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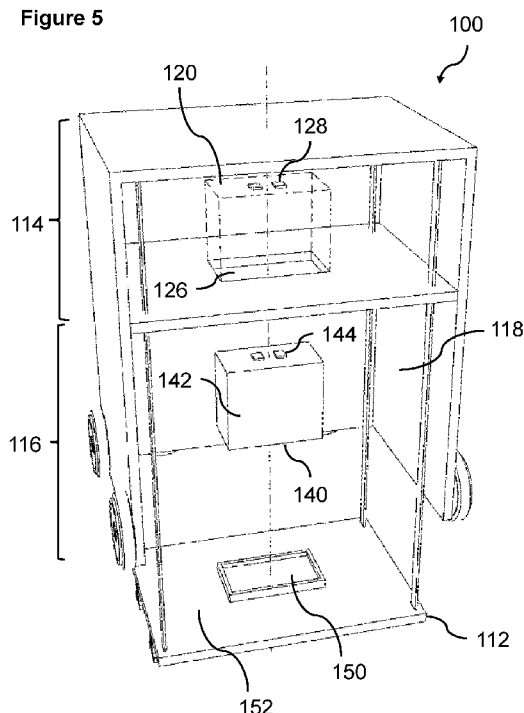
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(54) Title: LOAD HANDLING DEVICE & METHODS OF EXCHANGING A POWER SOURCE

Figure 5



(57) Abstract: A load handling device for lifting and moving containers arranged in stacks in a storage structure. The storage structure comprises a track structure arranged in a grid pattern which defines a plurality of grid cells above the stacks of containers. The load handling device comprises a driving assembly configured to horizontally move the load handling device on the track structure; a container-holding device configured to releasably hold a container from above; a lifting mechanism configured to raise and lower the container-holding device; a power source; and a power source compartment configured to removably receive and electrically couple to the power source. The power source compartment comprises a bottom-facing opening configured to allow the power source to be vertically inserted upwards into the power source compartment via the bottom-facing opening from a location external to the load handling device.

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LOAD HANDLING DEVICE & METHODS OF EXCHANGING A POWER SOURCE

TECHNICAL FIELD

The present invention relates to a load handling device with an exchangeable power source and a method of exchanging a power source of a load handling device operating in a storage system.

BACKGROUND

Some commercial and industrial activities require systems that enable the storage and retrieval of a large number of different products. WO2015019055A1 describes a storage and retrieval system in which stacks of storage containers are arranged within a grid storage structure. The system further comprises remotely operated load handling devices configured to move on rails or tracks located on the top of the grid storage structure. To access the containers in the grid storage structure, the load handling devices are equipped with a container-holding device for releasably gripping a container at the top of a stack and a lifting mechanism for raising and lowering the container.

Each load handling device is powered by a rechargeable battery. The rechargeable battery is typically charged in situ by driving a load handling device to a charging station located at the edge of the grid storage structure. The load handling device remains stationary at the charging station while the battery is recharged. The charging period is a significant source of downtime for the load handling device and can be on the order of hours.

To alleviate the problem of charging downtime, the load handling device may be powered by an exchangeable battery. When the battery in the load handling device is depleted, the depleted battery is exchanged for a fully charged battery and therefore the charging downtime is reduced to the time it takes to exchange the battery, rather than being the time to charge the battery.

There is therefore a need for a load handling device and storage system that decreases the downtime of the load handling device in an efficient manner. There is also a need to decrease the amount of infrastructure required to exchange the battery of the load handling device.

SUMMARY OF INVENTION

The invention is defined in the accompanying claims.

Load handling device

The present invention provides a load handling device for lifting and moving containers arranged in stacks in a storage structure, the storage structure comprising a track structure, the track structure comprising a first set of tracks and a second set of tracks, the first set of tracks extending in a first direction and the second set of tracks extending in a second direction, the second direction being substantially perpendicular to the first direction, to form a grid pattern defining a plurality of grid cells above the stacks of containers. The load handling device comprises:

- 5 a driving assembly configured to horizontally move the load handling device on the track structure;
- 10 a container-holding device configured to releasably hold a container from above;
- a lifting mechanism configured to raise and lower the container-holding device;
- a power source; and
- 15 a power source compartment configured to removably receive and electrically couple to the power source, the power source compartment comprising a bottom-facing opening configured to allow the power source to be vertically inserted upwards into the power source compartment via the bottom-facing opening from a location external to the load handling device.

Providing a power source compartment that is externally accessible from below the load handling device, opens up a number of convenient options for exchanging the power source of the load handling device. In particular, when the load handling device is operating on top of a storage structure, the power source may be exchanged using methods and equipment that make use of the space within the storage structure (under the load handling device), rather than requiring space above or next to the storage structure. Furthermore, the power source is typically one of the heaviest components of the load handling device, which can negatively affect the balance and handling of the load handling device when it is driving on the track structure. Having a power source compartment that needs to be externally accessible from below generally results in the power source compartment and the power source being located low within the load handling device, which lowers the centre of gravity of the load handling device, thereby improving balance and handling.

The load handling device may further comprise a locking mechanism configured to releasably lock the power source in the power source compartment. The locking mechanism may comprise locking protrusions that are selectively controlled to move between a locking position and a release position. The locking mechanism may further comprise recesses for engaging

with the locking protrusions in the locking position. The locking protrusions may be located in the power source compartment and the recesses may be located on the power source.

The power source compartment may be configured to transfer electrical power from the power source to the driving assembly and/or the lifting mechanism when the power source is electrically coupled to the power source compartment.

The power source compartment may be configured to electrically couple to the power source when the power source is vertically inserted upwards into the power source compartment and electrically uncouple from the power source when the power source is vertically removed downwards from the power source compartment. For example, the power source may comprise one or more electrical connectors and the power source compartment may comprise one or more corresponding electrical connectors that are configured to automatically connect to each other when the power source is vertically received in the power source compartment and automatically disconnect from each other when the power source is vertically removed from the power source compartment.

The power source may be a rechargeable power source, e.g. a rechargeable battery or a supercapacitor.

The load handling device may further comprise a container-receiving space configured to accommodate the container-holding device and a container held by the container-holding device. The lifting mechanism may be configured to raise and lower the container-holding device into and out of the container-receiving space respectively. The power source compartment may be located above the container-receiving space. The bottom-facing opening may extend into the container-receiving space to allow the power source to be upwardly inserted into the power source compartment from the container-receiving space.

The container-holding device may comprise a support portion for releasably supporting the power source. The support portion and the bottom-facing opening may be vertically aligned such that when the power source is occupying the support portion and the container-holding device is raised into the container-receiving space by the lifting mechanism, the power source is vertically inserted into the power source compartment. The support portion may be located on a top side of the container-holding device. The load handling device may comprise a plurality of power source compartments and the container-holding device may comprise a plurality of support portions. Each support portion may be vertically aligned with the bottom facing opening of a corresponding power source compartment.

With this configuration, the power source can be exchanged using existing components of the load handling device, namely the container-holding device and lifting mechanism, rather than requiring additional external equipment.

Alternatively, the container-holding device may comprise a pass-through opening configured to allow the power source to pass vertically through the container-holding device. The pass-through opening may be vertically aligned with the bottom-facing opening to allow the power source to be vertically inserted into the power source compartment via the pass-through opening. The load handling device may comprise a plurality of power source compartments and the container-holding device may optionally comprise a plurality of pass-through openings. Each pass-through opening may be vertically aligned with the bottom facing opening of a corresponding power source compartment.

With this configuration, the power source can be exchanged using equipment and replacement power sources located within the storage structure without the container-holding device blocking access to the power source compartment.

The load handling device may comprise an external body. The bottom-facing opening may be defined by the external body.

The load handling device may comprise a plurality of power source compartments. Each power source compartment may be configured to removably receive and electrically couple to the power source. Each power source compartment may comprise a bottom-facing opening configured to allow the power source to be vertically inserted upwards into each power source compartment via the bottom-facing opening from a location external to the load handling device. The load handling device may be configured to use power from only one power source in one of the power source compartments at any one time.

First storage and retrieval system

The present invention further provides a first storage and retrieval system comprising:
a storage structure comprising a track structure, the track structure comprising a first set of tracks and a second set of tracks, the first set of tracks extending in a first direction and the second set of tracks extending in a second direction, the second direction being substantially perpendicular to the first direction, to form a grid pattern defining a plurality of grid cells;

a plurality of stacks of containers arranged within the storage structure, each stack being arranged below a grid cell; and
the load handling device as defined above.

First power source exchanging system

- 5 The present invention further provides a first power source exchanging system comprising:
a loading handling device having a container-holding device with a pass-through opening as defined above; and
a power source cradle comprising a support portion configured to releasably support the power source, the power source cradle being configured to be held from above by the container-holding device such that the support portion, the pass-through opening and the bottom-facing opening are vertically aligned to allow the power source to be vertically inserted into the power source compartment via the pass-through opening and the bottom-facing opening when the container-holding device is raised into the container-receiving space by the lifting mechanism.
- 10
- 15 The power source cradle may be configured to charge the power source when the power source is occupying the support portion. For example, the power source cradle may comprise its own power source for charging the power source of the load handling device, or the power source may be configured to electrically couple to an external power source to charge the power source of the load handling device. The power source cradle may be configured to be vertically stackable. The power source cradle may be configured to electrically couple to adjacent power source cradles when vertically stacked.
- 20

The load handling device may comprise a plurality of power source compartments, the power source cradle may comprise a plurality of support portions, and the container-holding device may comprise a plurality of pass-through openings. The power source cradle may be configured to be held from above by the container-holding device such that each support portion is vertically aligned with a corresponding pass-through opening and a corresponding bottom-facing opening.

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Second storage and retrieval system

- The present invention further provides a second storage and retrieval system comprising:
a storage structure comprising a track structure, the track structure comprising a first set of tracks and a second set of tracks, the first set of tracks extending in a first direction and
- 30

the second set of tracks extending in a second direction, the second direction being substantially perpendicular to the first direction, to form a grid pattern defining a plurality of grid cells;

a plurality of stacks of containers arranged within the storage structure, each stack
5 being arranged below a grid cell; and

the first power source exchanging system as defined above;

wherein the power source cradle is located within the storage structure below a grid cell.

10 The storage and retrieval system may comprise a plurality of power source cradles arranged in a stack below a grid cell.

Second power source exchanging system

The present invention further provides a second power source exchange system comprising:

a load handling device having a container-holding device with a pass-through opening
15 as defined above, or a load handling device comprising an external body with the bottom-facing opening being defined by the external body as defined above; and

an exchanging arm configured to releasably hold the power source and move vertically upwards and downwards relative to the load handling device to insert the power source into the power source compartment and remove the power source from the power source
20 compartment respectively via the bottom-facing opening.

The exchanging arm may be a robotic exchanging arm. The exchanging arm may comprise a support portion for releasably supporting the power source. The exchanging arm may be configured to charge the power source when the power source is supported on the support portion. The exchanging arm may comprise a linear actuator configured to vertically move the
25 support portion upwards and downwards relative to the load handling device.

Third storage and retrieval system

The present invention further provides a third storage and retrieval system comprising:

a storage structure comprising a track structure, the track structure comprising a first set of tracks and a second set of tracks, the first set of tracks extending in a first direction and
30 the second set of tracks extending in a second direction, the second direction being

substantially perpendicular to the first direction, to form a grid pattern defining a plurality of grid cells;

a plurality of stacks of containers arranged within the storage structure, each stack being arranged below a grid cell; and

- 5 the second power source exchanging system as defined above;
 wherein the exchanging arm is located below a grid cell.

Method of exchanging a power source

The present invention further provides a method of exchanging a power source in the power source compartment of the load handling device defined above, the method comprising:

- 10 removing a first power source from the power source compartment in a downwards direction via the bottom-facing opening; and
 inserting a second power source into the power source compartment in an upwards direction via the bottom-facing opening.

- 15 The second power source may have a higher charge level than the first power source. The first power source may be charged after being removed.

The first power source may be removed and the second power source may be inserted by lowering and raising the container-holding device respectively using the lifting mechanism.

- 20 The first power source may be removed and the second power source may be inserted by lowering and raising an external exchanging arm respectively.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will now be described, by way of example only, with reference to the accompanying drawings, in which like reference numerals are used for like features, and in which:

- 25 Figure 1 is a schematic perspective view of a grid storage structure and containers.

Figure 2 is a schematic plan view of a track structure on top of the storage structure of Figure 1.

Figure 3 shows load handling devices on top of the track structure of the storage structure of Figure 1.

Figure 4 is a schematic perspective view of a first example load handling device with a container-holding device in a position below the bottom of the load handling device.

Figure 5 is a schematic perspective view of the first example load handling device with a side panel removed to show the configuration of a power source compartment within the first example bot.

Figure 6 is a schematic cross-sectional view of the first example load handling device through the middle of the power source compartment, showing a locking mechanism.

Figures 7A to 7F are a sequence of schematic cross-sectional views of the first example load handling device showing how a power source in the power source compartment can be exchanged.

Figure 8 is a schematic perspective view of a second example load handling device in combination with a power source cradle.

Figures 9A to 9E are a sequence of schematic cross-sectional views of the second example load handling device showing how a power source can be exchanged using the power source cradle

Figure 10 is a schematic perspective view of the second example load handling device in combination with an external exchanging arm.

Figure 11 is a schematic perspective view of a third example load handling device in combination with an external exchanging arm.

Figure 12 is a schematic perspective view of an external body of a load handling device with an open frame structure.

