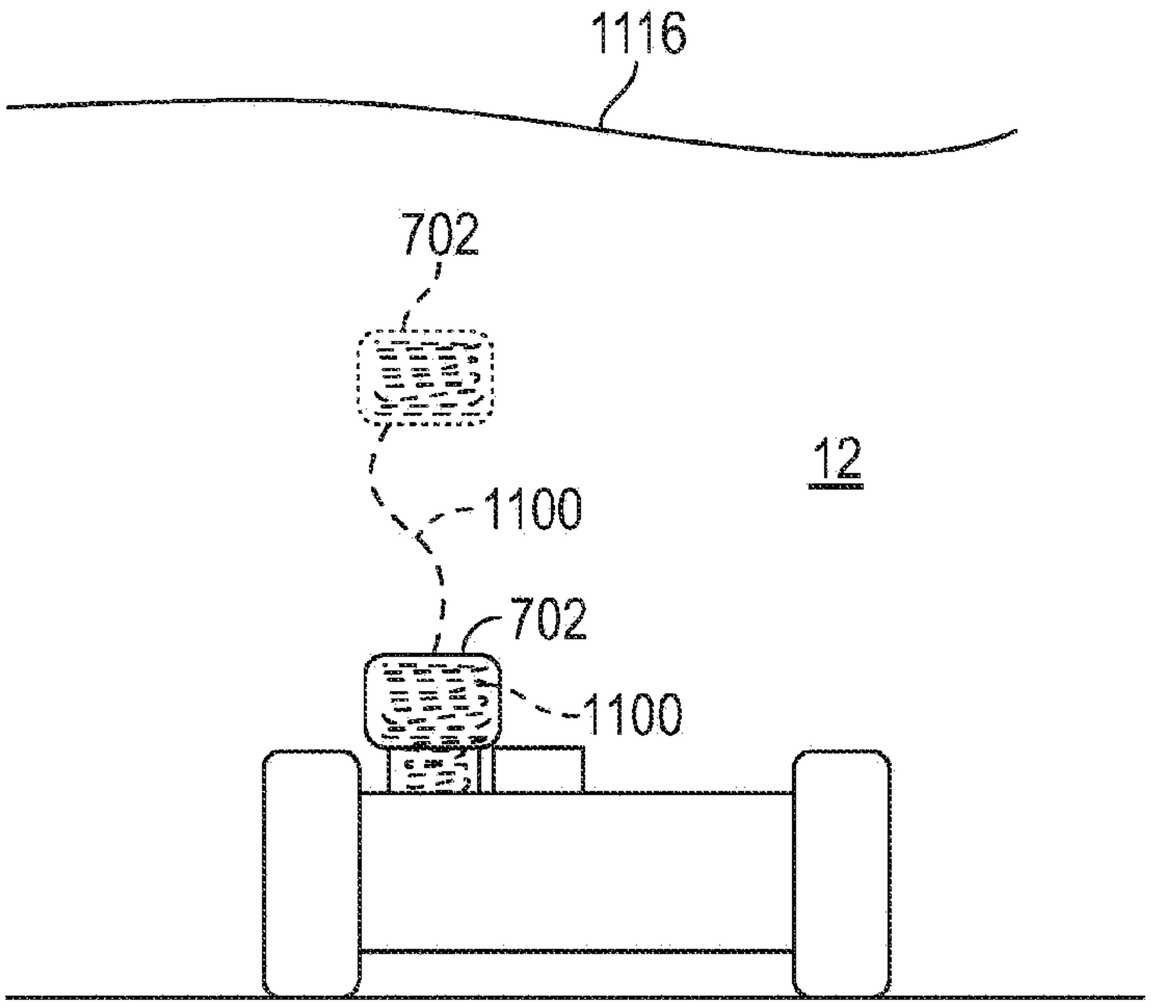


FIG. 20C

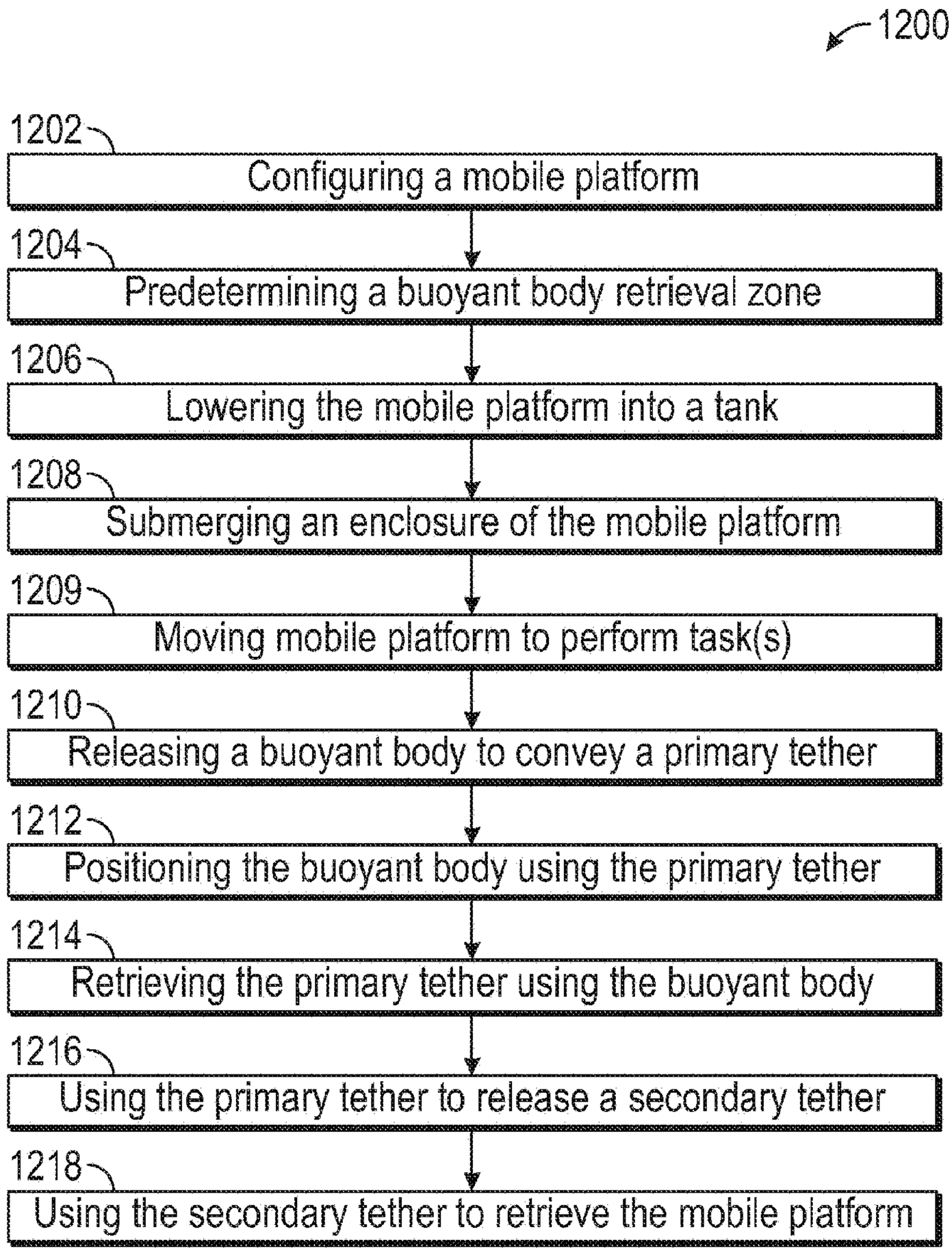

1200
1202
Configuring a mobile platform
1204
Predetermining a buoyant body retrieval zone
1206
Lowering the mobile platform into a tank
1208
Submerging an enclosure of the mobile platform
1209
Moving mobile platform to perform task(s)
1210
Releasing a buoyant body to convey a primary tether
1212
Positioning the buoyant body using the primary tether
1214
Retrieving the primary tether using the buoyant body
1216
Using the primary tether to release a secondary tether
1218
Using the secondary tether to retrieve the mobile platform

