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(54) **POWER SOURCE EXCHANGE SYSTEM AND METHOD OF EXCHANGING A POWER SOURCE**

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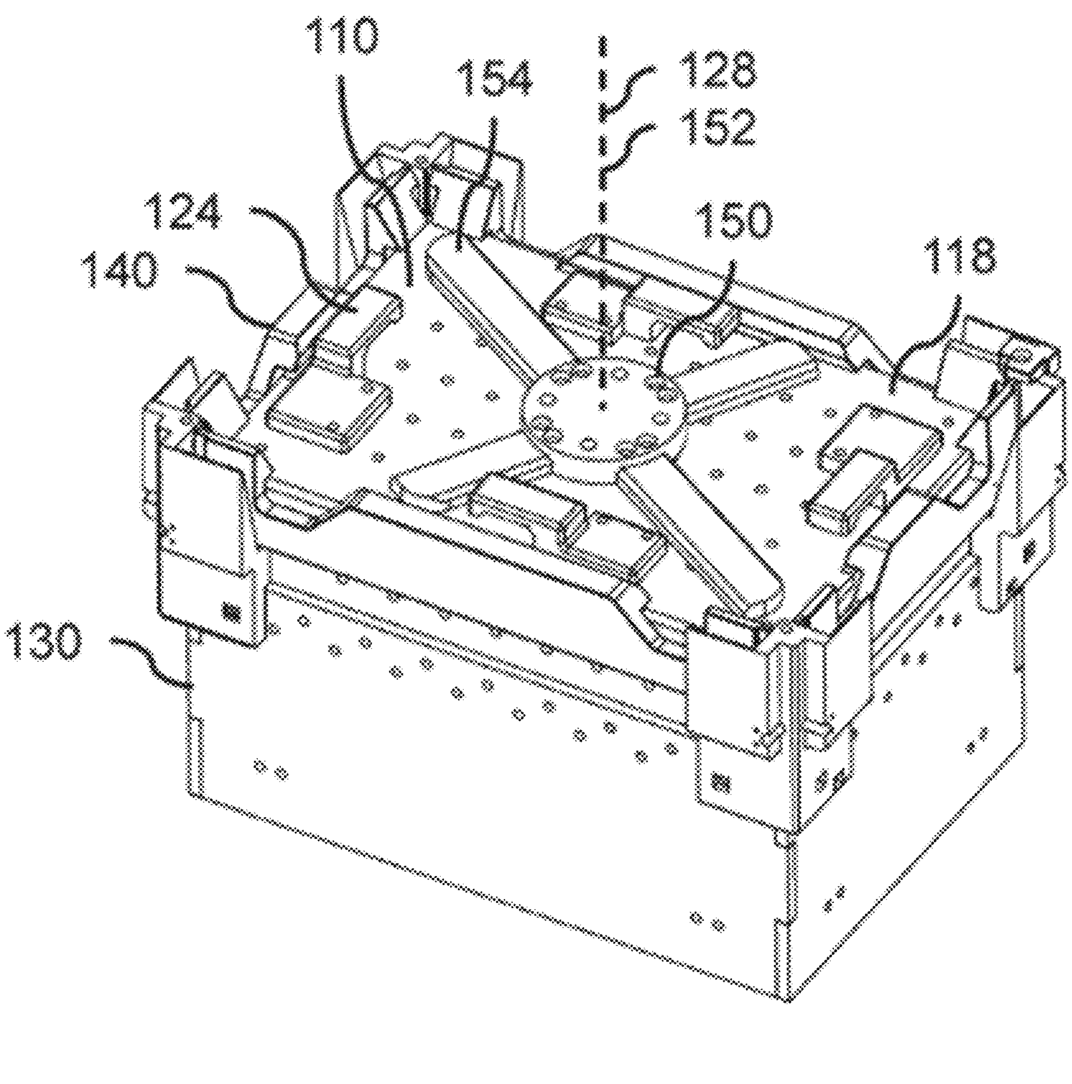
(57) **ABSTRACT**

The present disclosure relates to a power source exchange system and a method for exchanging a power source. The power source exchange system comprises a compartment configured to removably receive a power source, a rotatable end effector, and a locking assembly. Rotation of the end effector can move the locking member from the locked position to the unlocked position. A load handling device is provided for lifting and moving containers arranged in stacks in a storage structure. The load handling device comprises the compartment, and a power source received into the compartment is configured to deliver electrical power to the load handling device. A storage and retrieval system is provided, comprising the storage structure, load handling device, and power source exchange system. Methods are provided of inserting a power source into the compartment of the power source exchange system, removing a power source, and exchanging a power source.