DETAILED DESCRIPTION

Figure 1 illustrates a storage structure 1 of a storage and retrieval system. The storage structure 1 comprises a framework comprising upright members 3 and horizontal members 5, 7 which are supported by the upright members 3. The horizontal members 5 extend parallel to one another and the illustrated x-axis. The horizontal members 7 extend parallel to one another and the illustrated y-axis, and transversely to the horizontal members 5. The upright

members 3 extend parallel to one another and the illustrated z-axis, and transversely to the horizontal members 5, 7. The horizontal members 5, 7 form a grid pattern defining a plurality of grid cells 14. In the illustrated example, storage containers 9 are arranged in stacks 11 beneath the grid cells 14 defined by the grid pattern, one stack 11 of containers 9 per grid cell 14.

Figure 2 shows a large-scale plan view of a section of track structure 13 forming part of the storage structure 1 illustrated in Figure 1 and located on top of the horizontal members 5, 7 of the storage structure 1 illustrated in Figure 1. The track structure 13 may be provided by the horizontal members 5, 7 themselves (e.g. formed in or on the surfaces of the horizontal members 5, 7) or by one or more additional components mounted on top of the horizontal members 5, 7. The illustrated track structure 13 comprises x-direction tracks 17 and y-direction tracks 19, i.e. a first set of tracks 17 which extend in the x-direction and a second set of tracks 19 which extend in the y-direction, transverse to the tracks 17 in the first set of tracks 17. The tracks 17, 19 define apertures 15 at the centres of the grid cells 14. The apertures 15 are sized to allow containers 9 located beneath the grid cells 14 to be lifted and lowered through the apertures 15. The x-direction tracks 17 are provided in pairs separated by channels 21, and the y-direction tracks 19 are provided in pairs separated by channels 23. Other arrangements of track structure may also be possible.

Figure 3 shows a plurality of load handling devices 100 moving on top of the storage structure 1 illustrated in Figure 1. The load handling devices 100, hereinafter referred to as "bots", are provided with sets of wheels to engage with corresponding x- or y-direction tracks 17, 19 to enable the bots 100 to travel across the track structure 13 and reach specific grid cells 14. The illustrated pairs of tracks 17, 19 separated by channels 21, 23 allow bots 100 to occupy (or pass one another on) neighbouring grid cells 14 without colliding with one another.

As illustrated in Figure 4, a first example of a bot 100 comprises a body 102 in or on which are mounted one or more components which enable the bot 100 to perform its intended functions. These functions may include moving across the storage structure 1 on the track structure 13 and raising or lowering containers 9 (e.g. from or to stacks 11) so that the bot 100 can retrieve or deposit containers 9 in specific locations defined by the grid pattern.

The illustrated bot 100 comprises a driving assembly comprising first and second sets of wheels 104, 106 which are mounted on the body 102 of the bot 100 and enable the bot 100 to move in the x- and y-directions along the tracks 17 and 19, respectively. In particular, two wheels 104 are provided on the shorter side of the bot 100 visible in Figure 4, and a further

two wheels 104 are provided on the opposite shorter side of the bot 100. The wheels 104 engage with tracks 17 and are rotatably mounted on the body 102 of the bot 100 to allow the bot 100 to move along the tracks 17. Analogously, two wheels 106 are provided on the longer side of the bot 100 visible in Figure 4, and a further two wheels 106 are provided on the opposite longer side of the bot 100. The wheels 106 engage with tracks 19 and are rotatably mounted on the body 102 of the bot 100 to allow the bot 100 to move along the tracks 19.

To enable the bot 100 to move on the different wheels 104, 106 in the first and second directions, the driving assembly further comprises a wheel-positioning mechanism (not shown) for selectively engaging either the first set of wheels 104 with the first set of tracks 17 or the second set of wheels 106 with the second set of tracks 19. The wheel-positioning mechanism is configured to raise and lower the first set of wheels 104 and/or the second set of wheels 106 relative to the body 102, thereby enabling the load handling device 100 to selectively move in either the first direction or the second direction across the tracks 17, 19 of the storage structure 1.

The wheel-positioning mechanism may include one or more linear actuators, rotary components or other means for raising and lowering at least one set of wheels 104, 106 relative to the body 102 of the bot 100 to bring the at least one set of wheels 104, 106 out of and into contact with the tracks 17, 19. In some examples, only one set of wheels is configured to be raised and lowered, and the act of lowering the one set of wheels may effectively lift the other set of wheels clear of the corresponding tracks while the act of raising the one set of wheels may effectively lower the other set of wheels into contact with the corresponding tracks. In other examples, both sets of wheels may be raised and lowered, advantageously meaning that the body 102 of the bot 100 stays substantially at the same height and therefore the weight of the body 102 and the components mounted thereon does not need to be lifted and lowered by the wheel-positioning mechanism.

The bot 100 also comprises a lifting mechanism 108 and a container-holding device 112 configured to raise and lower containers 9. The illustrated lifting mechanism 108 comprises four tethers 110 which are connected at their lower ends to the container-holding device 112. The tethers 110 may be in the form of cables, ropes, tapes, or any other form of tether with the necessary physical properties to lift the containers 9. The container-holding device 112 comprises a gripping mechanism 113 configured to engage with features of the containers 9 to releasably hold the container 9 from above. In the illustrated example, the gripping mechanism 113 comprises legs that can be received in corresponding apertures 10 of a container 9 and then moved outwards to engage with the underside of the rim of the container

9. The tethers 110 can be wound up or down to raise or lower the container-holding device 112 as required. One or more motors and winches or other means may be provided to effect or control the winding up or down of the tethers 110.

In Figure 5, a side panel of the bot 100 has been omitted from view to allow the interior of the bot 100 to be seen. As can be seen in Figure 5, the body 102 of the illustrated bot 100 has an upper portion 114 and a lower portion 116. The upper portion 114 is configured to house or support one or more operation components (not shown), such as components (e.g. motors) of the lifting mechanism 108, wireless communication components, one or more processors for controlling operation of the bot 100, etc. The lower portion 116 is arranged beneath the upper portion 114. The lower portion 116 is externally open at the bottom and defines a container-receiving space 118 for accommodating at least part of a container 9 that has been raised into the container-receiving space 118 by the lifting mechanism 108. The container-receiving space 118 is sized such that enough of a container 9 can fit inside the space 118 to enable the bot 100 to move across the track structure 13 on top of storage structure 1 without the underside of the container 9 catching on the track structure 13 or another part of the storage structure 1. When the bot 100 has reached its intended destination, the lifting mechanism 108 controls the tethers 110 to lower the container-holding device 112 and the corresponding container 9 out of the space 118 and into the intended position. The intended position may be a stack 11 of containers 9 or an egress point of the storage structure 1 (or an ingress point of the storage structure 1 if the bot 100 has moved to collect a container 9 for storage in the storage structure 1). Although in the illustrated example the upper and lower portions 114, 116 are separated by a physical divider, in other examples, the upper and lower portions 114, 116 may not be physically divided by a specific component or part of the body 102 of the bot 100. The upper and lower configuration of the bot 100 allows the bot 100 to occupy only a single grid cell 14 on the track structure 13 of the storage system 1.

As shown in Figure 5, the bot 100 further comprises a power source compartment 120 located in the upper portion 114 of the body 102 of the bot 100, above the container-receiving space 118. The power source compartment 120 is configured to removably receive and electrically couple to a power source 140 in an upwards vertical direction. Once electrically coupled to the power source compartment 120, the power source 140 can provide power to one or more electrical components of the bot 100, such as the lifting mechanism 108 and/or the driving assembly. The power source 140 in Figure 5 is shown in a position vertically below the power source compartment 120 to allow both the power source compartment 120 and the power source 140 to be seen clearly. The power source comprises an outer casing 142 which houses

a battery or any other type of suitable power source for delivering electric power, such as a supercapacitor.

The outer boundary of the power source compartment 120 is depicted in Figure 5 with dashed lines. In reality, the power source compartment 120 can be defined by physical side walls and a top wall that separate the power source 140 from other components inside the upper portion 114 of the bot 100. Alternatively, the power source compartment 120 can be only partially defined by one or more side walls and/or a top wall, or the power source compartment 120 can simply be a reserved space (i.e. without any side walls or a top wall) in the upper portion 114 of the bot 100 that the power source 140 can occupy.

The bottom side of the power source compartment 120 comprises a bottom-facing opening 126. The bottom-facing opening 126 is configured such that the bottom of the power source compartment 120 opens into the top of the container-receiving space 118 via the bottom-facing opening 126. The bottom-facing opening 126 is sized to allow the power source 140 to pass vertically between the power source compartment 120 and the container-receiving space 118, i.e. the power source 140 can be inserted upwards from the container-receiving space 118 into the power source compartment 120 and the power source 140 can be removed downwards from the power source compartment 120 into the container-receiving space 118. Given that the container-receiving space 118 has an external opening at the bottom, this configuration of the container-receiving space 118, the power source compartment 120 and the bottom-facing opening 126 thus allows the power source 140 to be vertically inserted upwards into the power source compartment 120 from an external location below the bot 100 via the container-receiving space 118 and the bottom-facing opening 126.

The power source 140 can be electrically coupled to the power source compartment 120 via one or more electrical connectors 144 on the power source outer casing 142 and one or more electrical connectors 128 in the power source compartment 120. The electrical connectors 128, 144 are configured to connect when the power source 140 is vertically inserted in the power source compartment 120 and disconnect when the power source 140 is vertically removed from the power source compartment 120. For example, the electrical connectors 144 of the power source 140 can be located on an upward-facing surface of the power source outer casing 142 and the electrical connectors 128 of the power source compartment 120 can be located on a downward-facing surface of the power source compartment 120. When the power source 140 is vertically inserted into the power source compartment 120, the electrical connectors 128, 144 move towards each other until they connect. The electrical connectors may take any form of suitable electrical connector, such as male and female connectors (e.g.

pins and corresponding sockets) or electrical contacts. In alternative examples, the electrical connectors 114, 128 could be located on side surfaces of the power source compartment 120 and the power source 140. For example, the electrical connectors 114, 128 could take the form of spring-loaded electrical contacts that are biased in opposing horizontal directions such that they contact each other when the power source 140 is inserted upwards into the power source compartment 120.

The power source compartment 120 is shown as being centred horizontally within the bot 100, which can help the bot 100 to maintain balance when moving with a power source in the power source compartment 120. However, the power source compartment 120 could also be located elsewhere, e.g. towards one horizontal side of the bot 100.

As can be further seen in Figure 5, the container-holding device 112 comprises a support portion 150 for releasably supporting the power source 140. In this example, the support portion 150 comprises a recessed portion on the top surface 152 of the container-holding device 112 in which the base (i.e. the bottom side) of the power source 140 can sit. However, the support portion 150 could take other forms for supporting the power source 140, such as a portion having protrusions that engage with corresponding recesses in the power source outer casing 142. The support portion 150 could also simply be a flat portion of the top surface 152 of the container-holding device 112 with no other engagement features for engaging with the power source 140. When the power source 140 is occupying the support portion 150, the power source 140 protrudes higher than the top surface 152 of the container-holding device 112. The support portion 150 is positioned on the container-holding device 112 such that the support portion 150 and the bottom-facing opening 126 of the power source compartment 120 are vertically aligned. In this way, a power source 140 can be placed on the support portion 150 and the container-holding device 112 can be raised into the container-receiving space 118 (using the lifting mechanism 108) to vertically insert the power source 140 upwards into the power source compartment 120 via the bottom-facing opening 126. Similarly, a power source 140 in the power source compartment 120 can be vertically released downwards onto the support portion 150 of the container-holding device 112 and the container-holding device 112 can then be lowered to bring the power source 140 out from power source compartment 120.

Figure 6 shows an example locking mechanism for releasably locking the power source 140 inside the power source compartment 120. The locking mechanism 130 comprises locking pins 132 (or any other form of protrusion) at opposing sides of the power source compartment 120 and corresponding recesses 136 in opposing sides of the power source outer casing 142 for receiving the locking pins 132. The locking mechanism 130 further comprises linear

actuators 134 that can be controlled to selectively move the locking pins 132 between a locking position in which the locking pins 132 extend into the recesses 136 of the power source outer casing 142 and a release position in which the locking pins 132 are retracted from the recesses 136. When the locking pins 132 are in the locking position, the locking pins 132 engage with the power source outer casing 142 to prevent the power source 140 from falling downwards under gravity. When the locking pins 132 are in the release position, the power source 140 is free to fall downwards under gravity.

The above-described bot 100 thus allows the power source 140 of the bot 100 to be exchanged using existing components of the bot 100, namely the lifting mechanism 108 and container-holding device 112, rather than requiring further external hardware (such as a robotic arm) to perform the exchange.

Figures 7A to 7F show how a first power source 140a of the bot 100 can be exchanged with a second power source 140b using the container-holding device 112 once the bot 100 has moved to a designated grid cell 14.

In Figure 7A, the first power source 140a is in the power source compartment 120, with the locking mechanism 130 activated, i.e. the locking pins 132 are in the locking position. The base of the power source 140 is exposed through the bottom-facing opening 126. The container-holding device 112 is in the container-receiving space 118 in a normal raised operating position. The normal raised operating position is the position that the container-holding device 112 is raised to for holding a container 9 in the container-receiving space 118 for transport across the track structure 13. It is also the position that the container-holding device 112 occupies when the bot 100 is moving across the track structure 13 without a container 9.

In Figure 7B, the container-holding device 112 is raised further by the lifting mechanism 108 to an engagement position. In the engagement position, the support portion of the container-holding device 112 engages the base of the first power source 140a. The engagement position is preferably high enough such that the container-holding device pushes the first power source 140a upwards slightly within the power source compartment 120 to take the weight of the first power source 140a off the locking pins 132. This makes it easier for the locking pins 132 to retract.

In Figure 7C, the locking mechanism 130 is deactivated, i.e. the actuators 134 retract the locking pins 132 out of the recesses 136 in the power source outer casing 142. The power

first source 140a is now fully supported by support portion 150 of the container-holding device 112.

