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(54) AUTONOMOUS COVERAGE ROBOT WITH LIQUID APPLICATOR

AUTONOMER ROBOTER MIT FLÜSSIGKEITSAPPLIKATOR

ROBOT DE SURFACE AUTONOME AYANT UN APPLICATEUR DE LIQUIDE

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EP 2 661 209 B1

Description

TECHNICAL FIELD

[0001] The disclosure relates to surface cleaning robots, such as robots configured to perform autonomous cleaning tasks.

BACKGROUND

[0002] Wet cleaning of household surfaces has long been done manually using a wet mop or sponge. The mop or sponge is dipped into a container filled with a cleaning fluid to allow the mop or sponge to absorb an amount of the cleaning fluid. The mop or sponge is then moved over the surface to apply a cleaning fluid onto the surface. The cleaning fluid interacts with contaminants on the surface and may dissolve or otherwise emulsify contaminants into the cleaning fluid. The cleaning fluid is therefore transformed into a waste liquid that includes the cleaning fluid and contaminants held in suspension within the cleaning fluid. Thereafter, the sponge or mop is used to absorb the waste liquid from the surface. While clean water is somewhat effective for use as a cleaning fluid applied to household surfaces, most cleaning is done with a cleaning fluid that is a mixture of clean water and soap or detergent that reacts with contaminants to emulsify the contaminants into the water. In addition, it is known to clean household surfaces with water and detergent mixed with other agents such as a solvent, a fragrance, a disinfectant, a drying agent, abrasive particulates and the like to increase the effectiveness of the cleaning process.

[0003] The sponge or mop may also be used as a scrubbing element for scrubbing the floor surface, and especially in areas where contaminants are particularly difficult to remove from the household surface. The scrubbing action serves to agitate the cleaning fluid for mixing with contaminants as well as to apply a friction force for loosening contaminants from the floor surface. Agitation enhances the dissolving and emulsifying action of the cleaning fluid and the friction force helps to break bonds between the surface and contaminants.

[0004] After cleaning an area of the floor surface, the waste liquid must be rinsed from the mop or sponge. This is typically done by dipping the mop or sponge back into the container filled with cleaning fluid. The rinsing step contaminates the cleaning fluid with waste liquid and the cleaning fluid becomes more contaminated each time the mop or sponge is rinsed. As a result, the effectiveness of the cleaning fluid deteriorates as more of the floor surface area is cleaned.

[0005] Some manual floor cleaning devices have a handle with a cleaning fluid supply container supported on the handle and a scrubbing sponge at one end of the handle. These devices include a cleaning fluid dispensing nozzle supported on the handle for spraying cleaning fluid onto the floor. These devices also include a mechan-

ical device for wringing waste liquid out of the scrubbing sponge and into a waste container.

[0006] Manual methods of cleaning floors can be labor intensive and time consuming. Thus, in many large buildings, such as hospitals, large retail stores, cafeterias, and the like, floors are wet cleaned on a daily or nightly basis. Industrial floor cleaning "robots" capable of wet cleaning floors have been developed. To implement wet cleaning techniques required in large industrial areas, these robots are typically large, costly, and complex. These robots have a drive assembly that provides a motive force to autonomously move the wet cleaning device along a cleaning path. However, because these industrial-sized wet cleaning devices weigh hundreds of pounds, these devices are usually attended by an operator. For example, an operator can turn off the device and, thus, avoid significant damage that can arise in the event of a sensor failure or an unanticipated control variable. As another example, an operator can assist in moving the wet cleaning device to physically escape or navigate among confined areas or obstacles.

SUMMARY

[0007] The present invention relates to a surface treatment robot as set out in claim 1 and a method of surface treatment as set out in claim 14.

Presently disclosed is an autonomous robot for treating surfaces, such as floors and countertops, which has a form factor that facilitates cleaning in tightly dimensioned spaces, such as those found in many households. In one example, the robot may include a weight distribution that remains substantially constant throughout the cleaning process, the weight distributed between a cleaning element, a squeegee, and drive wheels. The weight distribution can provide sufficient pressure to the wetting assembly and the squeegee while allowing sufficient thrust to be applied at drive wheels. As an advantage, the robot can have a small volume required to navigate in tightly dimensioned spaces while having a weight distribution configured for wet-cleaning a surface.

[0008] U.S. Pat. Publ. No. 2006/0190134 A1 discloses an autonomous floor cleaning robot includes a transport drive and control system arranged for autonomous movement of the robot over a floor for performing cleaning operations. The robot chassis carries a first cleaning zone comprising cleaning elements arranged to suction loose particulates up from the cleaning surface and a second cleaning zone comprising cleaning elements arranged to apply a cleaning fluid onto the surface and to thereafter collect the cleaning fluid up from the surface after it has been used to clean the surface. The robot chassis carries a supply of cleaning fluid and a waste container for storing waste materials collected up from the cleaning surface.

[0009] Implementations of one or more of these aspects of the disclosure may include one or more of the following features. In some implementations, the liquid

applicator dispenses between about 30 percent and about 70 percent of the liquid forward of the collection assembly and at least about 30 percent of the liquid rear of the collection assembly. For example, the liquid applicator can dispense about 60 percent of the liquid forward of the collection assembly and about 40 percent of the liquid rear of the collection assembly.

[0010] In certain implementations, the liquid applicator includes a spray nozzle arranged to dispense liquid rear of the collection assembly as the robot moves in the forward direction. Additionally or alternatively, the liquid applicator can include a drip assembly configured to drip liquid rear of the collection assembly as the robot moves in the forward direction.

[0011] In some implementations, the collection assembly is a vacuum assembly including a collection region and a suction region in fluid communication with the collection region.

[0012] In certain implementations, a collection volume is carried by the robot body, and the collection volume is in fluid communication with the vacuum assembly to collect waste removed by the vacuum assembly.

[0013] In certain implementations, the collection assembly includes a squeegee formed with a longitudinal ridge disposed proximate to the cleaning surface and extending across a cleaning width for providing a liquid collection volume at a forward edge of the ridge as the robot moves in the forward direction. The squeegee can include a first edge portion and a second edge portion disposed on respective sides of the longitudinal ridge. In certain implementations, a vacuum chamber is at least partially formed by the squeegee. The vacuum chamber can be disposed proximate to the longitudinal ridge.

[0014] In some implementations, the collection assembly includes a surface agitation assembly. The surface agitation assembly can include one or more of the following: a stationary brush, a rotating brush, a woven cloth, a nonwoven cloth, a sponge, and a compliant blade. For example, the surface agitation assembly can include a rotating brush rotatable about an axis substantially parallel to the longitudinal ridge of the squeegee extending across the cleaning width.

[0015] In some implementations, the robot includes a humidity sensor and the surface agitation assembly includes an active scrubbing element configured to act on the cleaning surface based at least in part on detection of humidity on the cleaning surface.

[0016] In certain implementations, the differential drive system includes right and left drive wheels and the collection assembly is disposed rear of the right and left drive wheels.

[0017] In some implementations, the differential drive system includes right and left drive wheels and the collection assembly comprises a squeegee disposed rear of the right and left drive wheels as the robot moves in the forward direction over the cleaning surface.

[0018] In some implementations, a wetting assembly is carried by the robot body. At least a portion of the wet-

ting assembly can be disposed rear of the collection assembly and rear of the liquid applicator as the robot moves in the forward direction. At least a portion of the wetting assembly can contact the cleaning surface as the robot moves in the forward direction.

[0019] In certain implementations, the liquid applicator dispenses between about 100 percent to about 60 percent of the liquid rear of the collection assembly and forward of the wetting assembly. Preferably, the liquid applicator dispenses between about 95 percent and about 100 percent of the liquid rear of the collection assembly. In some implementations, the liquid applicator can dispense substantially all of the liquid rear of the collection assembly.

[0020] In some implementations, the differential drive system can include a right drive wheel and a left drive wheel and the collection assembly is disposed rear of the right and left drive wheels as the robot moves in the forward direction. Additionally, the collection module can include both a wet vacuum subsystem and a dry vacuum subsystem. In some implementations, the robot body includes a lower portion including a wet vacuum portion and a dry vacuum portion of the wet vacuum and dry vacuum system, respectively. A wet vacuum system is configured to pick up a substantial amount of fluid from the cleaning surface. For example, a wet vacuum portion can be closely followed by a longitudinal ridge of a squeegee to build up the thickness of a deposited water film for pick-up. A dry vacuum system is configured to pick up only a small amount of cleaning fluid. In a robot dispensing a majority or all of the fluid rear of the collection assembly, a dry vacuum can also be configured to operate on wet cleaning surfaces.

[0021] The wet vacuum portion can be disposed rear of the right and left drive wheels and the dry vacuum portion can be disposed in front of the right and left drive wheels as the robot moves in the forward direction. A surface agitation assembly can be disposed between the dry vacuum portion and the wet vacuum portion as the robot moves in the forward direction.

[0022] The robot comprises a controller in communication with the differential drive system to direct the robot over the cleaning surface, wherein the controller is configured to direct the robot to return one or several times to at least a portion of the cleaning surface a to collect from the cleaning surface at least some of the cleaning liquid dispensed. For instance, the controller can be configured to direct the robot to make multiple passes over at least a portion of the cleaning surface to collect at least a portion of liquid left on the cleaning surface. In other examples, the controller can be configured to direct the robot to return to positions where cleaning fluid has been deposited on the surface but not yet collected. In still further embodiments, the controller can be configured to maneuver the robot in a pseudo-random pattern across the cleaning surface to increase a probability that the robot returns to a portion of the cleaning surface (for instance, a probability that the robot returns to a portion of

the cleaning surface in a predetermined time span can be 75 percent). The controller can also combine two or more of these behaviors.

[0023] In some implementations, the wetting assembly includes a compliant blade extending in a direction substantially parallel to the cleaning surface. In certain implementations, the wetting assembly includes a plurality of bristles extending from the robot body, toward the cleaning surface. For example, at least some of the plurality of bristles and the cleaning surface can define an oblique angle therebetween (e.g., an acute angle in the direction toward the forward portion of the robot).

[0024] Implementations of one or more of these aspects of the disclosure may include one or more of the following features. In some implementations, dispensing liquid from the liquid applicator to the cleaning surface includes dispensing between about 30 percent and about 70 percent of the liquid forward of the collection assembly and at least about 30 percent of the liquid rear of the collection assembly. For example, dispensing liquid from the liquid applicator to the cleaning surface includes dispensing about 60 percent of the liquid forward of the collection assembly and about 40 percent of the liquid rear of the collection assembly.

[0025] In certain implementations, maneuvering the surface treatment robot includes returning to a portion of the cleaning surface to collect the liquid dispensed rear of the collection assembly.

[0026] Other aspects, features, and advantages will be apparent from the description and drawings, and from the claims.

DESCRIPTION OF DRAWINGS

[0027]

FIG. 1 is a schematic block diagram showing the interrelationship of subsystems of an autonomous cleaning robot.

FIG. 2 is a perspective view of an autonomous cleaning robot.

FIG. 3 is a bottom view of the autonomous cleaning robot of FIG. 2.

FIG. 4 is a side view of the autonomous cleaning robot of FIG. 2.

FIG. 5 is a front view of the autonomous cleaning robot of FIG. 2.

FIG. 6 is a rear view of the autonomous cleaning robot of FIG. 2.

FIG. 7 is an exploded perspective view of the autonomous cleaning robot of FIG. 2.

FIG. 8 is a schematic representation of a liquid applicator module of the autonomous cleaning robot of FIG. 2.

FIG. 9 is a block diagram of a pump control routine of an autonomous cleaning robot.

FIG. 10A is a perspective view of a baseplate of the autonomous cleaning robot of FIG. 2.

FIG. 10B is a bottom view of the baseplate of the autonomous cleaning robot of FIG. 2.

FIG. 10C is a top view of the baseplate of the autonomous cleaning robot of FIG. 2.

FIG. 10E is a side view of the baseplate of the autonomous cleaning robot of FIG. 2.

FIG. 11 is a perspective view of an active brush element.

FIG. 12 is a schematic representation of a vacuum module of an autonomous cleaning robot.

FIG. 13 is a perspective view of a squeegee of the autonomous cleaning robot of FIG. 2.

FIG. 14 is a side view of the squeegee of the autonomous cleaning robot of FIG. 2.

FIG. 15 is a bottom view of the squeegee of the autonomous cleaning robot of FIG. 1.

FIG. 16 is a block diagram of a method of selecting motors for an autonomous cleaning robot.

FIG. 17 is an exploded perspective view of a wheel of an autonomous cleaning robot.

FIG. 18A is a front view of a tire of the wheel of FIG. 17.

FIG. 18B is a side view of the tire of the wheel of FIG. 17.

FIG. 19 is an exploded perspective view of a signal channeler and omni-directional receiver of an autonomous cleaning robot.

FIG. 20 is a schematic side view of a potted printed circuit board of an autonomous cleaning robot.

FIGS. 21A-C are schematic top views of a method of potting a printed circuit board of an autonomous cleaning robot.

FIG. 22 is a perspective view of a printed circuit board cover of an autonomous cleaning robot.

FIG. 23 is a perspective exploded view of a printed circuit board cover of an autonomous cleaning robot.

FIG. 24 is a bottom view of a printed circuit board cover mounted on an autonomous cleaning robot.

FIG. 25 is a perspective exploded view of a trough of an autonomous cleaning robot.

FIG. 25 is a perspective exploded view of a trough of an autonomous cleaning robot.

DETAILED DESCRIPTION

[0028] An autonomous robot may be designed to clean flooring. For example, the autonomous robot may vacuum carpeted or hard-surfaces and wash floors via liquid-assisted washing and/or wiping and/or electrostatic wiping of tile, vinyl or other such surfaces. U.S. Application Serial No. 11/359,961 by Ziegler et al. entitled AUTONOMOUS SURFACE CLEANING ROBOT FOR WET AND DRY CLEANING.

[0029] An autonomous robot is movably supported on a surface and is used to clean the surface while traversing the surface. The robot can wet clean the surface by applying a cleaning liquid to the surface, spreading (e.g., smearing, scrubbing) the cleaning liquid on the surface,

and collecting the waste (e.g., substantially all of the cleaning liquid and debris mixed therein) from the surface. As compared to comparable-sized autonomous dry cleaning robots, an autonomous wet cleaning robot can remove more debris from a surface.

[0030] FIG. 1 is a schematic block diagram showing the interrelationship of subsystems of an autonomous cleaning robot. A controller 1000 is powered by a power module 1200 and receives inputs from a sensor module 1100 and an interface module 1700. The controller 1000 combines the inputs from the sensor module 1100 with information (e.g., behaviors) preprogrammed on the controller 1000 to control a liquid storage module 1500, a liquid applicator module 1400, and a collection module 1300 (e.g., a dry vacuum module, a wet-dry vacuum module, a woven cloth, a nonwoven cloth and/or a sponge) while also controlling a transport drive 1600 to maneuver the autonomous cleaning robot across a cleaning surface (also referred to hereinafter to as a "surface").

of the robot in response to any of various different signals from sensors (e.g., sensors carried on the robot, a navigation beacon). Additionally or alternatively, the controller can direct the robot across the surface in a substantially random pattern to improve the cleaning coverage provided by the robot.

[0031] Prior to the cleaning operation, cleaning liquid can be added to the liquid storage module 1500 via an external source of cleaning liquid. The robot can then be set on a surface to be cleaned, and cleaning can be initiated through an interface module 1700 (e.g., a user interface carried by the robot). The controller 1000 controls the transport drive 1600 to maneuver the robot in a desired pattern across the surface. As the controller 1000 controls the movements of the robot across the surface, the controller also controls a liquid applicator module 1400 to supply cleaning liquid to the surface and a collection module 1300 to collect waste from the surface. For example, as described below, the controller 1000 can control the liquid applicator module 1400 to dispense at least a portion of the total volume of dispensed liquid rear of the collection module 1300 as the drive 1600 maneuvers the robot in a forward direction over the surface. The collection module 1300 can collect the dispensed liquid from the surface as the robot returns to the area of the dispensed liquid. Additionally or alternatively, the liquid dispensed rear of the collection module 1300 can remain on the surface (e.g., to evaporate over time).

[0032] After the cleaning operation is complete (e.g., after all of the cleaning liquid has been dispensed from the robot, after the robot has completed a routine, after an elapsed period of time), waste can be removed from the robot. The robot is lightweight and has a compact form factor that each facilitate, for example, handling of the robot such that the robot can be moved to another area to be cleaned or put in storage until a subsequent use. The robot is substantially sealable (e.g., passively sealable, actively sealable) to minimize spillage of cleaning liquid and/or waste from the robot while the robot is

in use or while the robot is being handled.

[0033] Referring to FIGS. 2-7, a robot 10 includes a chassis 100 carrying a baseplate 200, a bumper 300, a user interface 400, and wheel modules 500, 501. Wheel modules 500, 501 are substantially opposed along a transverse axis defined by the chassis 100. Baseplate 200 is carried on a substantially bottom portion of chassis 100 and at least partially supports a front portion of the chassis 100 above the surface. As wheel modules 500, 501 propel the robot 10 across the surface during a cleaning routine, the baseplate 200 makes slidable contact with the surface and can wet-vacuum the surface by delivering a portion of the cleaning liquid to the surface forward of the wet-vacuum assembly, as described below. The baseplate 200 can spread the cleaning liquid on the surface, and collect waste from the surface and into the volume defined by the robot 10. A user interface 400 is carried on a substantially top portion of the chassis 100 and configured to receive one or more user commands and/or display a status of the robot 10. The user interface 400 is in communication with a controller (described in detail below) carried by the robot 10 such that one or more commands to the user interface 400 can initiate a cleaning routine to be executed by the robot 10. A bumper 300 is carried on a forward portion of the chassis 100 and configured to detect one or more events in the path of the robot 10 (e.g., as wheel modules 500, 501 propel the robot 10 across a surface during a cleaning routine). As described below, the robot 10 can respond to events (e.g., obstacles, cliffs, walls) detected by the bumper 300 by controlling wheel modules 500, 501 to maneuver the robot 10 in response to the event (e.g., away from the event). While some sensors are described herein as being arranged on the bumper, these sensors can additionally or alternatively be arranged at any of various different positions on the robot 10.

[0034] The robot 10 stores cleaning fluid and waste and, thus, substantially the entire electrical system is fluid-sealed and/or isolated from cleaning liquid and/or waste stored on the robot 10. Examples of sealing that can be used to separate electrical components of the robot 10 from the cleaning liquid and/or waste include covers, plastic or resin modules, potting, shrink fit, gaskets, or the like. Any and all elements described herein as a circuit board, PCB, detector, or sensor can be sealed using any of various different methods. An example of the use of a potting material to isolate electrical components of the robot from the cleaning liquid and/or waste is described below.

[0035] The robot 10 can move across a surface through any of various different combinations of movements relative to three mutually perpendicular axes defined by the chassis: a central vertical axis 20, a fore-aft axis 22 and a transverse axis 24. The forward travel direction along the fore-aft axis 22 is designated F (sometimes referred to hereinafter as "forward"), and the aft travel direction along the fore-aft axis 22 is designated A (sometimes referred to hereinafter as "rearward"). The

transverse axis extends between a right side, designated R, and a left side, designated L, of the robot 10 substantially along an axis defined by center points of wheel modules 500, 501. In subsequent figures, the R and L directions remain consistent with the top view, but may be reversed on the printed page.

[0036] In use, a user opens a fill door 304 disposed along the bumper 300 and adds cleaning fluid to the volume within the robot 10. After adding cleaning fluid to the robot 10, the user then closes the fill door 304 such that the fill door 304 forms a substantially water-tight seal with the bumper 300 or, in some implementations, with a port extending through the bumper 300. The user then sets the robot 10 on a surface to be cleaned and initiates cleaning by entering one or more commands on the user interface 400.

[0037] The controller carried by the robot 10 directs motion of the wheel modules 500, 501. The controller can control the rotational speed and direction of each wheel module 500, 501 independently such that the controller can maneuver the robot 10 in any of various different directions. For example, the controller can maneuver the robot 10 in the forward, reverse, right, and left directions. For example, as the robot 10 moves substantially along the fore-aft axis 22, the robot 10 can make repeated alternating right and left turns such that the robot 10 rotates back and forth around the center vertical axis 20 (hereinafter referred to as a wiggle motion). As described in detail below, such a wiggle motion of the robot 10 can allow the robot 10 to operate as a scrubber during the cleaning operation. Additionally or alternatively, a wiggle motion of the robot 10 can be used by the controller to detect stasis of the robot 10. The controller can maneuver the robot 10 to rotate substantially in place such that, for example, the robot can maneuver out of a corner or away from an obstacle. In some implementations, the controller directs the robot 10 over a substantially random (e.g., pseudo-random) path traversing the surface to be cleaned. The controller is responsive to any of various different sensors (e.g., bump sensors, proximity sensors, walls, stasis conditions, and cliffs) disposed about the robot 10. The controller can redirect wheel modules 500, 501 in response to signals from the sensors such that the robot 10 wet vacuums the surface while avoiding obstacles and clutter. If the robot 10 becomes stuck or entangled during use, the controller is configured to direct wheel modules 500, 501 through a series of escape behaviors such that the robot 10 can resume normal cleaning of the surface.

[0038] The robot 10 is generally advanced in a forward direction during cleaning operations. The robot 10 is generally not advanced in the aft (rear) direction during cleaning operations but may be advanced in the aft direction to avoid an object or maneuver out of a corner or the like. All or a portion of a cleaning operation can continue or be suspended during aft transport. For example, the robot 10 can dispense liquid rear of a vacuum assembly as the robot is advanced in a forward direction and can

suspend dispensing this liquid as the robot is advanced in the aft direction.

[0039] During wet vacuuming, cleaning liquid can be dispensed to the surface through an applicator mounted directly to the chassis (e.g., to be used as an attachment point for the bumper and/or to conceal wires). Additionally or alternatively, the cleaning liquid can be dispensed to the surface through an applicator mounted to a baseplate. For example, cleaning liquid can be dispensed through troughs 202a,b carried on the baseplate 200. The trough 202a is carried along a substantially forward portion of the robot 10, and trough 202b is carried along a substantially rear portion of the robot 10 such that the trough 202a is disposed forward of a collection assembly (e.g., a squeegee 208) and the trough 202b is disposed rear of the collection assembly. Each trough 202a,b can define respective injection orifices 210a,b to produce a spray or drip pattern of cleaning fluid to the surface. For example, a pump upstream of the trough 202a,b can force cleaning liquid through injection orifices 210a,b to deliver cleaning liquid to the surface. In some implementations, injection orifices 210a,b are substantially equally spaced along the length of each trough 202a,b to produce a substantially uniform spray pattern of cleaning liquid on the surface. In some embodiments, the injection orifices 210a,b are configured to allow cleaning liquid to drip from the injection orifices 210a,b.

[0040] A wetting assembly 204 is carried on the baseplate 200, substantially rearward of the trough 202a. The wetting assembly 204 includes rows 205 and row 206 of bristles substantially forward of the squeegee 208 and row 207 of bristles substantially rear of the squeegee 208. Rows 205 of bristles extend in a transverse direction substantially the entire width (e.g., diameter) of the robot 10. In use, at least a portion of the wetting assembly 204 slidably contacts the surface to support a forward portion and/or a rear portion of the robot 10 above the cleaning surface. As the robot 10 moves in a substantially forward direction, the sliding contact between the wetting assembly 204 and the surface spreads the cleaning liquid on the surface. In some implementations, additional rows of bristles and/or other types of wetting elements are carried on the baseplate 200 to further spread and/or agitate the cleaning liquid on the surface. As the robot continues to move forward, wheel modules 500, 501 pass through the cleaning liquid spread on the surface by rows 205 forward of the squeegee 208. A combination of weight distribution (e.g., drag) of the robot 10, material selection and tread geometry for the tires of the wheel modules 500, 501, and a biased-to-drop suspension system improve the traction of wheel modules 500, 501 through the cleaning liquid such that wheel modules 500, 501 can pass over the cleaning liquid without substantial slipping and can navigate small obstacles (e.g., grout lines, tile edges, etc.) that may be wet.

[0041] A squeegee 208 formed with a longitudinal ridge is carried on the baseplate 200 and, during use, extends from the baseplate 200 to movably contact the surface.

The squeegee 208 is positioned substantially rearward of the wheel modules 500, 501. As compared to a robot including a squeegee in a more forward position, such rearward positioning of the squeegee 208 can increase the dwell time of the cleaning liquid dispensed through the trough 202a on the surface and, thus, increase the effectiveness of the cleaning operation. Additionally or alternatively, such a rearward positioned squeegee 208 can stabilize the robot 10 by reducing rearward tipping of the robot 10 in response to thrust created by the wheel modules 500, 501 propelling the robot 10 in a forward direction. In another example, the rearward positioned squeegee 208 can stabilize the robot 10 by reducing rearward tipping of the robot 10 as the robot 10 climbs a grout line. In yet another example, squeegee 208 has about 0.25 mm to about 0.75 mm of interference with the cleaning surface such that the squeegee 208 biases the weight of the robot 10 toward the forward direction as the robot 10 maneuvers over an obstacle. In some implementations, the squeegee 208 is movable away from the cleaning surface by about 2 mm to about 4 mm to facilitate, for example, movement of the robot 10 over an obstacle such as a grout line.

[0042] As described in detail below, the movable contact between the squeegee 208 acts to lift waste (e.g., a mixture of cleaning liquid and debris) from the cleaning surface as the robot 10 is propelled in a forward direction. The squeegee 208 is configured to pool the waste substantially near suction apertures 262 defined by the squeegee 208. A vacuum assembly carried by the robot 10 suctions the waste from the cleaning surface and into the robot 10, leaving behind a wet vacuumed surface.

[0043] After all of the cleaning fluid has been dispensed from the robot 10, the controller stops movement of the robot 10 and provides an alert (e.g., a visual alert or an audible alert) to the user via the user interface 400. The user can then open an empty door 104 to expose a waste port defined by the waste collection volume remove collected waste from the robot 10. Because the fill door 304 and the empty door 104 are disposed along substantially opposite sides of the chassis, the fill door 304 and the empty door 104 can be opened simultaneously to allow waste to drain out of the robot 10 while cleaning liquid is added to the robot 10.

[0044] If the user wishes to move the robot 10 between uses, the user may move (e.g., rotate) a handle 401 away from the chassis 100 and lift the robot 10 using the handle 401. The handle 401 can pivot about a transverse axis (e.g., a center transverse axis) including the center of gravity of the robot 10 such that the handle 401 can be used to carry the robot 10 substantially like a pail. The robot 10 includes a sealing system 601 (e.g., a passive sealing system and/or an active sealing system) such that the robot 10 remains substantially water-tight during transport. The sealing system 601 can reduce the escape of waste and/or cleaning fluid from the robot 10 as the robot is moved from one area to another. Accordingly, the robot 10 can be moved and stored with little risk of

creating hazardous, slippery conditions resulting from liquid dripping from the robot. Additionally or alternatively, the robot 10 can be moved and stored with little risk of dripping liquid on the user or on surfaces that have already been cleaned.

[0045] After moving the robot 10, the user can position the handle 401 back into a position substantially flush with the top portion of the robot to reduce the potential for the handle 401 becoming entangled with an object while the robot 10 is in use. In some implementations, the handle 401 can be magnetized to bias the handle 401 toward a position flush with the top portion of the robot. In some implementations, the handle 401 includes a spring that biases the handle 401 toward a position substantially flush with the top portion of the robot 10.

[0046] Between uses, the user can recharge a power supply carried on-board the robot 10. To charge the power supply, the user can open a charge port door 106 on a back portion of the chassis 100. With the charge port door 106 open, the user can connect a wall charger to a charge port behind the charge port door 106. The wall charger is configured to plug into a standard household electrical outlet. During the charging process, one or more indicators (e.g., visual indicators, audible indicators) on the user interface 400 can alert the user to the state of charge of the power supply. Once the power supply has been recharged (e.g., as indicated by the user interface 400), the user can disconnect the robot 10 from the wall charger and close the charge port door 106. The charge port door 106 forms a substantially water-tight seal with the chassis 100 such that the charge port remains substantially free of liquid when the charge port door 106 is closed. In some implementations, the power supply is removed from the robot 10 and charged separately from the robot 10. In some implementations, the power supply is removed and replaced with a new power supply. In some implementations, the robot 10 is recharged through inductive coupling between the robot 10 and an inductive transmitter. Such inductive coupling can improve the safety of the robot 10 by reducing the need for physical access to electronic components of the robot 10.

Form Factor

[0047] The chassis 100, baseplate 200, bumper 300, user interface 400, and wheel modules 500, 501 fit together such that robot 10 has a substantially cylindrical shape with a top surface and a bottom surface that is substantially parallel to and opposite the top surface. Such a substantially cylindrical shape can reduce the potential for the robot 10 to become entangled (e.g., snagged) and/or break on obstacles as the robot 10 traverses a surface.

[0048] In some implementations, the substantially cylindrical shape of the robot 10 has a form factor that allows a user to lift and manipulate the robot 10 in a manner similar to the manipulation of a typical canteen carried

by hikers. For example, a user can fill the robot 10 with cleaning liquid by placing the robot 10 under a typical bathroom or kitchen faucet. With the robot 10 in the same orientation used to fill the robot with cleaning liquid, the robot can be emptied into the bathroom or kitchen sink. The robot 10 includes a front face 302 and a back face 102, each of which are substantially flat and configured to balance the robot 10 on end. For example, a user can place back face 102 on a substantially flat surface (e.g., a countertop, bottom of a kitchen sink, bottom of a bathtub) such that the robot 10 is balanced on the countertop with front face 302 facing upward toward the user. Such an orientation can allow a user to fill the robot 10 with cleaning liquid without holding the robot. Additionally or alternatively, a user can place front face 302 on a substantially flat surface to allow a user to more easily access components of the robot 10 (e.g., a battery compartment, a charging port).

[0049] The robot 10 performs cleaning operations in tightly dimensioned areas. In some implementations, the robot 10 can have a compact form factor for avoiding clutter or obstacles while dispensing liquid on a surface and/or removing waste from the surface. For example, the robot 10 can be dimensioned to navigate household doorways, under toe kicks, and under many typical chairs, tables, portable islands, and stools, and behind and beside some toilets, sink stands, and other porcelain fixtures. In certain implementations, the overall height of the robot 10 is less than a standard height of a toe-kick panel of a standard North American bathroom vanity. For example, the overall height of the robot 10 can be less than about 18 centimeters (e.g., about 15 centimeters, about 12 centimeters, about 9 centimeters). In certain implementations, the overall diameter of the robot 10 is approximately equal to the standard distance between the base of an installed toilet and a bathroom wall. As compared to larger diameter robots, such a diameter of the robot 10 can improve cleaning around the base of a toilet, e.g., substantially between the toilet and the wall. For example, the overall diameter of the robot 10 can be less than about 26 centimeters (e.g., about 12-18 cm to permit, for example, going behind many bathroom surfaces not reachable by conventional robots). In certain implementations, the wheel modules 500, 501 are configured to maneuver the robot 10 in such tightly dimensioned spaces (e.g., in a volume of less than about 3 L).

[0050] While the robot 10 is described as having a substantially cylindrical shape in the range of dimensions described above, the robot 10 can have other cross-sectional diameter and height dimensions, as well as other cross-sectional shapes (e.g. square, rectangular and triangular, and volumetric shapes, e.g. cube, bar, and pyramidal) to facilitate wet cleaning narrow or hard-to-reach surfaces.

[0051] Within a given size envelope, larger volumes of cleaning liquid can be stored by reducing, for example, the volume required for the other functions (e.g., liquid dispensing, collecting) of the robot 10. For example, the

volume of cleaning liquid that can be stored can be increased by increasing the fraction of cleaning liquid dispensed rear of the squeegee 208 as the robot moves in the forward direction such that a larger portion of the dispensed cleaning liquid can evaporate before the robot 10 can return to collect the cleaning liquid. In some implementations, the robot 10 carries a volume of cleaning fluid that is at least about 20 percent (e.g. at least about 30 percent, at least about 40 percent) of the volume of the robot 10.