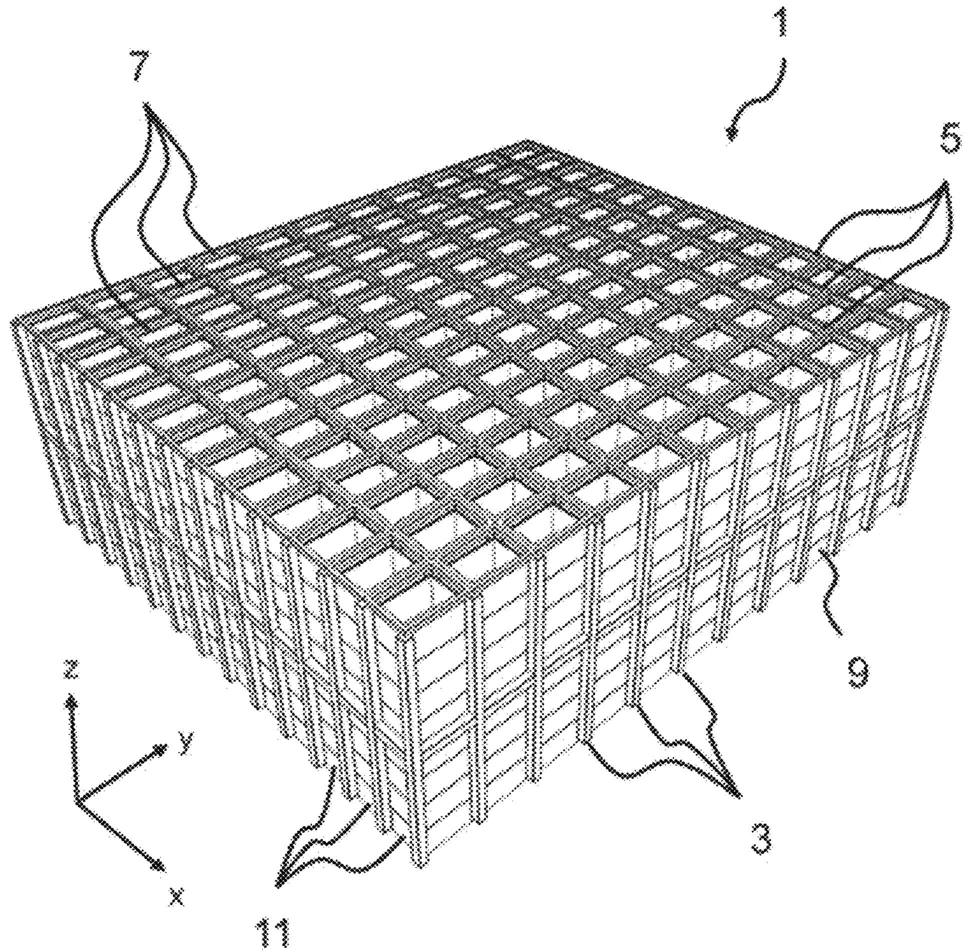


FIG. 1