In Figure 7D, the lifting mechanism 108 lowers the container-holding device 112, which is now supporting the first power source 140a, away from the power source compartment 120. The power source compartment 120 is now empty. In order to operate the lifting mechanism 108 or any other functions of the bot 100 while the power source compartment 120 is empty, the bot 100 may comprise a secondary power source located, for example, in the upper portion 114 of the bot 100 and/or in the container-holding device 112 (using the tethers 110 or a separate cable to transfer power to the lifting mechanism 108 and/or other components in the upper portion 114 of the bot 100).

In Figure 7E, the container-holding device 112 is lowered through the aperture 15 of the grid cell 14 to a position where the first power source 140 is removed from the container-holding device 112 and a second power source 140b is placed on the support portion 150 of the container-holding device 112. This operation may be carried out by a human or a robotic arm.

In Figure 7F, the container-holding device 112 is raised back into the container-receiving space 118 to the engagement position which causes the second power source 140b to be vertically inserted upwards into the power source compartment 120 to a position in which the power source 140 can electrically couple to the power source compartment 120 and the locking mechanism 130 can activate. Once the second power source 140b has been fully received in the power source compartment 120, the locking pins 132 are inserted into the recesses 136 of the power source casing 142 to lock the second power source 140b in the power source compartment 120. The container-holding device 112 can then be lowered to the normal raised operating position and the bot 100 can resume normal operation.

Figure 8 shows a second example bot 200. Similar to the first example bot 100, the second example bot 200 comprises a driving assembly for allowing the bot 200 to move on the track structure 13, a container-holding device 212 for releasably holding a container 9, a container-receiving space 218 and a lifting mechanism 208 for raising and lowering the container-holding device 212 into and out of the container-receiving space 218 respectively.

In contrast to the first example bot 100, the second example bot 200 comprises two power source compartments 220, each configured to removably receive and electrically couple to a power source 240. The bottom side of each power source compartment 220 comprises a bottom-facing opening 226 configured such that the bottom of each power source

compartment 220 opens into the top of the container-receiving space 218 via their respective bottom-facing openings 226.

Similar to the first example bot 100, each power source compartment 220 of the second example bot 200 comprises locking mechanisms 230 for releasably locking a power source 240 in each power source compartment 220. The locking mechanisms 230 can operate independently of each other such that power sources 240 can be locked or released from the two power source compartments independently. The locking mechanisms 230 can take any of the forms already described above and will therefore not be described in further detail. The locking mechanisms 230 have also been omitted from Figure 8 for clarity.

Although the bot 200 comprises two power source compartments 220, the bot 200 is configured, and a single power source 240 contains enough energy, such that the bot 200 only requires the power from one power source 240 to perform its normal operations (e.g. driving on the track structure 13 and raising and lowering containers 9). Thus, only one power source compartment 220 is required to be occupied by a power source at any one time during normal operation of the bot 200. If both power source compartments 220 are occupied by a power source 240, then the electronic circuitry of the bot 200 can be configured to use power from the power source 240 with the highest voltage (i.e. the power source 240 with the highest charge level).

The container-holding device 212 of the second example bot 200 differs from the container-holding device 112 of the first example bot 100 in that the container-holding device 212 does not support a power source 240 on the container-holding device 212 itself. Instead, a separate power source cradle 260 is provided for supporting up to two power sources 240. In particular, the power source cradle 260 comprises two support portions 262 in the form of two recesses in a top surface 264 of the power source cradle 260. As mentioned above for the support portions 150 of the first example bot 100, the support portions 262 of the power source cradle 260 could take other forms such as comprising protrusions that engage with corresponding recesses in the power source outer casing 242. Each support portion 262 is configured to support one power source 240 such that when a power source 240 is occupying a support portion 262, the power source 240 protrudes higher than the top surface 264 of the power source cradle 260.

The power source cradle 260 further comprises interfacing features similar to the interfacing features of the containers 9 that allow the container-holding device 112 to releasably hold the containers 9 from above. In the illustrated example, the power source cradle 260 comprises

apertures 266 that are of a similar size and in similar relative positions to the apertures 10 of the container 9 to allow the container-holding device 212 to use the same gripping mechanism 113 to releasably hold the power source cradle 260 from above.

5 The container-holding device 212 further comprises two pass-through openings 254 which extend completely through the container-holding device 212 in a vertical direction. Each pass-through opening is sized to allow a power source 240 to pass through it when the power source 240 is oriented for insertion into the power source compartment 220. The pass-through openings 254 are positioned on the container-holding device 212 such that when the container-holding device 212 is holding the power source cradle 260, each pass-through
10 opening 254 is vertically aligned with a corresponding support portion 262. Therefore, when the power source cradle 260 is being held by the container-holding device 212, any power sources 240 occupying any of the support portions 262 can protrude through a corresponding pass-through opening 254. Furthermore, when the power source cradle 260 is being held by the container-holding device 212, each support portion 262 and corresponding pass-through
15 opening 254 is also vertically aligned with a corresponding bottom-facing opening 226 of a corresponding power source compartment 220. In this way, a power source 240 can pass vertically from the power source cradle 260 to the power source compartment 220 and vice versa.

20 One or more power source cradles 260 can be stored in the storage structure 1 in a similar manner to the containers 9. The power source cradles 260 are preferably vertically stackable (with or without a power source 240 occupying a support portion 262). One or more stacks of power source cradles 260 can be stored below one or more corresponding dedicated grid cells 14 to allow the bot 200 to drive over a dedicated grid cell 14 and pick up a power source cradle 260 at the top of a stack using the container-holding device 212.

25 The power source cradle 260 is also preferably configured to charge a power source 240 when it is received on a support portion 262. For example, the power source cradle 260 can comprise its own power source within the body of the power source cradle 260 which can charge a bot power source 240 on a support portion 262 via electrical connectors on the power source outer casing 242 and the support portion 262. Alternatively, the power source cradle
30 260 can be connected to an external power source when it is stored in the storage structure 1, and the power source cradle 260 can be configured to transfer power from the external power source to the bot power source 240 to charge it. In this case, a plurality of power source cradles 260 can be configured to electrically couple to each other when vertically stacked (e.g. via electrical contacts), such that when the power source cradles 260 are being stored in a

stack in the storage structure 1, external power just needs to be supplied to one of the power source cradles 260 in the stack (e.g. the bottom-most power source cradle 260) to charge all the power sources 240 being supported by the power source cradles 260 in the stack. Alternatively, a vertical power rail may be provided in the storage structure 1 that electrically
5 couples to each power source cradle 260 in a stack to deliver external power for charging the power sources 240.

Alternatively, power sources 240 can be charged at a location remote from the storage structure 1 and then loaded onto power source cradles 260 before being stored in the storage structure 1.

10 Figures 9A to 9E show how the power source 240 of the second example bot 200 can be exchanged using a power source cradle 260 stored under a designated grid cell 14 in the storage structure 1.

In Figure 9A, the bot 200 has driven to a designated grid cell 14 below which a power source cradle 260 is located. The bot 200 is currently being powered by a first power source 240a
15 locked in a first power source compartment 220a. A second power source compartment 220b is unoccupied. On the power source cradle 260, a first support portion 262a is unoccupied and a second support portion 262b is occupied by a second power source 240b. The occupied first power source compartment 220a is vertically aligned with the unoccupied first support portion 262a and the unoccupied second power source compartment 220b is vertically aligned
20 with the occupied second support portion 262b. The lifting mechanism 208 of the bot 200 has lowered the container-holding device 212 out of the container-receiving space 218 towards the power source cradle 262.

In Figure 9B, the container-holding device 212 has picked up the power source cradle 260 and has been raised into the container-receiving space 218 by the lifting mechanism 208. The
25 second power source 240b is protruding through one of the pass-through openings 254b of the container-holding device 212.

In Figure 9C, the container-holding device 212 has been raised to an engagement position within the container-receiving space 218. In the engagement position, the base of the first power source 240a is supported by the first support portion 262a of the power source cradle
30 260 and the second power source 240b is vertically received in, and electrically coupled to, the second power source compartment 220b. At this point, the bot 200 can switch from using power from the first power source 240a to using power from the second power source 240b.

The locking mechanism 230 of the first power source compartment 220a can then be deactivated to release the first power source 240a from the first power source compartment 220a and the second locking mechanism 230 of the second power source compartment 220b can be activated to lock the second power source 240b in the second power source compartment 220b.

In Figure 9D, the container-holding device 212 and the power source cradle 260, now supporting the first power source 240a, has been lowered by the lifting mechanism 208 out of the container-receiving space 218 and below the designated grid cell 14 to return and release the power source cradle 260 to a storage position within the storage structure 1. The first power source 240a can now be charged on the power source cradle 260 (as described above) or replaced with a charged power source (e.g. manually or by a robotic arm).

In Figure 9E, the container-holding device 212 has been raised back into the container-receiving space 218 of the bot 200. The bot 200, now powered by the second power source 240b, is free to resume normal operation on the track structure 13.

The power source 240 of the second example bot 200 can also be exchanged using alternative methods that do not require a power source cradle 260. Figure 10 shows an exchanging arm 270 located in the storage structure 1 below a designated grid cell 14. The exchanging arm 270 comprises two support portions 272, each configured to releasably support a power source 240. In the illustrated example, the support portions 272 are in the form of protrusions that engage with the power source outer casing 242. However, the support portions 272 could also take other forms, such as a recessed portion for receiving a power source 240, or a gripping mechanism for actively gripping the power source outer casing 242. The exchanging arm 270 further comprises a linear actuator 274 configured to vertically move the support portions 272 upwards and downwards relative to a bot 200 on the track structure 13. When a bot 200 is above the designated grid cell 14, each support portion 272 is vertically aligned with a corresponding pass-through opening 254 of the container-holding device 212 and a corresponding power source compartment 220 of the bot 200. Each pass-through opening 254 of the container-holding device 212 of the bot 200 is sized to allow a power source 240 and any required portion of the exchanging arm 270 to pass vertically through the container-holding device 212. In this way, the exchanging arm can be used to insert or remove a power source 240 from any power source compartment 220 of the bot 200. The exchanging arm 270 can optionally be configured to deliver power from an external power source to charge a bot power source 240 supported in any of the support portions 272, e.g. via electrical contacts on the support portions 272 and the power sources 240.

In use, a first power source 240 in a first power source compartment 220 can be exchanged for a second power source 240 in a second power source compartment 220 in a similar way to the above-described method using the power source cradle 260, except that instead of using the container-holding device 212 to raise and lower the power sources 240, the external
5 exchanging arm 270 is used. In particular, a bot 200 powered by a first power source 240 in a first power source compartment 220 drives to a designated grid cell 14 with an exchanging arm 270 underneath. The container-holding device 212 remains in a raised position within the container-receiving space 218. One of the support portions 272 of the exchanging arm 270 is occupied by a second power source 240 and the other support portion 272 is unoccupied. The
10 support portions 272 are raised by the linear actuator 274 into the container-receiving space 218 such that the second power source 240 passes through one of the pass-through openings 254 of the container-holding device 212 and is inserted into the second power source compartment 220 where it is locked in place. At the same time, the first power source 240 is released out of the first power source compartment 220 onto the unoccupied support portion
15 272 of the exchanging arm 270. The exchanging arm 270 is then lowered away from the bot 200 back to its original position below the designated grid cell 14. The first power source 240 can then be charged on the exchanging arm 270 (as described above) or replaced with a charged power source 240 (e.g. manually or by a robotic arm).

Although the container-holding device 212 of the bot 200 has been described as having two
20 pass-through openings 254 corresponding to the number of support portions 262, 372 and power source compartments 220, the container-holding device 212 could instead comprise a single pass-through opening 254 that is large enough to allow a power source 240 on any support portion 262, 372 to pass vertically through it.

Figure 11 shows a third example bot 300. The bot 300 comprises a main body 300, which is
25 horizontally adjacent to a container-receiving space 318. The bot 300 is configured such that when it is operating on the track structure 13, the bot 300 covers two grid cells 14, with the main body 302 of the bot covering one grid cell 14 and the container-receiving space covering an adjacent grid cell 14. The main body 302 of the bot 300 can comprise components such as the driving assembly, some components (e.g. motors) of the lifting mechanism 308, wireless
30 communication components, one or more processors for controlling operation of the bot 300, etc. The bot 300 further comprises a side frame 309 that protrudes horizontally from the main body 302, over the container-receiving space 318. The side frame 309 supports parts of the lifting mechanism 308, e.g. the tethers 310. A container-holding device 312 is attached to the lowered end of the tethers 310 and the lifting mechanism 308 is configured to raise and lower
35 the container-holding device 312 (via the tethers 310) into and out of the container-receiving

space 318 adjacent to the main body 302. The container-holding device 312 is similar to the container-holding devices 112, 212 of the first and second example bots 100, 200 in that it comprises a gripping mechanism 313 for releasably holding a container 9 from above, but the container-holding device 312 of the third example bot 300 does not require the support portions 150 of the first example bot 100 or the pass-through openings 254 of the second example bot 200.

The power source compartment 320 of the third example bot 300 is similar to the power source compartments 120, 220 of the first and second example bots 100, 200 in that it vertically receives and electrically couples to a power source 340 in an upwards direction. The power source compartment 320 also comprises a locking mechanism as already described for the first and second example bots 100, 200, which has been omitted from Figure 11 for clarity. However, in contrast to the first and second example bots 100, 200, the power source compartment 320 of the third example bot 300 is not located above the container-receiving space 318. Instead, the power source compartment 320 is located in the main body 302 and comprises an external bottom-facing opening 326 at the bottom of the main body 302 that opens the power source compartment 320 into the external region below the main body 302 of the bot 300.