FIG. 21

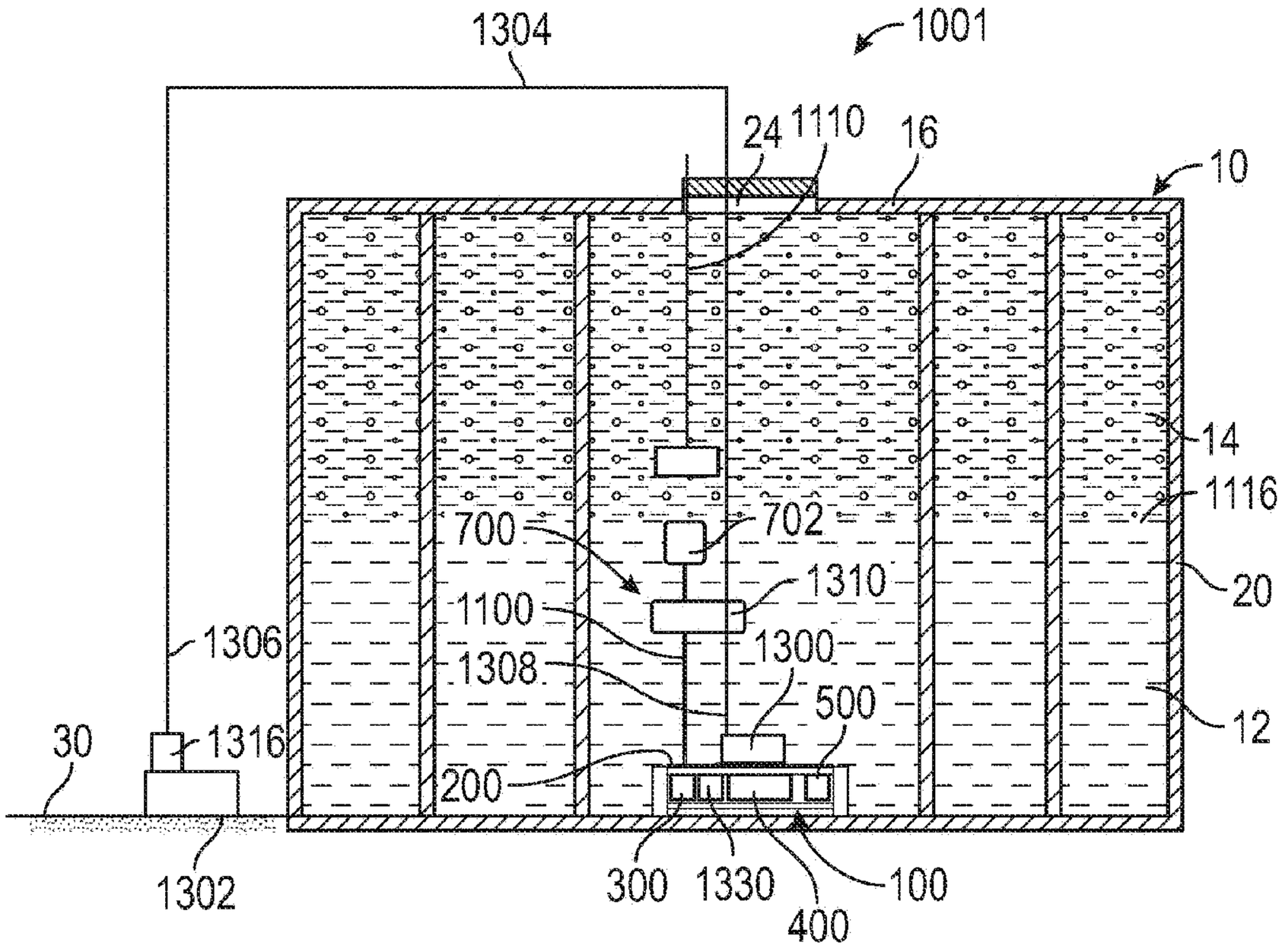

1304
1001
24
1110
16
10
14
1116
20
12
700
702
1310
1100
1300
1308
500
1306
1316
30
200
1302
300
1330
400
100