Physics and Mobility

[0052] The robot 10 is configured to clean approximately 150 square feet of cleaning surface in a single cleaning operation. A larger or smaller tank may permit this to range from 100 square feet to 400 square feet. The duration of the cleaning operation is approximately 45 minutes. In implementations with smaller, larger, or 2 or more batteries on board, the cleaning time can range down to 20 minutes or up to 2 hours. Accordingly, the robot 10 is configured (physically, and as programmed) for unattended autonomous cleaning for 45 minutes or more without the need to recharge a power supply, refill the supply of cleaning fluid or empty the waste materials collected by the robot.

[0053] In implementations in which the robot 10 is configured to collect substantially all of the cleaning fluid delivered to the surface upstream of the squeegee 208 in a single pass, the average forward travel speed of the robot 10 can be a function of the cleaning quality and/or the surface coverage area required for a given implementation. For example, slower forward travel speeds can allow a longer soak time (e.g., longer contact time) between the cleaning fluid (e.g., cleaning fluid dispensed through trough 202a) and the debris on the surface such that the debris can be more easily removed from the surface through suction with the squeegee 208. In some implementations, the average forward travel speed of the robot 10 can be increased by dispensing at least some of the cleaning liquid rear of the squeegee as the robot moves in the forward direction.

[0054] Additionally or alternatively, faster forward travel speeds can allow the robot 10 to clean a larger surface area before requiring refilling with cleaning liquid and/or recharging the power supply. Accordingly cleaning quality and surface coverage that is acceptable to consumers is achieved by configuring the robot 10 to dispense between about 30 percent and about 70 percent (e.g., about 60 percent by volume) of a cleaning liquid through the trough 202a forward of the squeegee, dispensing at least about 30 percent (e.g., about 40 percent by volume) of the cleaning liquid through the trough 202b rear of the squeegee, and allowing between about 0.3 and about 0.7 seconds of contact between the cleaning liquid dispensed through trough 202a and the surface before the cleaning liquid dispensed through the trough 202a is collected into the robot 10 through squeegee 208. In some

implementations, substantially all of the liquid dispensed through the trough 202a is collected (e.g., vacuumed) through the squeegee 208. Additionally or alternatively, the robot 10 may return to collect at least a portion of the liquid dispensed through the trough 202b. Given that the liquid dispensed through the trough 202a and collected through squeegee 208 cleans the surface in advance of application of liquid through the trough 202b as the robot moves in the forward direction, the liquid dispensed through the trough 202b is dispensed onto a substantially clean surface and, therefore, may be left on the cleaning surface to evaporate.

[0055] In one example, when the robot 10 has a diameter of about 17 centimeters and travels at a forward rate of about 25 centimeters/second, the contact time between the cleaning liquid and the surface is about 0.25 to about 0.6 seconds, the variation in contact time depending on the positioning of the cleaning fluid distribution relative to the forward edge of the robot 10 and the positioning of the collection assembly (e.g., squeegee 208) relative to the rearward edge of the robot.

[0056] In some implementations, the robot 10 the controller 1000 is configured to allow the robot 10 to subsequently return (e.g., through navigation) to collect from the surface at least some of the cleaning liquid dispensed, through trough 202b, rear of the squeegee 208. For example, the robot 10 may make multiple passes over the cleaning surface to collect at least a portion of the liquid left on the cleaning surface. As compared to dispensing all of the cleaning liquid forward of the squeegee 208 (e.g., through trough 202a), dispensing at least some of the cleaning liquid rear of the squeegee 208 allows cleaning liquid to be left on the surface for a longer period of time (e.g., to allow the cleaning liquid to react chemically with debris on the surface) while the robot 10 travels at a higher rate of speed. The controller 1000 allows the robot 10 to return to positions where the cleaning fluid has been deposited on the surface but not yet collected. In some implementations, the controller 1000 can maneuver the robot in a pseudo-random pattern across the surface such that the robot is likely to return to the portion of the surface upon which cleaning fluid has remained.

[0057] As described above, the transverse distance between wheel modules 500, 501 (e.g., the wheel base of robot 10) is substantially equal to the transverse cleaning width (e.g., the transverse width of the wetting assembly 204). Thus, during a cleaning operation, wheel modules 500, 501 are configured to grip a portion of the surface, including obstacles such as grout lines that may form part of the surface, covered with cleaning liquid. With sufficient traction force, the wheel modules 500, 501 can propel the robot 10 through the cleaning liquid. With insufficient traction force, however, the wheel modules 500, 501 can slip on the cleaning liquid and the robot 10 can become stuck in place. As described below, the wheel modules 500, 501 include tires with a surface roughness sufficient to penetrate the surface tension of

the cleaning liquid on the surface to facilitate gripping the surface. As also described below, the wheel modules 5001, 501 include tires with tread patterns that facilitate gripping small obstacles (e.g., tile edges) to propel the robot 10 over such small obstacles.

[0058] Heavier robots can apply sufficient pressure at wheels to avoid slipping as the wheels pass over the cleaning liquid. As compared to lighter robots, however, heavier robots are more difficult to handle (e.g., for refilling at a sink, for carrying to storage). Accordingly, the robot 10 is configured to weigh less than 3 kg (fully loaded with cleaning liquid) while wheel modules 500, 501 provide sufficient traction to propel robot 10 through cleaning liquid on distributed on the surface.

[0059] In some implementations, the center of gravity of the robot 10 is substantially along the transverse axis 24 such that much of the weight of the robot 10 is over the wheel modules 500, 501 during a cleaning operation. Such a weight distribution of robot 10 can exert a sufficient downward force on wheel modules 500, 501 to overcome slippage while also allowing wheel modules 500, 501 to overcome drag forces created as wetting assembly 204 and squeegee 208 movably contact the surface. In some implementations, the weight of the robot is distributed to overcome such drag forces while applying sufficient cleaning pressure to the surface (e.g., sufficient pressure to wetting assembly 204 and squeegee 208). For example, the wheel modules 500, 501 can support about 50 % to about 70 % of the weight of the robot 10 above the surface. The wetting assembly 204 can support at least about 10 % of the weight of the robot above the surface, along the forward portion of the robot. The squeegee 208 can support at least about 20 % of the weight of the robot above the surface, along the rearward portion of the robot. As described in detail below, the supply volume and the collection volume are configured to maintain the center of gravity of the robot substantially over the transverse axis 24 while at least about 25 percent of the total volume of the robot shifts from cleaning liquid in the supply volume to waste in the collection volume as the cleaning cycle progresses from start to finish.

[0060] In certain implementations, a robot of between 12-18 cm in diameter and less than 15 cm high is between 1-2 kg when full of fluid, the volume being largely occupied by water (specific gravity 1), plastic (close to specific gravity 1) and a few heavier components (ballast, motors, batteries). Exemplary ranges for physical dimensions of a robot intended to reach narrower bathroom areas (such as beside toilets) include: a full mass of 0.5-4 kg; a cleaning width of 5 cm - 20 cm within a diameter of 10-20 cm; a wheel diameter 1.5 cm-8 cm; drive wheel contact line 1 cm-3 cm for all drive wheels (two, three, four drive wheels); drive wheel contact patch for all wheels 0.5-1.5 cm² or higher.

[0061] The robot 10 can be less than about 0.5 kg empty, and less than approximately 3 kg full, and carry about 0.5 kg to about 2.5 kg (or 500-2500 ml) of clean or dirty fluid (in the case where the robot applies fluid as well as

picks it up). The waste tank can be sized according to the efficiency of the pick-up process and/or according to the fraction of liquid dispensed rear of the squeegee 208. For example, with a comparatively inefficient squeegee designed to or arranged to leave a predetermined amount of wet fluid on each pass (e.g., so that the cleaning fluid can dwell and progressively work on stains or dried food patches), the waste tank can be designed to be equal in size or smaller than the clean tank. A portion of the deposited fluid will never be picked up, and another portion will evaporate before it can be picked up. In an additional or alternative example, at least a portion of the liquid dispensed rear of the squeegee 208 will evaporate before the robot 10 returns to pick up this dispensed liquid and, in some instances, the robot 10 may not return to pick up the dispensed liquid. In implementations in which an efficient squeegee is used (e.g., silicone) and substantially all of the cleaning liquid is dispensed forward of the squeegee 208, then it may be necessary to size the waste tank to be equal to or bigger than the clean fluid tank. A proportion of the tank volume, e.g., 5% or higher, may also be devoted to foam accommodation or control, which can increase the size of the waste tank.

[0062] To effectively brush, wipe, or scrub the surface, the wetting assembly 204 and the squeegee 208 create drag that acts to agitate debris on the surface. For a robot under 3 kg, the wetting assembly 204 (e.g., rows 205, row 206, and row 207 of bristles) should have a length, stiffness, and height to balance (whether full or empty) at least about 1/3 of the empty weight of the robot per wheel (e.g., for an empty robot of 1 kg, at least 300 weight borne by each wheel). Drag forces (total drag associated with any blades, squeegees, dragging components such as bristles) should not exceed 25% of robot weight to ensure good mobility in the absence of active suspensions/constant weight systems, as any lifting will otherwise remove weight from the tires and affect motive force. Maximum available traction typically is no more than about 40% of robot weight on slick surfaces with a surfactant based (low surface tension) cleaning fluid, perhaps as high as 50% in best case situations, and traction/thrust must exceed drag/parasitic forces. However, in order to successfully navigate autonomously, to have sufficient thrust to overcome minor hazards and obstacles, to climb thresholds which may encounter the scrubbing or brushing member differently from the wheels, and to escape from jams and other panic circumstances, the robot 10 can have a thrust/traction, provided mostly by the driven wheels, of about 150% or more of average drag/parasitic force. In implementations including a rotating brush, depending on the direction of rotation, the rotating brush can create drag or thrust.

[0063] In some implementations, the robot 10 has a weight of about 1.4 kg fully loaded, with less than about 100 gram-force of drag (on a surface with a static coefficient of friction of about 0.38) caused by the wetting assembly 204 and less than about 320 gram-force of drag (on a surface with a static coefficient of friction of

about 0.77) caused by the squeegee 208, but more than 1100 gram-force of thrust contributed by wheel modules 500, 501 to propel the robot 10 at a maximum forward rate of about 200 mm/s to about 400 mm/s. In certain implementations, weight is added to the robot 10 to improve traction of wheel modules 500, 501 by putting more weight on the wheels (e.g., metal handle, clevis-like pivot mount, larger motor than needed, and/or ballast in one embodiment of the present device). With or without added weight, in some implementations, the robot can include a rotating brush and derive a functional percentage of thrust from a forwardly rotating brush (which is turned off generally in reverse), which is not a feature needed in a large industrial cleaner.

[0064] The width of the cleaning head for the mass of a household cleaning robot, under 10 kg (or even under 20 kg), differs from industrial self-propelled cleaners. This is especially true for wet cleaning. In some implementations, the robot 10 has at least about 1 cm of (wet) cleaning width for every 1 kg of robot mass (e.g., about 4, 5, or 6 cm of cleaning width for every 1 kg of robot mass), and up to about 20 cm of cleaning width for every kg of robot mass (the higher ratios generally apply to lower masses). For example, the robot 10 can weigh approximately 1.5 kg when fully loaded with cleaning liquid and can have a wet cleaning width of about 16.5 cm, such that the robot 10 can have about 11 cm of wet cleaning width for every 1 kg of robot mass.

[0065] In implementations in which cleaning liquid is dispensed rear of the squeegee 208 to remain on the cleaning surface as the robot 10 moves in the forward direction, larger cleaning widths per kg are possible. In such implementations, the use of mechanical agitation (e.g., wiping or scrubbing force) to remove debris from the cleaning surface is augmented by the increased chemical reactivity between cleaning liquid and the debris on the cleaning surface. For example, the increased time available for the liquid to remain in contact with the debris can increase the amount of chemical reaction that occurs between the cleaning liquid and the debris. Thus, as compared to implementations in which all of the cleaning liquid is dispensed forward of the squeegee 208 and is collected by the squeegee 208, larger cleaning widths for every kg of robot mass can result in effective cleaning of the surface. Thus, in implementations in which at least about 30 percent of the total dispensed volume of the cleaning liquid is dispensed rear of a collection assembly (e.g., rear of the squeegee 208), the robot can have up to about 50 cm of cleaning width for every kg of robot mass. For example, by dispensing higher percentages of cleaning fluid rear of the squeegee, higher ratios of cleaning width to robot mass can be used to achieve effective cleaning of the surface.

[0066] Lower cleaning widths per 1 kg of robot mass can lead to either an ineffective cleaning width or a very heavy robot unsuitable for consumer use, i.e., that cannot be carried easily by an ordinary (or frail) person. Self-propelled industrial cleaning machines typically have 1/3

cm of cleaning width or less per kg machine mass.

[0067] Ratios of these dimensions or properties determine whether a robot under 5 kg, and in some cases under 10 kg, will be effective for general household use. Although some such ratios are described explicitly above, such ratios (e.g., cm squared area of wheel contact per kg of robot mass, cm of wheel contact line per kg-force of drag, and the like) are expressly considered to be inherently disclosed herein, albeit limited to the set of different robot configurations discussed herein.

[0068] In certain implementations, the robot 10 includes tires having a 3 mm foam tire thickness with 2 mm deep sipes. This configuration performs best when supporting no more than 3 to 4 kg per tire. The ideal combination of sipes, cell structure and absorbency for a tire is affected by robot weight. In some implementations, rubber or vinyl tires are configured with surface features to reduce slippage.

[0069] As indicated above, the robot 10 includes the wetting assembly 204 and the collection assembly 1300 including, for example, the squeegee 208. In some implementations, a wet vacuum portion can be closely followed by a longitudinal ridge of the squeegee 208 to build up the thickness of a deposited water film for pick-up. The squeegee 208 can have sufficient flexibility and range of motion to clear any obstacle taller than 2 mm, but ideally to clear the ground clearance of the robot (e.g., about a 4 1/2 mm minimum height or the ground clearance of the robot).

[0070] Any reactionary force exhibited by the squeegee 208 that is directionally opposite to gravity, i.e., up, subtracts from available traction and should be less than about 20% of robot weight (e.g., less than about 10% of robot weight). A certain amount of edge pressure, which has an equal reactionary force, is necessary for the squeegee 208 to wipe and collect fluid. In order to obtain an effective combination of fluid collection, reactionary force, wear, and flexible response to obstacles, the physical parameters of the squeegee are controlled and balanced. In certain implementations, the squeegee 208 includes a working edge radius of 3/10 mm for a squeegee less than 300 mm. In some implementations, the squeegee 208 can have a working edge of about 1/10 to 5/10 mm. Wear, squeegee performance and drag force can be improved with a squeegee of substantially rectangular cross section (optionally trapezoidal) and/or 1 mm (optionally about 1/2 mm to 1 1/2 mm) thickness, 90 degree corners (optionally about 60 to 120 degrees), parallel to the floor within 1/2 mm over its working length (optionally within up to 3/4 mm), and straight to within 1/500 mm per unit length (optionally within up to 1/100), with a working edge equal to or less than about 3/10 mm as noted above. Deviations from the above parameters can require greater edge pressure (force opposite to gravity) to compensate, thus decreasing available traction.

[0071] The wetting assembly 204 and the squeegee 208 are configured to contact the floor over a broad range of surface variations (e.g., in wet cleaning scenarios, in-

cluding tiled, flat, wood, deep grout floors). In some implementations, the wetting assembly 204 and/or the squeegee 208 are mounted using a floating mount (e.g., on springs, elastomers, guides, or the like) to improve contact with the broad range of surface variations. In certain implementations, the wetting assembly 204 and the squeegee 208 are mounted to the chassis 100 with sufficient flexibility for the designed amount of interference or engagement of the wetting assembly 204 and/or the squeegee 208 to the surface. As described above, any reactionary force exhibited by the brushes / scrubbing apparatus that is opposite to gravity (up) subtracts from available traction and should not exceed 10% of robot weight.

[0072] In certain implementations, the robot includes more than one brush, e.g., two counter-rotating brushes with one or more brush on either fore-aft side of the center line of the robot, or more. The robot can also include a differential rotation brush such that two brushes, each substantially half the width of the robot at the diameter of rotation, are placed on either lateral side of the fore-aft axis 22, each extending along half of the diameter. Each brush can be connected to a separate drive and motor, and can rotate in opposite directions or in the same direction or in the same direction, at different speeds in either direction, which would provide rotational and translational impetus for the robot.

[0073] The center of gravity of the robot 10 will tend to move during recovery of fluids unless the cleaner and waste tanks are balanced to continually maintain the same center of gravity location. Maintaining the same center of gravity location (by tank compartment design) can allow a passive suspension system to deliver the maximum available traction. The robot 10 includes a tank design that includes a first compartment having a profile that substantially maintains the position of the compartment center of gravity as it empties, a second compartment having a profile that substantially maintains the position of the compartment center of gravity as it fills, wherein the center of gravity of the combined tanks is maintained substantially within the wheel diameter, as viewed from the top of the robot 10, and over the wheels, as viewed from the side of the robot 10. In some implementations, the robot 10 includes tanks stacked in a substantially vertical direction and configured to maintain the same location of the center of gravity of the robot 10.

[0074] In certain implementations, absent perfect fluid recovery or active suspension, superior mobility is achieved either by modeling or assuming a minimum percentage of fluid recovered across all surfaces (70% of fluid put down for example) and designing the profile of the compartments and center of gravity positions according to this assumption/model. In some implementations, superior mobility is achieved by assuming perfect (or near perfect) fluid and dispensing least about 30 percent by volume of cleaning liquid is dispensed rear of the squeegee 208 as the robot moves in the forward direction and designing the profile of the compartments and the

center of gravity positions based on this configuration. In the alternative, or in addition, setting spring force equal to the maximum unladen (empty tank) condition can contribute to superior traction and mobility. In some implementations, suspension travel is at least equal the maximum obstacle allowed by the bumper (and other edge barriers) to travel under the robot.

[0075] Maximizing the diameter of the wheels of the robot can decrease the energy and traction requirements for a given obstacle or depression. In certain implementations, maximum designed obstacle climbing capability should be 10% of wheel diameter or less. A 4.5 mm obstacle or depression should be overcome or tackled by a 45 mm diameter wheel. In certain implementations, the clearance of the robot is low for several reasons. The bumper is set low to distinguish between carpet, thresholds, and hard floors such that a bumper 3 mm from the ground will prevent the robot from mounting most carpets (2-5 mm bumper ground clearance, 3 mm being preferable). The remainder of the robot working surface, e.g., the collection assembly, also have members extending toward the floor (air guides, squeegees, brushes) that are made more effective by a lower ground clearance. Because the ground clearance of one embodiment is between 3-6 mm, the wheels need only be 30 mm - 60 mm. Other wheel sizes can also be used.

Assembly

[0076] Referring to FIG. 7, chassis 100 carries a liquid volume 600 substantially along an inner portion of the chassis 100. As described in detail below, portions of the liquid volume 600 are in fluid communication with liquid delivery and air handling systems carried on the chassis 100 to allow cleaning fluid to be pumped from the liquid volume 600 and to allow waste to be suctioned into the liquid volume 600. To allow the addition of cleaning liquid and the removal of waste, liquid volume 600 can be accessed through fill door 304 (not shown in FIG. 7) and empty door 104.

[0077] The wheel modules 500, 501 include respective drive motors 502, 503 and wheels 504, 505. The drive motors 502, 503 releasably connect to the chassis 100 on either side of the liquid volume 600 with the drive motors 502, 503 positioned substantially over respective wheels 504, 505. In some implementations, drive motors 502, 503 are positioned substantially horizontal to respective wheels 504, 505 to increase the size of the liquid volume 600 carried on chassis 100. In some implementations, wheel modules 500, 501 are releasably connected to chassis 100 and can be removed without the use of tools to facilitate, for example, repair, replacement, and cleaning of the wheel modules 500, 501. A signal channeler 402 is connected to a top portion of chassis 100 and substantially covers the liquid volume 600 to allow components to be attached along a substantially top portion of the robot 10. An edge 404 of the signal channeler is visible from substantially the entire outer

circumference of the robot 10 to allow the signal channeler 404 to receive a light signal (e.g., an infrared light signal) from substantially any direction. As described in detail below, the signal channeler 402 receives light from a light source (e.g., a navigation beacon) and internally reflects the light toward a receiver disposed within the signal channeler 402. For example, the signal channeler 402 can be at least partially formed of a material (e.g., polycarbonate resin thermoplastic) having an index of refraction of about 1.4 or greater to allow substantially total internal reflection within the signal channeler. Additionally or alternatively, the signal channeler 402 can include a first mirror disposed along a top surface of the signal channeler 402 and a second mirror disposed along a bottom surface of the signal channeler 402 and facing the first mirror. In this configuration, the first and second mirrors can internally reflect light within the signal channeler 402.

[0078] The signal channeler 402 includes a recessed portion 406 that can support at least a portion of the user interface 400. A user interface printed circuit board (PCB) can be arranged in the recessed portion 406 and covered by a membrane and/or a potting material, to form a substantially water-tight user interface 400. As described in detail below, a bottom portion of signal channeler 402 can form a top portion of the liquid volume 600.

[0079] Bumper 300 connects to the hinges 110 arranged substantially along the forward portion of the chassis 100. The hinged connection between bumper 300 and chassis 100 can allow the bumper to move a short distance relative to the chassis 100 when the bumper 300 contacts an obstacle. Bumper 300 is flexibly connected to a fill port 602 of the liquid volume 600 such that the bumper 300 and the fill port 602 can flex relative to one another as the bumper 300 moves relative to the chassis 100 upon contact with an obstacle.

[0080] The bumper 300 includes a substantially transparent section 306 near a top portion of the bumper. The transparent section 306 can extend substantially along the entire perimeter of the bumper 300. The transparent section 306 can be substantially transparent to a signal receivable by an omni-directional receiver disposed substantially near a center portion of the signal channeler 402 such that the omni-directional receiver can receive a signal from a transmitter positioned substantially forward of the bumper 300.

[0081] The baseplate 200 is carried on a substantially bottom portion of chassis 100. The baseplate 200 includes pivot hinges 212 that extend from a forward portion of the baseplate 200 and can allow the baseplate 200 to be snapped into complementary hinge features on the chassis 100. In some implementations, a user can unhinge the baseplate 200 from the chassis 100 without the use of tools. The baseplate 200 defines at least a portion of the trough 202b along a rear portion of the robot 10. The wetting assembly 204 is substantially rearward of the trough 202a. The baseplate 200 extends around a portion of each wheel module 500, 501 to form

portion of wheel wells for wheels 504, 505, substantially rearward of the wetting assembly 204. Rearward of the wheels 504, 505, the baseplate 200 carries a collection assembly including the squeegee 208 configured in slidable contact with the surface to pool waste near the contact edge between the squeegee 208 and the surface. As described in detail below, the squeegee 208 defines a plurality of orifices substantially near the contact edge between the squeegee 208 and the surface. The collection assembly 1300 can create suction such that waste is lifted from the surface and into the robot 10 through the plurality of orifices defined by the squeegee 208.

[0082] In some implementations, a user can unhinge the baseplate 200 from the chassis 100 in order to clean the baseplate 200. In certain implementations, the user can remove the trough 202b, the wetting assembly 204, and/or the squeegee 208 from the baseplate 200 to repair or replace these components. Additionally or alternatively, as described below, a portion of the squeegee 208 can be unattached to the baseplate such that the user can move the unattached portion of the squeegee 208 to facilitate cleaning and, during use, negative pressure created by a vacuum holds the unattached portion of the squeegee 208 in place relative to the baseplate 200.

Liquid Storage

[0083] Referring to FIG. 8, in some implementations, liquid volume 600 can function as both a liquid supply volume S and a waste collection volume W. Liquid volume 600 is configured such that liquid moves from the liquid supply volume S to the surface and then is picked up and returned to a waste collection volume W. In some implementations, the supply volume S and the waste collection volume W are configured to maintain a substantially constant center of gravity along the transverse axis 24 (see FIG. 2) while at least 25 percent of the total volume of the robot 10 shifts from cleaning liquid in the supply volume S to waste in the collection volume W as cleaning liquid is dispensed from the applicator and waste is collected by the vacuum assembly.

[0084] In some implementations, all or a portion of the supply volume S is a flexible bladder within the waste collection volume W and surrounded by the waste collection volume W such that the bladder compresses as cleaning liquid exits the bladder and waste filling the waste collection volume W takes place of the cleaning liquid that has exited the bladder. Such a system can be a self-regulating system which can keep the center of gravity of the robot 10 substantially in place (e.g., over the transverse axis 24). For example, at the start of a cleaning routine, the bladder can be full such that the bladder is expanded to substantially fill the waste collection volume W. As cleaning liquid is dispensed from the robot 10, the volume of the bladder decreases such that waste entering the waste collection volume W replaces the displaced cleaning fluid that has exited the flexible bladder. Toward the end of the cleaning routine, the flex-

ible bladder is substantially collapsed within the waste collection volume W and the waste collection volume is substantially full of waste.

[0085] In some implementations, the maximum volume of the flexible bladder (e.g., the maximum storage volume of cleaning liquid) is substantially equal to the volume of the waste collection volume W. In certain implementations, the volume of the waste collection volume W is larger (e.g., about 10 percent to about 20 percent larger) than the maximum volume of the flexible bladder. Such a larger waste collection volume W can allow the robot 10 to operate in an environment in which the volume of the waste collected is larger than the volume of the cleaning liquid dispensed forward of the collection assembly (e.g., when the robot 10 maneuvers over substantial spills).

[0086] While the supply volume S has been described as a flexible bladder substantially surrounded by the waste collection volume W, other configurations are possible. For example, the supply volume S and the waste collection volume W can be compartments that are stacked or partially stacked on top of one another with their compartment-full center of gravity within 10 cm of one another. Additionally or alternatively, the supply volume S and the waste collection volume W can be concentric (concentric such that one is inside the other in the lateral direction); or can be interleaved (e.g., interleaved L shapes or fingers in the lateral direction).

Liquid Applicator

[0087] Referring to FIGS. 3 and 8, a liquid applicator module 1400 applies a first volume of cleaning liquid onto the surface, through trough 202a, forward of the rows 205 and row 206 and applies a second volume of cleaning liquid onto the surface, through trough 202b, rear of the rows 205 and row 206 and forward of the row 207 as the robot 10 moves in the forward direction. In some implementations, the second volume of cleaning liquid is at least about 30 percent (e.g., about 50 percent) of the total volume of cleaning liquid dispensed by the liquid applicator module 1400 to the surface, and the first volume of cleaning liquid can be about 30 percent to about 70 percent of the total volume of liquid dispensed by the liquid applicator module 1400. For example, the first volume can be about 60 percent of the total volume of liquid dispensed by the liquid applicator module 1400 and the second volume can be about 40 percent of the total volume of liquid dispensed by the liquid applicator module. This ratio can result in superior cleaning of the surface by allowing the first volume of cleaning liquid to be mechanically agitated (e.g., by rows 205 and/or row 206 of bristles) in contact with debris on the surface and the second volume of cleaning liquid can remain on the cleaning surface to react chemically with debris that may remain on the cleaning surface after the first volume of cleaning liquid has been removed from the surface.

[0088] The liquid applicator module can spray the floor

directly, spray a fluid-bearing brush or roller, or apply fluid by dripping or capillary action to the floor, brush, roller, or pad. The liquid applicator module 1400 receives a supply of cleaning liquid from a supply volume S within the liquid volume 600 carried by the chassis 100. In some implementations, the liquid of the composition of the liquid of the first volume of cleaning liquid is the same as the composition of the liquid of the second volume of cleaning liquid. In certain implementations, the liquid of the first volume of cleaning liquid differs in composition from the liquid of the second volume of cleaning liquid. For example, the liquid of the second volume of cleaning liquid can be water.

[0089] A pump 240 (e.g., a peristaltic pump) pumps the cleaning fluid through the liquid applicator module 1400, through one or more injection orifices 210a,b defined by the trough 202a and the trough 202b (see, e.g. FIG. 3). In some implementations, the pump 240 pumps liquid to the trough 202a and the trough 202b and the relative distribution of cleaning liquid between the troughs is achieved by adjusting the total open area of the orifices 210a,b defined by each respective trough. Each injection orifice 210a,b is oriented to dispense cleaning liquid toward the cleaning surface. For example, at least a portion of the injection orifices 210a,b can be oriented to dispense cleaning liquid toward the cleaning surface, in a direction substantially toward the forward direction of travel of the robot 10. Additionally or alternatively, at least a portion of the injection orifices 210a,b can be oriented to spray cleaning liquid toward the cleaning surface, in a direction substantially toward the rear of the robot 10. The size of orifices 210a,b and the delivery pressure of pump 240 can be any of various different combinations such that the fluid can be dispensed toward the cleaning surface in a drip (e.g., with substantially large droplets and/or substantially continuous flow) and/or in a spray. For example, the orifices 210b can be sized to be one or more spray nozzles, dispensing substantially atomized droplets of cleaning liquid toward the cleaning surface rear of the squeegee 208. Such atomization facilitates exposure of a large surface area of the cleaning liquid to air, thus facilitating evaporation of the cleaning liquid. Additionally or alternatively, in another example, the orifices 210b can be sized to drip cleaning liquid toward the cleaning surface rear of the squeegee 208.

[0090] The speed of the pump 240 can be determined based at least in part on a signal received from an encoder 605. For example, the encoder can be an optical encoder including an emitter/receiver pair, with the emitter arranged to direct a signal toward the pump 240 and the receiver arranged to receive the signal reflected from the pump 240. Additionally or alternatively, the controller 1000 can be in communication with the encoder 605 and configured to receive a signal from the encoder 605 to determine speed of the pump 240 as a function of voltage supplied to the pump.

[0091] Referring to FIGS. 5, 7, 8, and 9, encoderless pumping 1002 includes receiving 1004 a signal from an

encoder (e.g., encoder 605) directed at a pump, determining 1006 the speed of the pump as a function of voltage supplied to the pump during a start-up period, and controlling 1008 the speed of the pump based at least in part on controlling voltage supplied to the pump after the start-up period. The start-up period can be greater than about 5 seconds and less than about 300 seconds. In some implementations, the controller 1000 receives 1002 the signal from the encoder at a first rate during the start-up period and receives 1002 the signal from the encoder at a second rate after the start-up period (e.g., the first rate is greater than the second rate).

[0092] The liquid applicator module 1400 includes a supply volume S which is a compartment within liquid volume 600. However, in some implementations, supply volume S is a separate volume carried by the chassis 100. Supply volume S defines an exit aperture 603 in fluid communication with a fluid conduit 606. During use, fluid conduit 606 delivers a supply of cleaning liquid to a pump assembly 240 (e.g., a peristaltic pump assembly). Pressure created by pump assembly 240 forces liquid to troughs 202a,b and through the respective injection orifices 210a,b toward the surface. In some embodiments, pump assembly 240 includes separate pumps to force liquid to respective troughs 202a, b.

[0093] The liquid applicator module 1400 applies cleaning liquid to the surface at a volumetric rate ranging from about 0.1 mL per square foot to about 6.0 mL per square foot (e.g., about 3 mL per square foot). However, depending upon the application, the liquid applicator module 1400 can apply any desired volume of cleaning liquid onto the surface. For example, the liquid applicator module 1400 can adjust the relative volumetric fraction of cleaning liquid dispensed through trough 202a and trough 202b (e.g., by adjusting the pressure drop along the respective paths between the pump assembly 240 and the orifices 210a,b of the respective troughs 202a and 202b). Additionally or alternatively, the liquid applicator module 1400 can be used to apply other liquids onto the surface such as water, disinfectant, chemical coatings, and the like.

[0094] The liquid applicator module 1400 can be a closed system (e.g., when pump 240 is a peristaltic pump) such that the liquid applicator module 1400 can be used to deliver a wide variety of cleaning solutions, without damaging other components (e.g., seals) of the robot 10. For example, as described below, a potting material can be disposed between the liquid applicator module 1400 and electrical components carried by the robot to isolate the liquid applicator module 1400 from fluid communication with the electrical components.

[0095] A user can fill the supply container S with a measured volume of clean water and a corresponding measured volume of a cleaning agent. The water and cleaning agent can be poured into the supply volume S through fill port 602 accessible through fill door 304 in bumper 300. The fill port 602 can include a funnel to allow for easier pouring of the cleaning liquid into the supply

volume S. In some implementations, a filter is disposed between fill port 602 and the supply volume S to inhibit foreign material from entering the supply volume S and potentially damaging the liquid applicator module 1400. The supply volume S has a liquid volume capacity of about 500 mL to about 2000 mL.