The power source 340 can be exchanged using an exchanging arm 370 located below a designated grid cell 14 in a similar manner to the exchanging arm 270 described in relation to the second example bot 200. The exchanging arm 370 has similar features to the exchanging arm 270 already described above, including a support portion 372 for releasably supporting a power source 340 and a linear actuator 374 for vertically moving the support portion 372 upwards and downwards relative to a bot 300 on the track structure 13. In the illustrated example, the exchanging arm 370 has only one support portion 372 for exchanging the power source 340 in the single power source compartment 320. When the main body 302 of the bot 300 is positioned over the designated grid cell 14, the bottom-facing opening 326 of the power source compartment 320 is vertically aligned with the support portion 372 of the exchanging arm 370 such that the exchanging arm 370 can vertically insert and remove a power source 340 from the power source compartment 320 via the bottom-facing opening 326.

To exchange a first power source 340 in the bot 300, the bot 300 drives to the designated grid cell 14 such that the main body 302 is positioned over the designated grid cell 14. The support portion 372 of the exchanging arm 370 is initially unoccupied and located below the grid cell 14. The linear actuator 374 then moves the support portion 372 upwards until it is engaged with the first power source 340 in the power source compartment 320. The locking mechanism

330 of the power source compartment 320 is then disengaged to release the first power source 340 onto the support portion 372. The linear actuator 374 then moves the support portion 372 (now supporting the first power source 340) downwards to a position where the first power source 340 can be removed from the support portion 372 and replaced with a second power source 340b (e.g. manually or by a robotic arm). The linear actuator 374 then moves the support portion 372 (now supporting the second power source 340) upwards until the second power source 340 is vertically inserted into the empty power source compartment 320. The locking mechanism 330 is then activated to lock the second power source 340 in the power source compartment 320 and the linear actuator 372 moves the support portion 372 downwards away from the bot 300. The bot 300 can then move away from the designated grid cell 14, powered by the second power source 340.

In the above described examples, the power source 140, 240, 340 in the bot 100, 200, 300 may be exchanged when the charge level of the power source has depleted below a minimum charge level. The charge level of the power source may be monitored by a power source management system, which sends a signal to a controller in the bot when the charge level in the power source is too low and needs to be replaced with a replacement power source (with a higher charge level). When the signal from the power source management system is received, the bot may move to a designated grid cell 14 for performing the power source exchange. The storage and retrieval system may further comprise a central control system for controlling the movement and functions of the bots on the track structure 13 and for controlling the activation of devices for performing the power source exchange (e.g. the container-holding device or the exchanging arm). In this case, when the signal from the power source management system is received by the controller in the bot, the controller may send a signal to the central control system, which commands the bot to travel along a calculated route to a designated grid cell 14 for performing a power source exchange. Once the bot has arrived at the designated grid cell 14, the bot can confirm its location to the central control system, which can then command the container-holding device or exchanging arm to perform a power source exchange. The bots and the central control system may comprise a wireless transmitter and receiver so that they can wirelessly communicate with each other using known wireless communication technologies such as 4G, 5G, Wi-Fi, etc.

The invention is not limited to the precise forms described above and various modifications and variations are possible without departing from the scope of the invention as defined in the accompanying claims. A non-exhaustive list of some example modifications and variations are described below.

The two power source compartments 220 of the second example bot 200 in which the bot 200 only requires the power from one power source 240 to operate, and the associated exchange method in which the current power source 240 is removed from the bot 200 at the same time as inserting a replacement power source 240, can also be applied to the first and third example bots 100, 300. If the first example bot 100 had two power source compartments 120, then the container-holding device 112 could have two support portions 150 arranged such that each support portion 150 is vertically aligned with a corresponding power source compartment 120 (similar to the power source cradle 260 for use with the second example bot 200). If the third example bot 300 had two power source compartments 320 in the main body 302, the exchanging arm 370 could have two support portions 372 arranged such that each support portion 372 is vertically aligned with a corresponding power source compartment 320 (similar to the exchanging arm 270 for use with the second example bot 200). The power source 140, 340 of the first and third example bots 100, 300 could then be exchanged using a similar method to that described for the second example bot 200 in which a first power source 140, 340 is removed at the same time as inserting a second power source 140, 340 and the bot is configured to switch to using power from the second power source during the exchange. Alternatively, only one support portion 150, 372 on the container-holding device 112 or the exchanging arm 370 could be provided, and the second power source could be inserted into the unoccupied power source compartment before removing the first power source from its power source compartment.

Conversely, instead of the second example bot 200 having two power source compartments 220, the bot 200 could have just one power source compartment 220, similar to the first and third example bots 100, 300. In this case, the power source cradle 260 could have just a single support portion 262 and the container-holding device 212 could have just a single pass-through opening 254. A first power source 240 in the power source compartment 220 could be exchanged by first releasing the first power source 240 from the power source compartment 220 onto the power source cradle 260, replacing the first power source 240 with a second power source 240 on the power source cradle 260, then inserting the second power source 240 into the power source compartment 220.

The bots 100, 200, 300 are also not limited to just have one or two power source compartments 120, 220, 320. More than two power source compartments could be provided, with an optional corresponding increase in the number of support portions on the container-holding device, power source cradle or exchanging arm.

Instead of a single exchanging arm 270 comprising more than one support portion 272 (as described in relation to Figure 10), a plurality of exchanging arms 270 could be provided under a single designated grid cell 14, each exchanging arm 270 comprising a single support portion 272. In the case of a bot having two power source compartments, one exchanging arm could be used to remove a power source from the bot and another exchanging arm could be used
5 to insert a replacement power source into the bot.

Although the illustrated third example bot 300 is an example of a bot in which the power source compartment 320 is not located above the container-receiving space 318, the bot 300 could alternatively be arranged with the power source compartment 320 located above the container
10 receiving space 318 (e.g. within the side frame 309) so that the power source compartment 320 and the container-receiving space 318 are both located horizontally adjacent to the main body 302. In this case, the container-holding device 312 may comprise support portions for supporting a power source 340 (similar to the first example bot 100), or pass-through openings (similar to the second example bot 200). The power source 340 could then be exchanged
15 using the methods described in relation to the first and second example bots 100, 200, e.g. using the container-holding device 312 to raise and lower power sources 340 (optionally in combination with a power source cradle), or using an external exchanging arm.

The locking mechanism 130, 230, 330 of the power source compartments 120, 220, 320 is not limited to using linearly actuated locking pins (or other protrusions). Instead, the locking
20 mechanism could comprise rotary actuators for rotating the locking pins between a locking and release position. The locking mechanism is also not limited to selectively controlled locking pins or protrusions. Instead, the locking mechanism could comprise a mechanical mechanism in which the power source is automatically locked in the power source compartment when the power source is vertically pushed upwards into the power source compartment and
25 automatically released when the power source is vertically pushed upwards again within the power source compartment. Such mechanisms are generally known in the art and are sometimes referred to as "push latch" or "push to open" mechanisms. Pushing the power source upwards within the power source compartment to lock and release the power source could be performed by raising the container-holding device 112, 212 or extending the
30 exchanging arm 370 to a position high enough to engage and push the base of the power source upwards.

In the above examples, although the external body 102, 302 of the bot 100, 200, 300 has been depicted with outer panels, the body 102, 302 of the bot 100, 200, 300 is not limited to this structure. Instead, the external body 102, 302 of the bot 100, 200, 300 may be defined by an

open frame structure, as schematically shown in Figure 12. In this example, the body 402 of the bot comprises corner blocks 404 connected to each other by horizontal connecting elements 406 (e.g. rods) to form frames. In particular, four corner blocks 404 are connected by four horizontal connecting elements 406 to form rectangular frames. The external body

5 402 of the bot is formed as a vertical stack of rectangular frames, with vertically adjacent corner blocks 404 being connecting using vertical connecting elements 408. In the case of a bot 100, 200, 300 having an open frame structure, the bottom-facing opening 126 of the power source compartment 120 may be part of, or may be accessed via, an opening defined by the open frame structure. The power source compartment 120 may also be defined by a similar open

10 frame structure, e.g. corner blocks connected by horizontal and vertical connecting elements.

CLAIMS

1. A load handling device for lifting and moving containers arranged in stacks in a storage structure, the storage structure comprising a track structure, the track structure comprising a first set of tracks and a second set of tracks, the first set of tracks extending in a first direction and the second set of tracks extending in a second direction, the second direction being substantially perpendicular to the first direction, to form a grid pattern defining a plurality of grid cells above the stacks of containers, the load handling device comprising:
- 5 a driving assembly configured to horizontally move the load handling device on the track structure;
- 10 a container-holding device configured to releasably hold a container from above;
- a lifting mechanism configured to raise and lower the container-holding device;
- a power source; and
- a power source compartment configured to removably receive and electrically couple to the power source, the power source compartment comprising a bottom-facing opening
- 15 configured to allow the power source to be vertically inserted upwards into the power source compartment via the bottom-facing opening from a location external to the load handling device.
2. The load handling device of claim 1, wherein the power source is configured to electrically couple to the power source compartment when the power source is vertically inserted upwards into the power source compartment and electrically uncouple from the power source compartment when the power source is vertically removed downwards from the power source compartment.
- 20
3. The load handling device of claim 1 or claim 2, further comprising a locking mechanism configured to releasably lock the power source in the power source compartment.
- 25
4. The load handling device of any one of the preceding claims, wherein the power source compartment is configured to transfer electrical power from the power source to the driving assembly and/or the lifting mechanism when the power source is electrically coupled to the power source compartment.
- 30
5. The load handling device of any one of the preceding claims, further comprising a container-receiving space configured to accommodate the container-holding device and a container held by the container-holding device, wherein: the lifting mechanism is configured to raise and lower the container-holding device into and out of the container-receiving space
- 35

respectively, the power source compartment is located above the container-receiving space, and the bottom-facing opening extends into the container-receiving space to allow the power source to be upwardly inserted into the power source compartment from the container-receiving space.

5

6. The load handling device of claim 5, wherein the container-holding device comprises a support portion for releasably supporting the power source, and the support portion and the bottom-facing opening are vertically aligned such that when the power source is occupying the support portion and the container-holding device is raised into the container-receiving space by the lifting mechanism, the power source is vertically inserted into the power source compartment.

10

7. The load handling device of claim 6, wherein the support portion is located on a top side of the container-holding device.

15

8. The load handling device of claim 5, wherein the container-holding device comprises a pass-through opening configured to allow the power source to pass vertically through the container-holding device and, the pass-through opening is vertically aligned with the bottom-facing opening to allow the power source to be vertically inserted into the power source compartment via the pass-through opening.

20

9. The load handling device of any one of the preceding claims, wherein the load handling device comprises an external body, and the bottom-facing opening is defined by the external body.

25

10. The load handling device of any one of the preceding claims, further comprising a plurality of power source compartments, each power source compartment being configured to removably receive and electrically couple to the power source, each power source compartment comprising a bottom-facing opening configured to allow the power source to be vertically inserted upwards into each power source compartment via the bottom-facing opening from a location external to the load handling device.

30

11. A storage and retrieval system comprising:

a storage structure comprising a track structure, the track structure comprising a first set of tracks and a second set of tracks, the first set of tracks extending in a first direction and the second set of tracks extending in a second direction, the second direction being

35

substantially perpendicular to the first direction, to form a grid pattern defining a plurality of grid cells;

a plurality of stacks of containers arranged within the storage structure, each stack being arranged below a grid cell; and

5 the load handling device of any one of claims 1 to 10.

12. A power source exchanging system comprising:

the loading handling device of claim 8; and

a power source cradle comprising a support portion configured to releasably support
10 the power source, the power source cradle being configured to be held from above by the container-holding device such that the support portion, the pass-through opening and the bottom-facing opening are vertically aligned to allow the power source to be vertically inserted into the power source compartment via the pass-through opening and the bottom-facing opening when the container-holding device is raised into the container-receiving space by the
15 lifting mechanism.

13. The power source exchanging system of claim 12, wherein the power source cradle is configured to charge the power source when the power source is occupying the support portion.

20

14. A storage and retrieval system comprising:

a storage structure comprising a track structure, the track structure comprising a first set of tracks and a second set of tracks, the first set of tracks extending in a first direction and the second set of tracks extending in a second direction, the second direction being
25 substantially perpendicular to the first direction, to form a grid pattern defining a plurality of grid cells;

a plurality of stacks of containers arranged within the storage structure, each stack being arranged below a grid cell; and

the power source exchanging system of claim 12 or claim 13;

30 wherein the power source cradle is located within the storage structure below a grid cell.

15. The storage and retrieval system of claim 14, further comprising a plurality of power source cradles arranged in a stack below a grid cell.

35

16. A power source exchanging system comprising:
the load handling device of claim 8 or claim 9; and
an exchanging arm configured to releasably hold the power source and move vertically upwards and downwards relative to the load handling device to insert the power source into the power source compartment and remove the power source from the power source compartment respectively via the bottom-facing opening.
17. A storage and retrieval system comprising:
a storage structure comprising a track structure, the track structure comprising a first set of tracks and a second set of tracks, the first set of tracks extending in a first direction and the second set of tracks extending in a second direction, the second direction being substantially perpendicular to the first direction, to form a grid pattern defining a plurality of grid cells;
a plurality of stacks of containers arranged within the storage structure, each stack being arranged below a grid cell; and
the power source exchanging system of claim 16;
wherein the exchanging arm is located within the storage structure below a grid cell.
18. A method of exchanging a power source in the power source compartment of the load handling device of any one of claims 1 to 10, the method comprising:
removing a first power source from the power source compartment in a downwards direction via the bottom-facing opening; and
inserting a second power source into the power source compartment in an upwards direction via the bottom-facing opening.
19. The method of claim 18, wherein the first power source is removed and the second power source is inserted by lowering and raising the container-holding device respectively using the lifting mechanism.
20. The method of claim 18, wherein the power source removed and inserted by lowering and raising an external exchanging arm respectively.