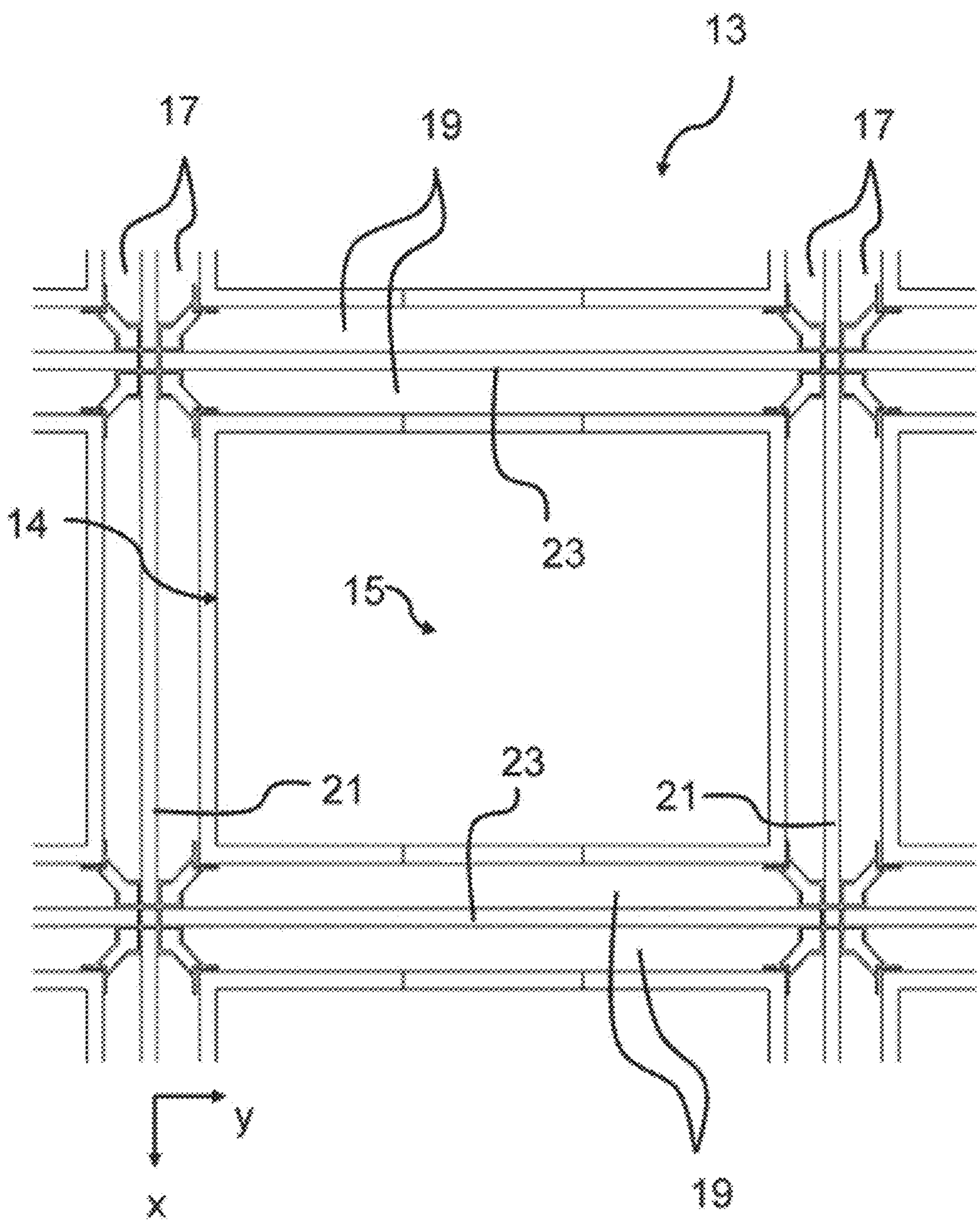


FIG. 2

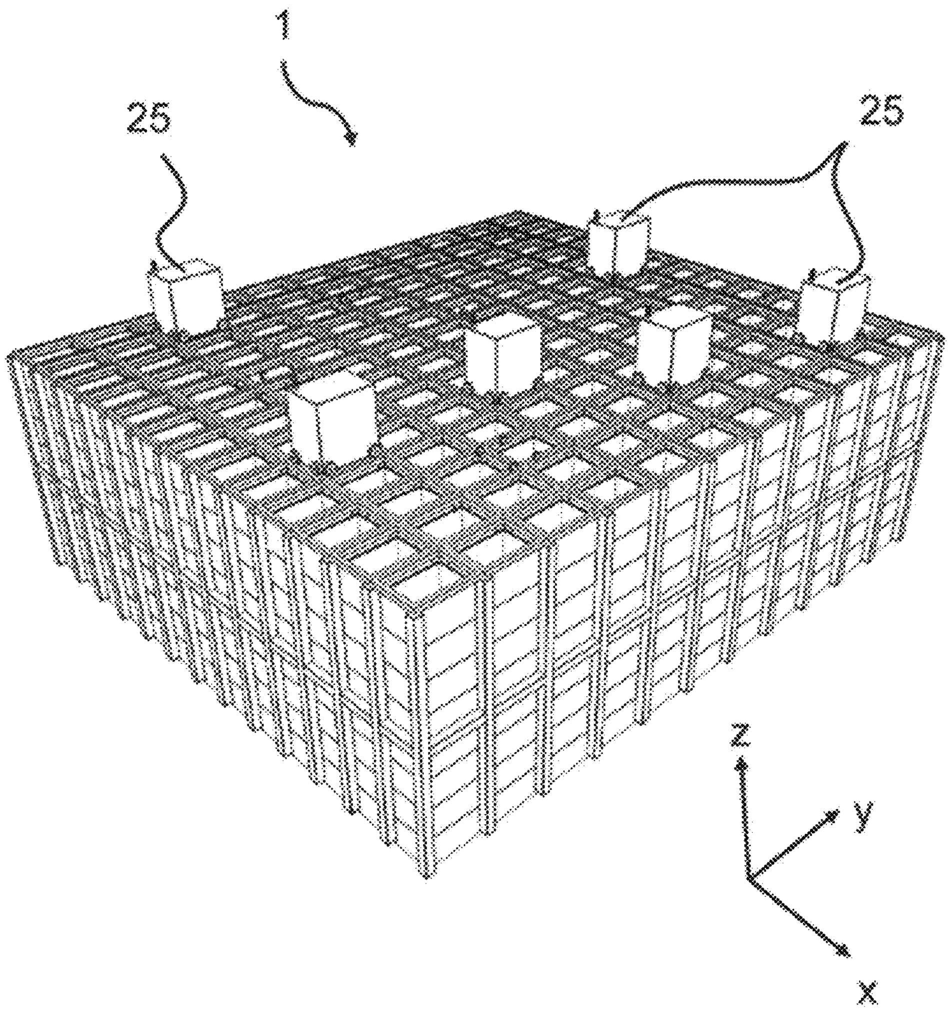