[0096] Fig. 22 depicts the PCB cover 103, which seals the PCB in a hermetically sealed enclosed volume (which is later filled with a potting compound via the shown valve 157, as disclosed herein) and a support for a bypass channel 155 formed from a T-shaped channel 155a in the PCB cover 103 wall and a T-shaped cover assembly 155b which hermetically seals the channel 155a and provides 3-5 (preferably 5) nozzles 155c to dispense liquid therefrom. The seal is ideally air-tight, but may be hermetic or hydraulically sealed.

[0097] As shown in Fig. 23, the T-shaped cover assembly 155b is optionally formed separately from the PCB cover 103, and is then welded (e.g., shear welded using conventional plastics forming process) to the channel in the PCB cover. The T-shape of the channel 155, divides to cover the cleaning width of the robot and/or rows of bristles 205, and connects both T-arms of the bypass channel 155 to the pump 240 system. The nozzles 155c and fluid pressure of the pump 240 system are arranged to eject fluid (either spraying and/or dripping, depending on factors such as back pressure, viscosity, nozzle diameter, process variation), but in any event dispensing sufficient fluid to fall into or through the orifices 210b in rear trough 202b. The nozzles 155c can be arranged to face the orifices 210b in the trough 202b (to spray, drip, or flow onto the floor surface) and/or face walls of the trough 202b (so as to distribute fluid to orifices 210b that are not facing a nozzle 155c).

[0098] Fig. 24 shows a bottom view of the PCB cover 103 assembled to the robot 10, before the T-shaped channel cover assembly 155b is in place. In this view, portions of the robot remain unassembled (e.g., the bumper, wheel drives, peristaltic pump tube, and front trough 202a).

[0099] The leading trough 202a, as shown in Figs. 3 and 25, is formed as a substantially actuate (following the bumper profile, therefore flattened if the bumper is also flattened to provide a flat resting surface for the robot 10) hermetically sealed trough which directs (again, spraying or dripping depending on various factors) fluid substantially rearwards, ideally spraying onto the wetting assembly 204 formed in part by the immediately following row of bristles 205 (the leading row of bristles 205) so that the row of bristles 205 wicks the sprayed water and evenly dispenses it to the floor. As shown in Fig. 25, each dispensing orifice 210a is formed as an arched orifice 210a-1 in a channel portion 202a-1 of the trough 202a matched to an arched plug 210a-2 in a cover portion 202a-2 of the trough 202s. In this manner, the orifices (nozzles) 210a can be formed by welding a channel to a cover. It is sufficient for operation if either spraying or dripping directly onto the bristles 205 or floor occurs. The

T-shaped bypass channel 155 is arranged at a bypass end 155d to mate to a corresponding receptacle 202a-3 in the leading trough 202a together forming a sealed connection controlled to distribute fluid in differing proportions as disclosed herein. The leading trough 202a is assembled after the T-shaped channel 155 is formed in the PCB cover 103 so as to close and mate the receptacle 202a-3 to the bypass orifice end 155d - these are welded to form a hermetic/hydraulic seal (alternatively, solvent bonded).

[0100] While the T-shaped bypass channel 155 has been described as directing a fraction of the total amount of cleaning liquid rear of the squeegee 208, other implementations are possible. For example, in some implementations, the squeegee 208 can be lifted (e.g., through an actuator) from the cleaning surface such that liquid dispensed through the forward trough 202a remains distributed on the cleaning surface. Additionally or alternatively, the T-shaped bypass channel 155 can allow water to be dispensed forward and rear of the squeegee 208 such that, when all of the clean water is dispensed from the robot 10 to the cleaning surface, the robot 10 only picks up water.

[0101] In one implementation, a lesser proportion of cleaning liquid is dispensed rear of the squeegee 208. For example, about 50 to about 90 percent of the cleaning liquid is dispensed forward of the squeegee 208 and about 50 to about 10 percent of the cleaning liquid is dispensed rear of the squeegee 208. The robot 10 can clean with a random component such that the robot partially cleans with the fore wetting even if the robot 10 never returns to the same spot on the cleaning surface, but will have the significant benefit of the rear wetting if it does return to the same spot. Additionally or alternatively, dispensing a lesser proportion of cleaning fluid rear of the squeegee 208 can be desirable if there is a reason to avoid leaving fluid on the floor (e.g., cultural preference, hardwood floors, etc). In still another example, a robot 10 with a navigation approach and a single-pass requirement would also benefit from more wetting in front of the squeegee 208, along with a slow speed.

[0102] In another implementation, a lesser proportion of cleaning liquid is dispensed forward of the squeegee 208. For example, about 0 to about 40 percent of the cleaning liquid is dispensed forward of the squeegee 208 and about 100 to about 60 percent of the cleaning liquid (or between about 95 percent and about 100 percent of the cleaning liquid) is dispensed rear of the squeegee 208. Dispensing a majority or all of the cleaning liquid rear of the collection assembly can increase the time some or all of the cleaning liquid remains on the cleaning surface before it is picked up by the robot. This can expand a time span the cleaning fluid interacts with dust and dirt on the cleaning surface and thus improve the amount of dirt detached from the cleaning surface and picked up by the robot. This can be facilitated by further adapting a controller of the robot to allow the robot to perform multiple passes over a cleaning surface or at

least portions of a cleaning surface. Such a distribution of cleaning liquid rear of the squeegee 208 can be coupled with a navigation component mandating two passes such that the robot is highly likely (e.g., greater than about 75 percent likely) to return to each spot twice (once for dispensing the cleaning liquid and once for picking up the cleaning liquid).

[0103] In yet another implementation, the relative proportions of cleaning liquid dispensed forward of the squeegee 208 and rear of the squeegee 208 can be adjusted (e.g., manually or through an actuator) to match the requirements of a particular application. For example, the robot in a single pass approach can be wetter in front and the robot in a double pass mode can be wetter in the rear.

[0104] Referring to FIGS. 2 and 10A-E, the wetting element 204 can slidably contact the surface such that the movement of the robot 10 across the surface causes the wetting assembly 204 to spread the cleaning liquid across the surface. At least some of rows 205 are arranged substantially parallel to trough 202a and extend past each end of the trough 202a to allow, for example, for suitable smearing near the edges of the trough 202a. Ends 215, 216 of rows 205 extend substantially in front of respective wheels 504, 505, and the bristles disposed along the ends 215, 216 are disposed at an angle. By smearing cleaning liquid directly in front of wheels 504, 505, rows 205 can improve the traction between the wheels 504, 505 and the surface.

[0105] At least some of the rows 205 of bristles can have a substantially arcuate shape that extends substantially parallel to the forward perimeter of the robot 10. As the substantially arcuate rows make slidable contact with the floor during operation of the robot 10, the substantially arcuate shape can facilitate movement of the robot 10 across the surface. For example, as compared to a substantially straight row of bristles, the substantially arcuate shape of the forwardmost of rows 205 can gradually engage a grout line (e.g., of a tiled floor) such the robot 10 can adjust to the force required to traverse the grout line.

[0106] While the wetting element 204 has been described as rows 205, 206, and 207 of bristles, other implementations are possible. For example, the wetting element 204 can include one or more compliant blades extending in a direction substantially parallel to the cleaning surface. The compliant blade can be in contact with the cleaning surface to smear the cleaning liquid on the surface as the robot moves in the forward direction.

[0107] Referring to FIG. 10B, in some implementations, rows 205, 206, and 207 are disposed on the baseplate 200. The rows 205, 206, and 207 include a plurality of bristle clusters 222 extending from the baseplate 200 toward the cleaning surface. The bristle clusters 222 are spaced (e.g., substantially evenly spaced) along each row 205, 206, and 207. Bristle clusters 222 can each include a plurality of soft compliant bristles. In some implementations, a first end of each bristle is secured in a holder such as a crimped metal channel, or other suitable

holding element. In certain implementations, bristle clusters 222 are individual plugs press fit into the baseplate 200. A second end of each bristle is free to bend as each bristle makes contact with the cleaning surface. Additionally or alternatively, bristle clusters 222 are plugs (e.g., about 1 mm in diameter) with respective ends of each bristle cluster 222 disposed toward the cleaning surface and a middle portion of each bristle cluster 222 glued and/or stapled to the baseplate 200. These multiple points of contact between the bristles of each bristle cluster 222 and the surface can allow the robot 10 to traverse smoothly over perturbations in the surface (e.g., grout lines).

[0108] The length and diameter of the bristles of bristle clusters 222, as well as a nominal interference dimension that the smearing bristles make with respect to the cleaning surface can be varied to adjust bristle stiffness and to thereby affect the smearing action and drag. In certain implementations, the bristle clusters 222 includes nylon bristles with an average bristle diameter in the range of about 0.05-0.2 mm (0.002 - 0.008 inches) and an average coefficient of friction on a wet cleaning surface of about 0.1 to about 0.3 (e.g., about 0.2).

[0109] The rows 205 and 206 of bristles have an angle of incidence of about 90 degrees with the cleaning surface as the robot moves in the forward direction. At least some of the rows 205 have about zero interference with the cleaning surface and at least row 206 has an interference with the cleaning surface. For example, rows 205 closest to the forward portion of the chassis 100 can have about zero interference with the cleaning surface while row 206 (e.g., the row closest to the squeegee 208) has an interference with the cleaning surface. This combination balances the scrubbing action of the rows 205 and 206 with mobility of the robot 10 (e.g., reducing drag and/or reducing the likelihood that the robot will attempt to climb an obstacle that it cannot surmount).

[0110] In some implementations, the bristles of rows 205 having about zero interference with the cleaning surface are longer than the bristles of row 206 having an interference with the cleaning surface. For example, rows 205 can be disposed along a recessed portion 221 of the baseplate 200 while row 206 can be disposed along an unrecessed portion 223 of the baseplate 200. In this configuration, 205 can have a longer effective beam length than row 206.

[0111] The baseplate 200 of the robot can be supported about 4 mm above the cleaning surface as the robot 10 moves across the cleaning surface in the forward direction. The bristles of the row 207 rear of the squeegee 208 have an average length of about 5 mm to about 6 mm (e.g., about 5.4 mm). The bristles of row 207 also have an angle of incidence of about 45 degrees with the cleaning surface as the robot moves in the forward direction. This angled orientation of the bristles of row 207 can allow the bristles to act as a spring to assist the robot 10 in climbing obstacles. For example, as the bristles of row 207 move over an obstacle, each bristle has a ten-

dency to return to the angle of about 45 degrees relative to the surface. The tendency to return to this position results in each bristle exerting a force on the obstacle. Additionally or alternatively, the 45 degree orientation of the bristles of row 207 can facilitate smearing of the cleaning liquid on the surface.

[0112] While wetting assembly 204 has been described as having rows 205, 206, and 207 of bristles, other implementations are additionally or alternatively possible. For example, the wetting assembly 204 can include a woven or nonwoven material, e.g., a scrubbing pad or sheet material configured to contact the surface.

[0113] Cleaning liquid can be introduced to the rows 205, row 206, and row 207 in any of various different ways. For example, cleaning liquid can be injected or dripped on the surface immediately forward of the scrubbing brush. Additionally or alternatively, cleaning liquid can be introduced through bristle clusters 222 such that the bristle clusters 222 substantially wick the cleaning liquid toward the surface. Additionally or alternatively, the baseplate 200 can carry other elements configured to spread the cleaning liquid on the surface. For example, the baseplate 200 can carry a sponge or a rolling member in contact with the surface.

[0114] In some implementations, the baseplate 200 carries one or more active scrubbing elements that are movable with respect to the cleaning surface and with respect to the robot chassis. Movement of the active scrubbing elements can increase the work done between the scrubbing element and the cleaning surface. Each active scrubbing element can be driven for movement with respect to the chassis 100 by a drive module, also attached to the chassis 100. Active scrubbing element can also include a scrubbing pad or sheet material held in contact with the cleaning surface, or a compliant solid element such a sponge or other compliant porous solid foam element held in contact with the surface and vibrated by a vibrated backing element. Additionally or alternatively, active scrubbing elements can include a plurality of scrubbing bristles, and/or any movably supported conventional scrubbing brush, sponge, or scrubbing pad used for scrubbing. In certain implementations, an ultrasound emitter is used to generate scrubbing action. The relative motion between active scrubbing elements and the chassis can include linear and/or rotary motion and the active scrubbing elements can be configured to be replaceable or cleanable by a user.

[0115] Referring to FIG. 11, in some implementations, surface agitation assembly 604 includes a rotatable brush assembly disposed across the cleaning width, rearward of injection orifices 210, for actively scrubbing the surface after the cleaning fluid has been applied thereon. The surface agitation assembly 604 includes a cylindrical bristle holder element 618 defining a longitudinal axis 629. The bristle holder element 618 supports scrubbing bristles 616 extending radially outward therefrom. The surface agitation assembly 604 can be supported on chassis 100 for rotation about a rotation axis that ex-

tends substantially parallel with the cleaning width. The scrubbing bristles 616 are long enough to interfere with the cleaning surface during rotation such that the scrubbing bristles 616 are bent by the contact with the cleaning surface. Additional bristles can be introduced into receiving holes 620. The spacing between adjacent bristle clusters (e.g., bristle clusters 622, 624) can be reduced to increase scrubbing intensity.

[0116] Scrubbing bristles 616 can be installed in the brush assembly in groups or clumps with each clump including a plurality of bristles held by a single attaching device long enough to interfere with the cleaning surface during rotation such that the scrubbing bristles 616 are bent by the contact with the cleaning surface. Additional bristles can be introduced into receiving holes 620. The spacing between adjacent bristle clusters (e.g., bristle clusters 622, 624) can be reduced to increase scrubbing intensity.

[0117] Scrubbing bristles 616 can be installed in the brush assembly in groups or clumps with each clump including a plurality of bristles held by a single attaching device or holder. Clump locations can be disposed along a longitudinal length of the bristle holder element 618 in one or more patterns 626, 628. The one or more patterns 626, 628 place at least one bristle clump in contact with cleaning surface across the cleaning width during each revolution of the rotatable brush element 604. The rotation of the brush element 604 is clockwise as viewed from the right side such that relative motion between the scrubbing bristles 616 and the cleaning surface tends to move loose contaminants and waste liquid toward the rearward direction. Additionally or alternatively, the friction force generated by clockwise rotation of the brush element 604 can drive the robot in the forward direction thereby adding to the forward driving force of the robot transport drive system. The nominal dimension of each scrubbing bristles 616 extended from the cylindrical holder 618 can cause the bristle to interfere with the cleaning surface and there for bend as it makes contact with the surface. The interference dimension is the length of bristle that is in excess of the length required to make contact with the cleaning surface. Each of these dimensions along with the nominal diameter of the scrubbing bristles 616 may be varied to affect bristle stiffness and therefore the resulting scrubbing action. For example, scrubbing brush element 604 can include nylon bristles having a bend dimension of approximately 16 -40 mm (0.62 -1.6 inches), a bristle diameter of approximately 0.15 mm (0.006 inches), and an interference dimension of approximately 0.75 mm (0.03 inches) to provide scrubbing performance suitable for many household scrubbing applications.

[0118] While the surface agitation assembly 604 has been described as including a rotating brush, other implementations are possible. For example, the surface agitation assembly 604 can be one or more of the following: a stationary brush, a woven cloth, a nonwoven cloth, a sponge, and a compliant blade. Additionally or alternatively, the sensor module 1100 can include a humidity

sensor and the agitation assembly 604 can act on the cleaning surface based at least in part on detection of humidity on the cleaning surface. Details of such a humidity sensor are disclosed in U.S. Pat. App. No. 11/688,225, entitled "Lawn Care Robot."

[0119] In some implementations, an autonomous cleaning robot includes an extension element 230 carried by the robot along a substantially forward portion of the robot such that the extension element extends beyond the perimeter of the robot. Details of such an extension element are disclosed in U.S. Pat. App. No. 12/118,250, entitled "Autonomous Coverage Robot Sensing."

Air Moving

[0120] Referring to FIG. 12, a collection module 1300 is a vacuum assembly including a fan 112 in fluid communication with the waste collection volume W and the squeegee 208 in contact with the surface. In use, the fan 112 creates a low pressure region along the fluid communication path including the waste collection volume W and the squeegee 208. As described in further detail below, the fan 112 creates a pressure differential across the squeegee 208, resulting in suction of waste from the surface and through the squeegee 208. The suction force created by the fan 112 can further suction the waste through one or more waste intake conduits 232 (e.g., conduits disposed on either end of the squeegee 208) toward a top portion of the waste collection volume W.

[0121] The top portion of the waste collection volume W defines a plenum 608 between exit apertures 234 of waste inlet conduits 232 and inlet aperture 115 of fan intake conduit 114. While the fan 112 is in operation, the flow of air and waste through plenum 608 generally moves from exit apertures 234 toward the inlet aperture 115. In some implementations, plenum 608 has a flow area greater than the combined flow area of the one or more waste intake conduits 232 such that, upon expanding in the top portion of the waste collection volume W, the velocity of the moving waste decreases. At this lower velocity, heavier portions of the moving waste (e.g. water and debris) will tend to fall into the waste collection volume W under the force of gravity while lighter portions (e.g., air) of the moving waste will continue to move toward one or more fan inlet conduits 114. The flow of air continues through the fan inlet conduit 114, through the fan 112, and exits the robot 10 through a fan exit aperture 116.

[0122] In some implementations, at least a portion of the fan 112 is disposed in the fan inlet conduit 114 such that air drawn through the fan inlet conduit can cool the fan. For example, the portion of the fan disposed in the fan inlet conduit 114 can be a heat sink (e.g., a finned heat sink). In some implementations, a portion of the fan 112 that is not disposed in the fan inlet conduit is disposed in a potting material (e.g., potting material 105). The thermal conductivity of the potting material can be greater than the thermal conductivity of air and the potting ma-

terial can isolate the fan 112 and the fan inlet conduit 114 from fluid communication with at least a portion of the chassis 100 (shown in FIG. 7). Additionally or alternatively, the potting material can substantially isolate the fan 112 from fluid communication with the liquid applicator 1400. The collection module 1300 can include an anti-spill system 601 (e.g., a passive anti-spill system and/or an active anti-spill system) that substantially prevents waste from exiting waste collection volume W when the robot 10 is not in use (e.g., when a user lifts the robot 10 from the surface). By reducing the likelihood that waste will spill from the robot, such anti-spill systems can protect the user from coming into contact with the waste during handling. Additionally or alternatively, such anti-spill systems can reduce the likelihood that waste will contact the fan and potentially diminish the performance of the fan over time. Details of the anti-spill system 601 are disclosed in U.S. Pat. App. No. 12/118,250, entitled "Autonomous Coverage Robot Sensing."

[0123] Details of the fan 112 are disclosed in U.S. Pat. App. No. 12/118,250, entitled "Autonomous Coverage Robot Sensing," the entire contents of which are incorporated herein by reference.

[0124] The air flow rate of the fan 112 may range from about 60-100 CFM in free air and about 60 CFM in the robot. In some implementations, the collection module 1300 includes both a wet vacuum subsystem and a dry vacuum subsystem and squeegee 208 and row 207 substantially rearward of the wheels 504, 505 can stabilize the motion of the robot 10. For example, during sudden acceleration of the robot 10, the squeegee 208 and row 207 can prevent the robot from substantially rotating about the transverse axis 24. By providing such stabilization, the squeegee 208 and/or row 207 can prevent the rows 205 carried on a forward portion of the robot 10 from substantially lifting from the surface. When the overall weight of the robot 10 is less than 3.6 kg, for example, such positioning of the squeegee 208 and/or row 207 can be particularly useful for providing stabilization. For such lightweight robots, the center of gravity of the robot 10 can be positioned substantially over the transverse axis 24 of the robot such that substantial weight is placed over the wheels 504, 505 for traction while the squeegee 208 and/or row 207 provide stabilization for the forward direction of travel and the rows 205 and/or row 206 provide stabilization for the reverse direction of travel. For example, the center of gravity of the robot 10 can be positioned substantially at the center of the robot as viewed from the above the robot as the robot moves across the cleaning surface and the robot is full of cleaning liquid.

[0125] Referring to FIGS. 3 and 13-15, the squeegee 208 includes a base 250 extending substantially the entire width of the baseplate 200. A substantially horizontal lower section 252 extends downwardly from the base 250 toward the surface. Edge guides 253, 254 are disposed near each transverse end of the base 250 and extend downwardly from the base 250. A plurality of fas-

tener elements 256 extend upwardly from the base 250 and are configured to fit (e.g., interference fit) within corresponding apertures defined by baseplate 200 to hold a forward edge portion 257 of the squeegee 208 securely in place as the robot 10 moves in the forward direction about the surface. A rear edge portion 259 of the squeegee 208 is unattached to the baseplate 200 such that a user can move the rear edge portion 259 of the squeegee away from the baseplate 200 to clean the squeegee 208 and/or the baseplate 200. During use, the rear edge portion 259 of the vacuum created by the fan 112 holds the rear edge 259 of the squeegee 208 in place relative to the base plate 200.

[0126] The horizontal lower section 252 includes a scraper section 258 extending substantially downwardly from an intake section 260. The scraper section 258 defines a substantially rearward edge of the horizontal lower section 252. During use, the scraper section 258 forms a slidable contact edge between the squeegee 208 and the surface. The scraper section 258 is a substantially longitudinal ridge disposed between the forward edge portion 257 and the rear edge portion 259. The scraper section 258 is substantially thin and formed of a substantially compliant material to allow the scraper section 258 to flex during slidable contact with the surface. In some implementations, the scraper section 258 is angled slightly forward to improve collection of waste from the surface. In certain implementations, the scraper section 258 is angled slightly rearward to reduce the frictional force required to propel the robot 10 in the forward direction.

[0127] The intake section 260 defines a plurality of suction ports 262 substantially evenly spaced in the direction of the transverse axis 24 to allow, for example, substantially uniform suction in the direction of the transverse axis 24 as the robot 10 moves in the forward direction to perform cleaning operations. The suction ports 262 each extend through the squeegee 208 (e.g., from a lower portion of the horizontal lower section 252 to a top portion of the base 250). The suction ports 262 extend through the base such that a lower portion of each suction port 262 is substantially near the forward edge of the scraper section 258. When negative air pressure (e.g., a vacuum) is generated by the fan 112, waste is suctioned from the forward edge of the scraper section 258, through the suction ports 262, and toward the waste collection volume W (e.g., as described above).

[0128] Edge guides 253, 254 are arranged on respective ends of squeegee 208 and extend downwardly from the base 250 to contact the surface during a cleaning operation. The edge guides 253, 254 can be configured to push waste toward the fore-aft axis 22 of the robot 10. By guiding waste toward a center portion of the squeegee 208, the edge guides 253, 254 can improve the efficiency of waste collection at the transverse edges of the robot 10. For example, as compared to robots without edge guides 253, 254, the edge guides 253, 254 can reduce streaks left behind by the robot 10.

[0129] Edge guides 253, 254 include respective fasteners 263, 264 extending upward from the edge guides 253, 254 and through the base 250. The edge guide fasteners 263, 264 extend further from the base 250 than fastener elements 256 and, in some implementations, fasten into the baseplate 200 to reduce the likelihood that the squeegee 250 will become detached from the robot 10 during a cleaning operation. In some implementations, fasteners 263, 264 are pressed into the baseplate 200 and held in place through an interference fit. In certain implementations fasteners 263, 264 are screwed into the chassis 100. Additionally or alternatively, the edge guide fasteners 263 can be fastened to the chassis 100.

[0130] Fastener elements 256 extend upwardly from the base 250, along the forward edge portion 257 of the base 250. Each fastener element 256 is substantially elongate along the transverse axis 24 and includes a stem portion 265 and a head portion 266. The squeegee 208 is secured to the baseplate 200 by pushing fastener elements 256 into corresponding apertures on the baseplate 200. As the fastener elements 256 are pushed into apertures on the baseplate 200, the head portions 266 deform to pass through the apertures. Upon passing through the apertures, each head portion 266 expands to its substantially original shape and the head portion 266 substantially resists passing through the aperture in the opposite direction. Accordingly, fastener elements 256 substantially secure the forward edge portion 257 of the squeegee 208 to the baseplate 200. As described above, the rear edge portion 259 of the squeegee 208 can be unattached to the baseplate 200 such that a user can move the rear edge portion 259 away from the baseplate 200 (e.g., pivoting away from the baseplate 200 about the forward edge portion 257) to access the portion of the squeegee 208 in contact with the baseplate 200 and, during use, suction created by the fan 112 (see FIG. 12) can hold the rear edge portion 259 of the squeegee 208 in place.

[0131] While the squeegee 208 has been described as being fixed relative to the baseplate 200, other implementations are possible. In some implementations, the squeegee can pivot relative to the baseplate 200. For example, the squeegee can pivot about the central vertical axis 20 (FIG. 7) when a lower edge of the squeegee encounters a bump or discontinuity in the cleaning surface. When the lower edge of the squeegee is free of the bump or discontinuity, the squeegee can return to its normal operating position.

[0132] As shown in FIG. 14, the squeegee 208 is a split squeegee such that the scraper section 258 and the intake section 260 define a channel 261 extending across the width of the squeegee 208. In some implementations, the squeegee can include a forward portion and a rearward portion as two separate pieces that can be separately removed from the baseplate for repair and replacement.

[0133] In certain implementations, the squeegee is split into a left portion and a right portion. As the robot

spins in place or turns, the squeegee can assume a configuration in which one side is bent backward and one side is bent forward. For non-split squeegees, the point at which the bend switches from backward to forward can act as a more or less solid column under the robot, tending to high center it and interfere with mobility. By providing a split in the center of the squeegee, this tendency can be mitigated or eliminated, increasing mobility.

Transport Drive System

[0134] Referring again to FIGS. 1-7, the robot 10 is supported for transport over the surface by a transport system 1600. The transport system 1600 includes a pair of independent wheel modules 500, 501 respectively arranged on the right side and the left side of the chassis. The wetting assembly 204 and the squeegee 208 are in slidable contact with the surface and form part of the transport system 1600. In some implementations, the transport system 1600 can include a caster positioned substantially forward and/or substantially rearward of the wheel modules 500, 501. The wheel modules 500, 501 are rotatable about and aligned along the transverse axis 24 of the robot 10. The wheel modules 500, 501 are independently driven and controlled by the controller 1000 to advance the robot 10 in any direction along the surface. The wheel modules 500, 501 each include a respective motor 502, 503 and each is coupled to a gear assembly. Outputs of the respective gear assemblies drive the respective wheel 504, 505.

[0135] The controller 1000 measures the voltage and current to each motor and calculates the derivative of the measured current to each motor. The controller 1000 uses the measured voltage, measured current, and the calculated derivative of the measured current to determine the speed of the motor. For example, the controller 1000 can use a mathematical model (e.g., a DC motor equation) to determine motor speed from the measured voltage, measured current, and the calculated derivative. In certain implementations, the same mathematical model can be used for each drive motor. The mathematical model can include one or more constants (e.g., mechanical constants) are calibrated for a given motor. The one or more constants can be calibrated using any of various different methods. For example, motors 502, 503 can be matched at the factory to have the same constant. As another example, the constants can be calibrated at the factory and stored onboard the robot 10 (e.g. on the controller 1000). As another example, the controller 1000 can include code that learns (e.g., using a neural network) the motor constants over time.

[0136] As yet another example, referring to FIGS. 1, 7, and 16, binning 800 includes testing 802 performance of a plurality of motors on an encoder station (e.g., at a factory), classifying 804 each motor based at least in part on the performance test results, selecting 806 a first and a second motor (e.g., motors 502, 503) from the same class, and mounting 808 the first and second motors on

a robot body (e.g., chassis 100) of an autonomous coverage robot (e.g., robot 10) such that the first motor drives a right wheel of the robot and the second motor drives a left wheel of the robot. Testing 802 performance of the plurality of motors on the encoder station includes providing power to each motor and determining the speed of the output shaft of each respective motor. In some implementations, based on this testing 802, a relationship between motor voltage and speed can be determined. Classifying 804 each motor can include identifying motors with output speed varying by less than about ten percent from one another as a function of power to each motor. By selecting motors from the same class, the robot can be driven in a substantially straight line by providing substantially the same amount of power to the first and second drive motors disposed on respective sides of the robot. Selection of motors based on binning 800 can allow the robot to be driven in a substantially straight line without the use of an encoder.

[0137] The wheel modules 500, 501 are releasably attached to the chassis 100 and forced into engagement with the surface by respective springs. The wheel modules 500, 501 are substantially sealed from contact with water using one or more the following: epoxy, ultrasonic welding, potting welds, welded interfaces, plugs, and membranes.

[0138] The springs are calibrated to apply substantially uniform force to the wheels along the entire distance of travel of the suspension. The wheel modules 500, 501 can each move independently in a vertical direction to act as a suspension system. For example, the wheel modules 500, 501 can allow about 4 mm of suspension travel to about 8 mm of suspension travel (e.g., about 5 mm of suspension travel) to allow the robot 10 to navigate over obstacles on the surface, but to prevent the robot 10 from crossing larger thresholds that mark the separation of cleaning areas (e.g., marking the separation between a kitchen floor and a living room floor). When the robot 10 is lifted from the surface, the respective suspension systems of wheel modules 500, 501 drop the wheel modules 500, 501 to the lowest point of travel of the respective suspension system. This configuration is sometimes referred to as a biased-to-drop suspension system. In some implementations, the wheel modules 500, 501 can include a wheel drop sensor that senses when a wheel 504, 505 of wheel modules 500, 501 moves down and sends a signal to the controller 1000. Additionally or alternatively, the controller 1000 can initiate behaviors that can allow the robot 10 to navigate toward a more stable position on the surface.

[0139] The biased-to-drop suspension system of the robot 10 includes a pivoted wheel assembly including resilience and/or damping, having a ride height designed considering up and down force. In some implementations, the suspension system delivers within 1-5% (e.g., about 2%) of the minimum downward force of the robot 10 (i.e., robot mass or weight minus upward forces from the resilient or compliant contacting members such as

brushes / squeegees, etc.). That is, the suspension is resting against "hard stops" with only 2% of the available downward force applied (spring stops having the other 98%, optionally 99%-95%), such that almost any obstacle or perturbation capable of generating an upward force will result in the suspension lifting or floating the robot over the obstacle while maintaining maximum available force on the tire contact patch. This spring force (and in corollary, robot traction) can be maximized by having an active system that varies its force relative to the changing robot payload (relative clean and dirty tank level). In some implementations, actuation for an active suspension is provided by electrical actuators or solenoids, fluid power, or the like, with appropriate damping and spring resistance. While a pivoted wheel assembly has been described, other implementations are possible. For example, the biased-to-drop suspension system can include a vertically traveling wheel module including conical springs to produce a biased-to-drop suspension system.

[0140] Wheels 504, 505 are configured to propel the robot 10 across a wet soapy surface. Referring to FIGS. 17 and 18A-B, wheel 504 includes a rim 512, snaps 513 slidable into a recesses defined by the rim 512 to couple to the rim 512 to the wheel module 500, and an annular tire 516. For the sake of clarity of explanation, wheel 504 is explained. However, it should be appreciated that wheel 505 is analogous to wheel 504. The drive wheel module includes a drive motor and a drive train transmission for driving the wheel for transport. The drive wheel module can also include a sensor for detecting wheel slip with respect to the surface.

[0141] The rim 512 is formed from a stiff material such as a hard molded plastic to maintain the wheel shape and to provide stiffness. The rim 512 provides an outer diameter sized to receive an annular tire 516 thereon. The annular tire 516 is configured to provide a non-slip, high friction drive surface for contacting the surface and for maintaining traction on the soapy surface.

[0142] In one implementation, the annular tire 516 has an internal diameter of approximately 37 mm and is sized to fit appropriately over the outer diameter 514 of rim 512. The rim 516 includes a ridge 517 extending radially outward from the outer diameter 514 of the rim and extending around the circumference of the rim. The annular tire 516 defines a circumferential channel 518 that is engageable with the ridge 517 such that the ridge 517 can serve as an alignment feature for mounting the annular tire 516 and can hold the annular tire 516 in place. In certain implementations, the annular tire 516 can be removed from the rim 512, and the annular tire 516 can be reversed such that the inner diameter of the annular tire 516 becomes the outer diameter of the annular tire 516. For example, as discussed below, the annular tire 516 can have a tread pattern on the outer diameter and a tread pattern on the inner diameter. As the tread pattern on the outer diameter of the annular tire 516 wears down over time, the annular tire 516 can be reversed such that the tread pattern on the inner diameter becomes exposed

toward the cleaning surface. In some implementations, the annular tire 516 can be additionally or alternatively bonded, taped or otherwise interference fit to the outer diameter 514 to prevent slipping between an inside diameter of the annular tire 516 and the outer diameter 514 of the rim 512.