FIG. 22

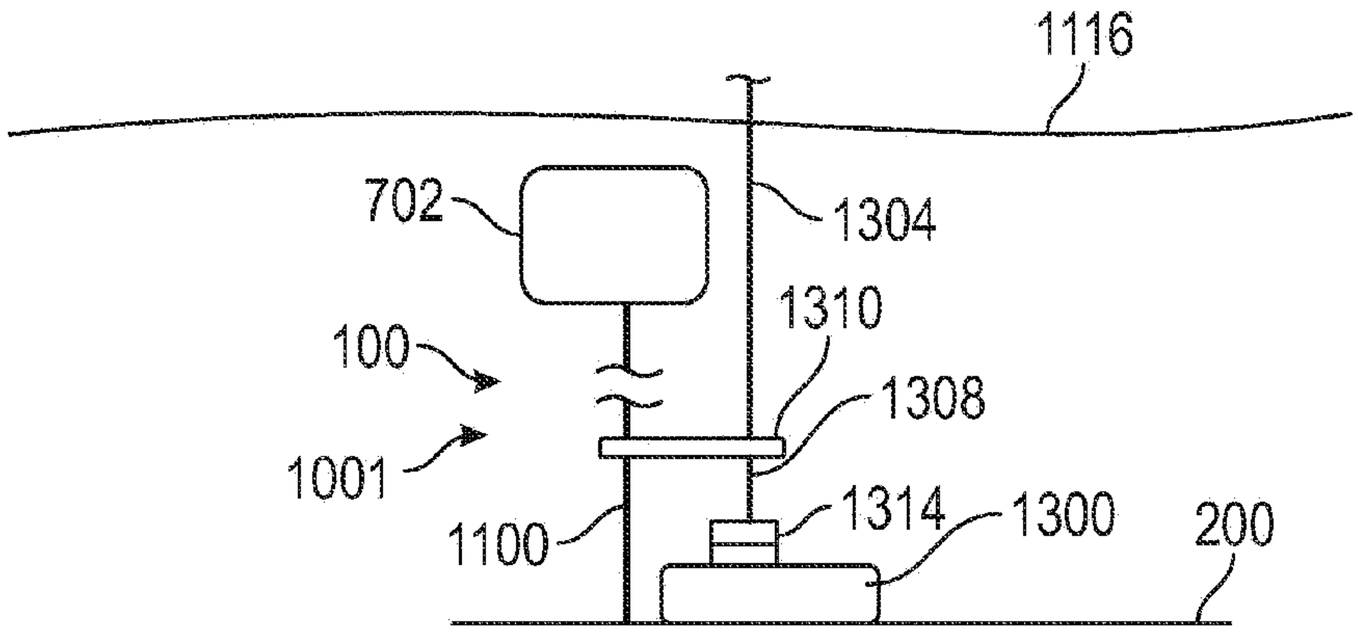

1116
702
1304
1310
100
1308
1001
1314
1300
200
1100

FIG. 23

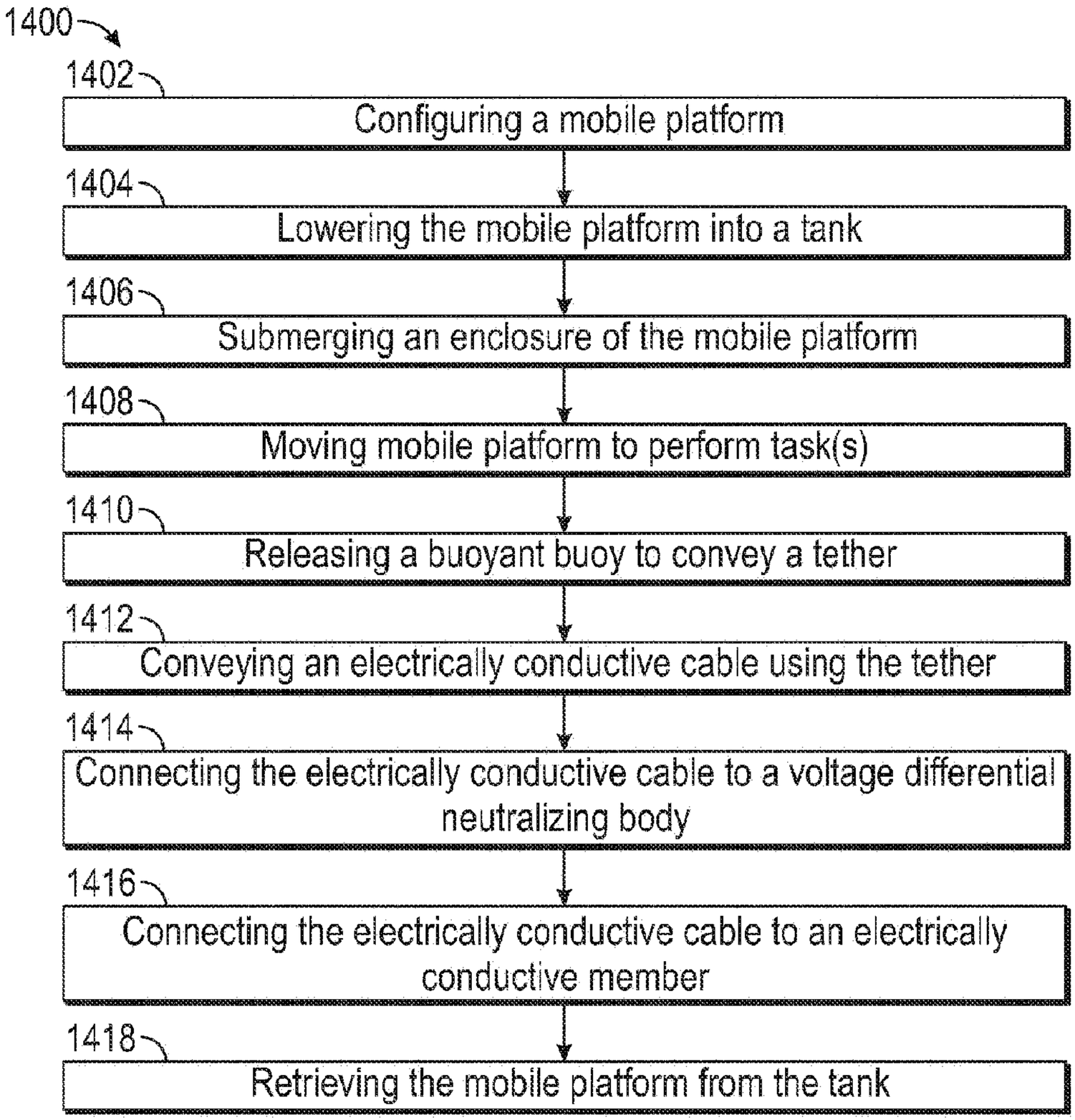


FIG. 24