FIG. 3

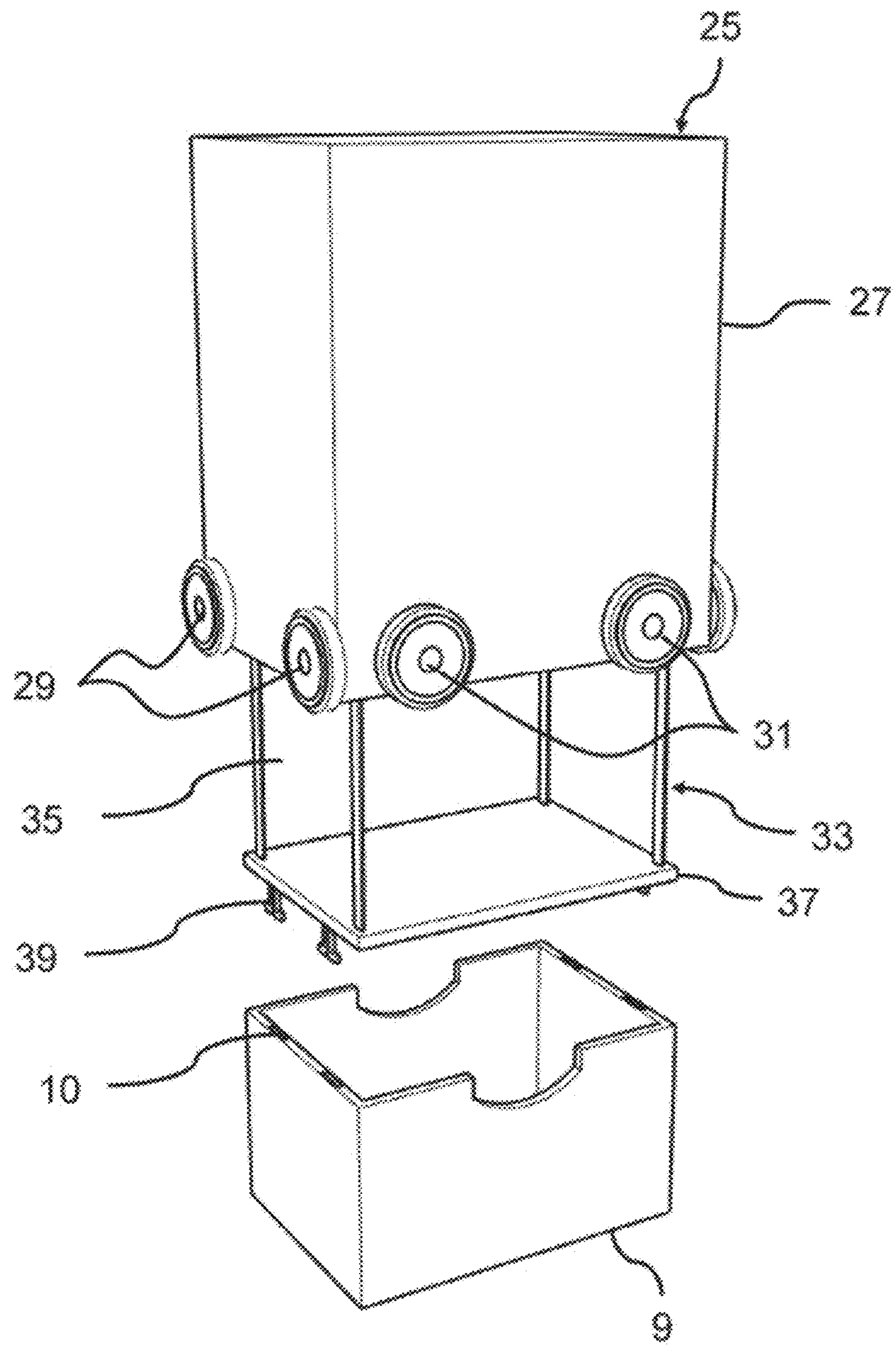