[0143] The annular tire 516 includes a base 520 having a first side 522 and a second side 524 substantially opposite the first side. The base 520 can have a radial thickness sufficient to allow the annular tire 516 to be easily reversed by the user while resisting tearing. For example, the base 520 can have a radial thickness of about 3 mm.

[0144] The annular tire 516 also includes a first set of treads 526 and a second set of treads 528. Each tread 530 of the first and second set of treads 526, 528 extends radially from the first side 522 of the base 520 toward the cleaning surface and is an elongate rib extending in a direction substantially parallel to the transverse axis. In this transverse orientation, each tread 530 can grip an obstacle (e.g., a tile edge and/or a discontinuity in the cleaning surface) to move a wet cleaning robot under about 3 kg over the obstacle, which may be wet.

[0145] Each tread 530 of the first set of treads 526 is circumferentially offset from each of the treads of the second set of treads 528 such that, as viewed along the transverse axis, treads 530 of the first set of treads 526 are not aligned with the treads 530 of the second set of treads 528. This offset configuration of the treads can facilitate movement of the robot 10 over an uneven surface. Each tread 530 can have at least one substantially square edge disposed toward the cleaning surface. Such a substantially square edge can reduce the likelihood that the tread 530 will become disengaged from an obstacle once the tread engages the obstacle.

[0146] Each tread 530 of each of the first and second set of treads 526, 528 can be substantially identical to facilitate smooth movement of the robot 10 over the surface. For example, each tread 530 can have substantially the same width in the circumferential direction. Additionally or alternatively, each tread 530 of a given set of treads 526, 528 can be circumferentially spaced from a preceding tread of the respective set of treads 526, 528 by a distance about three times the circumferential width of the tread. This circumferential spacing of the treads 530 can provide spacing that allows the annular tire 516 to engage an obstacle between the treads 530 such that each tread 530 can come into contact with the obstacle and act as a lever to move the robot 10 over the obstacle. To achieve sufficient leverage while maintaining a smooth ride for efficient cleaning, each tread 530 can extend radially from the base 520 by a distance between about 1/5 to about 1/2 the radial thickness of the base.

[0147] The annular tire 516 also includes a third set of treads 532 and a fourth set of treads 534. The third set of treads 532 extends radially inward from the second side 524 of the base 520, substantially opposite the first set of treads 526. Similarly, the fourth set of treads 534 extends radially inward from the second side 524 of the

base 520, substantially opposite the second set of treads 528. Each tread 530 of the third set of treads 532 is circumferentially offset from each tread of the first set of treads 526, and each tread 530 of the fourth set of treads 534 is circumferentially offset from each tread of the second set of treads 528. In some implementations, this offset allows the base to move toward the wheel when a tread 530 of the first or second set of treads 526, 528 contacts the cleaning surface. Such movement of the base can provide some cushioning to the ride of the robot 10 to reduce the likelihood that cleaning functions of the robot 10 will be adversely impacted as the robot moves over a rough surface.

[0148] The relative orientation of the third set of treads 532 relative to the fourth set of treads 534 is analogous to the relative orientation of the first set of treads 526 relative to the second set of treads 528. For example, each tread of the third set of treads 532 is circumferentially offset from each tread of the fourth set of treads 534.

[0149] The third set of treads 532 is spaced from the fourth set of treads 534 in the transverse direction to define at least a portion of the circumferential channel 518. As indicated above, the circumferential channel 518 can be disengaged from the ridge 517 and the annular tire 516 can be reversed. For example, the annular tire can be reversed such that the third and fourth sets of treads 532, 534 extend radially outward and toward the cleaning surface while the first and second sets of treads 526, 528 extend radially inward toward the rim 512.

[0150] The tire material includes particulate matter suspended in rubber (e.g., natural rubber). At least some of the particulate matter is disposed toward the portion of the annular tire 516 in contact with the cleaning surface such that the particulate matter penetrates the surface tension of liquid disposed on the cleaning surface. Thus, as compared to natural rubber without particulate matter, the particulate matter disposed in the natural rubber can improve traction of the annular tire 516. In some implementations, the tire material is about 20 percent to about 30 percent particulate matter (e.g., about 25 percent particulate matter). Examples of the particulate matter disposed in the natural rubber can include one or more of the following: kaolin clay and calcium carbonate. These materials improve traction of the annular tire to propel a wet-cleaning robot under about 3 kg across a wet surface without creating a surface roughness that can damage (e.g., scratch) the cleaning surface.

[0151] Other tire materials are contemplated, depending on the particular application. For example, the tire material can include a chloroprene homopolymer stabilized with thiuram disulfide black with a density of 14-16 pounds per cubic foot, or approximately 15 pounds per cubic foot foamed to a cell size of 0.1 mm plus or minus 0.02 mm. The tire has a post-foamed hardness of about 69 to 75 Shore 00. The tire material is sold by Monmouth Rubber and Plastics Corporation under the trade name DURAFOAM DK5151HD.

[0152] Still other tire materials are contemplated, de-

pending on the particular application, including, for example, those made of neoprene and chloroprene, and other closed cell rubber sponge materials. Tires made of polyvinyl chloride (PVC) (e.g., injection molded, extruded) and acrylonitrile-butadiene (ABS) (with or without other extractables, hydrocarbons, carbon black, and ash) may also be used. Additionally, tires of shredded foam construction may provide some squeegee-like functionality, as the tires drive over the wet surface being cleaned. Tires made from materials marketed under the trade names RUBATEX R411, R421, R428, R451, and R4261 (manufactured and sold by Rubatex International, LLC); ENSOLITE (manufactured and sold by Armacell LLC); and products manufactured and sold by American Converters/VAS, Inc.; are also functional substitutions for the DURAFOAM DK5151 HD identified above.

[0153] In certain embodiments, the tire material may contain natural rubber(s) and/or synthetic rubber(s), for example, nitrile rubber (acrylonitrile), styrene-butadiene rubber (SBR), ethylene-propylene rubber (EPDM), silicone rubber, fluorocarbon rubber, latex rubber, silicone rubber, butyl rubber, styrene rubber, polybutadiene rubber, hydrogenated nitrile rubber (HNBR), neoprene (polychloroprene), and mixtures thereof.

[0154] In certain embodiments, the tire material may contain one or more elastomers, for example, polyacrylics (i.e. polyacrylonitrile and polymethylmethacrylate (PMMA)), polychlorocarbons (i.e. PVC), polyfluorocarbons (i.e. polytetrafluoromethylene), polyolefins (i.e. polyethylene, polypropylene, and polybutylene), polyesters (i.e. polyethylene terephthalate and polybutylene terephthalate), polycarbonates, polyamides, polyimides, polysulfones, and mixtures and/or copolymers thereof. The elastomers may include homopolymers, copolymers, polymer blends, interpenetrating networks, chemically modified polymers, grafted polymers, surface-coated polymers, and/or surface-treated polymers.

[0155] In certain embodiments, the tire material may contain one or more fillers, for example, reinforcing agents such as carbon black and silica, non-reinforcing fillers, sulfur, cross linking agents, coupling agents, clays, silicates, calcium carbonate, waxes, oils, antioxidants (i.e. para-phenylene diamine antiozonant (PPDA), octylated diphenylamine, and polymeric 1,2-dihydro-2,2,4-trimethylquinoline), and other additives.

[0156] In certain embodiments, the tire material may be formulated to have advantageous properties, for example, desired traction, stiffness, modulus, hardness, tensile strength, impact strength, density, tear strength, rupture energy, cracking resistance, resilience, dynamic properties, flex life, abrasion resistance, wear resistance, color retention, and/or chemical resistance (i.e. resistance to substances present in the cleaning solution and the surface being cleaned, for example, dilute acids, dilute alkalis, oils and greases, aliphatic hydrocarbons, aromatic hydrocarbons, halogenated hydrocarbons, and/or alcohols).

[0157] It is noted that cell size of the closed cell foam

tires may impact functionality, in terms of traction, resistance to contaminants, durability, and other factors. Cell sizes ranging from approximately 20 μm to approximately 400 μm may provide acceptable performance, depending on the weight of the robot and the condition of the surface being cleaned. Particular ranges include approximately 20 μm to approximately 120 μm , with a mean cell size of 60 μm , and more particularly approximately 20 μm to approximately 40 μm , for acceptable traction across a variety of surface and contaminant conditions.

[0158] In certain embodiments, the tires are approximately 13 mm wide, although wider tires may provide additional traction. As indicated above, tires may be approximately 3 mm thick, although tires of 4 mm-5 mm in thickness or more may be utilized for increased traction. Thinner tires of approximately 1.5 mm and thicker tires of approximately 4.5 mm may be beneficial, depending on the weight of the robot, operating speed, movement patterns, and surface textures. Thicker tires may be subject to compression set. If the cleaning robot is heavier, larger tires may be desirable nonetheless. Tires with outer rounded or square edges may also be employed.

[0159] To increase traction, the outside diameter of the tire can be siped. Siping generally provides traction by (a) reducing the transport distance for fluid removal from the contact patch by providing a void for the fluid to move into, (b) allowing more of the tire to conform to the floor, thereby increasing tread mobility, and (c) providing a wiping mechanism that aids in fluid removal. In at least one instance, the term "siped" refers to slicing the tire material to provide a pattern of thin grooves 1110 in the tire outside diameter. In one embodiment, each groove has a depth of approximately 1.5 mm and a width of approximately 20 to 300 microns. The siping may leave as little as 1/2 mm or less of tire base, for example, 3.5 mm deep siping on a 4 mm thick tire. The groove pattern can provide grooves that are substantially evenly spaced apart, with approximately 2 to 200 mm spaces between adjacent grooves. "Evenly spaced" may mean, in one instance, spaced apart and with a repeating pattern, not necessarily that every siped cut is the same distance from the next. The groove cut axis makes an angle G with the tire longitudinal axis. The angle G ranges from about 10-50 degrees, in certain embodiments.

[0160] In other embodiments, the siping pattern is a diamond-shaped cross hatch at 3.5 mm intervals, which may be cut at alternating 45 degree angles (± 10 degrees) from the rotational axis. Substantially circumferential siping, siping that forces away liquid via channels, and other siping patterns are also contemplated. Depth and angle of siping may be modified, depending on particular applications. Moreover, while increased depth or width of siping may increase traction, this benefit should be balanced against impacting the structural integrity of the tire foam. In certain embodiments, for example, it has been determined that 3 mm-4 mm thick tires with diamond crossed siping at 7 mm intervals provides good tire traction. Larger tires may accommodate a finer pat-

tern, deeper siping, and/or wider siping. Additionally, particularly wide tires or tires made from certain materials may not require any siping for effective traction. While certain siping patterns may be more useful on wet or dry surfaces, or on different types of surfaces, siping that provides consistent traction across a variety of applications may be the most desirable for a general purpose robot cleaner.

[0161] While the tires have been described as including a siped outside diameter and/or elongate ribs, other implementations are possible. For example, the tires can be Natural Rubber tires with an aggressive diagonal V-rib pattern.

[0162] The various tire materials, sizes, configurations, siping, etc., impact the traction of the robot during use. In certain embodiments, the robot's wheels roll directly through the spray of cleaning solution, which affects the traction, as do the contaminants encountered during cleaning. A loss of traction of the wheels may cause operating inefficiencies in the form of wheel slippage, which can lead to the robot deviating from its projected path. This deviation can increase cleaning time and reduce battery life. Accordingly, the robot's wheels should be of a configuration that provides good to excellent traction on all surfaces, with the smallest corresponding motor size.

[0163] Typical contaminants encountered during cleaning include chemicals, either discharged by the robot or otherwise. Whether in a liquid state (e.g., pine oil, hand soap, ammonium chloride, etc.) or a dry state (e.g., laundry powder, talcum powder, etc.), these chemicals may break down the tire material. Additionally, the robot tires may encounter moist or wet food-type contaminants (e.g., soda, milk, honey, mustard, egg, etc.), dry contaminants (e.g., crumbs, rice, flour, sugar, etc.), and oils (e.g., corn oil, butter, mayonnaise, etc.). All of these contaminants may be encountered as residues, pools or slicks, or dried patches. The tire materials described above have proven effective in resisting the material breakdown caused by these various chemicals and oils. Additionally, the cell size and tire siping described has proven beneficial in maintaining traction while encountering both wet and dry contaminants, chemical or otherwise. Dry contaminants at certain concentrations, however, may become lodged within the siping. The chemical cleaner used in the device, described below, also helps emulsify certain of the contaminants, which may reduce the possible damage caused by other chemical contaminants by diluting those chemicals.

[0164] In addition to contaminants that may be encountered during use, the various cleaning accessories (e.g., brushes, squeegees, etc.) of the device affect the traction of the device. The drag created by these devices, the character of contact (i.e., round, sharp, smooth, flexible, rough, etc.) of the devices, as well as the possibility of slippage caused by contaminants, varies depending on the surface being cleaned. Limiting the areas of contact between the robot and the surface being cleaned reduces

attendant friction, which improves tracking and motion. One and one-half pounds of drag force versus three to five pounds of thrust has proven effective in robots weighing approximately 5-15 pounds. Depending on the weight of the robot cleaner, these numbers may vary, but it is noted that acceptable performance occurs at less than about 50% drag, and is improved with less than about 30% drag.

[0165] The tire materials (and corresponding cell size, density, hardness, etc.), siping, robot weight, contaminants encountered, degree of robot autonomy, floor material, and so forth, all impact the total traction coefficients of the robot tires. For certain robot cleaners, the coefficient of traction (COT) for the minimum mobility threshold has been established by dividing a 0.9 kg-force drag (as measured during squeegee testing) by 2.7 kg-force of normal force, as applied to the tires. Thus, this minimum mobility threshold is approximately 0.33. A target threshold of 0.50 was determined by measuring the performance of shredded black foam tires. Traction coefficients of many of the materials described above fell within a COT range of 0.25 to 0.47, thus within the acceptable range between the mobility threshold and the target threshold. Additionally, tires that exhibit little variability in traction coefficients between wet and dry surfaces are desirable, given the variety of working conditions to which a cleaning robot is exposed.

[0166] The robot cleaning device may also benefit by utilizing sheaths or booties that at least partially or fully surround the tires. Absorbent materials, such as cotton, linen, paper, silk, porous leather, chamois, etc., may be used in conjunction with the tires to increase traction. Alternatively, these sheaths may replace rubberized wheels entirely, by simply mounting them to the outer diameter of the cup shaped wheel element. Whether used as sheaths for rubber tires or as complete replacements for the rubber tires, the materials may be interchangeable by the user or may be removed and replaced via automation at a base or charging station. Additionally, the robot may be provided to the end user with sets of tires of different material, with instructions to use particular tires on particular floor surfaces.

[0167] The cleaning solution utilized in the robot cleaner should be able to readily emulsify contaminants and debond dried waste from surfaces, without damaging the robot or surface itself. Given the adverse effects described above with regard to robot tires and certain chemicals, the aggressiveness of the cleaning solution should be balanced against the short and long-term negative impacts on the tires and other robot components. In view of these issues, virtually any cleaning material that meets the particular cleaning requirements may be utilized with the cleaning robot. In general, for example, a solution that includes both a surfactant and a chelating agent may be utilized. Additionally, a pH balancing agent such as citric acid may be added. Adding a scent agent, such as eucalyptus, lavender, and/or lime, for example, may improve the marketability of such a cleaner, contributing to

the perception on the part of the consumer that the device is cleaning effectively. A blue, green, or other noticeable color may also help distinguish the cleaner for safety or other reasons. The solution may also be diluted and still effectively clean when used in conjunction with the robot cleaner. During operation, there is a high likelihood that the robot cleaner may pass over a particular floor area several times, thus reducing the need to use a full strength cleaner. Also, diluted cleaner reduces the wear issues on the tires and other components, as described above. One such cleaner that has proven effective in cleaning, without causing damage to the robot components, includes alkyl polyglucoside (for example, at 1-3% concentration) and tetrapotassium ethylenediamine-tetraacetate (tetrapotassium EDTA) (for example, at 0.5-1.5% concentration). During use, this cleaning solution is diluted with water to produce a cleaning solution having, for example, approximately 3-6% cleaner and approximately 94-97% water. Accordingly, in this case, the cleaning solution actually applied to the floor may be as little as 0.03% to 0.18% surfactant and 0.01 to 0.1% chelating agent. Of course, other cleaners and concentrations thereof may be used with the disclosed robot cleaner. In certain embodiments, the cleaning solution utilized in the robot cleaner includes (or is) one or more embodiments of the hard surface cleaners described in U.S. Pat. Nos. 5,573,710, 5,814,591, 5,972,876, 6,004,916, 6,200,941, and 6,214,784, and cleaning solution having, for example, approximately 3-6% cleaner and approximately 94-97% water. Accordingly, in this case, the cleaning solution actually applied to the floor may be as little as 0.03% to 0.18% surfactant and 0.01 to 0.1% chelating agent. Of course, other cleaners and concentrations thereof may be used with the disclosed robot cleaner. In certain embodiments, the cleaning solution utilized in the robot cleaner includes (or is) one or more embodiments of the hard surface cleaners described in U.S. Pat. Nos. 5,573,710, 5,814,591, 5,972,876, 6,004,916, 6,200,941, and 6,214,784, and 6,774,098, and U.S. Pat. App. No. 12/118,250, entitled "Autonomous Coverage Robot Sensing."

Controller Module

[0168] Referring to FIGS. 1-7, control module 1000 is interconnected for two-way communication with each of a plurality of other robot subsystems. The interconnection of the robot subsystems is provided via network of interconnected wires and or conductive elements, e.g. conductive paths formed on an integrated printed circuit board or the like, as is well known. In some implementations, the two-way communication between the control module 1000 one or more of the robot subsystems occurs through a wireless communication path. The control module 1000 at least includes a programmable or pre-programmed digital data processor, e.g. a microprocessor, for performing program steps, algorithms and or mathematical and logical operations as may be required.

The control module 1000 also includes a digital data memory in communication with the data processor for storing program steps and other digital data therein. The control module 1000 also includes one or more clock elements for generating timing signals as may be required.

[0169] In general, the robot 10 is configured to clean uncarpeted indoor hard floor surface, e.g. floors covered with tiles, wood, vinyl, linoleum, smooth stone or concrete and other manufactured floor covering layers that are not overly abrasive and that do not readily absorb liquid. Other implementations, however, can be adapted to clean, process, treat, or otherwise traverse abrasive, liquid-absorbing, and other surfaces. Additionally or alternatively, the robot 10 can be configured to autonomously transport over the floors of small enclosed furnished rooms such as are typical of residential homes and smaller commercial establishments. The robot 10 is not required to operate over predefined cleaning paths but may move over substantially all of the cleaning surface area under the control of various transport algorithms designed to operate irrespective of the enclosure shape or obstacle distribution. For example, the robot 10 can move over cleaning paths in accordance with preprogrammed procedures implemented in hardware, software, firmware, or combinations thereof to implement a variety of modes, such as three basic operational modes, i.e., movement patterns, that can be categorized as: (1) a "spot-coverage" mode; (2) a "wall/obstacle following" mode; and (3) a "bounce" mode. In addition, the robot 10 is preprogrammed to initiate actions based upon signals received from sensors incorporated therein, where such actions include, but are not limited to, implementing one of the movement patterns above, an emergency stop of the robot 10, or issuing an audible alert. These operational modes of the robot are specifically described in U.S. Pat. No. 6,809,490, by Jones et al., entitled Method and System for Multi-Mode Coverage for an Autonomous Robot. However, the present disclosure also describes alternative operational modes.

[0170] The robot 10 also includes the user interface 400. The user interface 400 provides one or more user input interfaces that generate an electrical signal in response to a user input and communicate the signal to the controller 1000. A user can input user commands to initiate actions such as power on/off, start, stop or to change a cleaning mode, set a cleaning duration, program cleaning parameters such as start time and duration, and or many other user initiated commands. While the user interface 400 has been described as a user interface carried on the robot 10, other implementations are additionally or alternatively possible. For example, a user interface can include a remote control device (e.g., a hand held device) configured to transmit instructions to the robot 10. Additionally or alternatively, a user interface can include a programmable computer or other programmable device configured to transmit instructions to the robot 10. In some implementations, the robot can

include a voice recognition module and can respond to voice commands provided by the user. User input commands, functions, and components contemplated for use with the present invention are specifically described in U.S. patent application Ser. No. 11/166,891, by Dubrovsky et al., filed on Jun. 24, 2005, entitled Remote Control Scheduler and Method for Autonomous Robotic Device.

10 Sensor Module

[0171] The robot 10 includes a sensor module 1100. The sensor module 1100 includes a plurality of sensors attached to the chassis and integrated with the robot subsystems for sensing external conditions and for sensing internal conditions. In response to sensing various conditions, the sensor module 1100 can generate electrical signals and communicate the electrical signals to the controller 1100. Individual sensors can perform any of various different functions including, but not limited to, detecting walls and other obstacles, detecting drop offs in the surface (sometimes referred to as cliffs), detecting debris on the surface, detecting low battery power, detecting an empty cleaning fluid container, detecting a full waste container, measuring or detecting drive wheel velocity distance traveled or slippage, detecting cliff drop off, detecting cleaning system problems such rotating brush stalls or vacuum system clogs or pump malfunctions, detecting inefficient cleaning, cleaning surface type, system status, temperature, and many other conditions. In particular, several aspects of the sensor module 1100 as well as its operation, especially as it relates to sensing external elements and conditions are specifically described in U.S. Pat. No. 6,594,844, by Jones, entitled Robot Obstacle Detection System, and U.S. patent application Ser. No. 11/166,986, by Casey et al., filed on Jun. 24, 2005, entitled Obstacle Following Sensor Scheme for a Mobile Robot.

[0172] The robot 10 includes control and sensor components in close proximity to the wet cleaning components. As described above, the robot 10 can be sized to fit within any of various different confined spaces typically encountered in household cleaning applications. Accordingly, much of the volume of robot 10 is occupied by the liquid storage 1500, liquid applicator 1400, and collection subsystems 1300, each of which can include the transport of water, solvents, and/or waste throughout the robot 10. As distinguished from many dry vacuuming robots that do not use wet cleaners and do not generate waste, some of the sensors and control elements of the robots 10 are sealed and/or positioned to minimize exposure to water or more damaging cleaning fluids or solvents. As distinguished from many industrial cleaners, some of the sensors and control elements of the robot 10 are packaged in close proximity to (e.g., within less than about an inch of) cleaning elements, cleaning fluids, and/or waste.

[0173] Referring to FIGS. 7, 20, and 21A-C, the controller 1000 can be implemented using a printed circuit

board (PCB) 101 carried by the chassis 100 and secured in any of various different positions along the chassis. For example, the PCB can be carried between a bottom portion of the chassis 100 and a PCB cover 103 such that, as described below, a potting material can be introduced around the PCB 101 and the weight of the potting material can act as a ballast to lower the center of gravity of the robot 10. The entire PCB 101 can be fluid sealed, either in a water resistant or waterproof housing having at least JIS grade 3 (mild spray) water/fluid resistance, but grade 5 (strong spray), grade 7 (temporary immersion), and ANSI/IEC 60529-2004 standards for equivalent water ingress protection are also desirable. In some implementations, the main control PCB is sealed in a JIS grade 3-7 housing (1) by a screwed-down and gasketed cover over the main housing; (2) by a welded, caulked, sealed, or glued cover secured to the main housing; (3) by being pre-assembled in a water resistant, water-tight, water-proof, or hermetically sealed compartment or module; or (4) by being positioned in a volume suitable for potting or pre-potted in resin or the like.

[0174] Referring to FIGS. 20-21A-C, in one implementation, the PCB 101 is disposed between the chassis 100 (e.g., a bottom portion of the chassis) and the PCB cover 103, which is engageable with the baseplate 200 (see FIG. 7). The space defined between the chassis 100 and the PCB cover 103 is filled with a potting material 105 such that the potting material substantially surrounds the PCB 101 to isolate the PCB from fluid communication with the liquid applicator 1400 and/or from fluid communication with the collection assembly 1300. In some implementations, the controller 1000 includes components in addition or to the PCB. For example, the controller can include a plurality of proximity sensors and/or a plurality of cliff sensors, and the potting material 105 can be disposed about these components as well.

[0175] The potting material is a surface mount component grade potting material which, as used herein, is a potting material that having a low coefficient of linear thermal expansion (e.g., a coefficient of linear thermal expansion of less than about 250 ppm/°C) and/or a low glass transition temperature (e.g., a glass transition temperature of less than about -40 °C). The expansion and contraction of such potting material through temperature extremes spanning -40 °C to 150 °C places an acceptable amount of stress on surface mount components embedded in the potting material such that the surface mount components do not become dislodged.

[0176] The potting material 105 is a two-component urethane with a set time of less than about ten minutes. Such a ratio can be useful, for example, for simplifying the mixing process used during manufacturing.

[0177] As indicated above, the potting material 105 can be added to the robot 10 in a quantity sufficient to act as a ballast to lower the center of gravity of the robot. In some implementations, the potting material is between about 5 percent and about 20 percent of the overall mass of the robot 10. For example, the potting material 105

can have a mass of between about 110 g and about 140 g. Given the volume available for the addition of the potting material 105, a potting material with a specific gravity of between about 1.2 and about 1.6 can be used to add this range of mass to the robot 10.

[0178] In addition to isolating the PCB 101 from fluid communication with the liquid applicator 1400, the potting material 105 has a higher thermal conductivity than air and can, thus, facilitate dissipation of heat generated by the PCB 101 during operation of the robot 10. For example, the potting material can have a thermal conductivity of about 0.15 W/(m·K) to about 0.40 W/(m·K).

[0179] The potting material 105 is disposed around the PCB 105 by placing the chassis 100 in a substantially vertical orientation, with a substantially flat rear portion 102 of the chassis below a forward portion 111 of the chassis 100 (e.g., by placing the substantially flat rear portion 102 of the chassis on a table). With the chassis 100 in this vertical orientation, the potting material 105 is introduced into the space between the chassis 100 and the PCB cover 103 by introducing the potting material through a valve 107 defined by the PCB cover 103. The valve 107 is defined through the portion of the PCB cover 103 disposed toward the rear portion 102 of the chassis. Accordingly, the potting material 105 is moved in a vertical direction over the PCB 100 disposed between the chassis 100 and the PCB cover 103. Through such vertical movement, the potting material 105 displaces air from the space between the chassis 100 and the PCB cover 103 such that the air exits through the forward portion 111 of the chassis 100.

[0180] The potting material 105 has an uncured viscosity at room temperature between about 8000 centipoise and about 10000 centipoise for curing in a short period of between the chassis 100 and the PCB cover 103 by introducing the potting material through a valve 107 defined by the PCB cover 103. The valve 107 is defined through the portion of the PCB cover 103 disposed toward the rear portion 102 of the chassis. Accordingly, the potting material 105 is moved in a vertical direction over the PCB 100 disposed between the chassis 100 and the PCB cover 103. Through such vertical movement, the potting material 105 displaces air from the space between the chassis 100 and the PCB cover 103 such that the air exits through the forward portion 111 of the chassis 100.

[0181] The potting material 105 has an uncured viscosity at room temperature between about 8000 centipoise and about 10000 centipoise for curing in a short period of time (e.g., less than an hour). However, in some implementations, the potting material 105 is heated to an uncured viscosity of between about 3000 centipoise to about 5000 centipoise before the potting material is introduced through the valve 107. Such heating can facilitate flow of the potting material 105 around wires 115 while reducing the likelihood of formation of air pockets around the wires 115. After a predetermined mass of potting material 105 is introduced into the volume

in which the PCB 101 is disposed, the potting material cures around the PCB 101. In some implementations, the potting material 105 seals the orifice 107. For example, the orifice can be an x-shape and the cured potting material 105 seals together the portions of material forming the x-shape.

[0182] Many sensor elements have a local small circuit board, sometimes with a local microprocessor and/or A/D converter and the like, and these components are often sensitive to fluids and corrosion. In some implementations, sensor circuit boards distributed throughout the body of the robot 10 are sealed in a JIS grade 3-7 housing in a similar manner. In some implementations, multiple circuit boards, including at least the main circuit board and one remote circuit board (e.g., a user interface circuit board) several centimeters from the main board, may be sealed by a single matching housing or cover. For example, all or some of the circuit boards can be arranged in a single plastic or resin module having extensions which reach to local sensor sites. Additionally or alternatively, a distributed cover can be secured over all of the circuit boards. Exposed electrical connections and terminals of sensors, motors, or communication lines can be sealed in a similar manner, with covers, modules, potting, shrink fit, gaskets, or the like. In this manner, substantially the entire electrical system is fluid-sealed and/or isolated from cleaning liquid and/or waste. Any and all electrical or electronic elements defined herein as a circuit board, PCB, detector, sensor, etc., are candidates for such sealing.

[0183] In some implementations, electrical components (e.g., a PCB, the fan 112) of the robot 10 can be substantially isolated from moisture and/or waste using a wire seal. Details of such a wire seal are disclosed in U.S. Pat. App. No. 12/118,250, entitled "Autonomous Coverage Robot Sensing."

Omni-Directional Receiver

[0184] Referring to FIGS. 7, 12, and 19, the robot 10 includes an omni-directional receiver 410 disposed along a bottom portion of signal channeler 402. For the purpose of illustration, FIG. 19 shows the signal channeler 402 without waste intake conduits 234 and without fan intake conduit 114 attached. Several aspects of the omni-directional sensor 410 as well as its operation, especially as it relates to the navigation and direction of the robot 10 are specifically described in United States Patent Application Serial No. 11/633869, by Ozick et al., entitled "AUTONOMOUS COVERAGE ROBOT NAVIGATION SYSTEM."

[0185] The omni-directional receiver 410 is positioned on the signal channeler 402, substantially off-center from (e.g., substantially forward of) the central vertical axis 20 of the robot 10. The off-center positioning of omni-directional receiver 410 can allow the control module 1000 to be more sensitive in one direction. In some implementations, such sensitivity allows the robot 10 to discern di-

rectionality during maneuvers. For example, if the omni-directional receiver 410 receives a signal, the control module 1000 can direct the robot 10 to turn in place until the signal received by the omni-directional receiver 410 weakens and/or disappears. In some implementations, the control module 1000 directs the robot 10 to drive in the direction in which a weakened signal and/or no signal is detected (e.g., away from the source of the signal)

[0186] In some implementations, the omni-directional receiver 410 can be configured to receive transmissions of infrared light (IR). In such implementations, a guide (e.g. a light pipe) can guide emissions reflected off a conical reflector and channel them to an emission receiver.

[0187] The omni-directional receiver 410 is disposed substantially within a cavity 414 defined by a housing 412. A cover 416 extends over the cavity 414 and forms a substantially water-tight seal with the housing 412 to enclose the omni-directional receiver 410. In some implementations, the cover 416 is releasably attached to the housing 412 to allow, for example, replacement and/or repair of the omni-directional receiver 410. The substantially water-tight seal between the housing 412 and the cover 414 can include any of various different seals. Examples of seals include epoxy, ultrasonic welding, potting wells, welded interfaces, plugs, gaskets, and polymeric membranes.

[0188] During use, an active external device (e.g., a navigation beacon) can send a signal toward the signal channeler 402. The signal channeler 402 is configured for total internal reflection of the incident signal such that the signal moves substantially unattenuated within the signal channeler 402 (e.g., within the material forming the signal channeler). In some implementations, the signal channeler 402 is a substantially uniform layer of polished polycarbonate resin thermoplastic. The signal moving through the signal channeler 402 is internally reflected through the signal channeler 402. The omni-directional receiver 410 is arranged to detect signal reflected through the signal channeler. The omni-directional receiver 416 is in communication (e.g., electrical communication) with the control module 1000. Upon detecting a signal traveling through the signal channeler 402, the omni-directional receiver 416 sends a signal to the control module 1000.