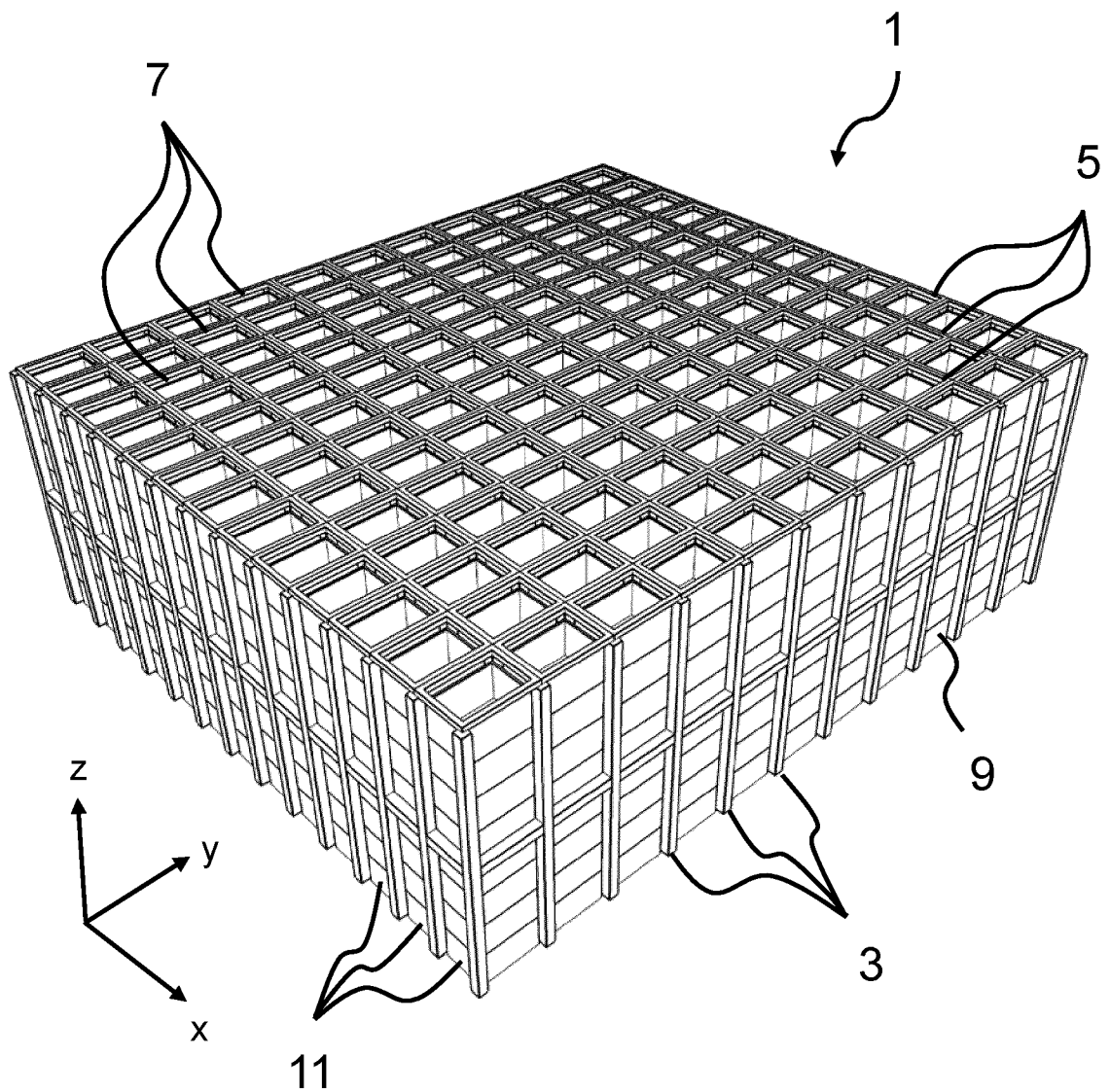


Figure 1

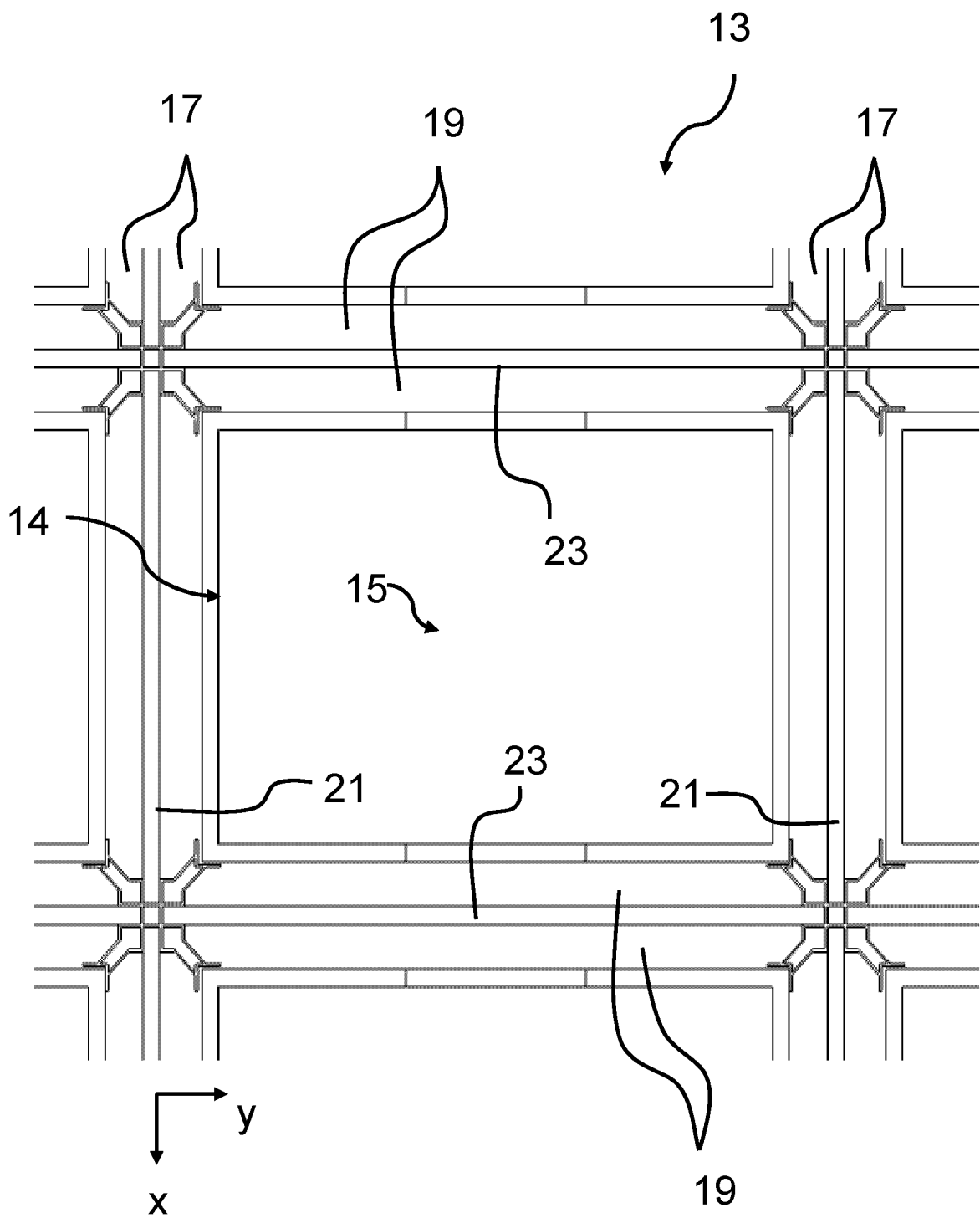


Figure 2

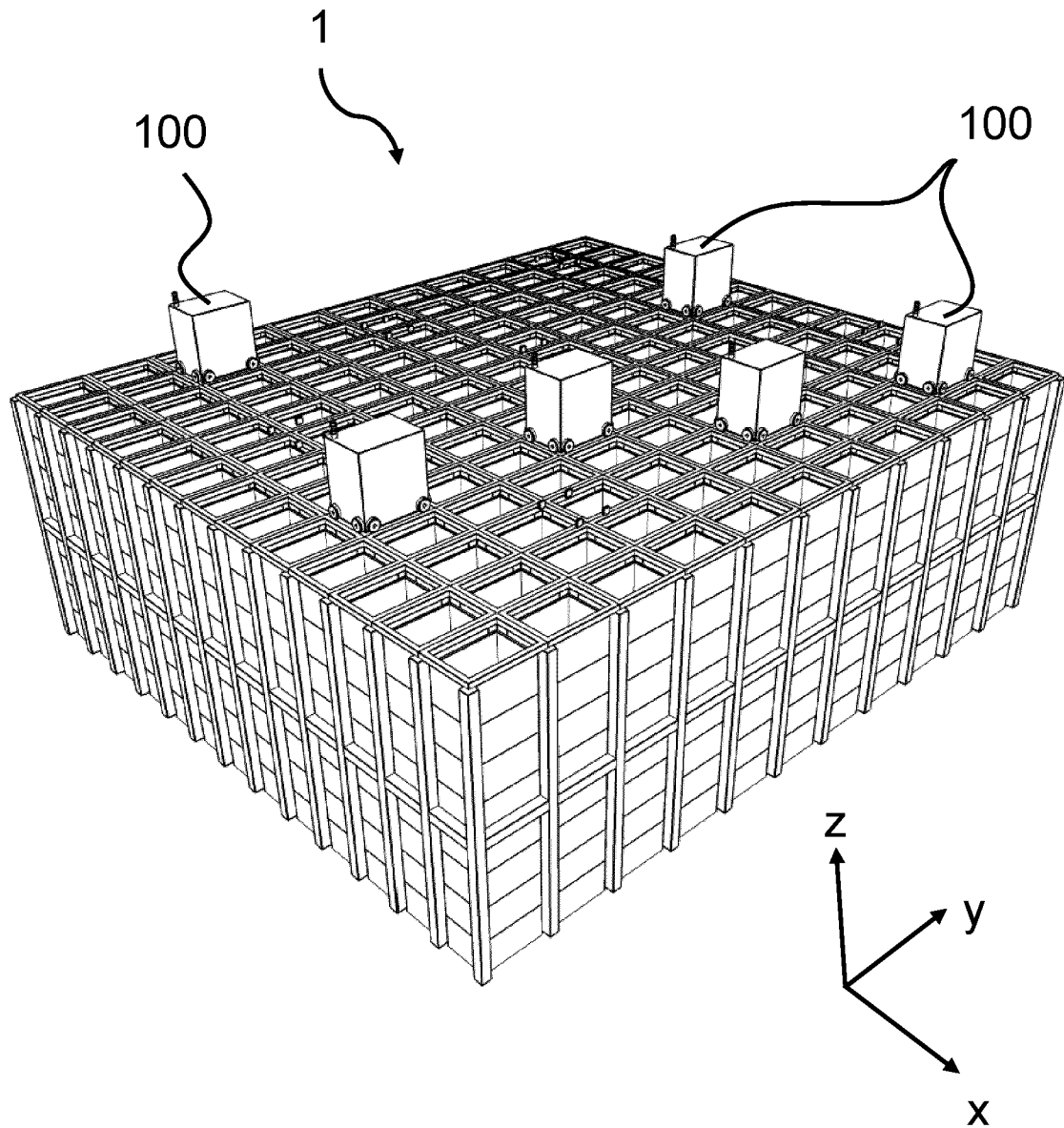


Figure 3

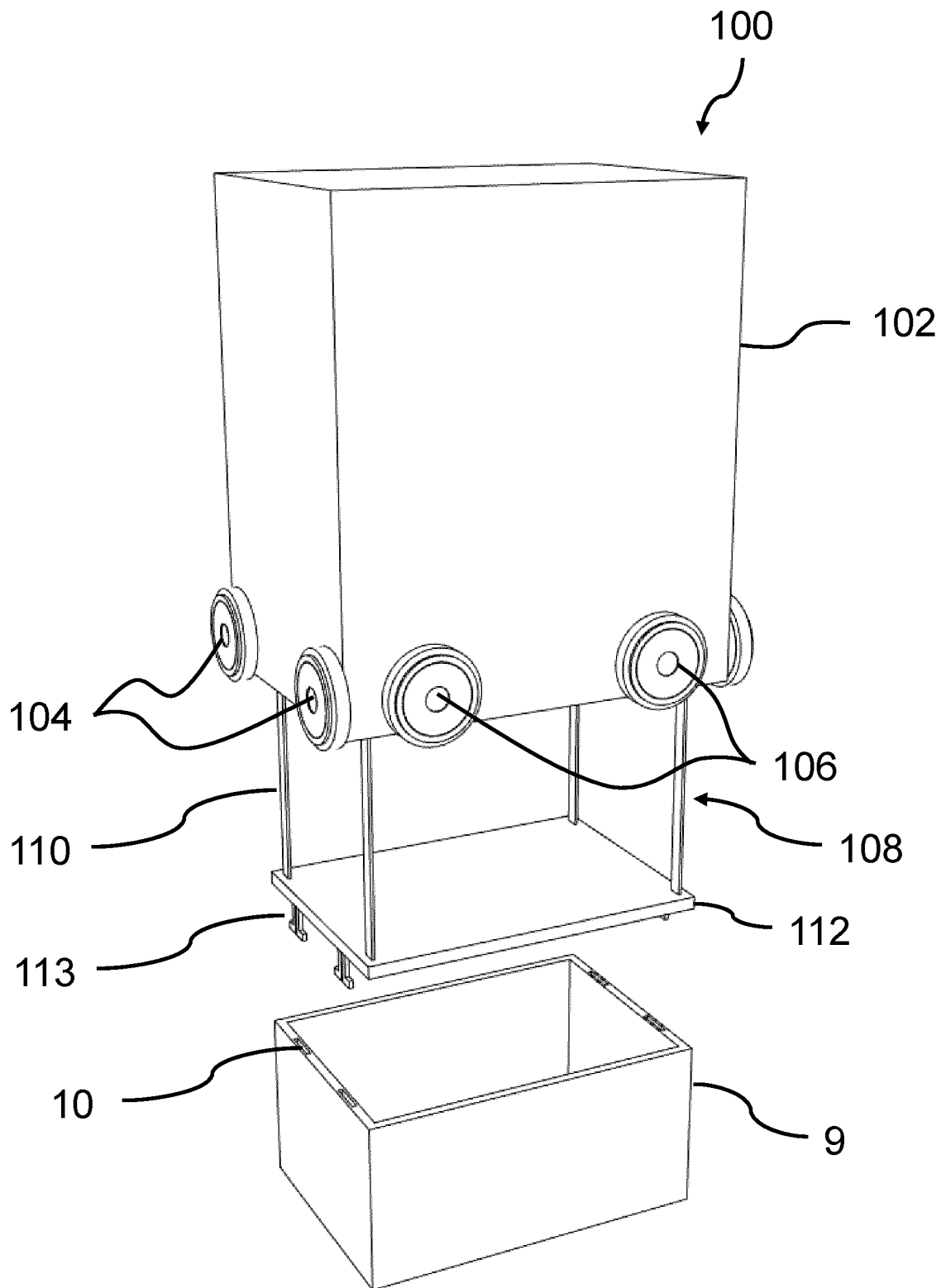


Figure 4

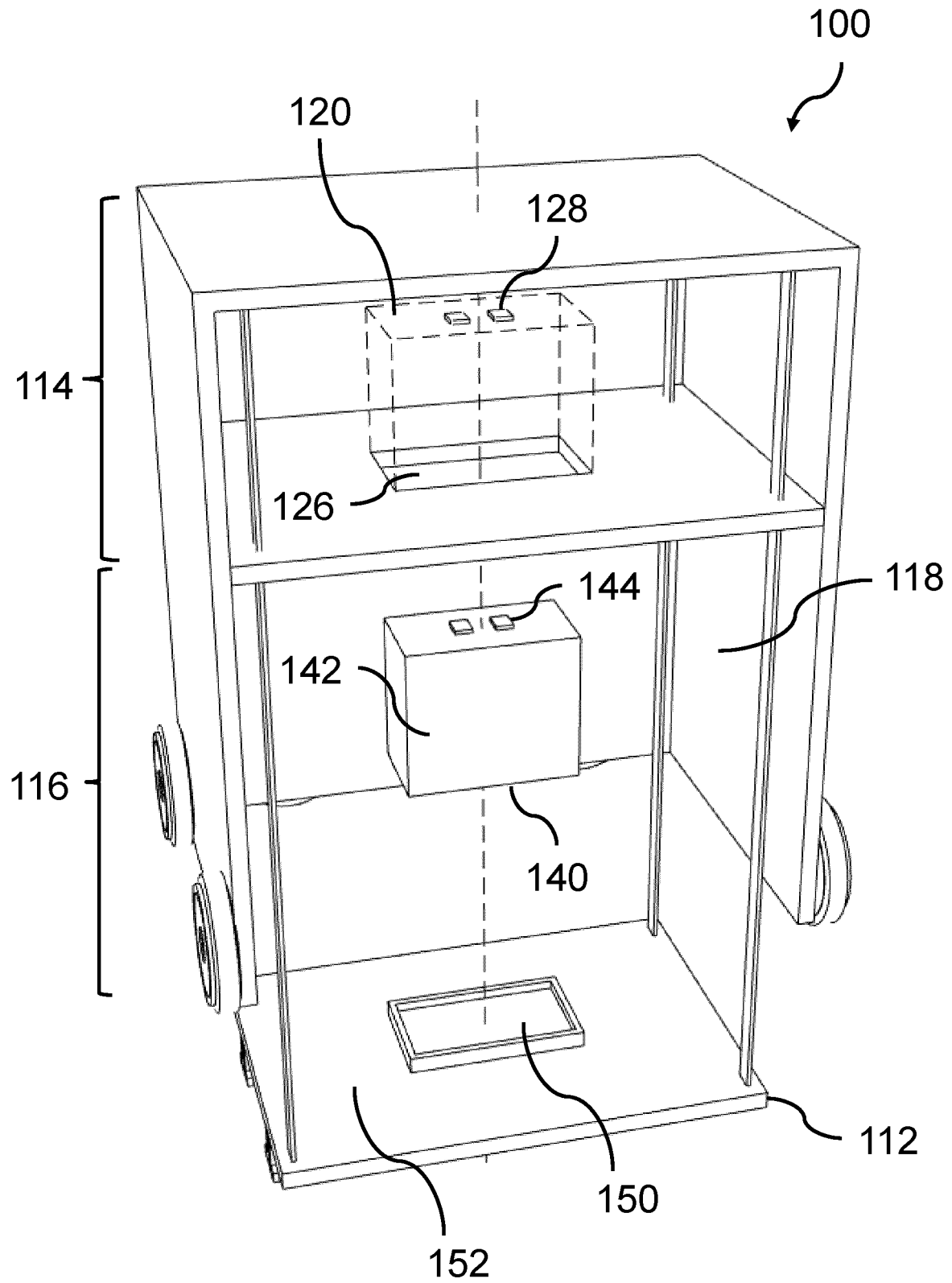


Figure 5

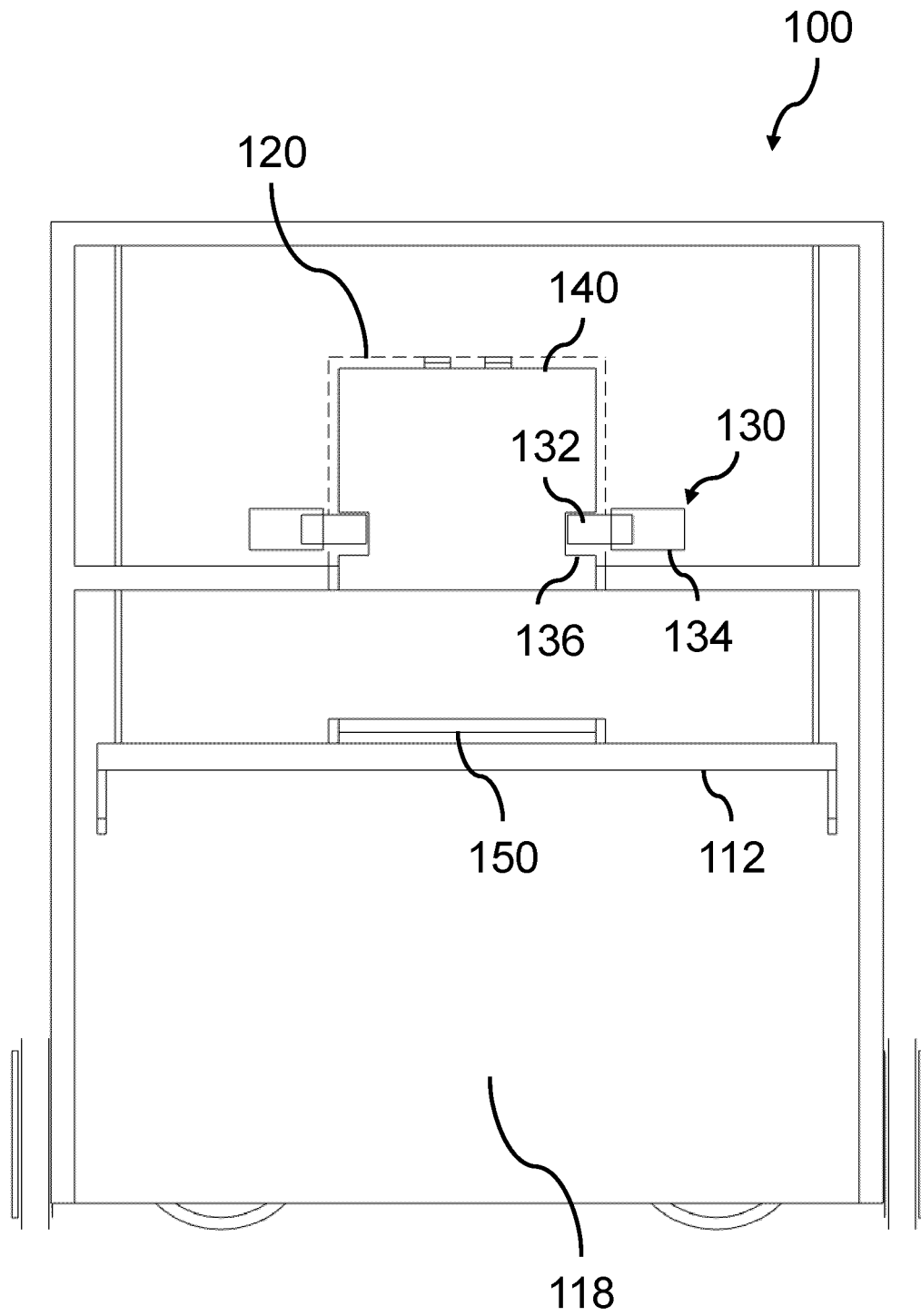


Figure 6

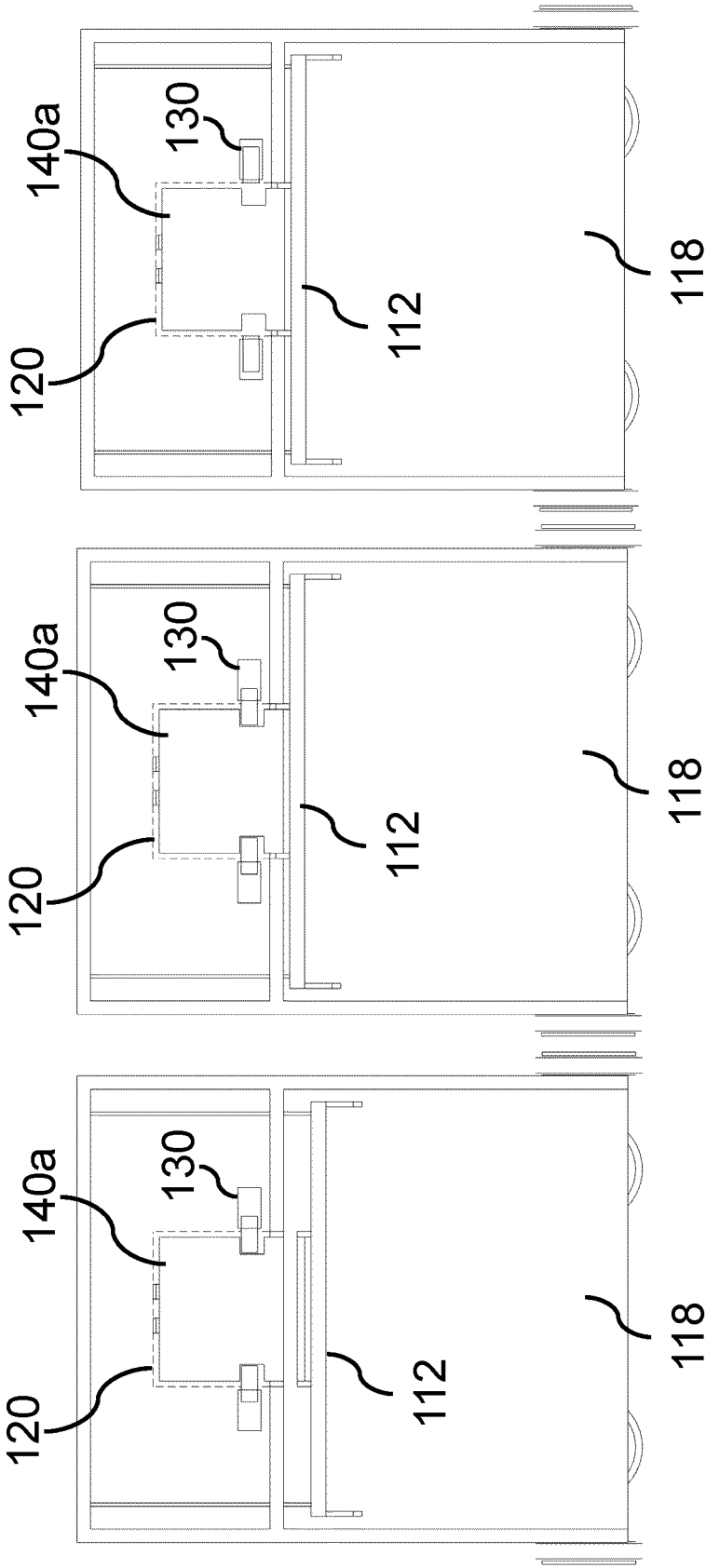


Figure 7C

Figure 7B

Figure 7A

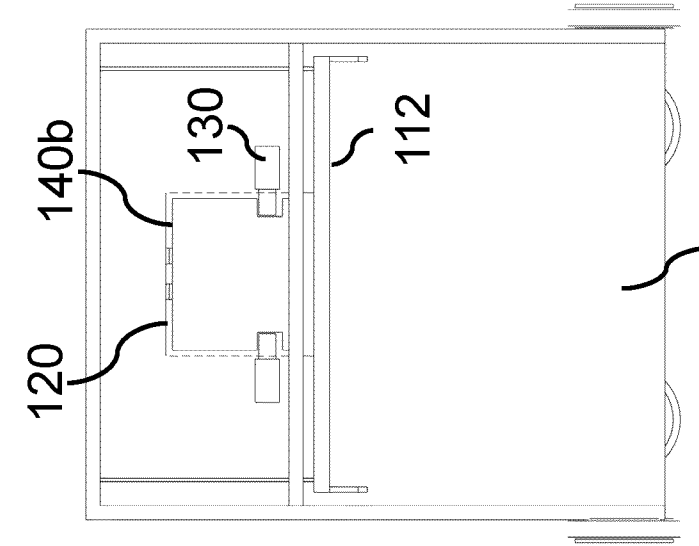


Figure 7D

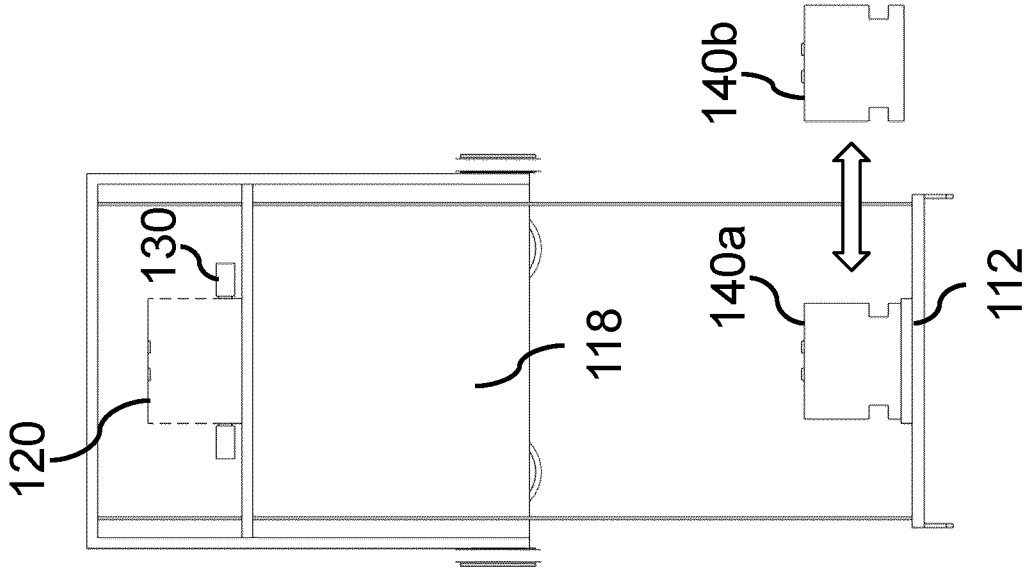


Figure 7E

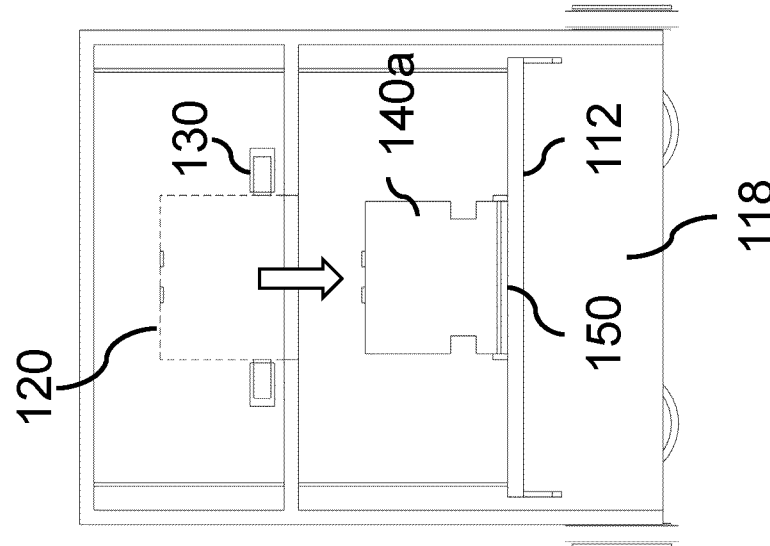


Figure 7F