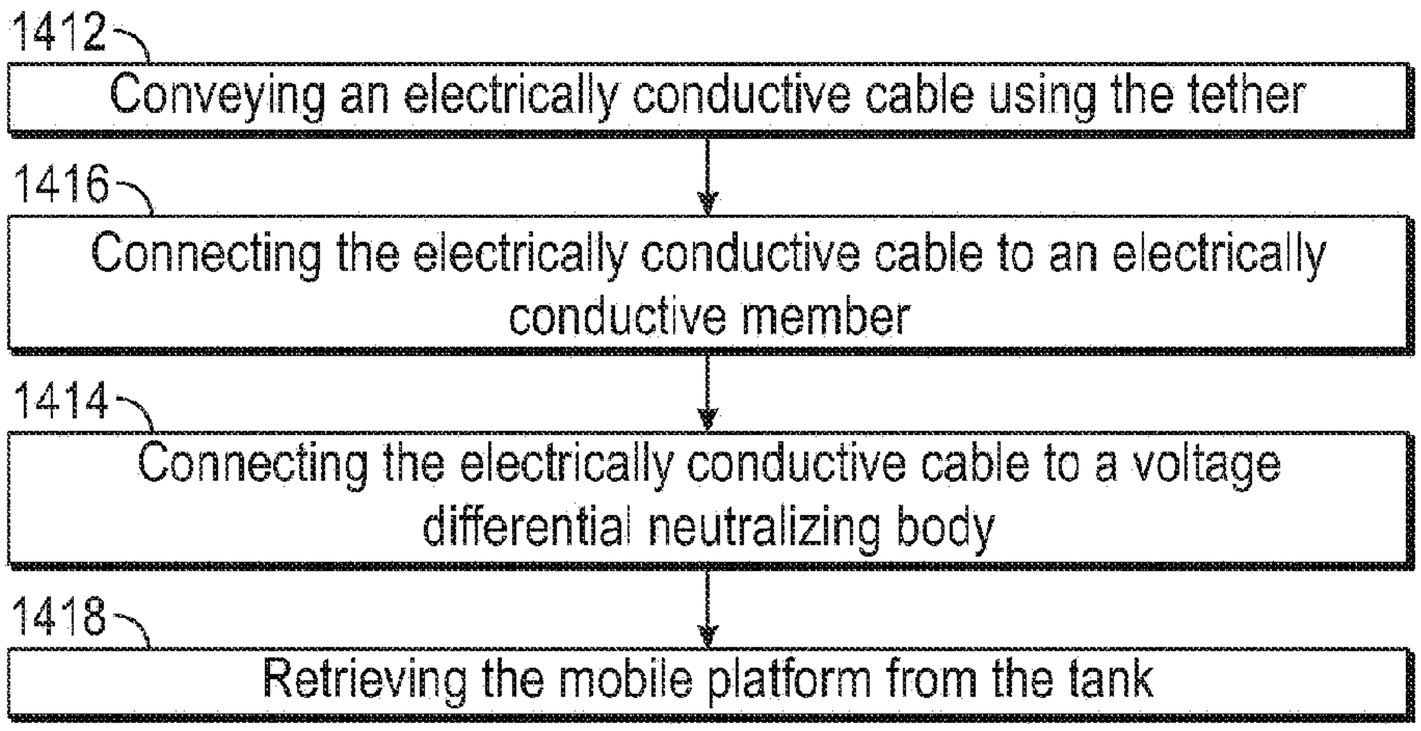


FIG. 25A

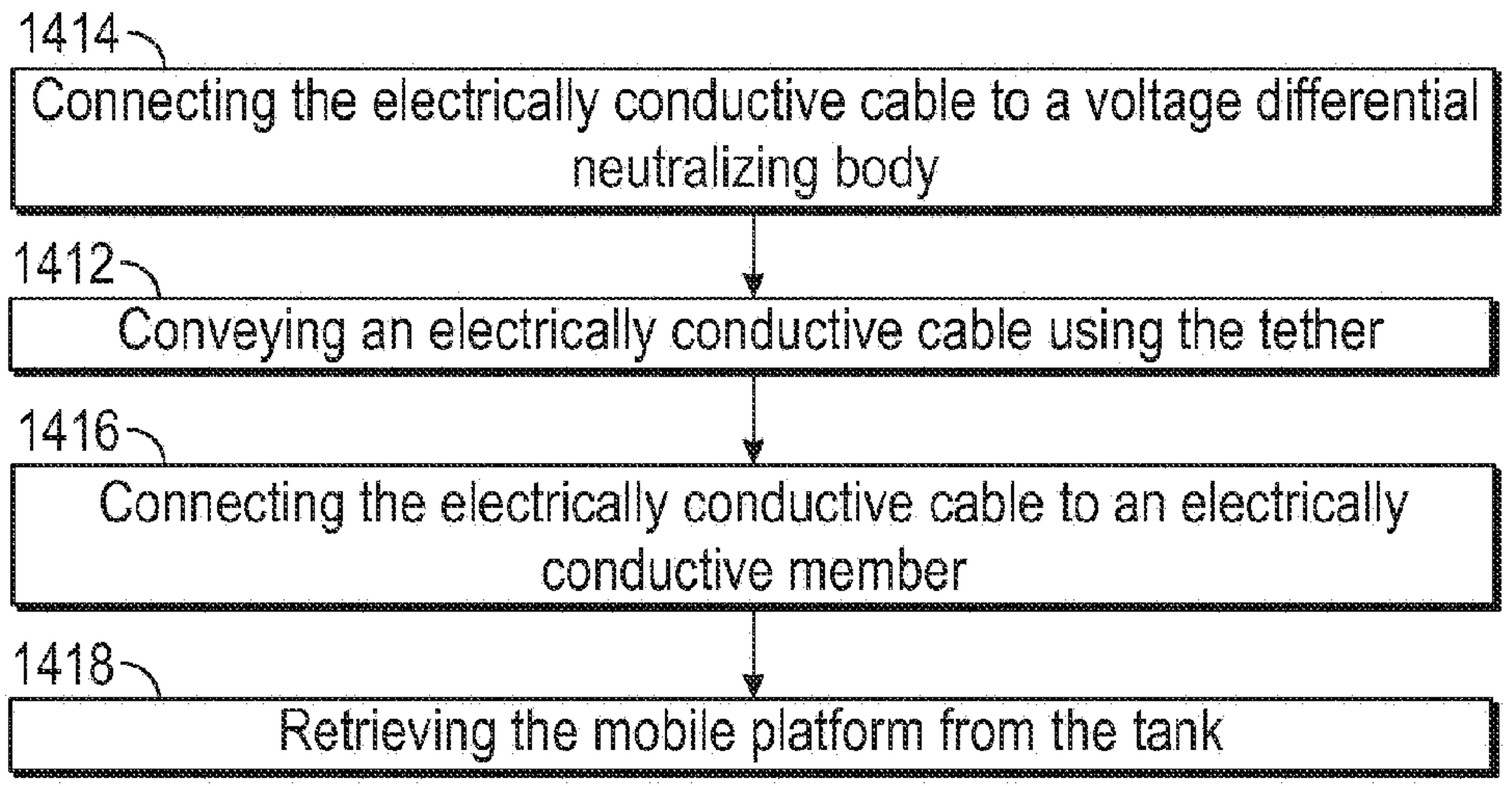


FIG. 25B

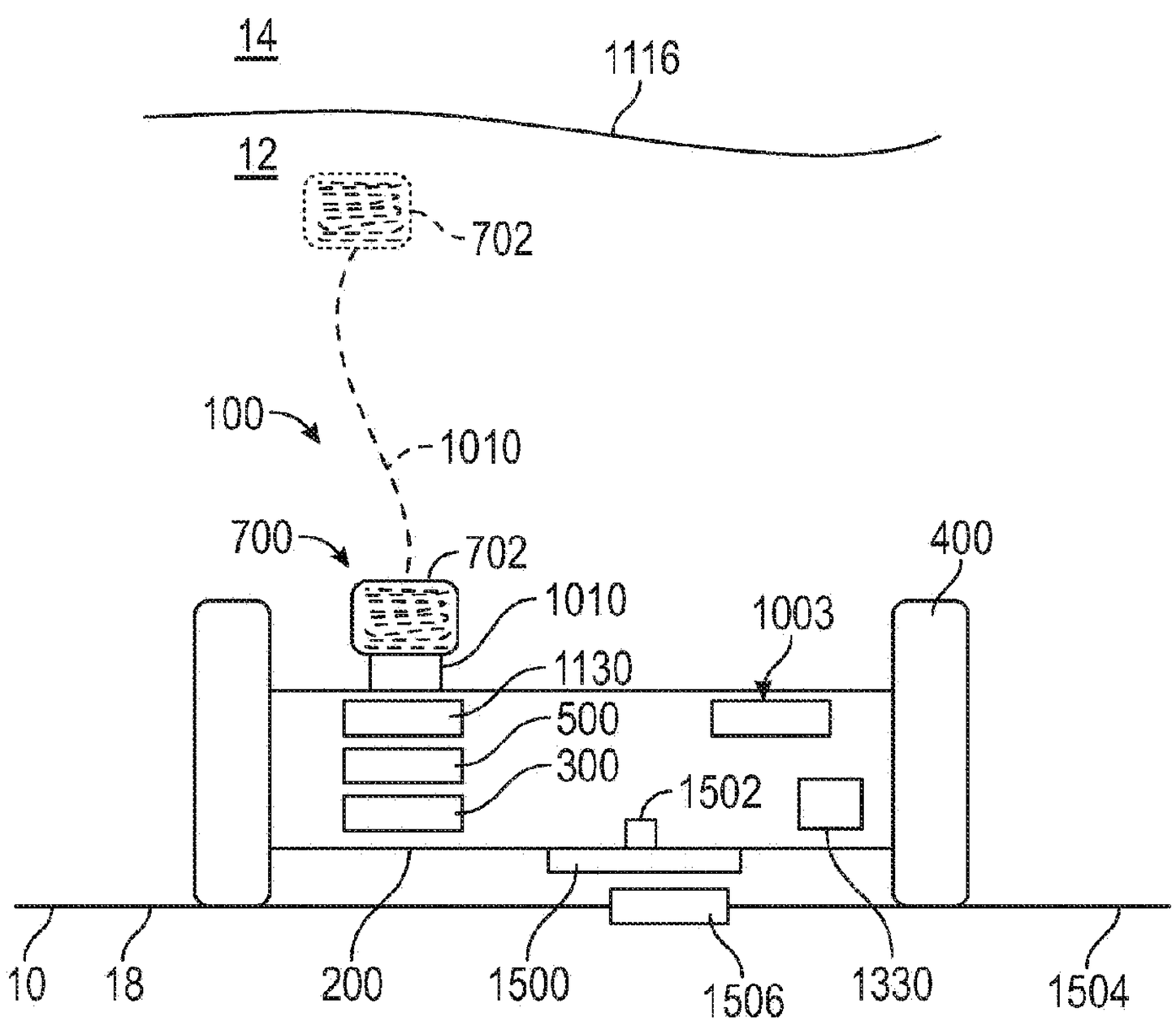


FIG. 26

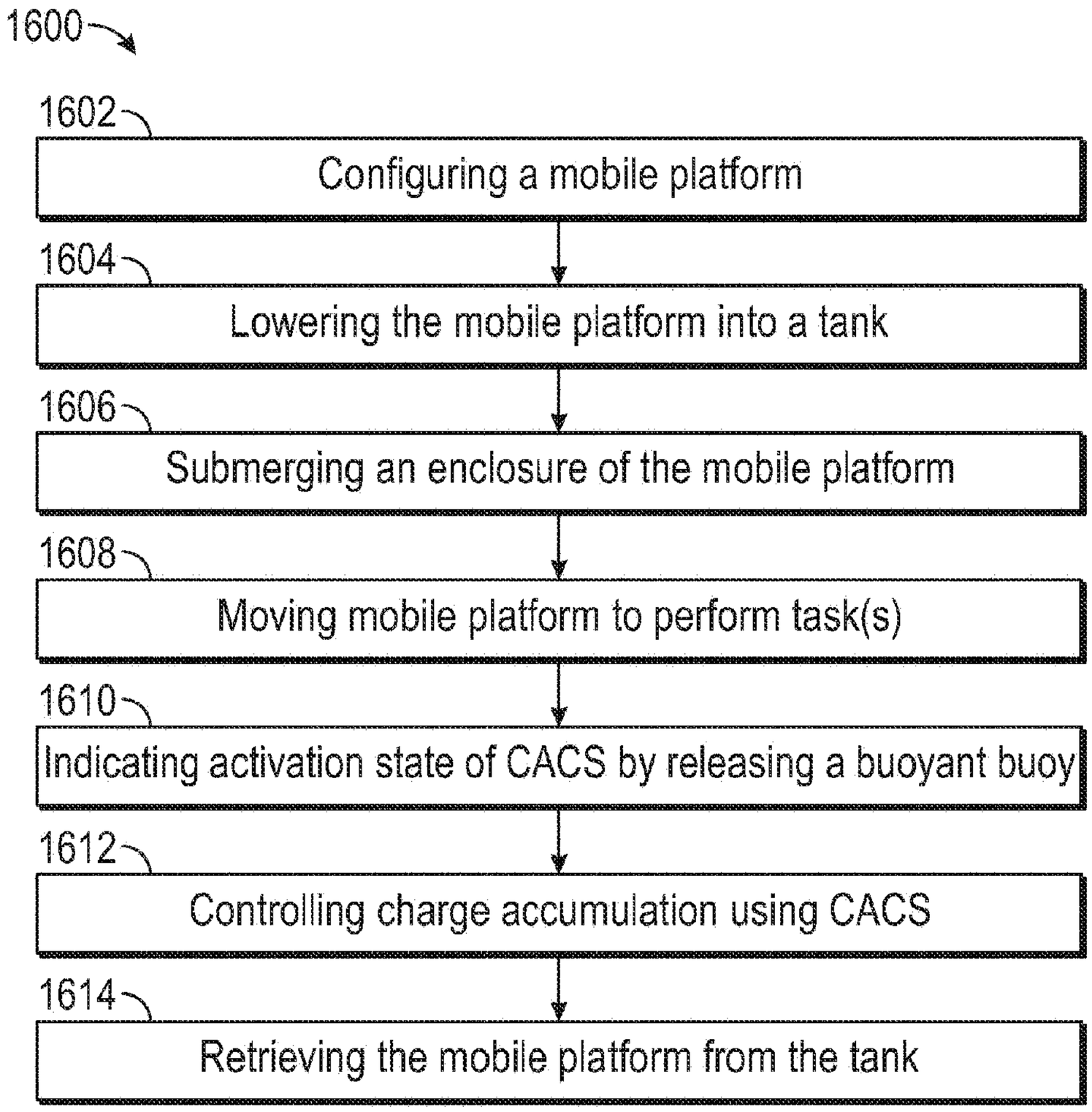

1600
1602
Configuring a mobile platform
1604
Lowering the mobile platform into a tank
1606
Submerging an enclosure of the mobile platform
1608
Moving mobile platform to perform task(s)
1610
Indicating activation state of CACS by releasing a buoyant buoy
1612
Controlling charge accumulation using CACS
1614
Retrieving the mobile platform from the tank