[0189] In some implementations, the control module 1000 responds to the signal from the omni-directional receiver 416 by controlling the wheel modules 500, 501 to navigate the robot 10 away from the source of the signal. For example, as an initial escape procedure, the control module 1000 can direct the wheel modules 500, 501 to move the robot 10 in a rearward direction. Such movement in the rearward direction, can position the robot 10 further away from the beam such that robot 10 can determine directionality (e.g., spin out of the beam) by rotating substantially in place. In a subsequent escape procedure, the controller 1000 can direct the robot 10 in a direction away from the signal.

[0190] In some implementations, the robot 10 is con-

figured to detect the virtual wall pattern and is programmed to treat the virtual wall pattern as a room wall so that the robot does not pass through the virtual wall pattern.

[0191] In some implementations, the robot 10 includes a radio to control the state of the navigation beams through commands transmitted over a packet radio network.

[0192] Control module 1000 can be configured to maneuver the robot 10 about a first area while the robot 10 is in a cleaning mode. In the cleaning mode, the robot 10 can be redirected in response to detecting a gateway marking emission (e.g., from a beacon). In addition, the control module 1000 can be configured to maneuver the robot 10 through a gateway into the second bounded area while in a migration mode.

[0193] In some implementations, the control module 1000 is configured to move the robot 10 in a first bounded area in the cleaning mode for a preset time interval. When the present time interval elapses, the control module 1000 can move the robot 10 in a migration mode. While in migration mode, the controller 1000 can direct the wheel modules 500, 501 to maneuver the robot while substantially suspending the wet cleaning process. In some implementations, the migration mode can be initiated when the omni-directional receiver 410 encounters the gateway marking emission a preset number of times.

Wall Follower

[0194] Dust and dirt tend to accumulate at room edges. To improve cleaning thoroughness and navigation, the robot 10 can follow walls. Additionally or alternatively, the robot 10 can follow walls as part of a navigation strategy (e.g., a strategy to promote full coverage). Using such a strategy, the robot can be less prone to becoming trapped in small areas. Such entrapments could otherwise cause the robot to neglect other, possibly larger, areas.

[0195] Using a wall follower, the distance between the robot and the wall is substantially independent of the reflectivity of the wall. Such consistent positioning can allow the robot 10 to clean with substantially equal effectiveness near dark and light colored walls alike. The wall follower includes a dual collimation system including an infrared emitter and detector. In such a collimation system, the field of view of the infrared emitter and detector can be restricted such that there is a limited, selectable volume where the cones of visibility intersect. Geometrically, the sensor can be arranged so that it can detect both diffuse and specular reflection. This arrangement can allow the wall following distance of the robot 10 to be precisely controlled, substantially independently of the reflectivity of the wall. The distance that the robot 10 maintains between the robot and the wall is independent of the reflectivity of the wall.

[0196] Referring to FIG. 4, the robot 10 includes a wall follower sensor 310 disposed substantially along the right

side of the bumper 300. The wall follower sensor 310 includes an optical emitter 312 substantially forward of a photon detector 314. In some implementations, the position of the wall follower sensor 310 and the optical emitter 312 can be reversed such that the wall follower sensor 310 is substantially forward of the optical emitter 312. Details of the wall follower sensor 310 are disclosed in U.S. Pat. App. No. 12/118,250, entitled "Autonomous Coverage Robot Sensing."

Bump Sensors

[0197] Bump sensors can be used to detect if the robot physically encounters an obstacle. Bump sensors can use a physical property such as capacitance or physical displacement within the robot to determine the robot has encountered an obstacle.

[0198] Referring to FIG. 7, the chassis 100 carries at least one bump sensor 330 along a forward portion of the chassis 100. In some implementations, bump sensors 330 are substantially uniformly positioned on either side of the fore-aft axis 22 and are positioned at substantially the same height along the center vertical axis 20. As described above, bumper 300 is attached to chassis 100 by hinges 110 such that the bumper 300 can move a distance rearward along the fore-aft axis 22 if the bumper 300 encounters an obstacle. In the absence of a bump, the bumper 300 is hingedly supported on the chassis 100 at a short distance substantially forward of the at least one bump sensor 330. If the bumper 300 is moved rearward (e.g., through an encounter with an obstacle), the bumper 300 can press on one or more of the at least one bump sensors 330 to create a bump signal detectable by the control module 1000.

[0199] Details of the at least one bump sensor 330 are disclosed in U.S. Pat. App. No. 12/118,250, entitled "Autonomous Coverage Robot Sensing."

Cliff Sensor

[0200] Cliff sensors can be used to detect if a portion (e.g., a forward portion) of the robot has encountered an edge (e.g., a cliff). Cliff sensors can use an optical emitter and photon detector pair to detect the presence of a cliff. In response to a signal from a cliff detector, the robot can initiate any of various different cliff avoidance behaviors. Details of cliff sensors carried on bumper 300 are disclosed in U.S. Pat. App. No. 12/118,250, entitled "Autonomous Coverage Robot Sensing."

Stasis Sensor

[0201] A stasis sensor can be used to detect whether or not the robot is in fact moving. For example, a stasis sensor can be used to detect if the robot is jammed against an obstacle or if the drive wheels are disengaged from the floor, as when the robot is tilted or becomes stranded on an object. In a wet cleaning application, a

stasis sensor can detect whether the wheels are slipping on a cleaning liquid applied to the surface. In such circumstances, the drive wheels may spin when the mobile robot applies power to them, but the robot is not moving. Details of stasis sensors for detecting whether the robot is moving are disclosed in U.S. Pat. App. 12/118, 250, entitled "Autonomous Coverage Robot Sensing."

Power Module/Interface Module

[0202] Referring to FIGS. 1-7, the power module 1200 delivers electrical power to all of the major robot subsystems. The power module 1200 includes a self-contained power source releasably attached to the chassis 100, e.g., a rechargeable battery, such as a nickel metal hydride battery, or the like. In addition, the power source is configured to be recharged by any of various different recharging elements and/or recharging modes. In some implementations, the battery can be replaced by a user when the battery becomes discharged or unusable. The controller 1000 can also interface with the power module 1200 to control the distribution of power, to monitor power use and to initiate power conservation modes as required.

[0203] The robot 10 can include one or more interface modules 1700. Each interface module 1700 is attached to the chassis 100 and can provide an interconnecting element or port for interconnecting with one or more external devices. Interconnecting elements are ports can be accessible on an external surface of the robot 10. The controller 1000 can also interface with the interface modules 1700 to control the interaction of the robot 10 with an external device. In particular, one interface module element can be provide for charging the rechargeable battery via an external power supply or power source such as a conventional AC or DC power outlet. The interface module for charging the rechargeable battery can include a short-circuit loop that will prevent the rechargeable battery from taking charge if there is water in the charge port of the robot 10. In some implementations, the rechargeable battery includes a fuse that will trip if there is water in the battery recharging path.

[0204] Another interface module element can be configured for one or two way communications over a wireless network and further interface module elements can be configured to interface with one or more mechanical devices to exchange liquids and loose particles therewith, e.g., for filling a cleaning fluid reservoir.

[0205] Active external devices for interfacing with the robot 10 can include, but are not limited to, a floor standing docking station, a hand held remote control device, a local or remote computer, a modem, a portable memory device for exchanging code and/or data with the robot 10 and a network interface for interfacing the robot 10 with any device connected to the network. In addition, the interface modules 1700 can include passive elements such as hooks or latching mechanisms for attaching the robot 100 to a wall for storage or for attaching the robot

to a carrying case or the like.

[0206] In some implementations, an active external device can confine the robot 10 in a cleaning space such as a room by emitting a signal in a virtual wall pattern. The robot 10 can be configured to detect the virtual wall pattern (e.g., using an omni-directional receiver as described above) and is programmed to treat the virtual wall pattern as a room wall so that the robot does not pass through the virtual wall pattern. Such a configuration is described in U.S. Pat. No. 6,690,134 by Jones et al., entitled Method and System for Robot Localization and Confinement.

[0207] In some implementations, an active external device includes a base station used to interface with the robot 10. The base station can include a fixed unit connected with a household power supply, e.g., an AC power wall outlet and/or other household facilities such as a water supply pipe, a waste drain pipe and a network interface. The robot 10 and the base station can each be configured for autonomous docking and the base station can be further configured to charge the robot power module 1200 and to service the robot in other ways. A base station and autonomous robot configured for autonomous docking and for recharging the robot power module are described in U.S. Patent App. Ser. No. 10/762,219, by Cohen, et al., filed on January 21, 2004, entitled Autonomous Robot Auto-Docking and Energy Management Systems and Methods.

[0208] Other robot details and features combinable with those described herein may be found in U.S. Pat. App. No. 12/118,117, entitled "COMPACT AUTONOMOUS COVERAGE ROBOT", U.S. Pre-grant Publications 2008/00652565, 2007/0244610, and 2007/0016328, 2006/0200281, and 2003/0192144, and also U.S. Patents 6,748,297 and 6,883,201.

[0209] A number of implementations have been described. Nevertheless, it will be understood that various modifications may be made without departing from the scope of the following claims.

Claims

1. A surface treatment robot (10) comprising:

- a robot body (100) having a forward portion and a rear portion, the forward portion preceding the rear portion as the robot (10) moves in a forward direction over a cleaning surface;
- a differential drive system mounted on the robot body and configured to maneuver the robot (10) over a cleaning surface;
- a liquid applicator (1400) carried by the robot body (100), the liquid applicator (1400) configured to dispense a liquid to the cleaning surface;
- a collection assembly (1300) carried by the robot body (100) and configured to remove waste from the cleaning surface, wherein the liquid applica-

- tor (1400) dispenses at least a portion of the liquid rear of the collection assembly (1300) as the robot moves in the forward direction, wherein the liquid applicator (1400) dispenses between about 60 percent and 100 percent of the liquid rear of the collection assembly (1300); and
a controller (1000) in communication with the differential drive system to direct the robot (10) over the cleaning surface, wherein the controller (1000) is configured to direct the robot (10) to return to at least a portion of the cleaning surface to collect from the cleaning surface at least some of the dispensed cleaning liquid.
2. The surface treatment robot (10) of claim 1 wherein the liquid applicator (1400) dispenses between about 30 percent and about 70 percent of the liquid forward of the collection assembly (1300) and at least about 30 percent of the liquid rear of the collection assembly (1300).
 3. The surface treatment robot (10) of any of claims 1 or 2 wherein the liquid applicator (1400) dispenses between about 95 percent and 100 percent of the liquid rear of the collection assembly (1300).
 4. The surface treatment robot (10) of any of claims 1 to 3 wherein the liquid applicator (1400) comprises a spray nozzle (155c, 210a) arranged to dispense liquid rear of the collection assembly (1300) as the robot (10) moves in the forward direction or a drip assembly (155c, 210a) configured to drip liquid rear of the collection assembly (1300) as the robot (10) moves in the forward direction.
 5. The surface treatment robot (10) of any of claims 1 to 4 wherein the collection assembly (1300) includes a vacuum assembly comprising a collection region and a suction region in fluid communication with the collection region.
 6. The surface treatment robot (10) of any of claims 1 to 5 wherein the collection assembly (1300) comprises a surface agitation assembly (604).
 7. The surface treatment robot (10) of any of claims 1 to 6 further comprising a humidity sensor, wherein the surface agitation assembly (604) comprises an active scrubbing element configured to act on the cleaning surface based at least in part on detection of humidity on the cleaning surface.
 8. The surface treatment robot (10) of any of claims 1 to 7 wherein the differential drive system comprises right and left drive wheels (504, 505).
 9. The surface treatment robot (10) of claim 8, wherein the collection assembly (1300) is disposed rear of the right and left drive wheels (504, 505).
 10. The surface treatment robot (10) of any of claims 1 to 9 further comprising a wetting assembly (204) carried by the robot body (100), at least a portion of the wetting assembly (204) disposed rear of the collection assembly (1300) and rear of the liquid applicator (1400) as the robot (10) moves in the forward direction, wherein at least a portion of the wetting assembly (204) contacts the cleaning surface as the robot (10) moves in the forward direction.
 11. The surface treatment robot (10) of claim 10 wherein the wetting assembly (204) comprises a compliant blade extending in a direction substantially parallel to the cleaning surface.
 12. The surface treatment robot (10) of any of claims 9 or 10 wherein the wetting assembly (204) comprises a plurality of bristles (205; 206; 207) extending from the robot body (100), toward the cleaning surface.
 13. The surface treatment robot (10) of any of claims 1 to 8 and 10 to 12 wherein the collection assembly (1300) includes a wet vacuum subsystem and a dry vacuum subsystem, wherein the robot body (100) includes a lower portion including a wet vacuum portion of the wet vacuum subsystem and a dry vacuum portion of the dry vacuum subsystem, respectively, wherein the differential drive system comprises right and left drive wheels (504, 505), wherein the wet vacuum portion is disposed rear of the right and left drive wheels (504, 505) and wherein the dry vacuum portion is disposed in front of the right and left drive wheels (504, 505) as the robot (10) moves in the forward direction, and wherein a surface agitation assembly (604) is disposed between the dry vacuum portion and the wet vacuum portion as the robot (10) moves in the forward direction.
 14. A method of surface treatment comprising:
maneuvering a surface treatment robot (10) over a cleaning surface, the robot having a forward portion and a rear portion, the forward portion preceding the rear portion over the cleaning surface as the robot (10) moves in a forward direction, the robot (10) comprising a liquid applicator (1400) and a collection assembly (1300);
dispensing a liquid from the liquid applicator (1400) to the cleaning surface;
collecting waste into the collection assembly (1300) from the cleaning surface, wherein at least a portion of the liquid is dispensed rear of

the collection assembly (1300) as the robot moves in the forward direction; and returning to at least a portion of the cleaning surface to collect from the cleaning surface at least some of the dispensed cleaning liquid within a predetermined time span.

Patentansprüche

1. Oberflächenbehandlungsroboter (10), umfassend:

einen Roboterkörper (100) mit einem vorderen Teil und einem hinteren Teil, wobei der vordere Teil dem hinteren Teil vorausgeht, wenn sich der Roboter (10) in eine Vorwärtsrichtung über eine Reinigungsfläche bewegt;
ein Differenzialantriebssystem, das an dem Roboterkörper angebracht und dazu konfiguriert ist, den Roboter (10) über eine Reinigungsfläche zu manövrieren;
einen Flüssigkeitsapplikator (1400), der von dem Roboterkörper (100) getragen wird, wobei der Flüssigkeitsapplikator (1400) dazu konfiguriert ist, eine Flüssigkeit an die Reinigungsfläche abzugeben;
eine Sammelanordnung (1300), die von dem Roboterkörper (100) getragen wird und dazu konfiguriert ist, Abfall von der Reinigungsfläche zu entfernen, wobei der Flüssigkeitsapplikator (1400) mindestens einen Teil der Flüssigkeit hinter der Sammelanordnung (1300) abgibt, wenn sich der Roboter in die Vorwärtsrichtung bewegt,
wobei der Flüssigkeitsapplikator (1400) zwischen ca. 60 Prozent und 100 Prozent der Flüssigkeit hinter der Sammelanordnung (1300) abgibt; und
eine Steuerung (1000), die mit dem Differenzialantriebssystem in Verbindung steht, um den Roboter (10) über die Reinigungsfläche zu lenken, wobei die Steuerung (1000) dazu konfiguriert ist, den Roboter (10) zu mindestens einem Teil der Reinigungsfläche zurückzuführen, um von der Reinigungsfläche mindestens einen Teil der abgegebenen Reinigungsflüssigkeit aufzusammeln.

2. Oberflächenbehandlungsroboter (10) nach Anspruch 1, wobei der Flüssigkeitsapplikator (1400) zwischen ca. 30 Prozent und ca. 70 Prozent der Flüssigkeit vor der Sammelanordnung (1300) und mindestens ca. 30 Prozent der Flüssigkeit hinter der Sammelanordnung (1300) abgibt.

3. Oberflächenbehandlungsroboter (10) nach Anspruch 1 oder 2, wobei der Flüssigkeitsapplikator (1400) zwischen ca. 95 Prozent und 100 Prozent der

Flüssigkeit hinter der Sammelanordnung (1300) abgibt.

4. Oberflächenbehandlungsroboter (10) nach einem der Ansprüche 1 bis 3, wobei der Flüssigkeitsapplikator (1400) eine Sprühdüse (155c, 210a), die zur Abgabe von Flüssigkeit hinter der Sammelanordnung (1300), wenn sich der Roboter (10) in die Vorwärtsrichtung bewegt, konfiguriert ist, oder eine Tropfanordnung (155c, 210a), die zum Tropfen von Flüssigkeit hinter der Sammelanordnung (1300), wenn sich der Roboter (10) in die Vorwärtsrichtung bewegt, konfiguriert ist, umfasst.

5. Oberflächenbehandlungsroboter (10) nach einem der Ansprüche 1 bis 4, wobei die Sammelanordnung (1300) eine Absauganordnung enthält, die einen Sammelbereich und einen Saugbereich, der in fluidischer Verbindung mit dem Sammelbereich steht, umfasst.

6. Oberflächenbehandlungsroboter (10) nach einem der Ansprüche 1 bis 5, wobei die Sammelanordnung (1300) eine Oberflächenbewegungsanordnung (604) umfasst.

7. Oberflächenbehandlungsroboter (10) nach einem der Ansprüche 1 bis 6, ferner umfassend einen Feuchtigkeitssensor, wobei die Oberflächenbewegungsanordnung (604) ein aktives Scheuerelement umfasst, das dazu konfiguriert ist, zumindest teilweise auf Detektion von Feuchtigkeit auf der Reinigungsfläche basierend, auf die Reinigungsfläche einzuwirken.

8. Oberflächenbehandlungsroboter (10) nach einem der Ansprüche 1 bis 7, wobei das Differenzialantriebssystem ein rechtes und ein linkes Antriebsrad (504, 505) umfasst.

9. Oberflächenbehandlungsroboter (10) nach Anspruch 8, wobei die Sammelanordnung (1300) hinter dem rechten und dem linken Antriebsrad (504, 505) angeordnet ist.

10. Oberflächenbehandlungsroboter (10) nach einem der Ansprüche 1 bis 9, ferner umfassend eine Benetzungsanordnung (204), die von dem Roboterkörper (100) getragen wird, wobei mindestens ein Teil der Benetzungsanordnung (204) hinter der Sammelanordnung (1300) und hinter dem Flüssigkeitsapplikator (1400) angeordnet ist, wenn sich der Roboter (10) in die Vorwärtsrichtung bewegt, wobei mindestens ein Teil der Benetzungsanordnung (204) die Reinigungsfläche berührt, wenn sich der Roboter (10) in die Vorwärtsrichtung bewegt.

11. Oberflächenbehandlungsroboter (10) nach An-

spruch 10, wobei die Benetzungsanordnung (204) einen nachgiebigen Wischer umfasst, der sich in einer im Wesentlichen parallel zur Reinigungsfläche verlaufenden Richtung erstreckt.

12. Oberflächenbehandlungsroboter (10) nach Anspruch 9 oder 10, wobei die Benetzungsanordnung (204) mehrere Borsten (205; 206; 207) umfasst, die sich von dem Roboterkörper (100) zur Reinigungsfläche erstrecken.

13. Oberflächenbehandlungsroboter (10) nach einem der Ansprüche 1 bis 8 und 10 bis 12, wobei die Sammelanordnung (1300) ein Nasssauguntersystem und ein Trockensauguntersystem enthält, wobei der Roboterkörper (100) einen unteren Teil enthält, der einen Nasssaugteil des Nasssauguntersystems bzw. einen Trockensaugteil des Trockensauguntersystems enthält, wobei das Differenzialantriebssystem ein rechtes und ein linkes Antriebsrad (504, 505) enthält, wobei der Nasssaugteil hinter dem rechten und dem linken Antriebsrad (504, 505) angeordnet ist und wobei der Trockensaugteil vor dem rechten und dem linken Antriebsrad (504, 505) angeordnet ist, wenn sich der Roboter (10) in die Vorwärtsrichtung bewegt, und wobei eine Oberflächenbewegungsanordnung (604) zwischen dem Trockensaugteil und dem Nasssaugteil angeordnet ist, wenn sich der Roboter (10) in die Vorwärtsrichtung bewegt.

14. Verfahren zur Oberflächenbehandlung, umfassend:

Manövrieren eines Oberflächenbehandlungsroboters (10) über eine Reinigungsfläche, wobei der Roboter einen vorderen Teil und einen hinteren Teil aufweist, wobei der vordere Teil dem hinteren Teil über die Reinigungsfläche vorausgeht, wenn sich der Roboter (10) in eine Vorwärtsrichtung bewegt; wobei der Roboter (10) einen Flüssigkeitsapplikator (1400) und eine Sammelanordnung (1300) umfasst; Abgeben einer Flüssigkeit aus dem Flüssigkeitsapplikator (1400) an die Reinigungsfläche; Sammeln von Abfall in die Sammelanordnung (1300) von der Reinigungsfläche, wobei mindestens ein Teil der Flüssigkeit hinter der Sammelanordnung (1300) abgegeben wird, wenn sich der Roboter in die Vorwärtsrichtung bewegt; und Zurückführen zu mindestens einem Teil der Reinigungsfläche, um von der Reinigungsfläche mindestens einen Teil der abgegebenen Reinigungsflüssigkeit aufzusammeln, innerhalb einer vorbestimmten Zeitspanne.

Revendications

1. Robot de traitement de surface (10), comprenant :

5 un corps de robot (100) ayant une portion avant et une portion arrière, la portion avant précédant la portion arrière lorsque le robot (10) se déplace dans une direction vers l'avant sur une surface à nettoyer ;
10 un système d'entraînement différentiel monté sur le corps de robot et configuré pour manoeuvrer le robot (10) sur une surface à nettoyer ;
un applicateur de liquide (1400) porté par le corps de robot (100), l'applicateur de liquide (1400) étant configuré pour distribuer un liquide sur la surface à nettoyer ;
15 un ensemble de collecte (1300) porté par le corps de robot (100) et configuré pour éliminer la saleté de la surface à nettoyer, l'applicateur de liquide (1400) distribuant au moins une partie du liquide à l'arrière de l'ensemble de collecte (1300) lorsque le robot se déplace dans la direction vers l'avant,
20 l'applicateur de liquide (1400) distribuant entre environ 60 % et 100 % du liquide à l'arrière de l'ensemble de collecte (1300) ; et
25 un dispositif de commande (1000) en communication avec le système d'entraînement différentiel pour diriger le robot (10) sur la surface à nettoyer, le dispositif de commande (1000) étant configuré pour diriger le robot (10) de manière à ce qu'il revienne vers au moins une partie de la surface à nettoyer pour recueillir de la surface à nettoyer au moins une partie du liquide de nettoyage distribué.

2. Robot de traitement de surface (10) selon la revendication 1, dans lequel l'applicateur de liquide (1400) distribue entre environ 30 % et environ 70 % du liquide à l'avant de l'ensemble de collecte (1300) et au moins environ 30 % du liquide à l'arrière de l'ensemble de collecte (1300).

3. Robot de traitement de surface (10) selon l'une quelconque des revendications 1 et 2, dans lequel l'applicateur de liquide (1400) distribue entre environ 95 % et 100 % du liquide à l'arrière de l'ensemble de collecte (1300).

4. Robot de traitement de surface (10) selon l'une quelconque des revendications 1 à 3, dans lequel l'applicateur de liquide (1400) comprend une buse de pulvérisation (155c, 210a) prévue pour distribuer du liquide à l'arrière de l'ensemble de collecte (1300) lorsque le robot (10) se déplace dans la direction vers l'avant, ou un ensemble de goutte-à-goutte (155c, 210a) configuré pour distribuer au goutte-à-goutte du liquide à l'arrière de l'ensemble de collecte

(1300) lorsque le robot (10) se déplace dans la direction vers l'avant.

5. Robot de traitement de surface (10) selon l'une quelconque des revendications 1 à 4, dans lequel l'ensemble de collecte (1300) comporte un ensemble de vide comprenant une région de collecte et une région d'aspiration en communication fluïdique avec la région de collecte. 5
6. Robot de traitement de surface (10) selon l'une quelconque des revendications 1 à 5, dans lequel l'ensemble de collecte (1300) comprend un ensemble d'agitation de surface (604). 10
7. Robot de traitement de surface (10) selon l'une quelconque des revendications 1 à 6, comprenant en outre un capteur d'humidité, l'ensemble d'agitation de surface (604) comprenant un élément de recyclage actif configuré pour agir sur la surface à nettoyer basé au moins en partie sur la détection d'humidité sur la surface à nettoyer. 15
8. Robot de traitement de surface (10) selon l'une quelconque des revendications 1 à 7, dans lequel le système d'entraînement différentiel comprend des roues d'entraînement droite et gauche (504, 505). 20
9. Robot de traitement de surface (10) selon la revendication 8, dans lequel l'ensemble de collecte (1300) est disposé à l'arrière des roues d'entraînement droite et gauche (504, 505). 25
10. Robot de traitement de surface (10) selon l'une quelconque des revendications 1 à 9, comprenant en outre un ensemble de mouillage (204) porté par le corps de robot (100), au moins une portion de l'ensemble de mouillage (204) étant disposée à l'arrière de l'ensemble de collecte (1300) et à l'arrière de l'applicateur de liquide (1400) lorsque le robot (10) se déplace dans la direction vers l'avant, au moins une portion de l'ensemble de mouillage (204) venant en contact avec la surface à nettoyer lorsque le robot (10) se déplace dans la direction vers l'avant. 30
11. Robot de traitement de surface (10) selon la revendication 10, dans lequel l'ensemble de mouillage (204) comprend une lame flexible s'étendant dans une direction substantiellement parallèle à la surface à nettoyer. 35
12. Robot de traitement de surface (10) selon l'une quelconque des revendications 9 et 10, dans lequel l'ensemble de mouillage (204) comprend une pluralité de poils (205 ; 206 ; 207) s'étendant depuis le corps de robot (100) vers la surface à nettoyer. 40
13. Robot de traitement de surface (10) selon l'une quel-

conque des revendications 1 à 8 et 10 à 12, dans lequel l'ensemble de collecte (1300) comporte un sous-système de vide humide et un sous-système de vide sec,

le corps de robot (100) comportant une portion inférieure comportant une portion de vide humide du sous-système de vide humide et une portion de vide sèche du sous-système de vide sec, respectivement, le système d'entraînement différentiel comprenant des roues d'entraînement droite et gauche (504, 505), la portion de vide humide étant disposée à l'arrière des roues d'entraînement droite et gauche (504, 505) et la portion de vide sèche étant disposée à l'avant des roues d'entraînement droite et gauche (504, 505) lorsque le robot (10) se déplace dans la direction vers l'avant, et un ensemble d'agitation de surface (604) étant disposé entre la portion de vide sèche et la portion de vide humide lorsque le robot (10) se déplace dans la direction vers l'avant. 45

14. Procédé de traitement de surface, comprenant les étapes suivantes :

manoeuvrer un robot de traitement de surface (10) sur une surface à nettoyer, le robot ayant une portion avant et une portion arrière, la portion avant précédant la portion arrière sur la surface à nettoyer lorsque le robot (10) se déplace dans une direction vers l'avant, le robot (10) comprenant un applicateur de liquide (1400) et un ensemble de collecte (1300) ; distribuer un liquide à partir de l'applicateur de liquide (1400) sur la surface à nettoyer ; recueillir la saleté dans l'ensemble de collecte (1300) depuis la surface à nettoyer, au moins une portion du liquide étant distribuée à l'arrière de l'ensemble de collecte (1300) lorsque le robot se déplace dans la direction vers l'avant ; et revenir sur au moins une portion de la surface à nettoyer pour recueillir, de la surface à nettoyer, au moins une partie du liquide de nettoyage distribué dans un intervalle de temps prédéterminé. 50