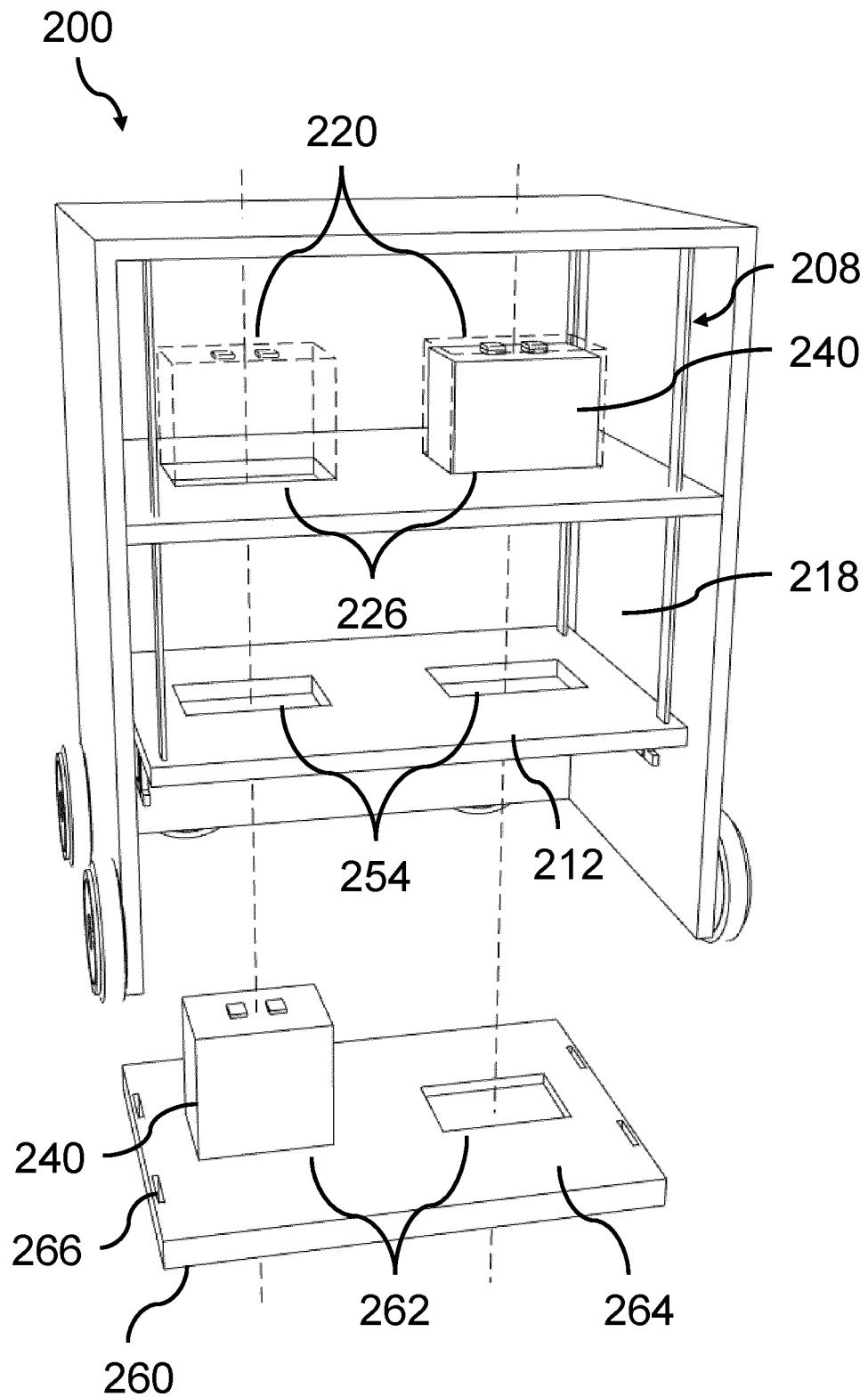


Figure 8

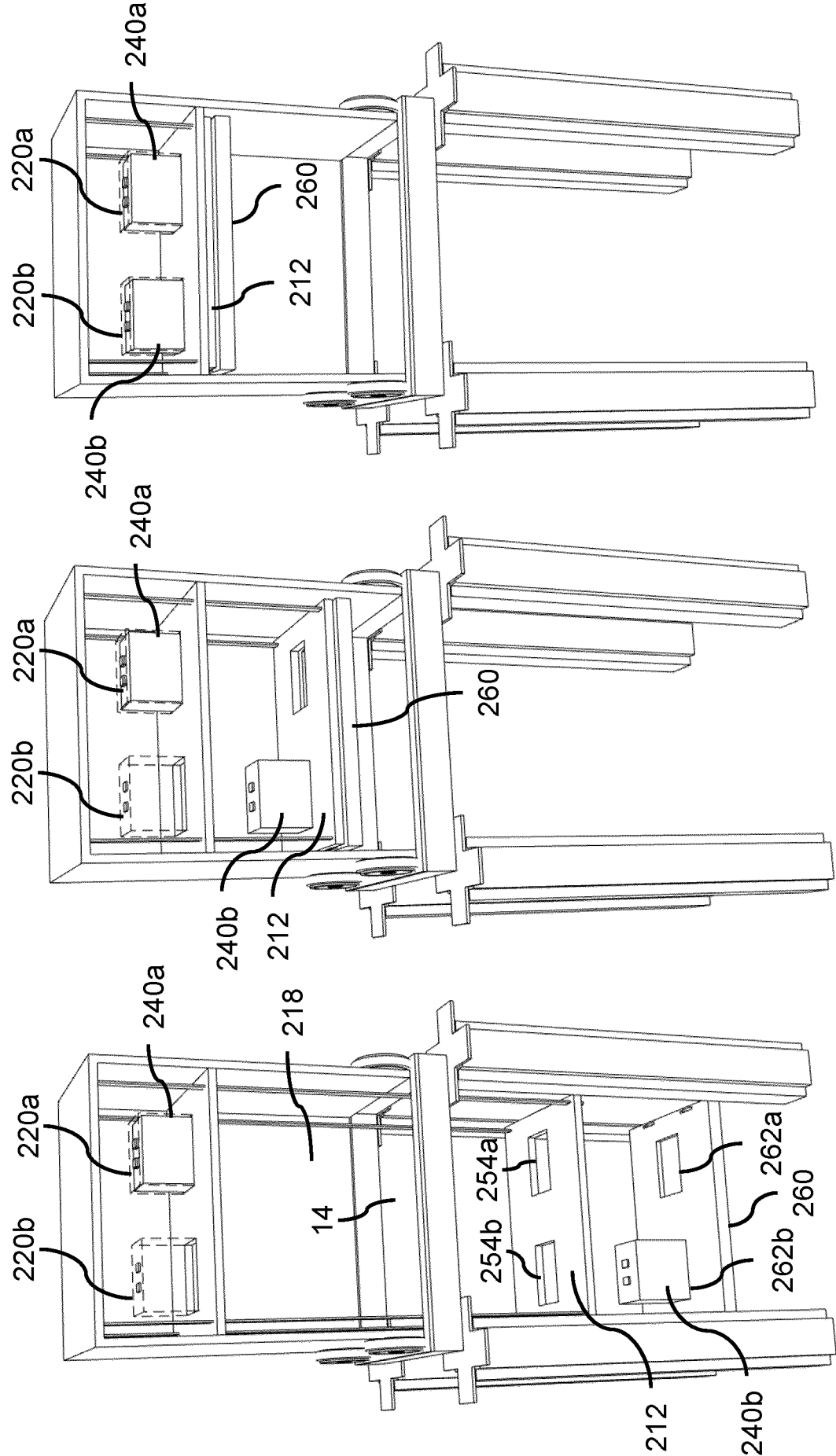


Figure 9C

Figure 9B

Figure 9A

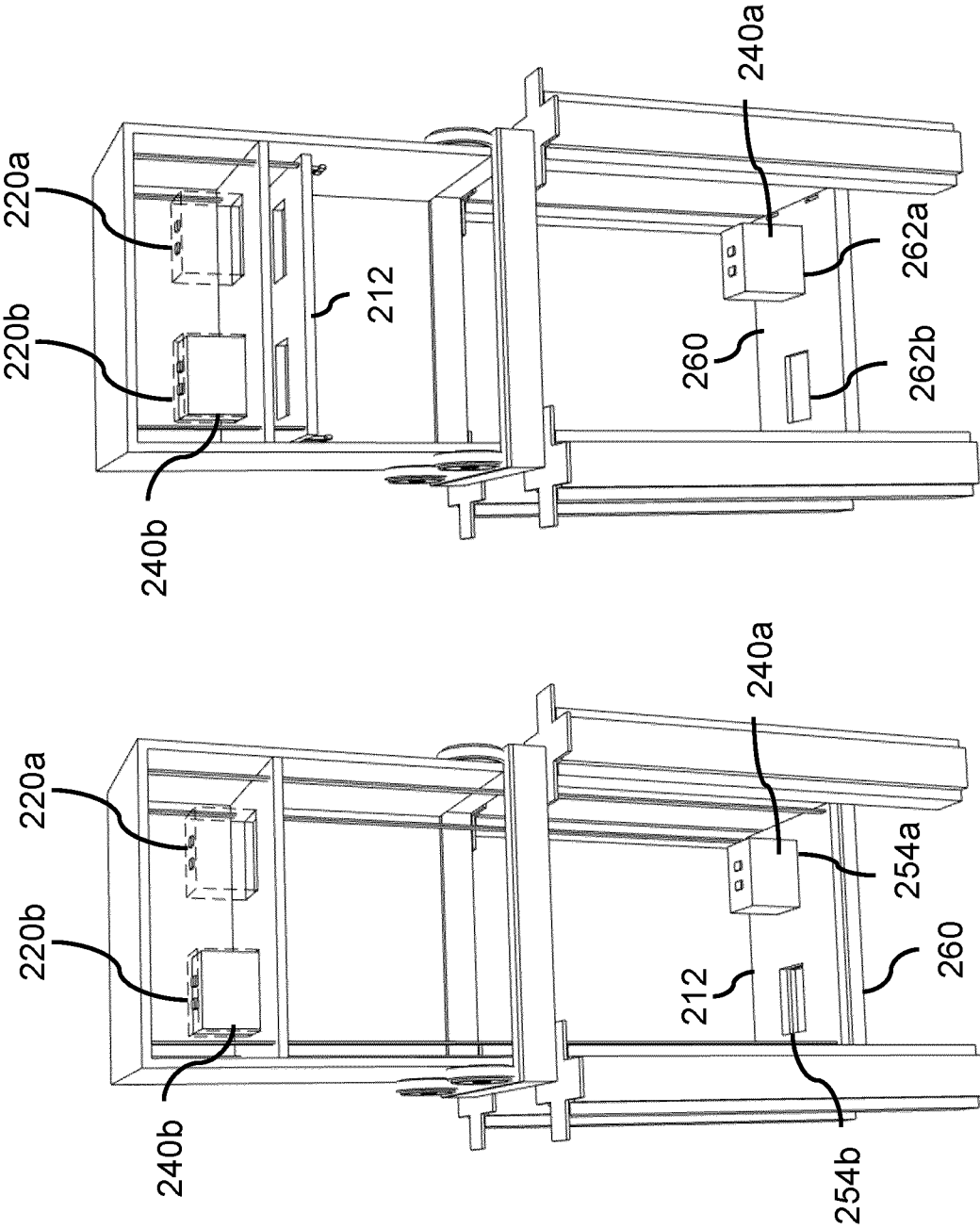


Figure 9E

Figure 9D

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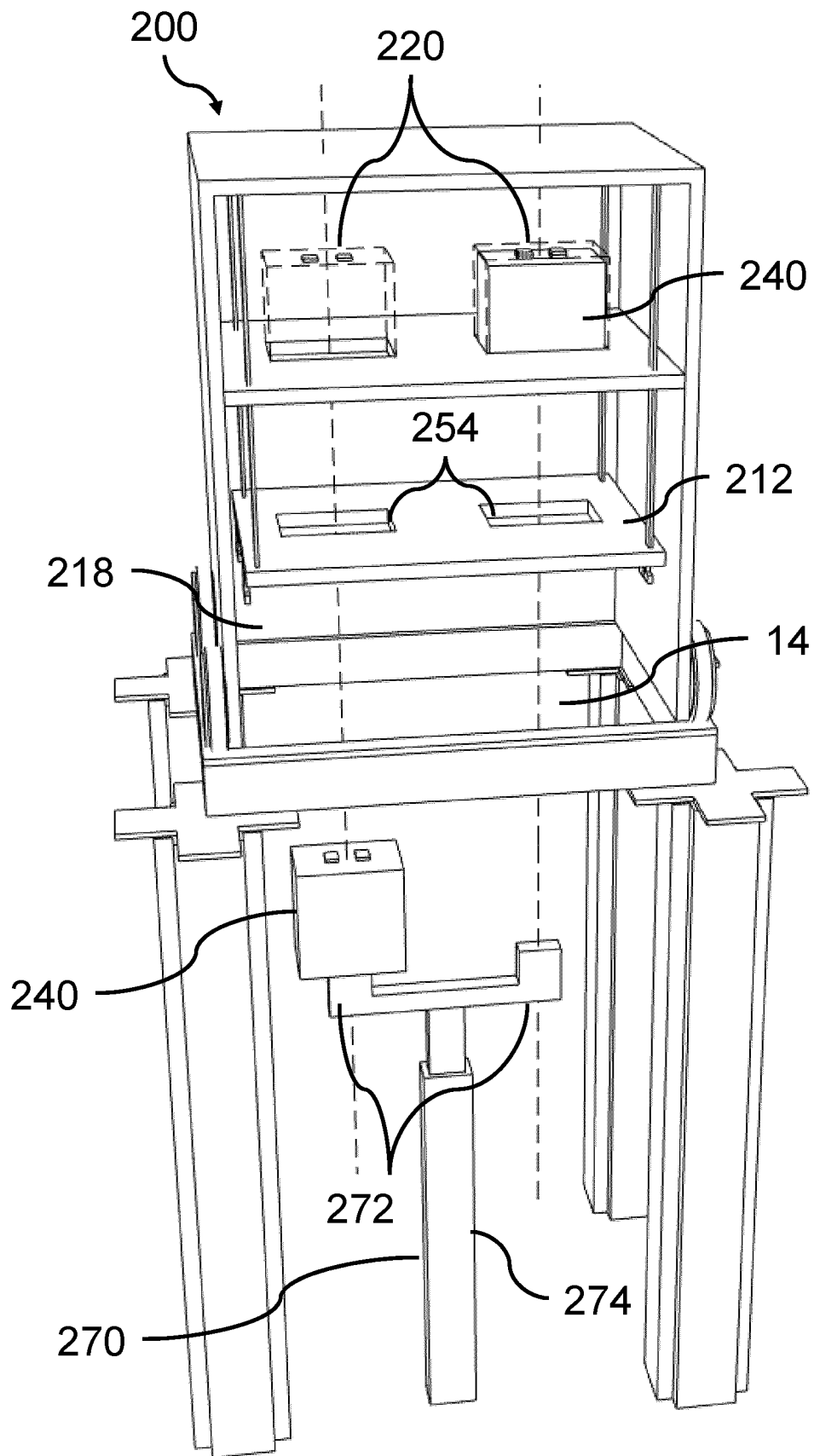


Figure 10

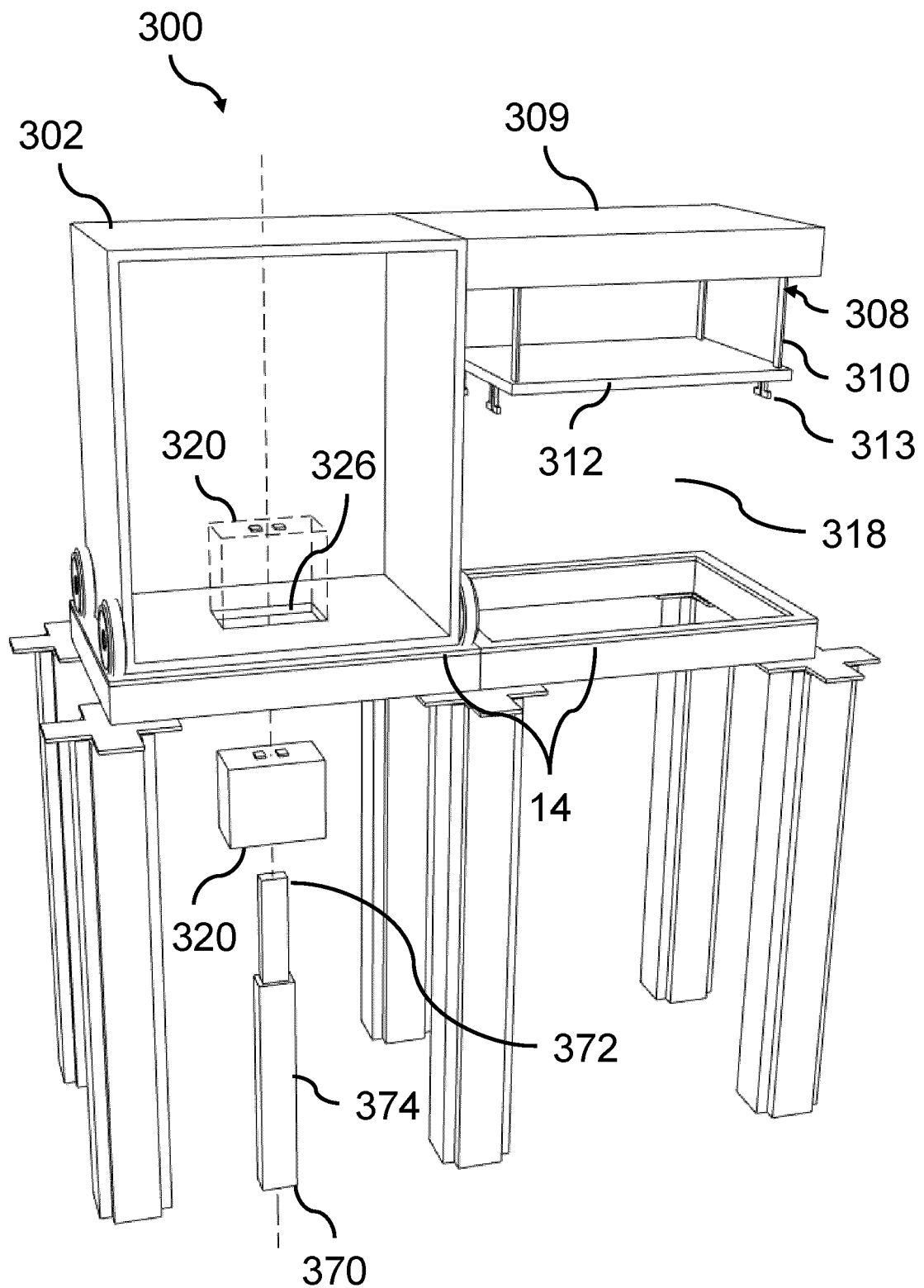


Figure 11

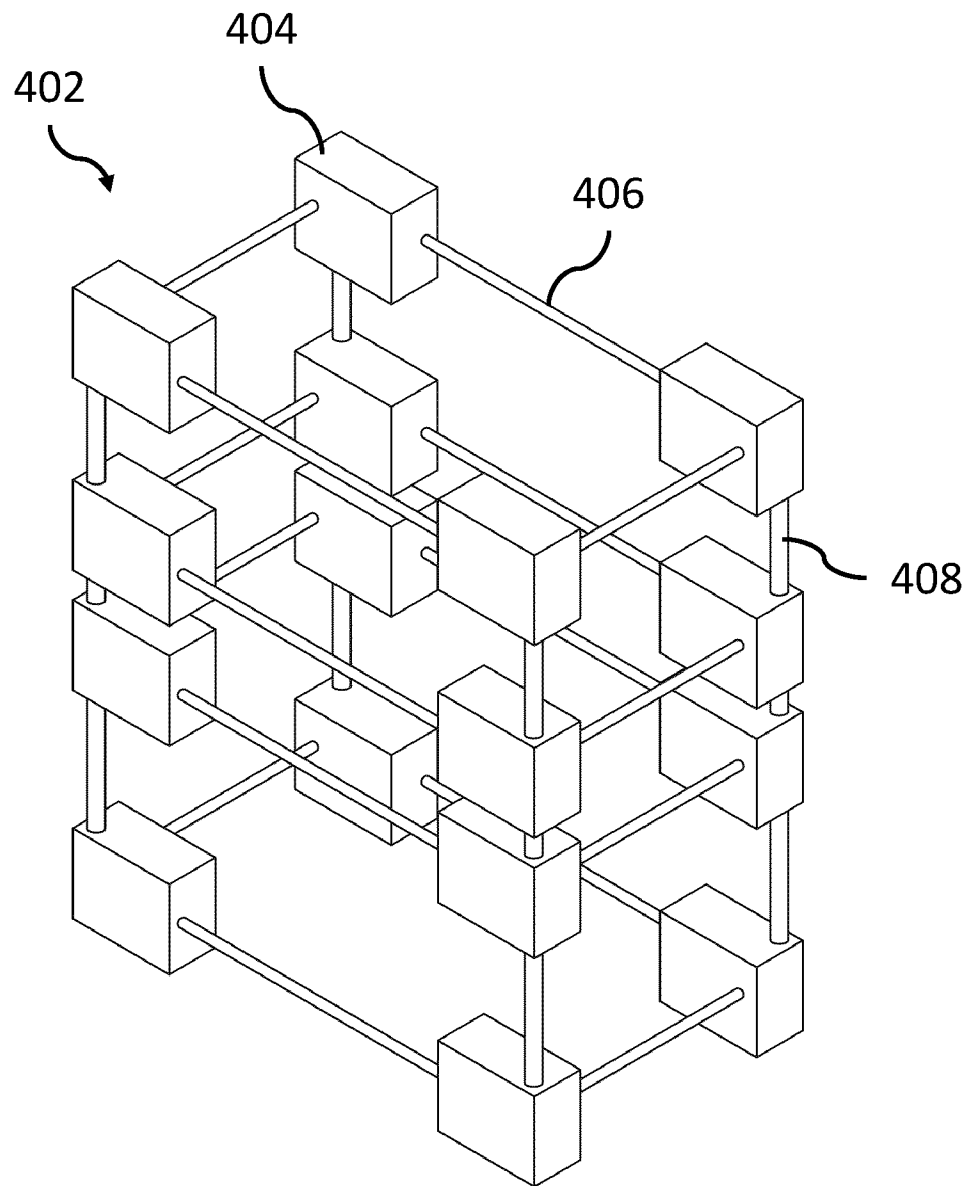


Figure 12

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2022/072737

A. CLASSIFICATION OF SUBJECT MATTER INV. B65G1/04 B60L53/80 B60S5/06 ADD.		
According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) B65G B60L B60S B66C		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) EPO-Internal, WPI Data		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2017/220627 A1 (AUTOSTORE TECH AS [NO]) 28 December 2017 (2017-12-28) page 9, lines 12-22 figures 1-6 -----	1, 18
A	US 2021/206571 A1 (AUSTRHEIM TROND [NO]) 8 July 2021 (2021-07-08) figures 1-21 -----	1, 18
A	DE 10 2011 004839 A1 (CONTINENTAL AUTOMOTIVE GMBH [DE]) 30 August 2012 (2012-08-30) figures 1-10 -----	1, 18
☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.		
* Special categories of cited documents : "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance;; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance;; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search 4 November 2022		Date of mailing of the international search report 14/11/2022
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016		Authorized officer Thenert, Alexander

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2022/072737

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