FIG. 27

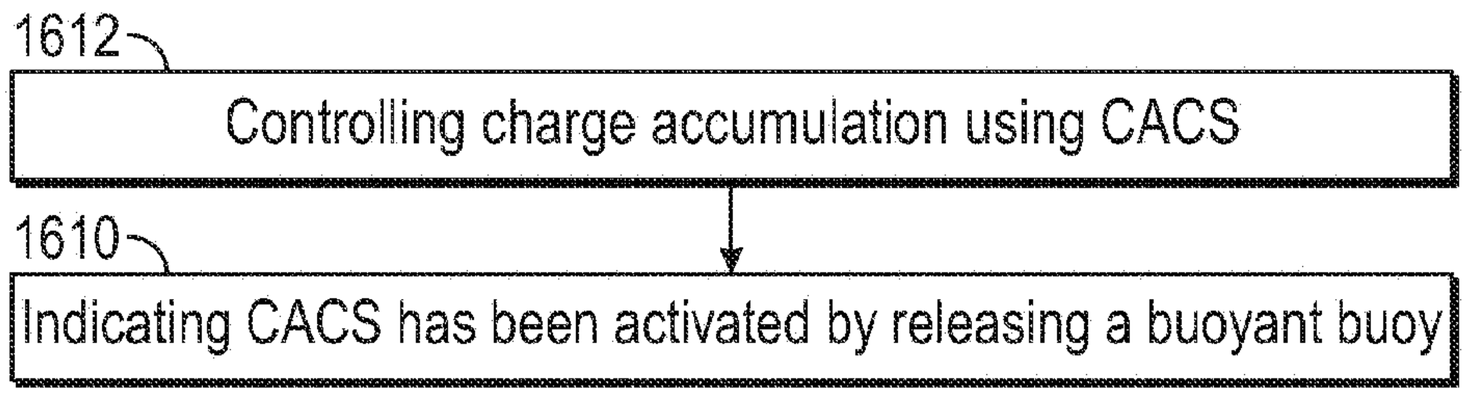

1612
Controlling charge accumulation using CACS
1610
Indicating CACS has been activated by releasing a buoyant buoy

FIG. 28

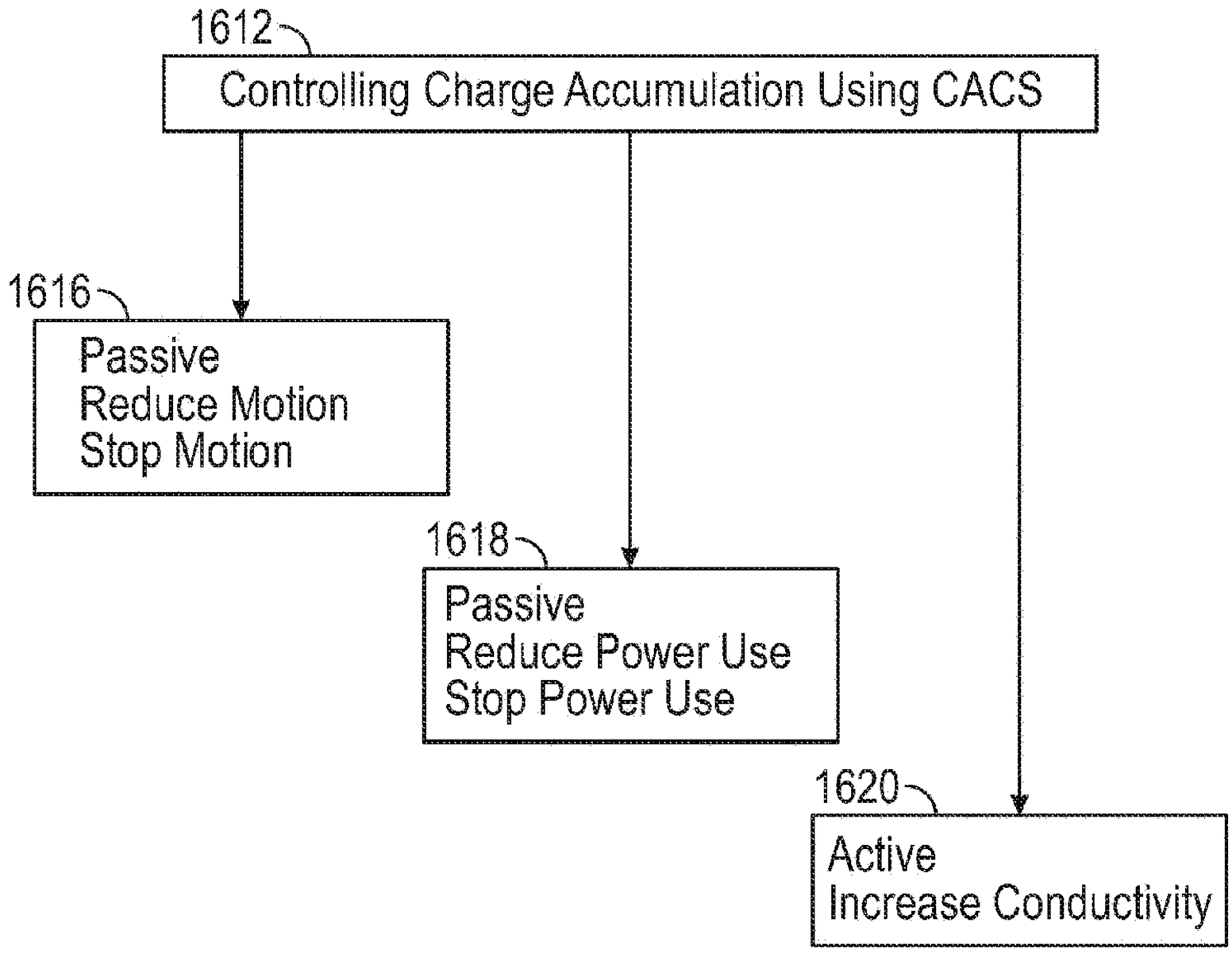

1612
Controlling Charge Accumulation Using CACS
1616
Passive
Reduce Motion
Stop Motion
1618
Passive
Reduce Power Use
Stop Power Use
1620
Active
Increase Conductivity

FIG. 29