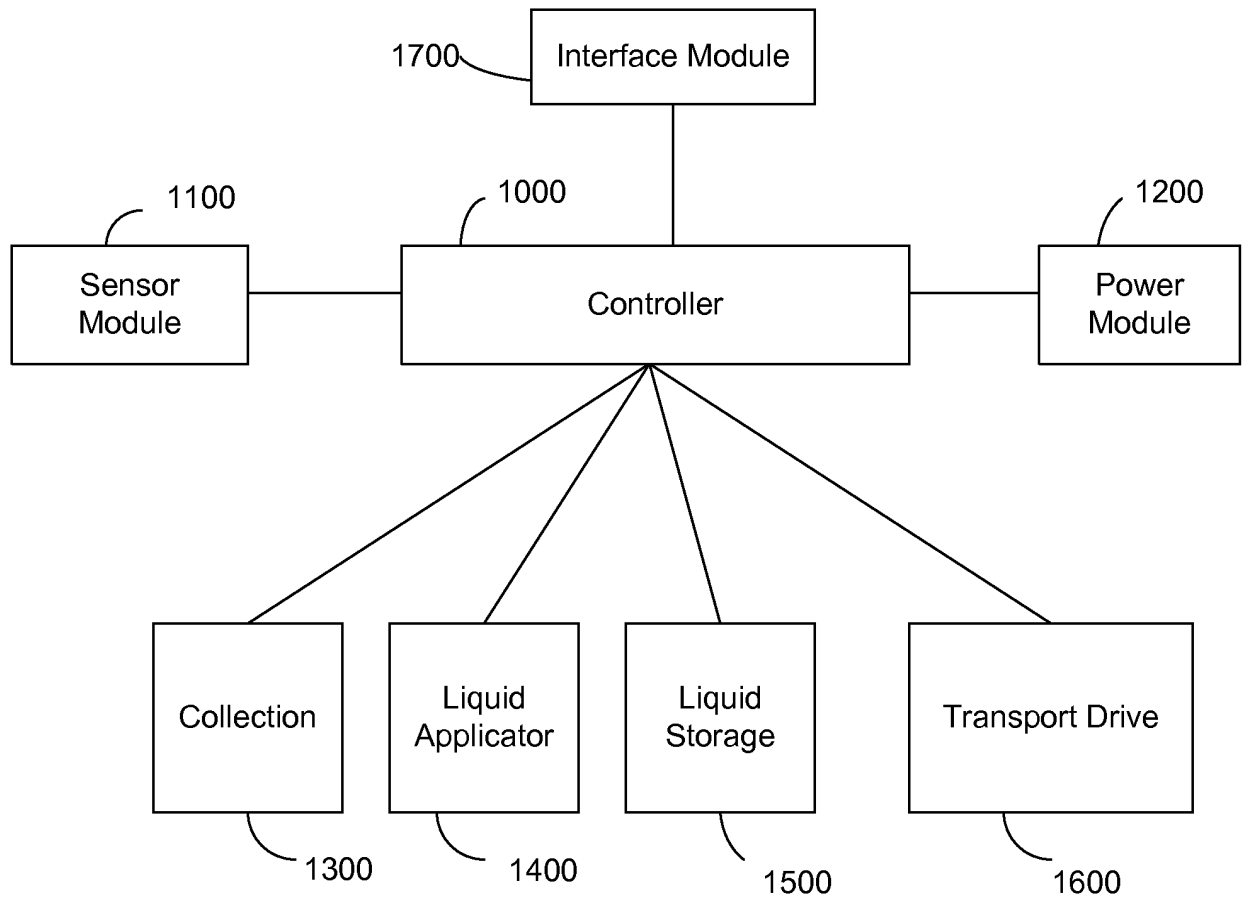


FIG. 1

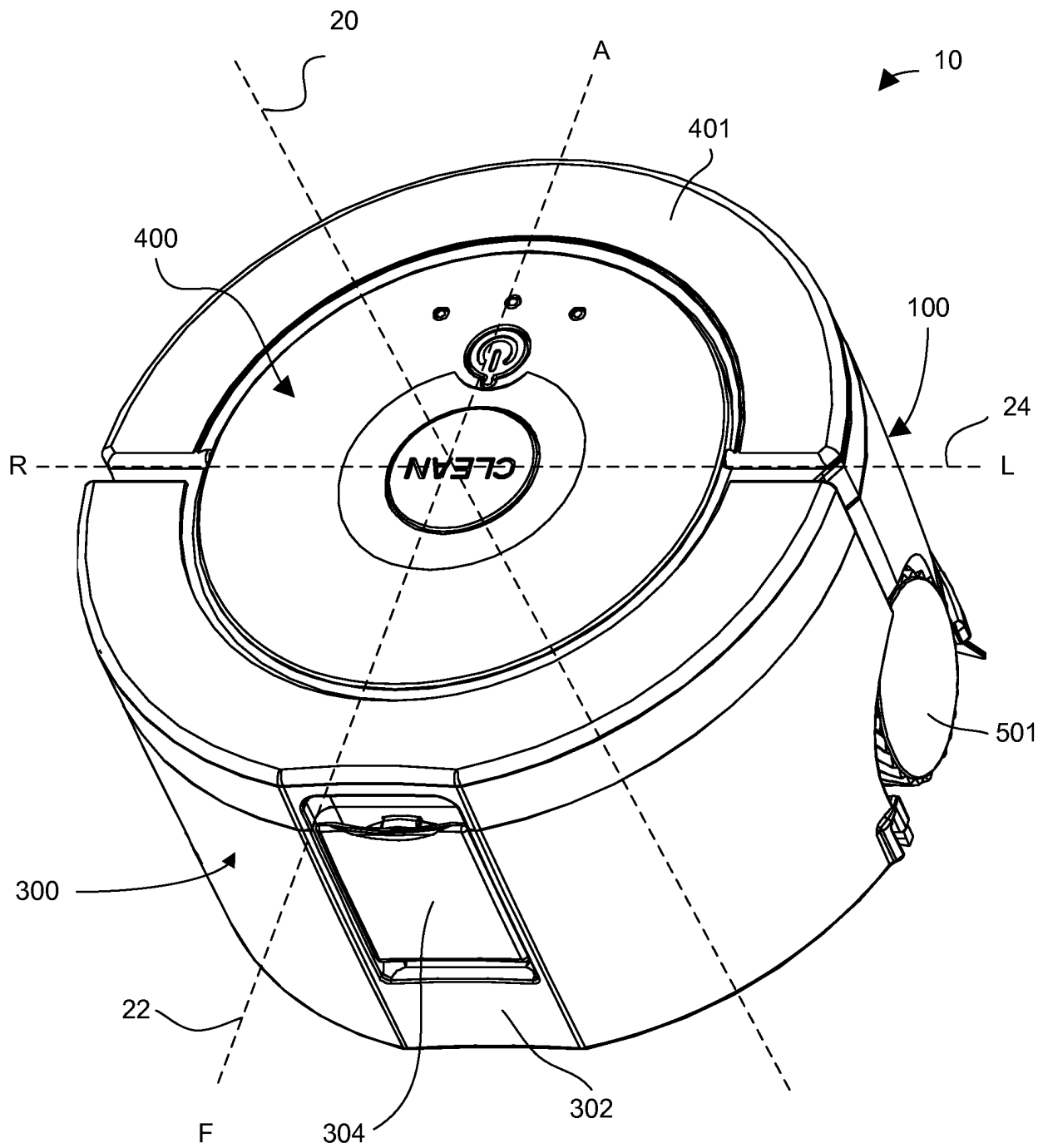


FIG. 2

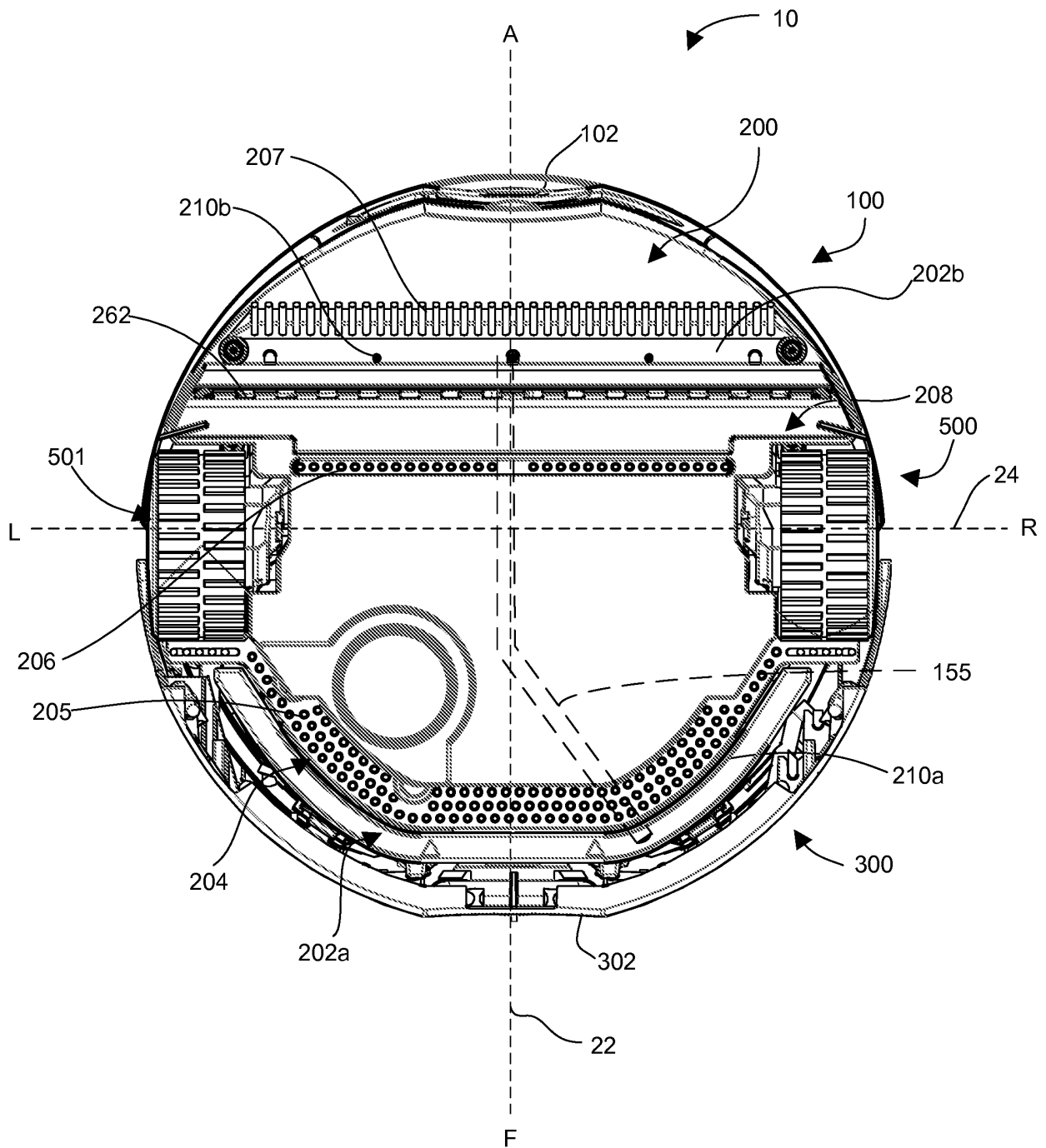


FIG. 3

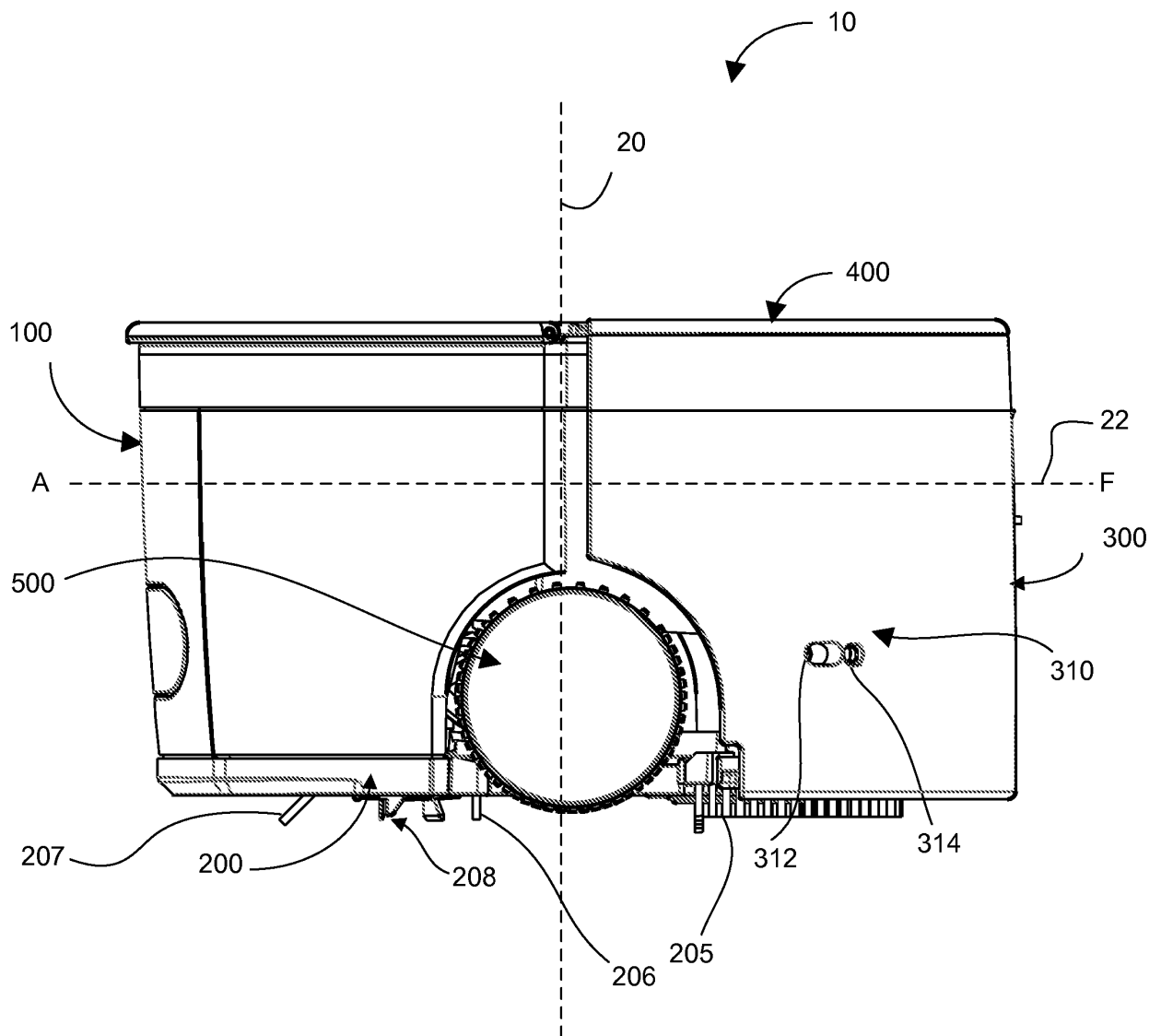


FIG. 4

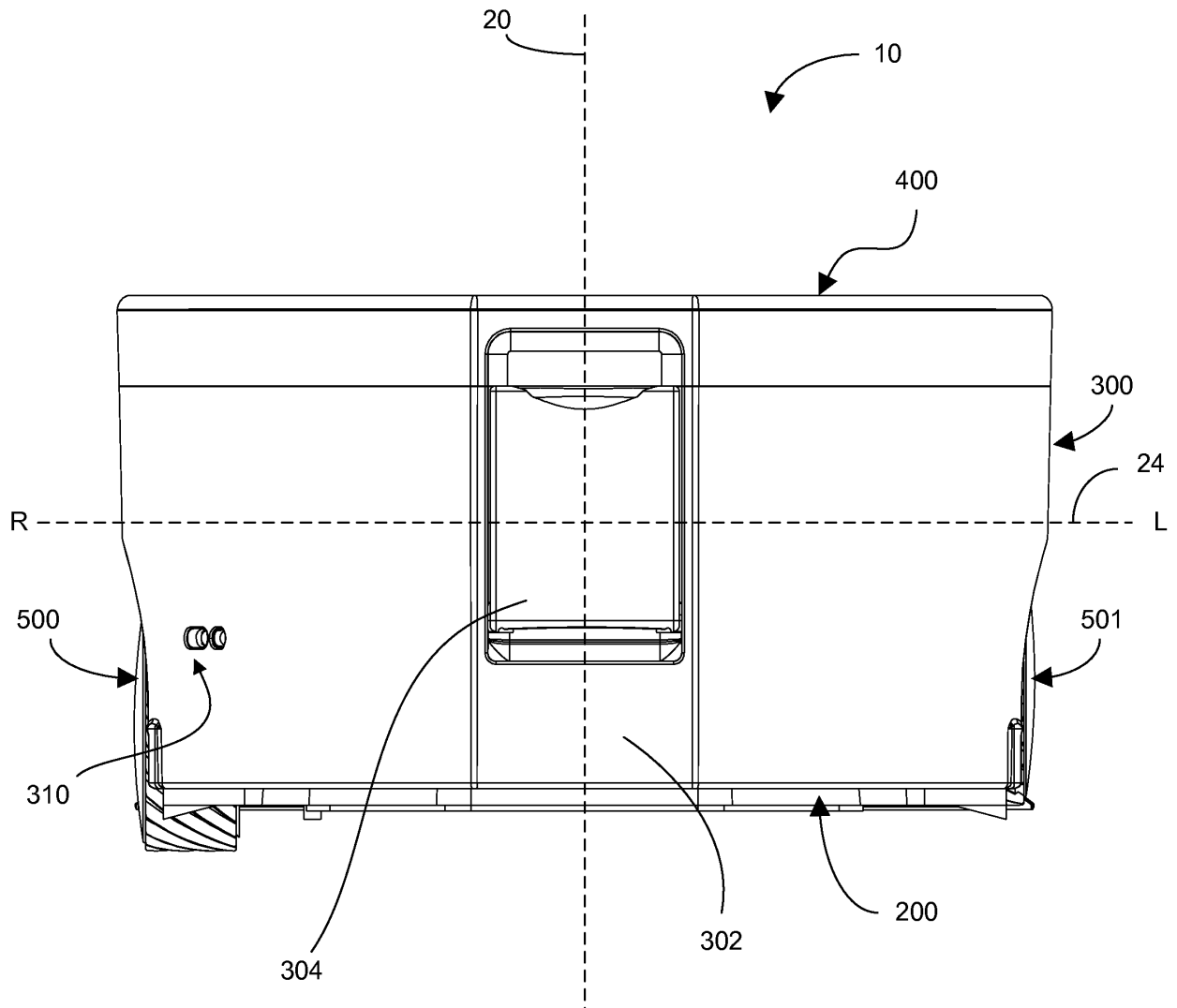


FIG. 5

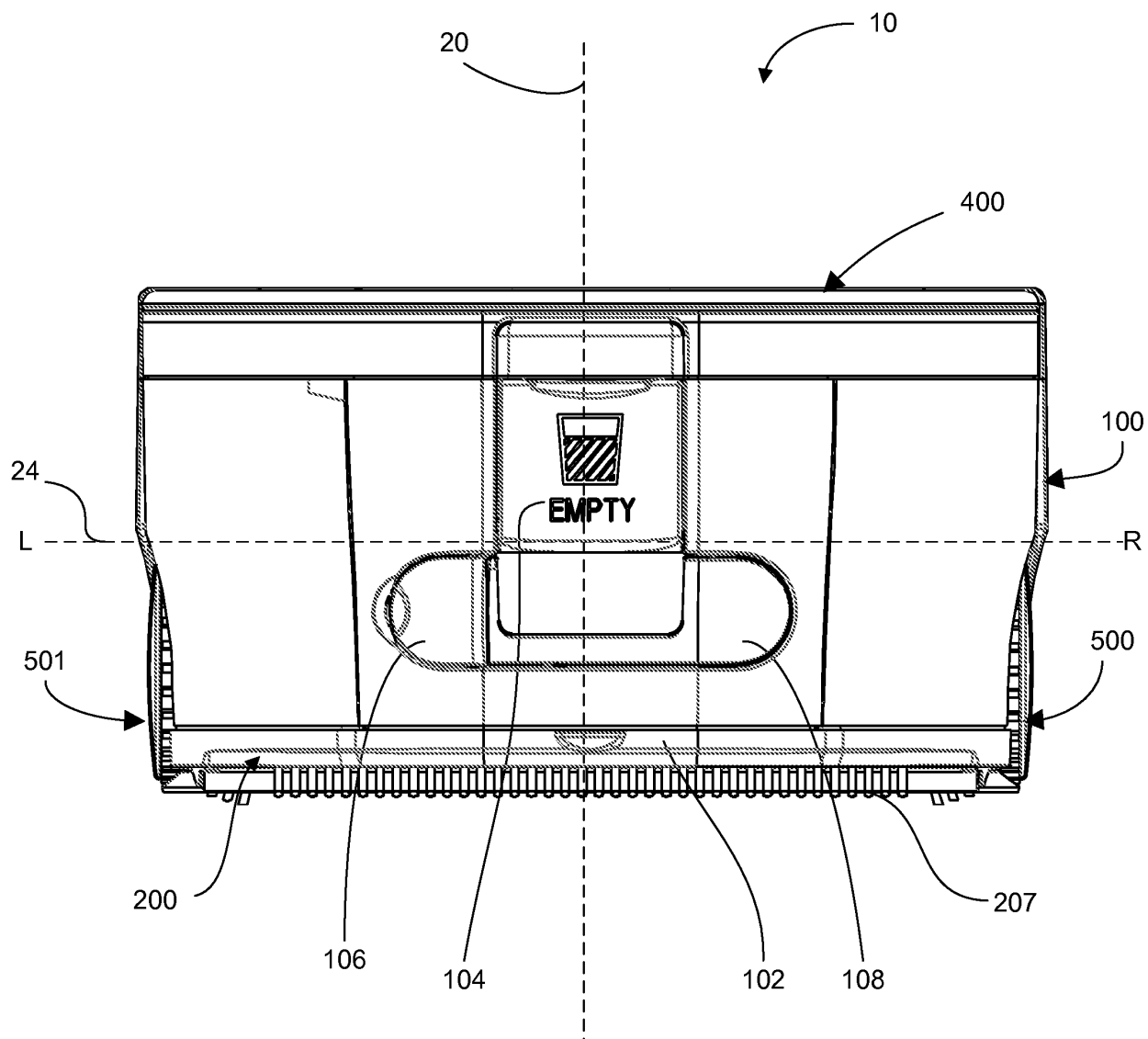
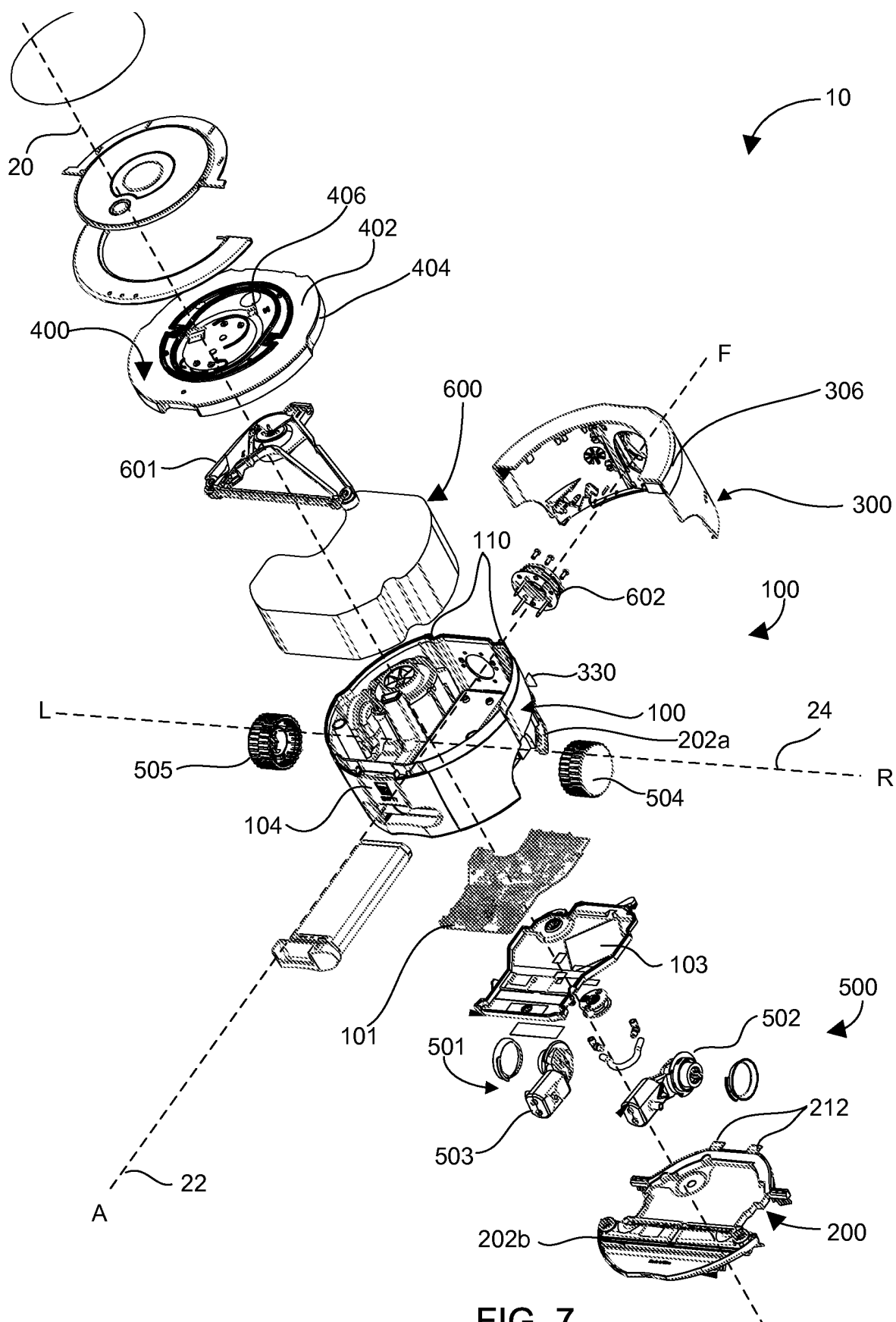


FIG. 6



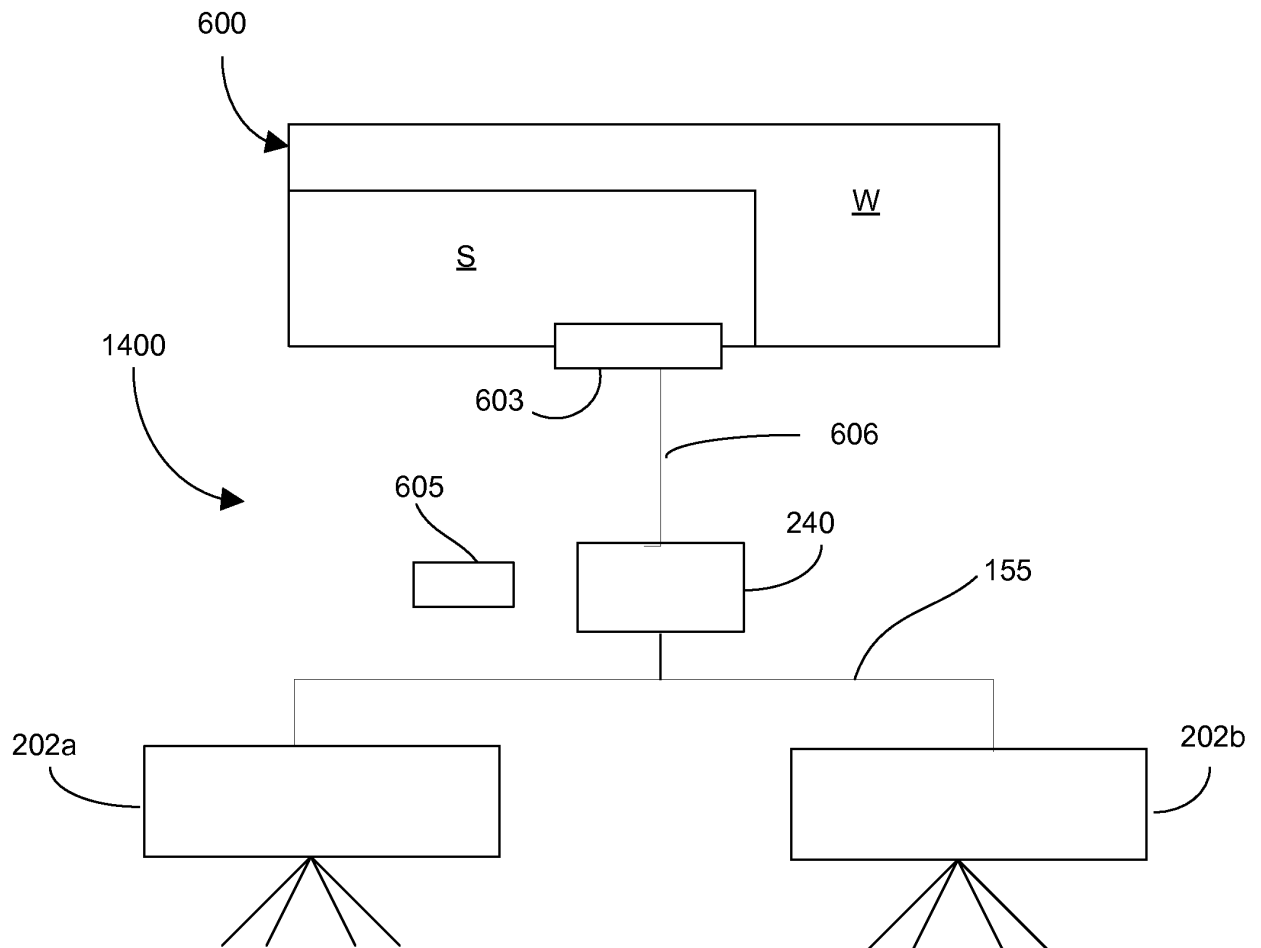


FIG. 8

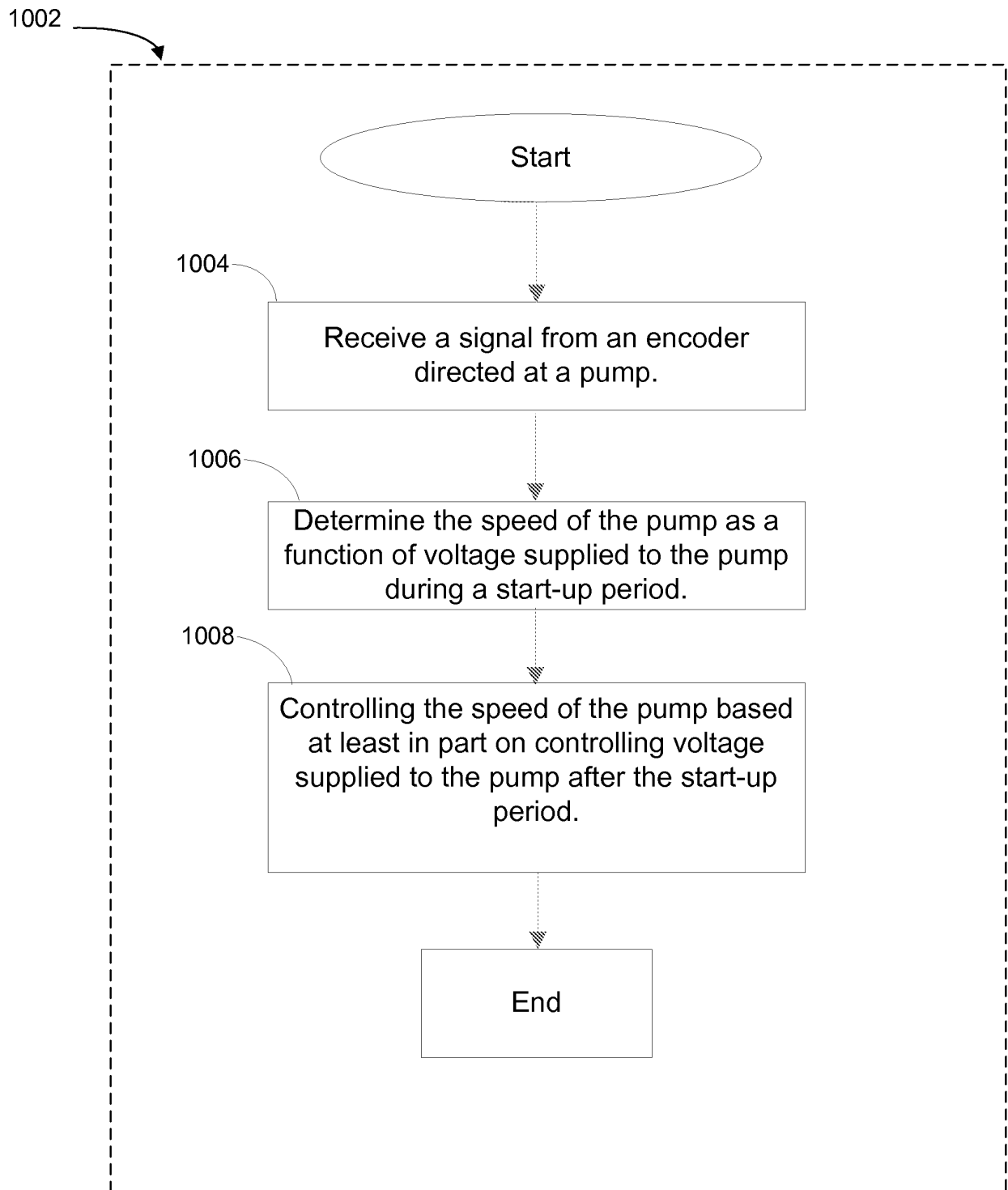


FIG. 9

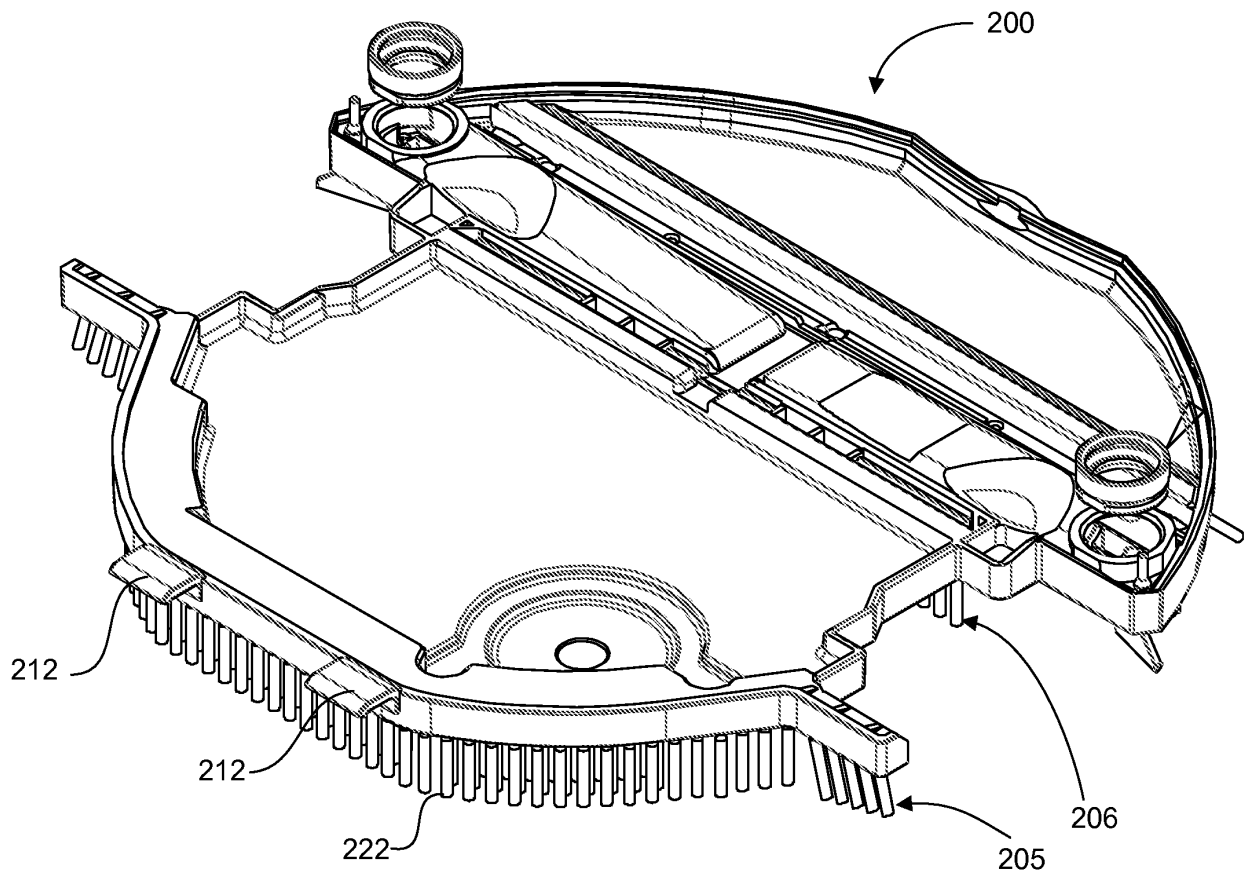


FIG. 10A

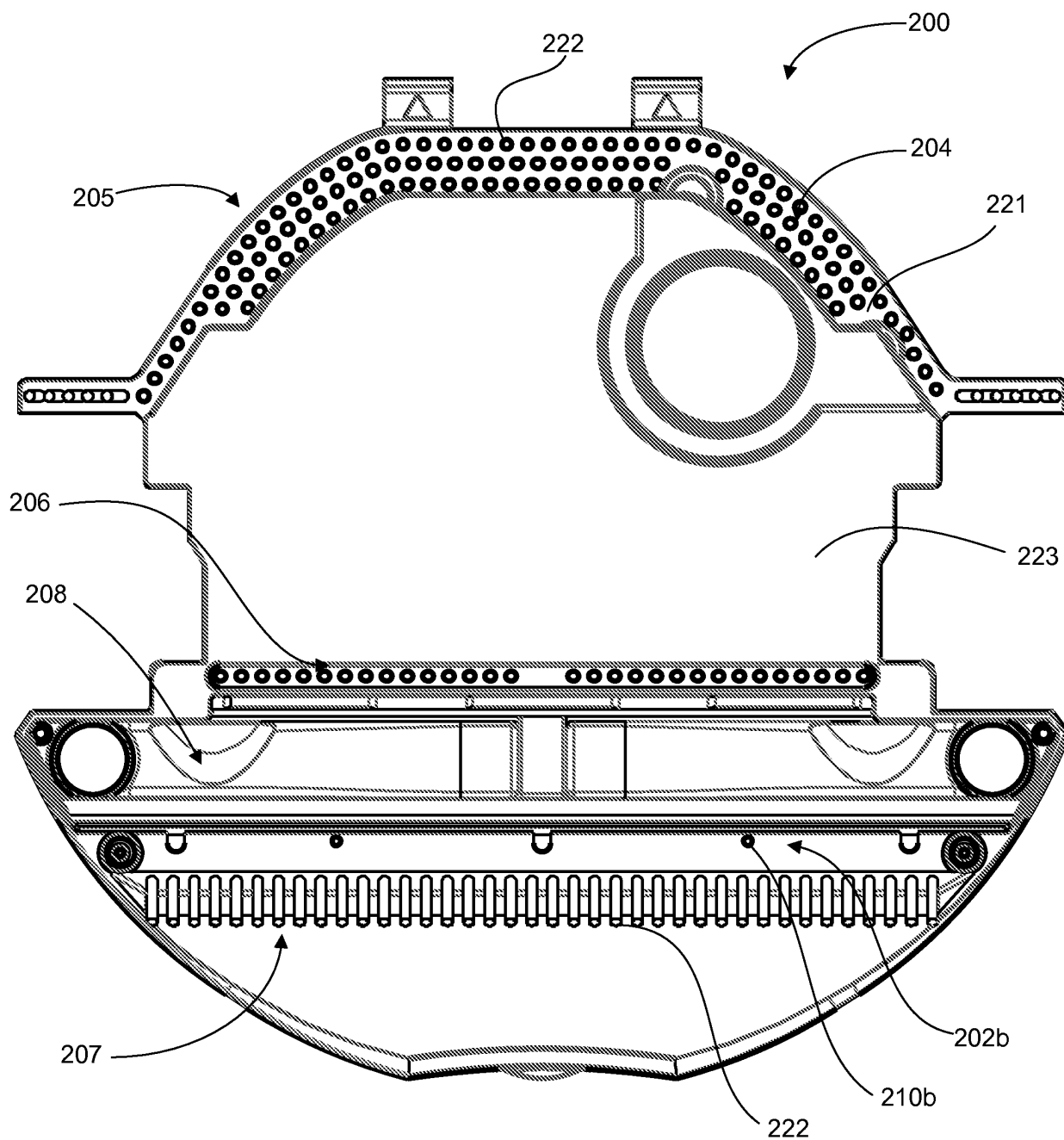


FIG. 10B

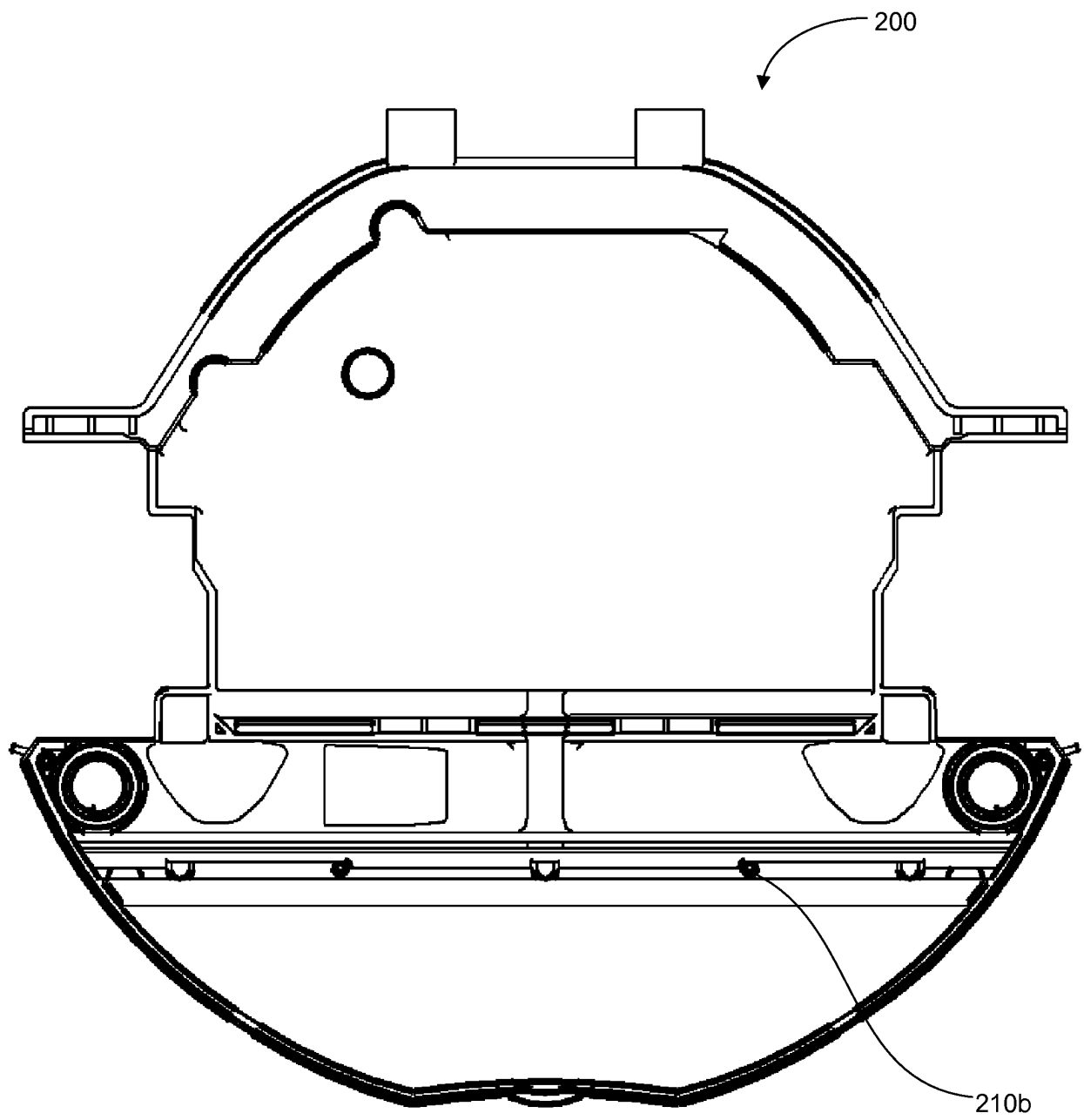


FIG. 10C

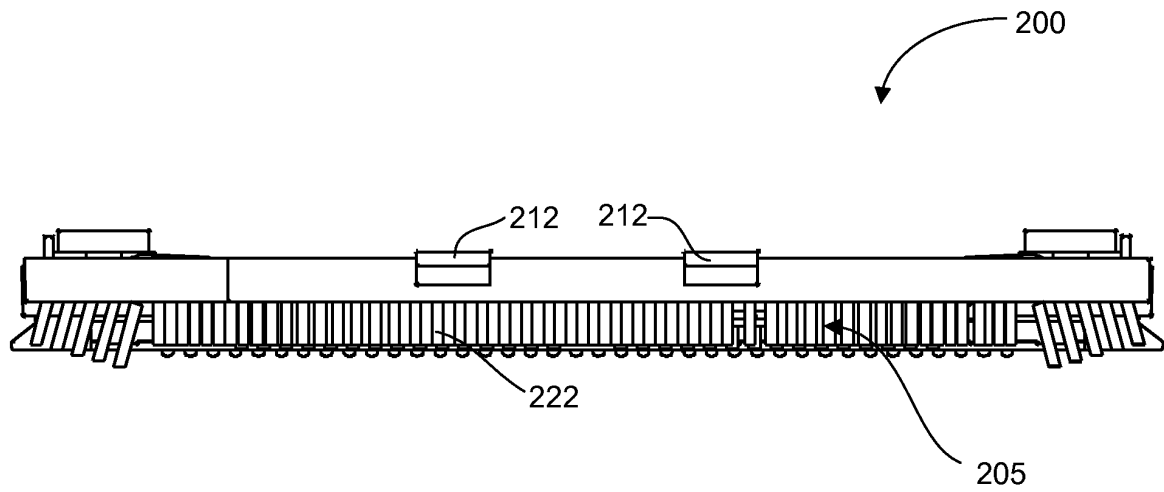


FIG. 10D

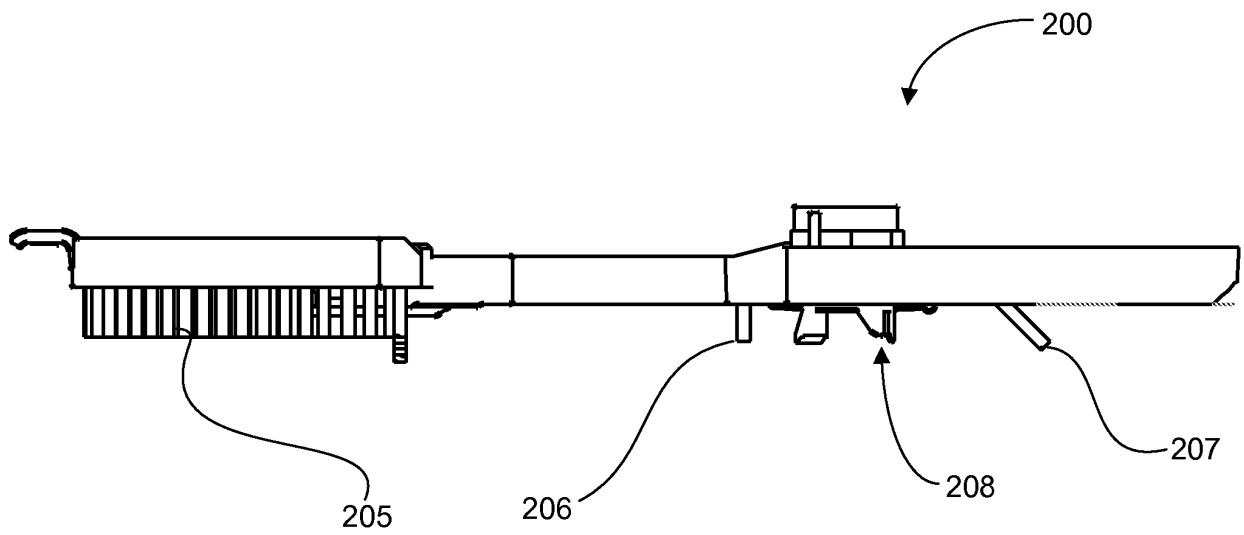
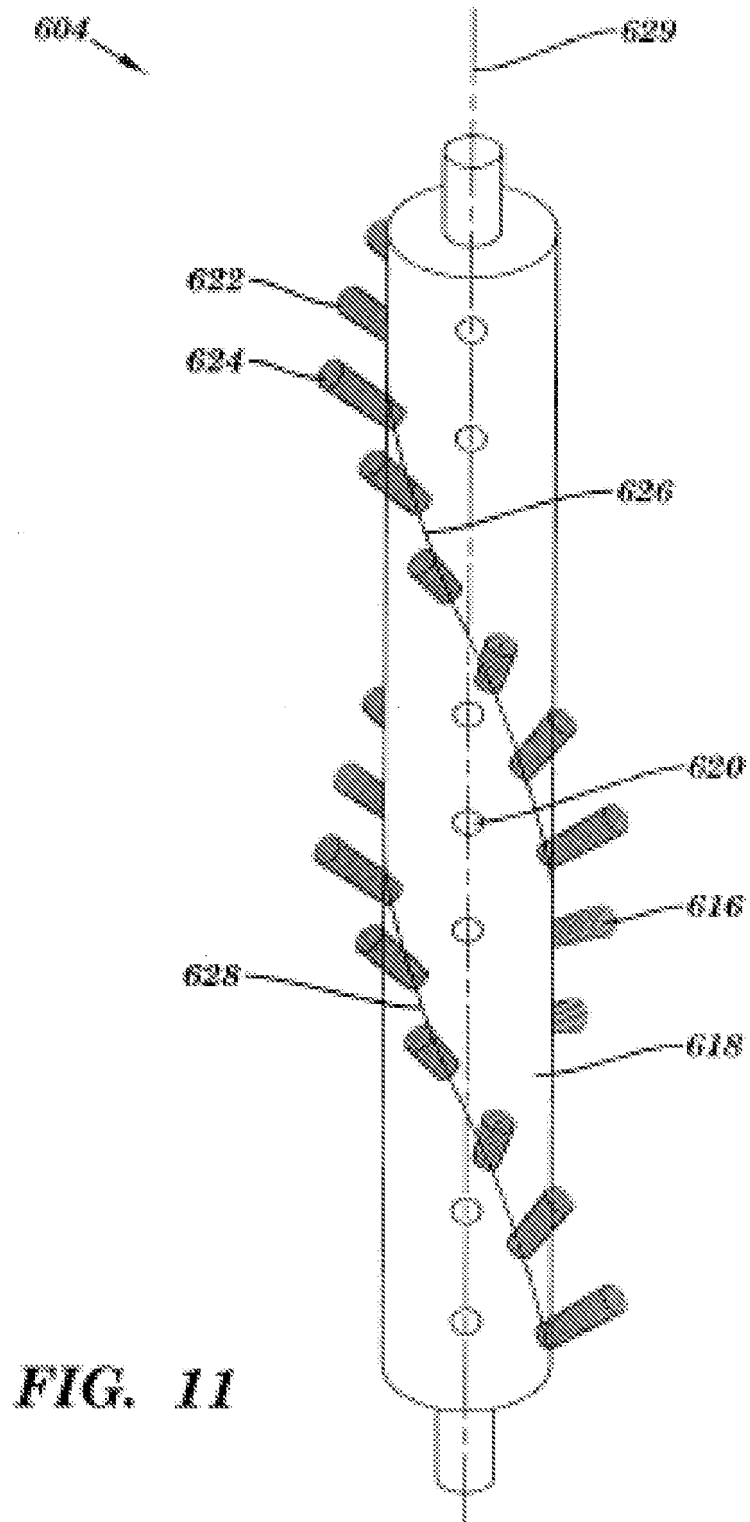


FIG. 10E



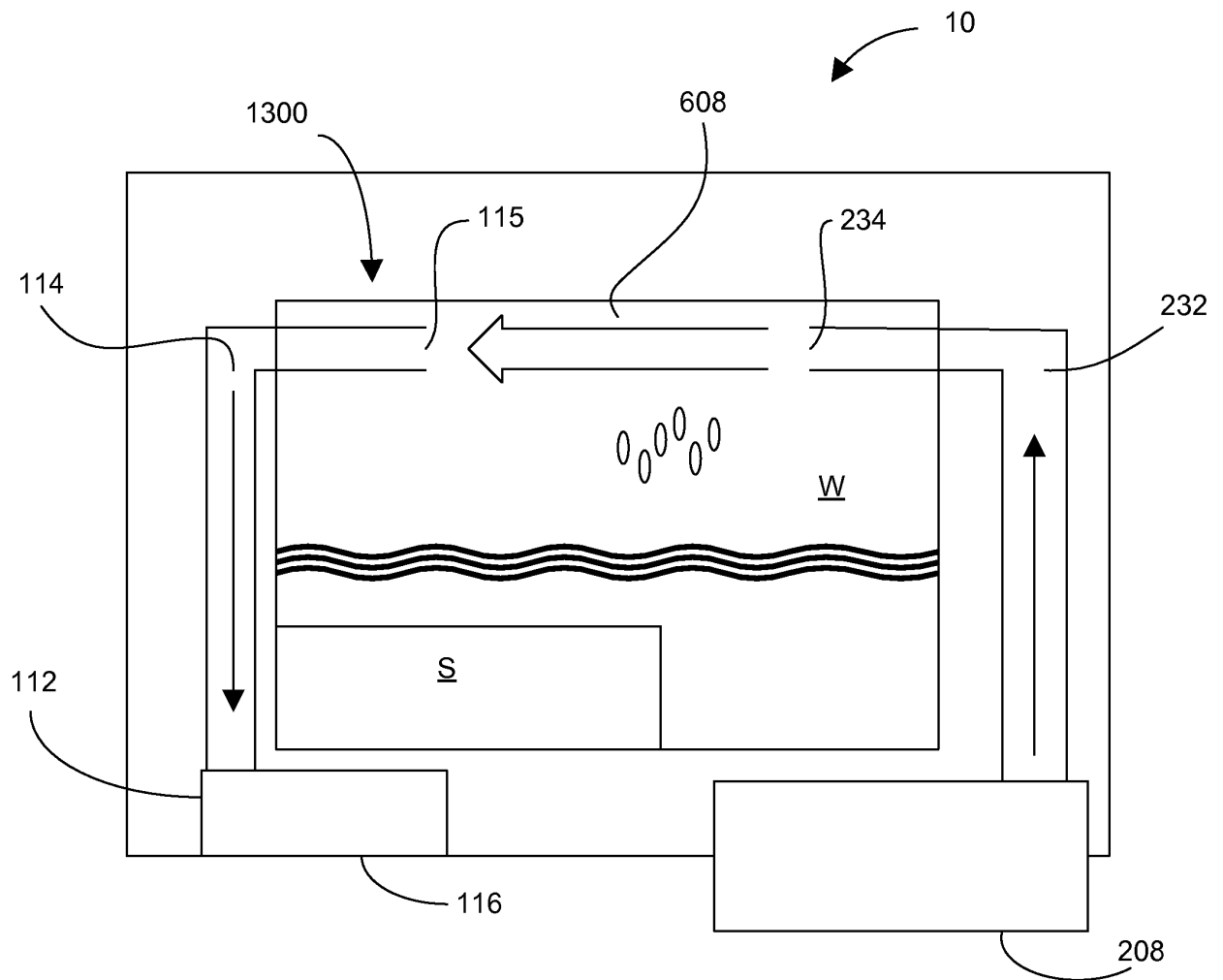


FIG. 12

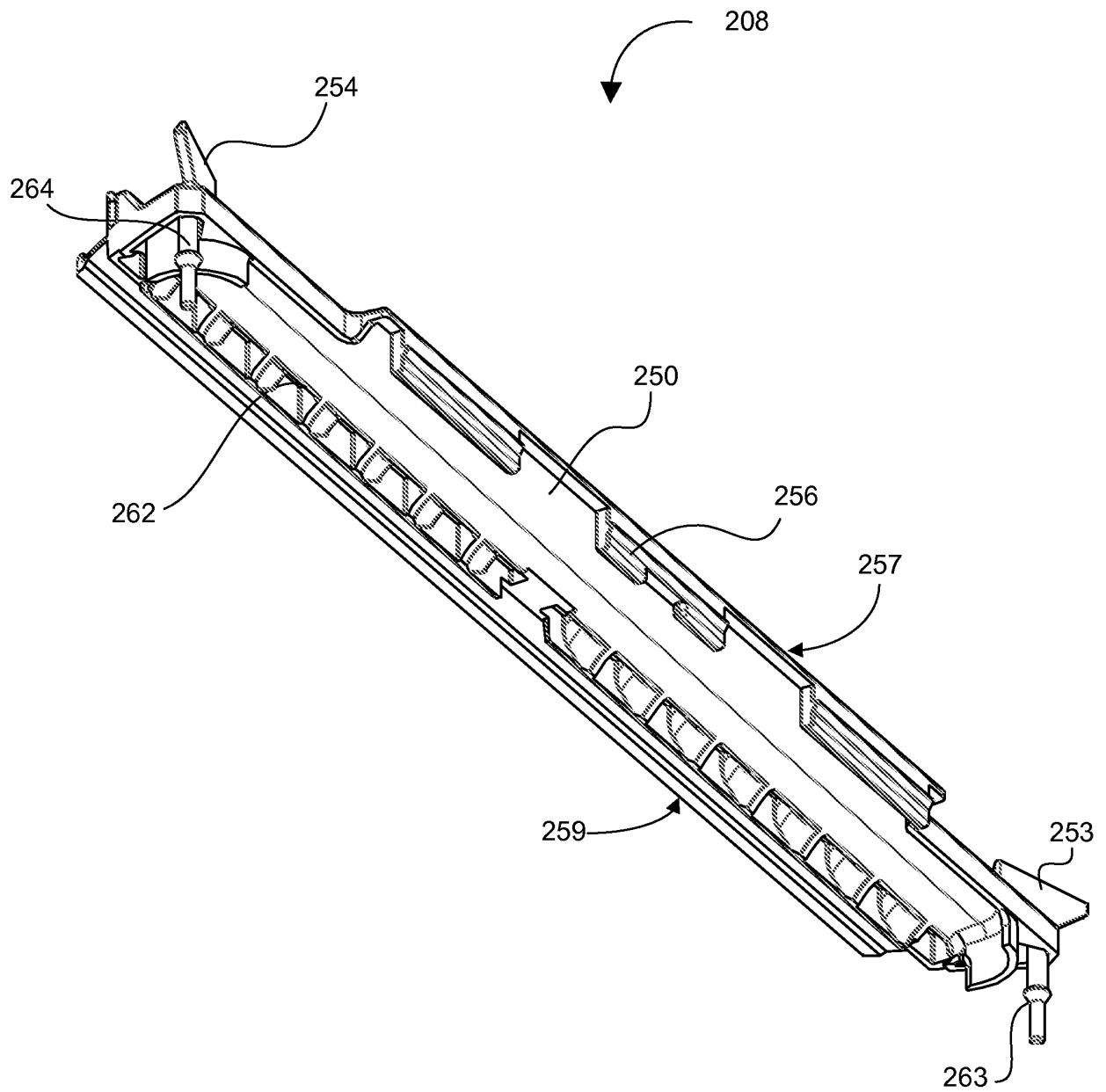


FIG. 13

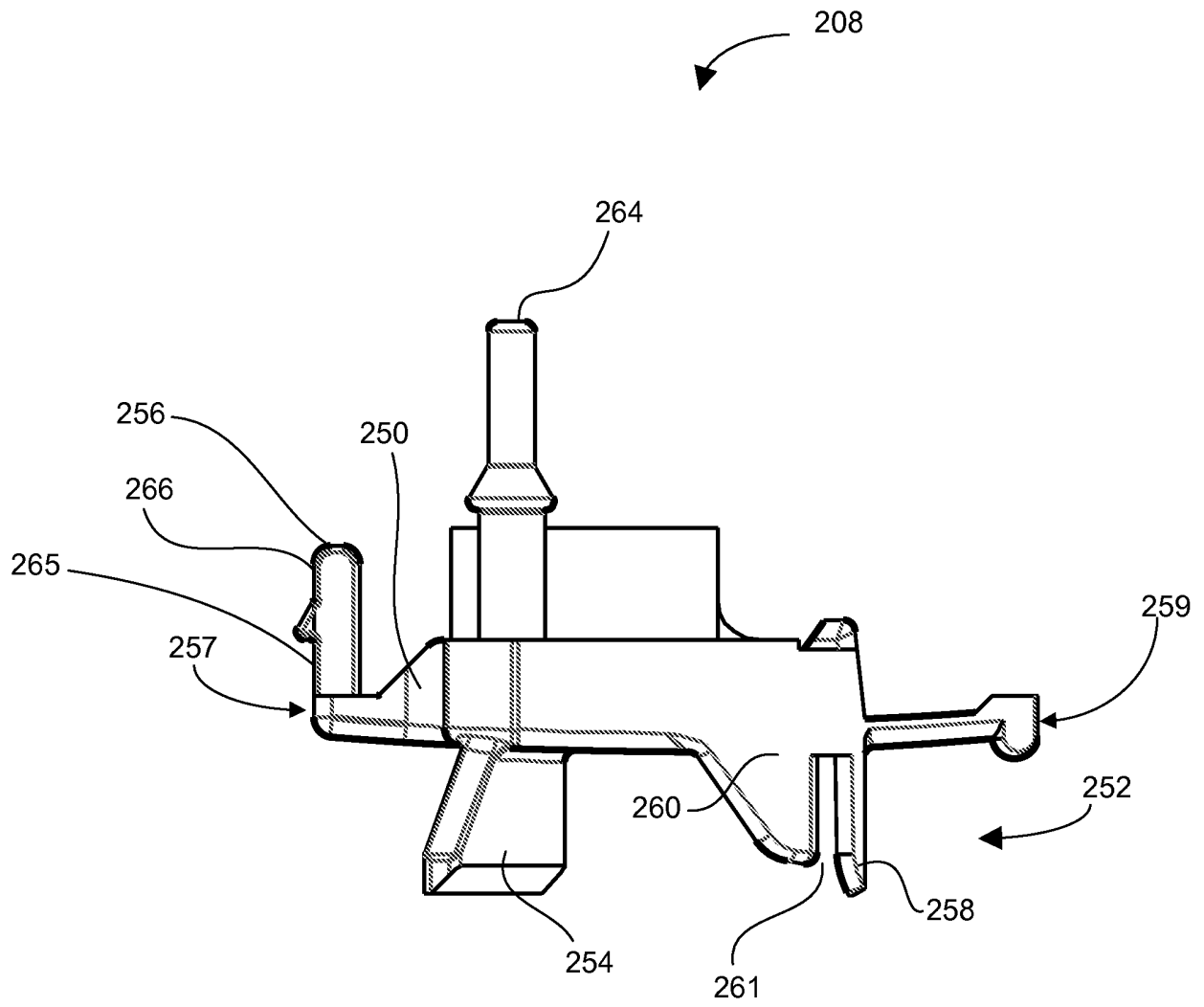


FIG. 14

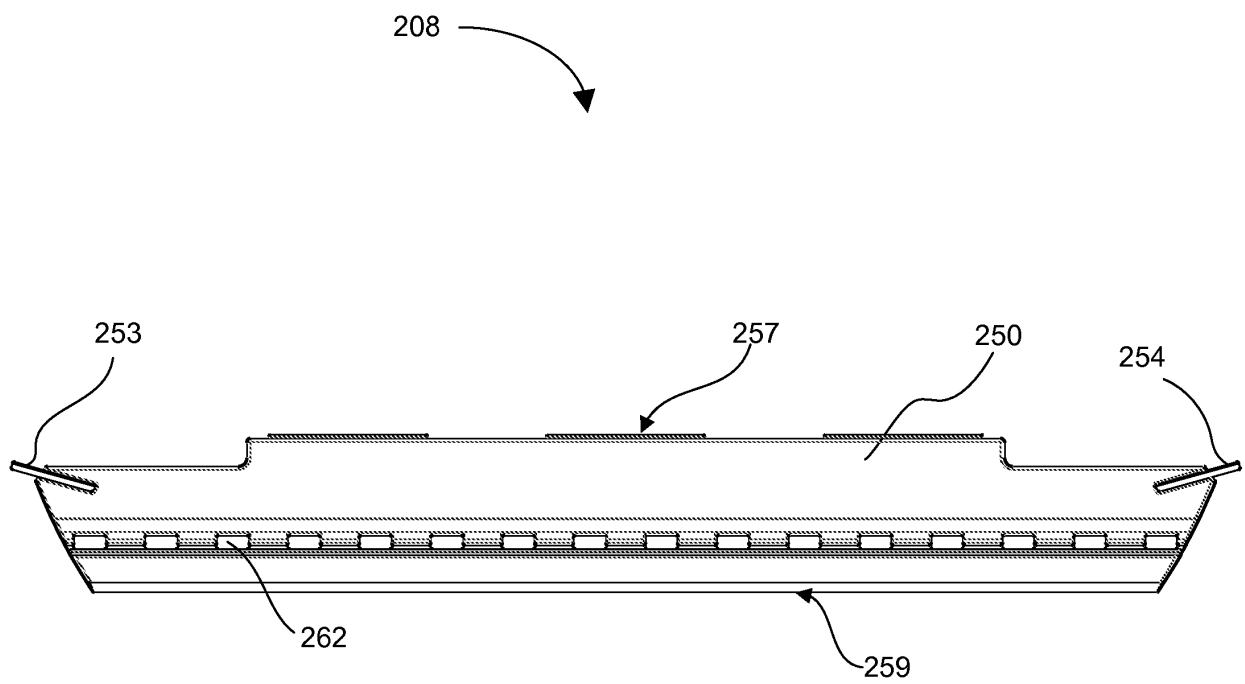


FIG. 15

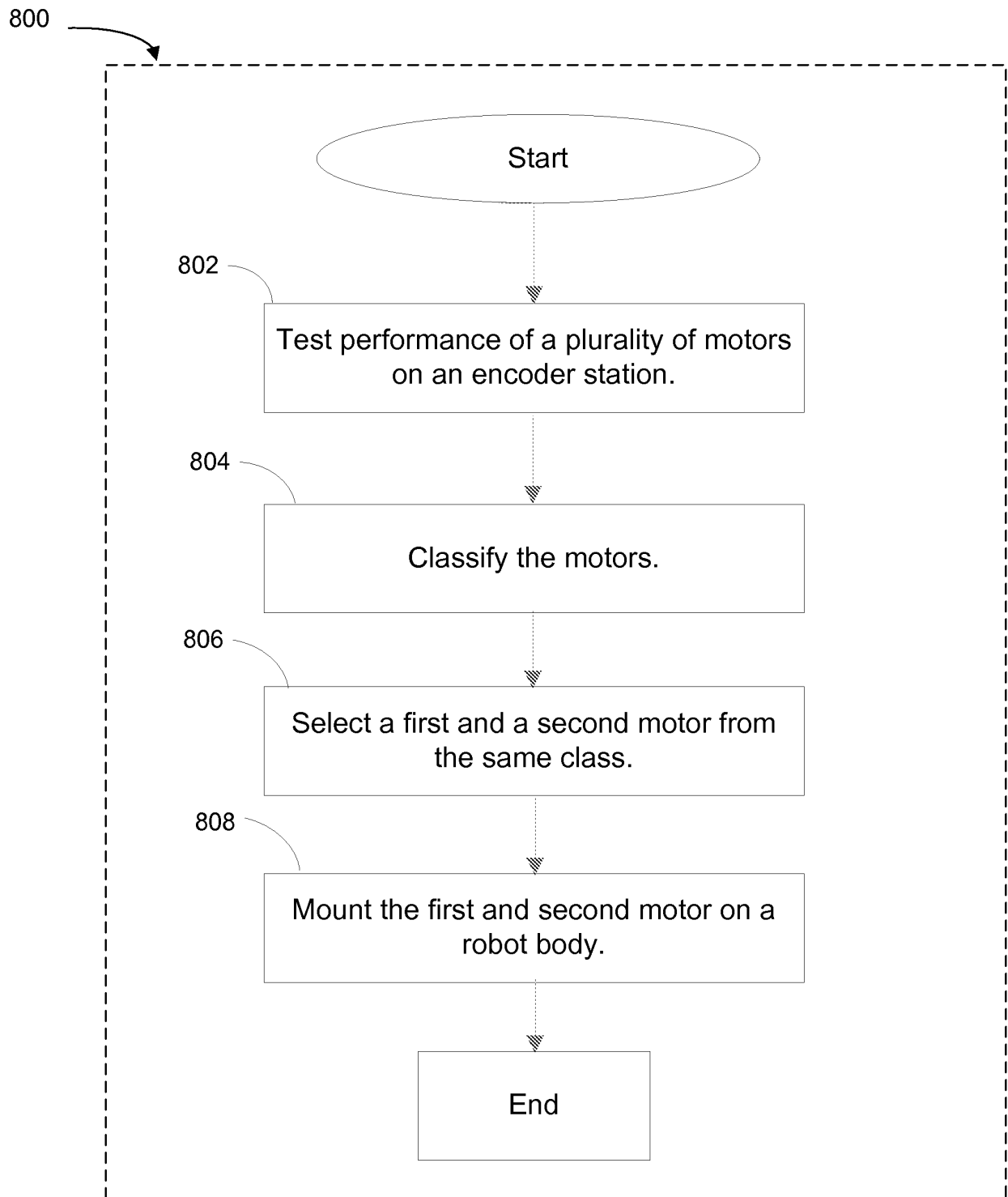


FIG. 16

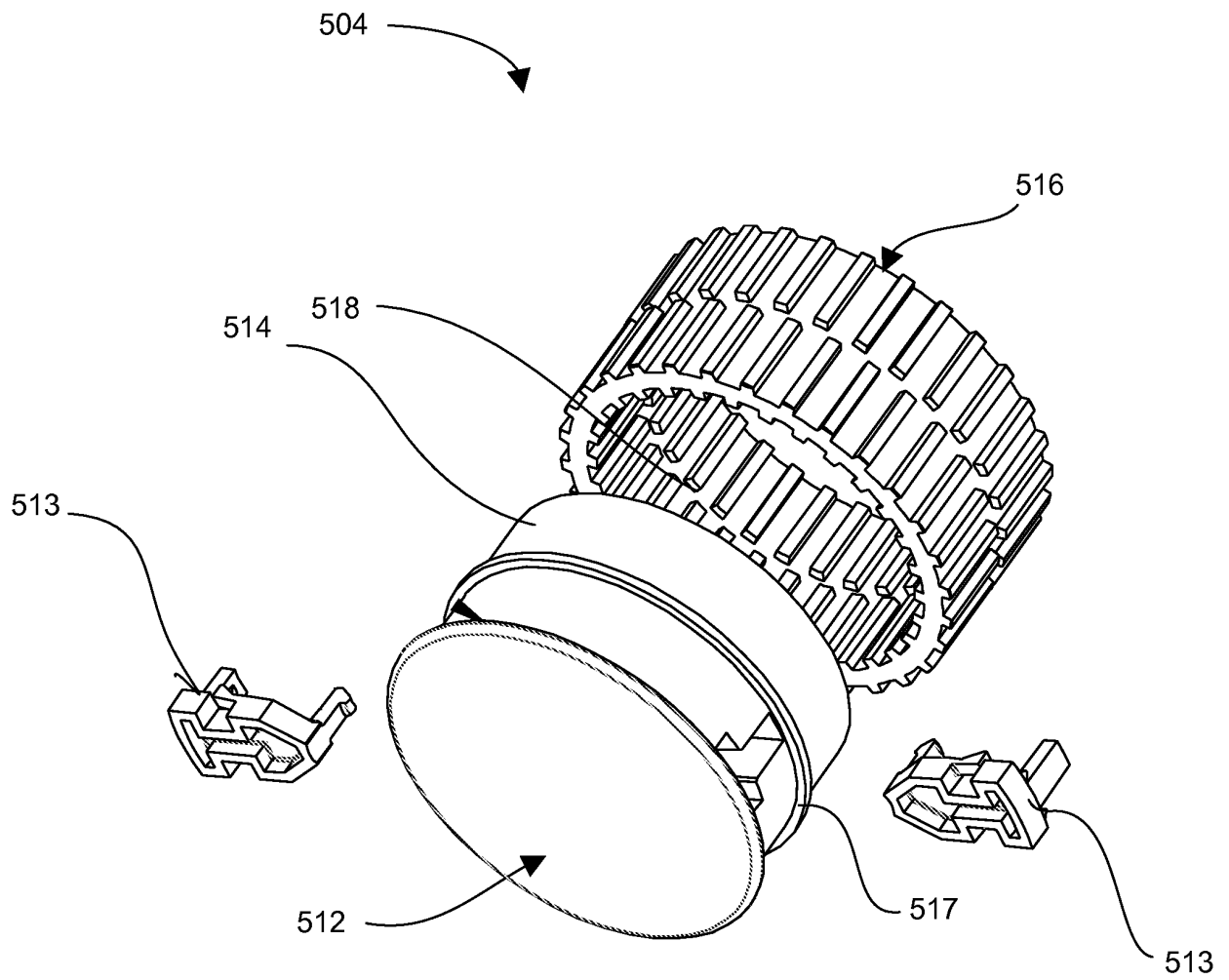


FIG. 17

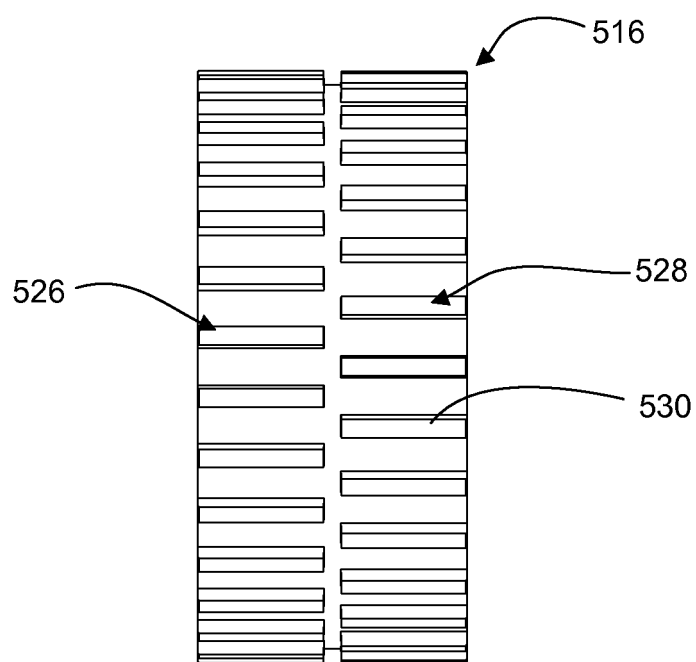


FIG. 18A

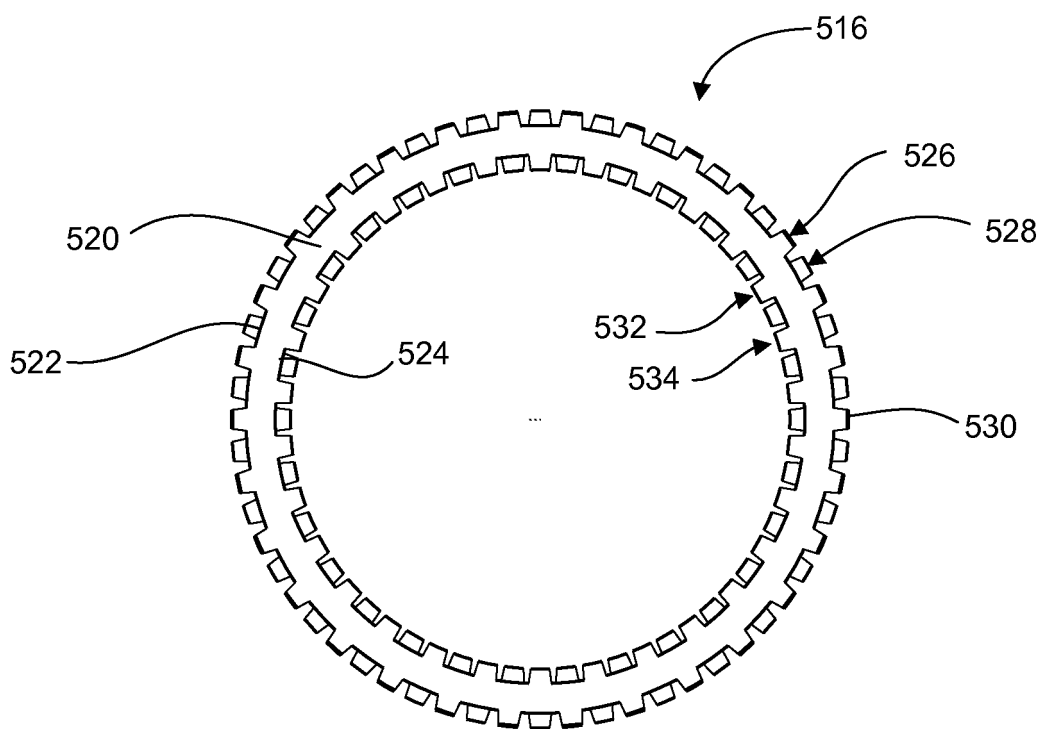


FIG. 18B

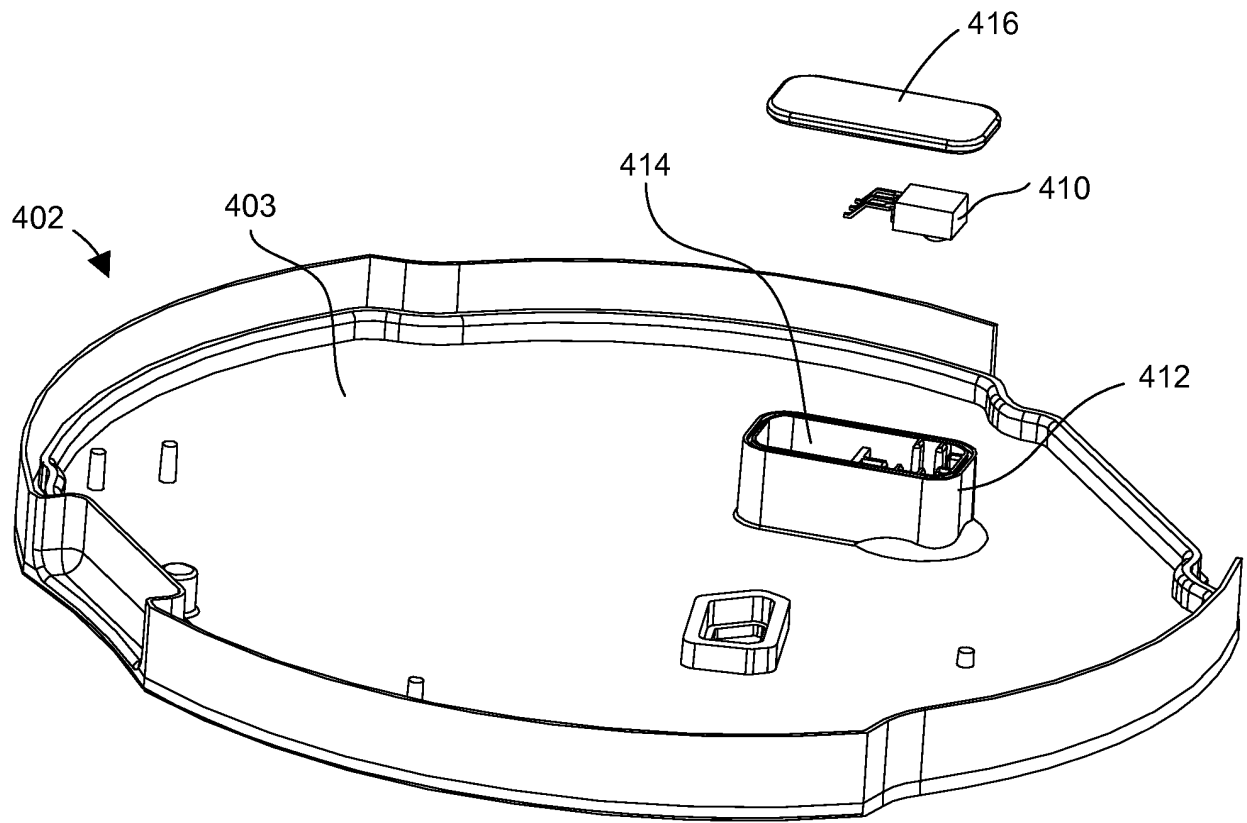


FIG. 19

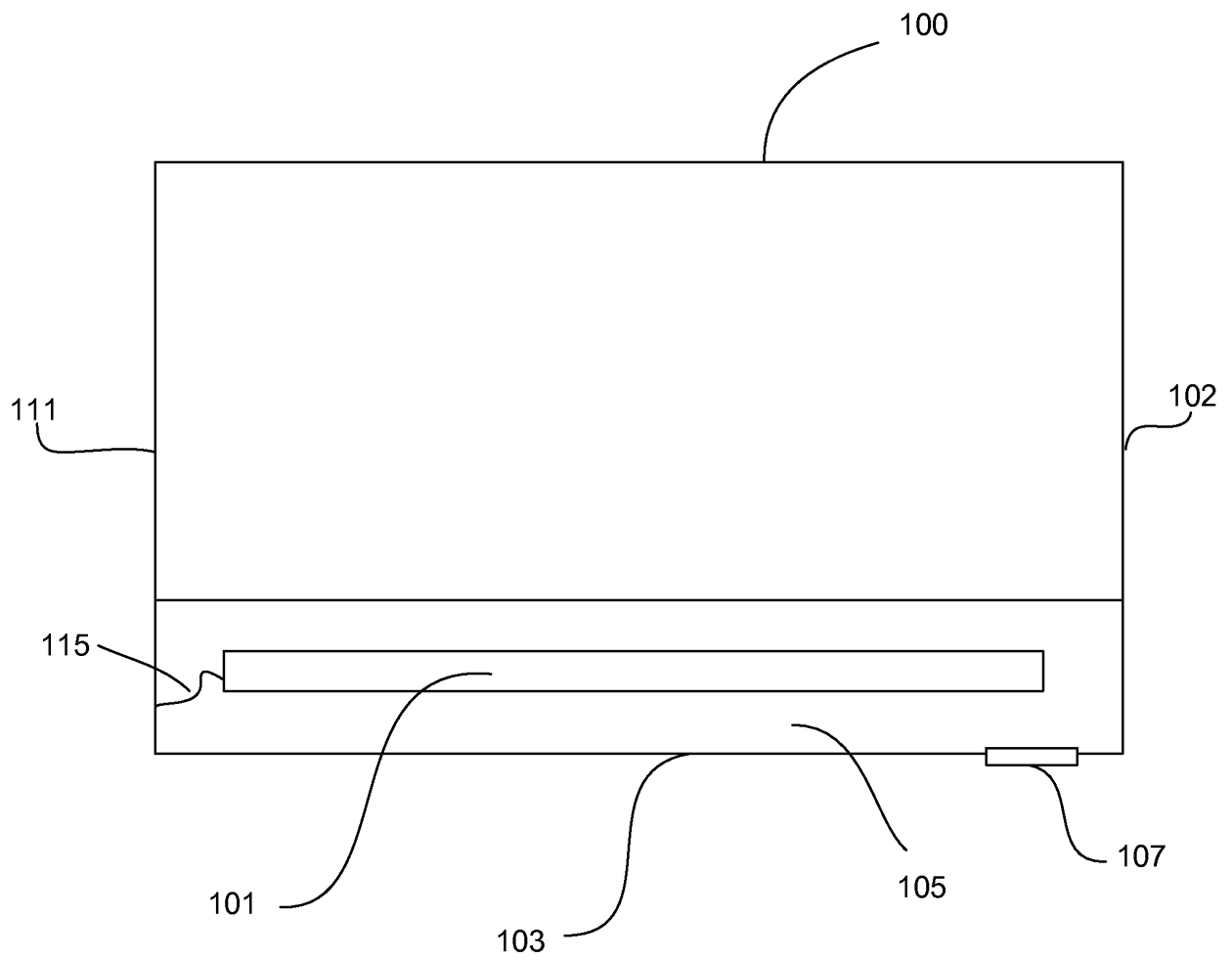


FIG. 20

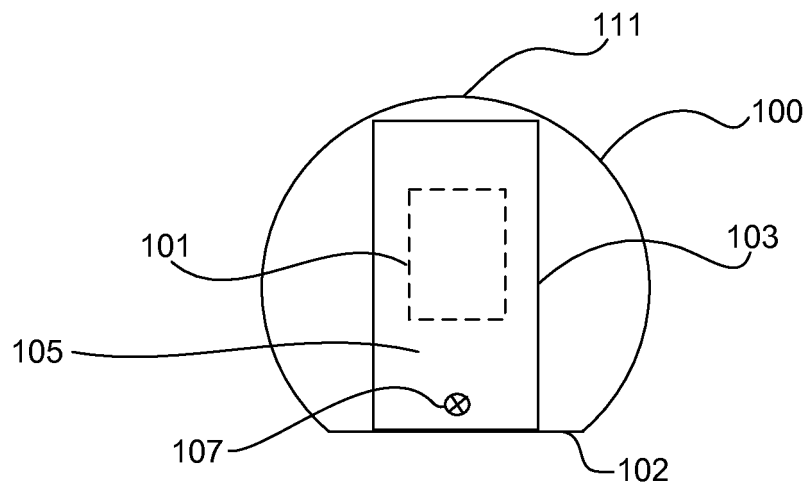


FIG. 21C

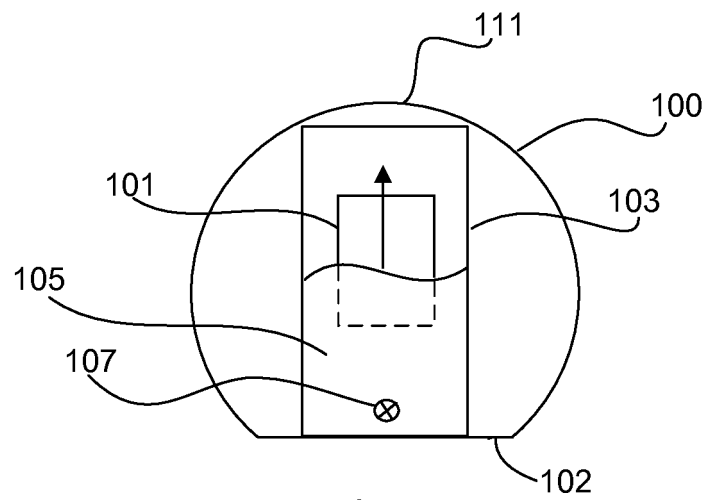


FIG. 21B

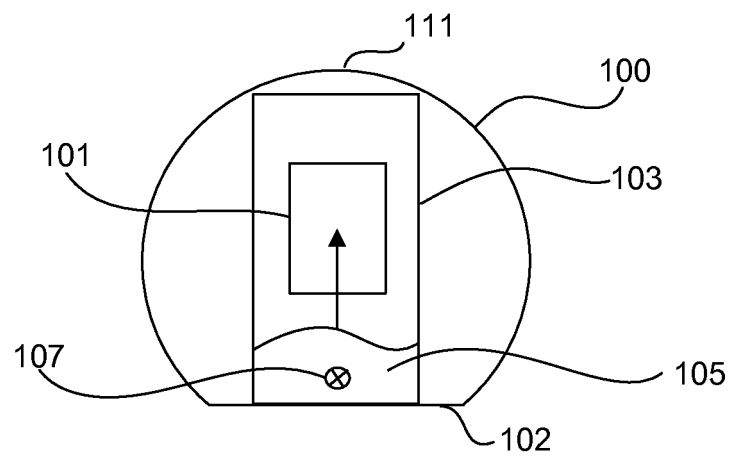


FIG. 21A

FIG. 22

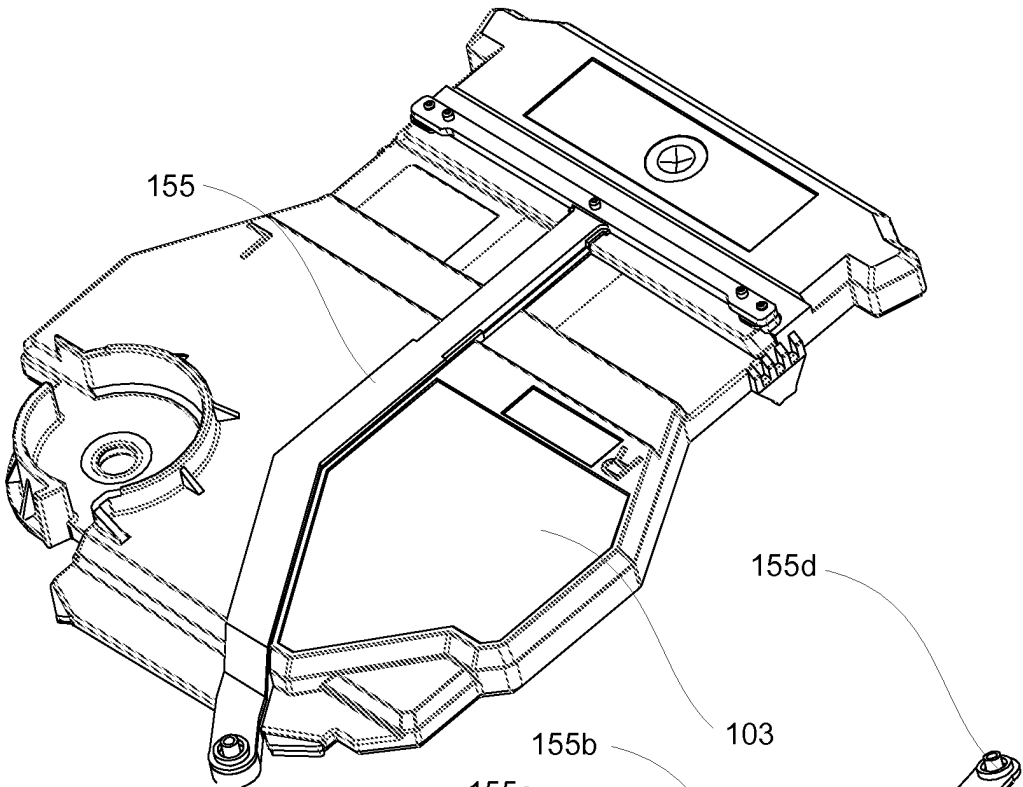
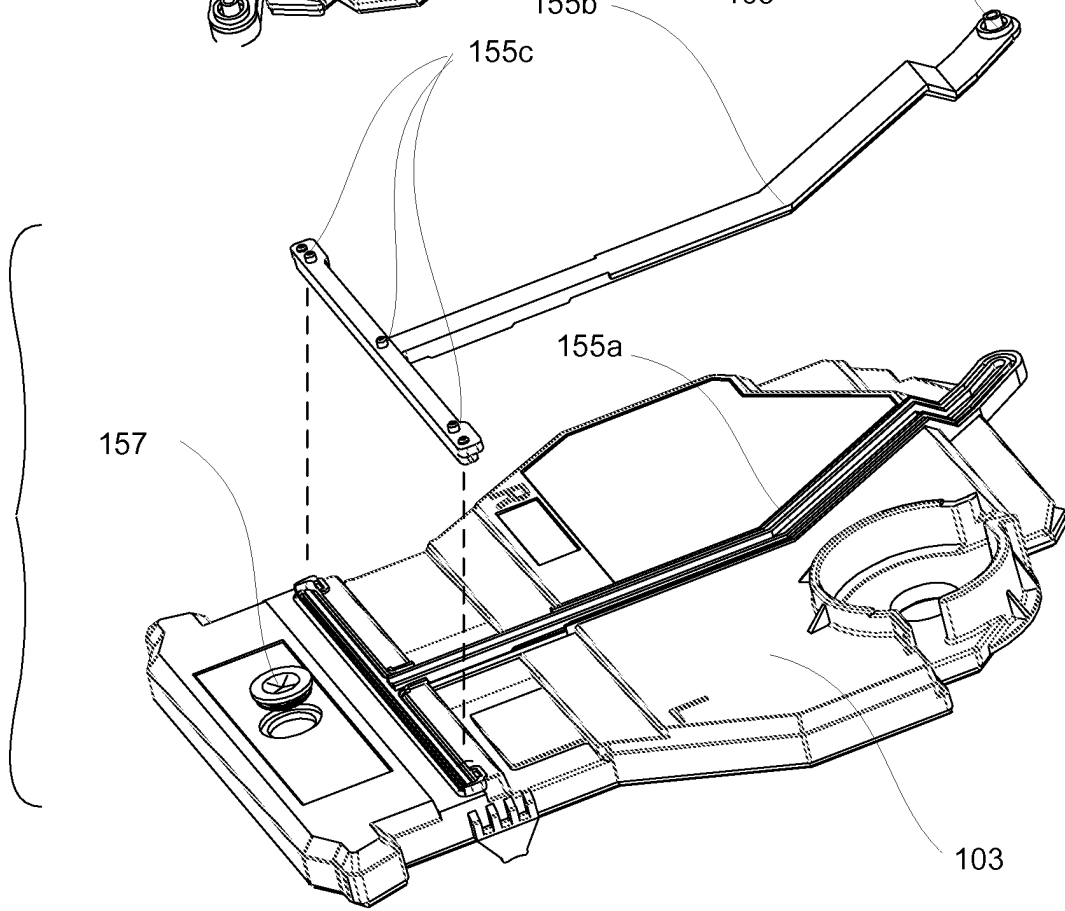


FIG. 23



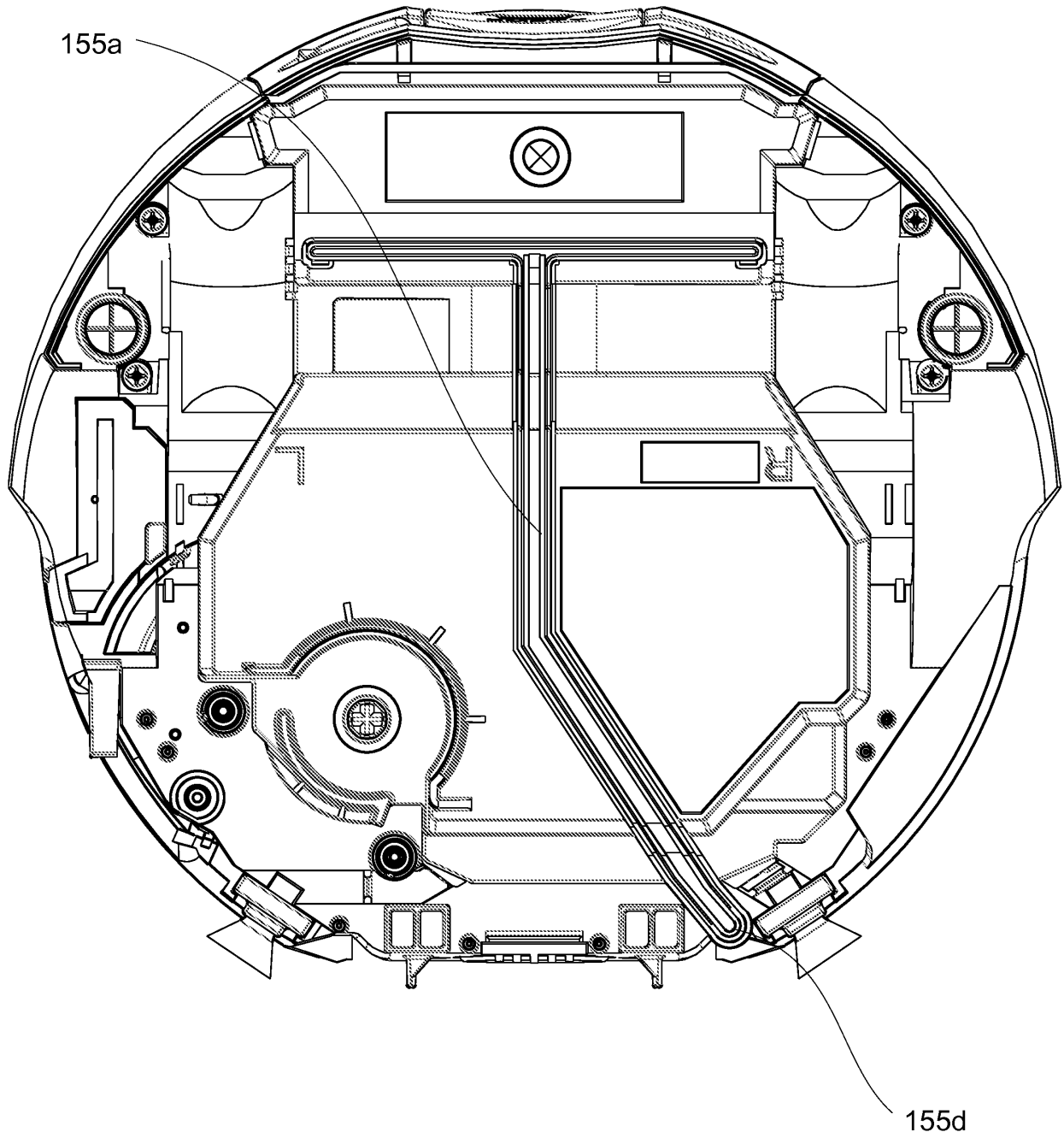
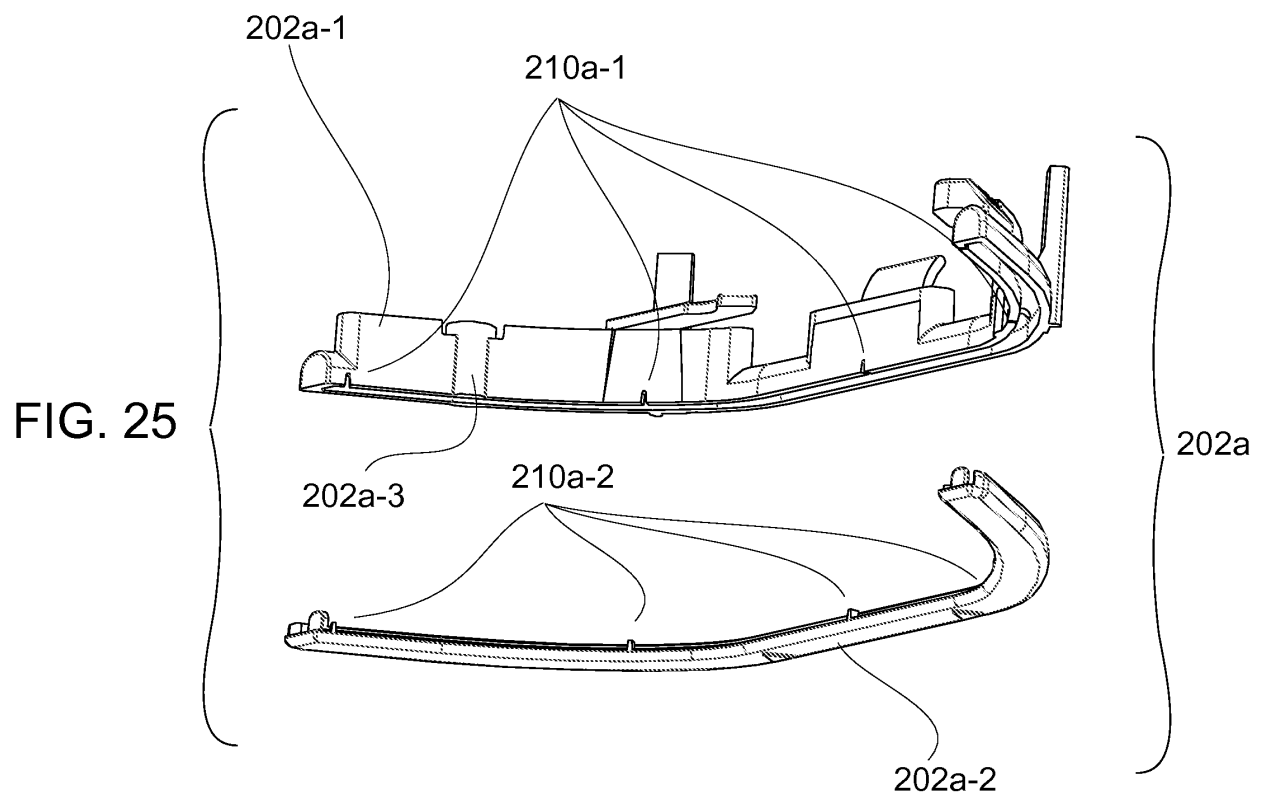


FIG. 24



REFERENCES CITED IN THE DESCRIPTION

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