FIG. 4

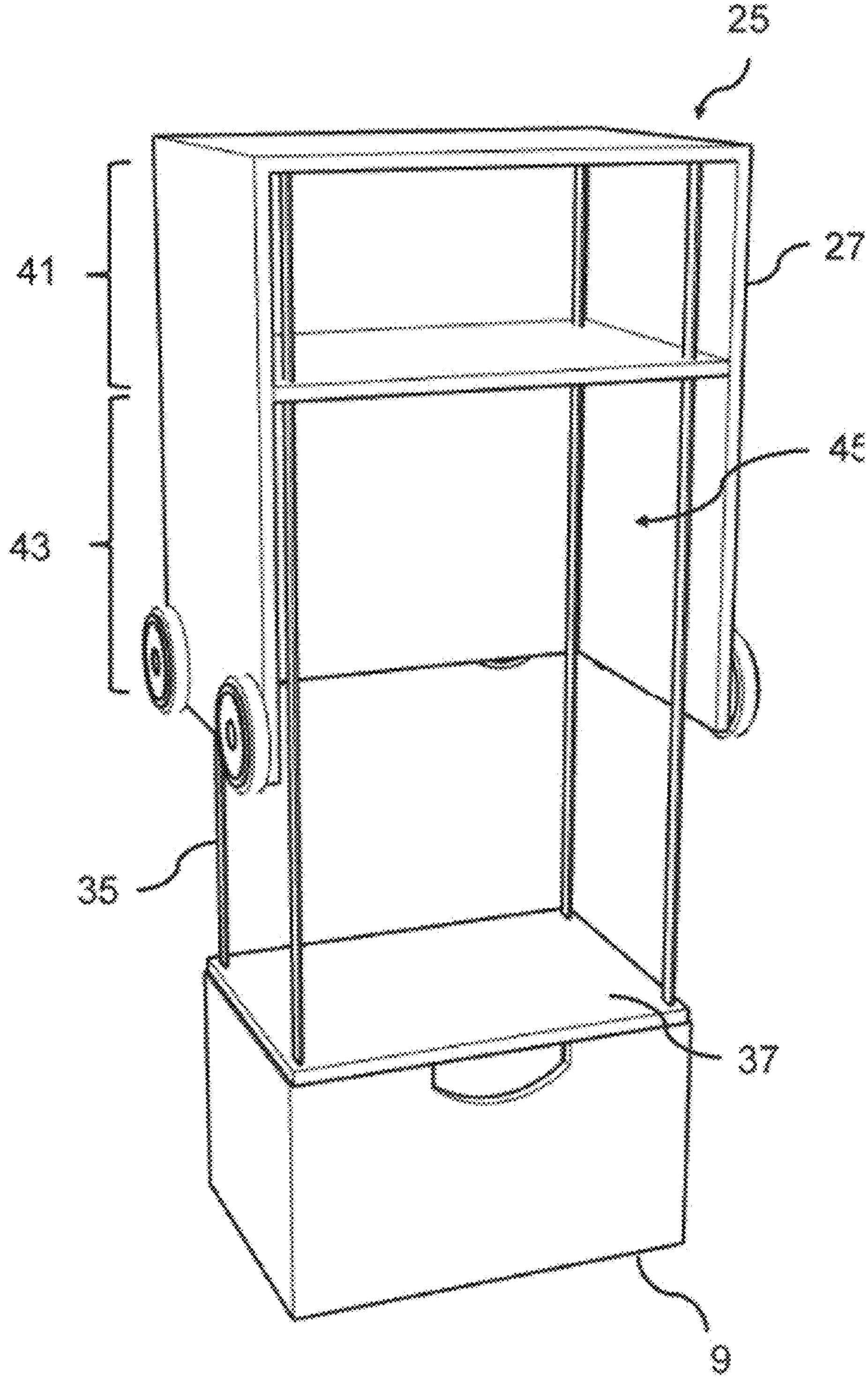


FIG. 5

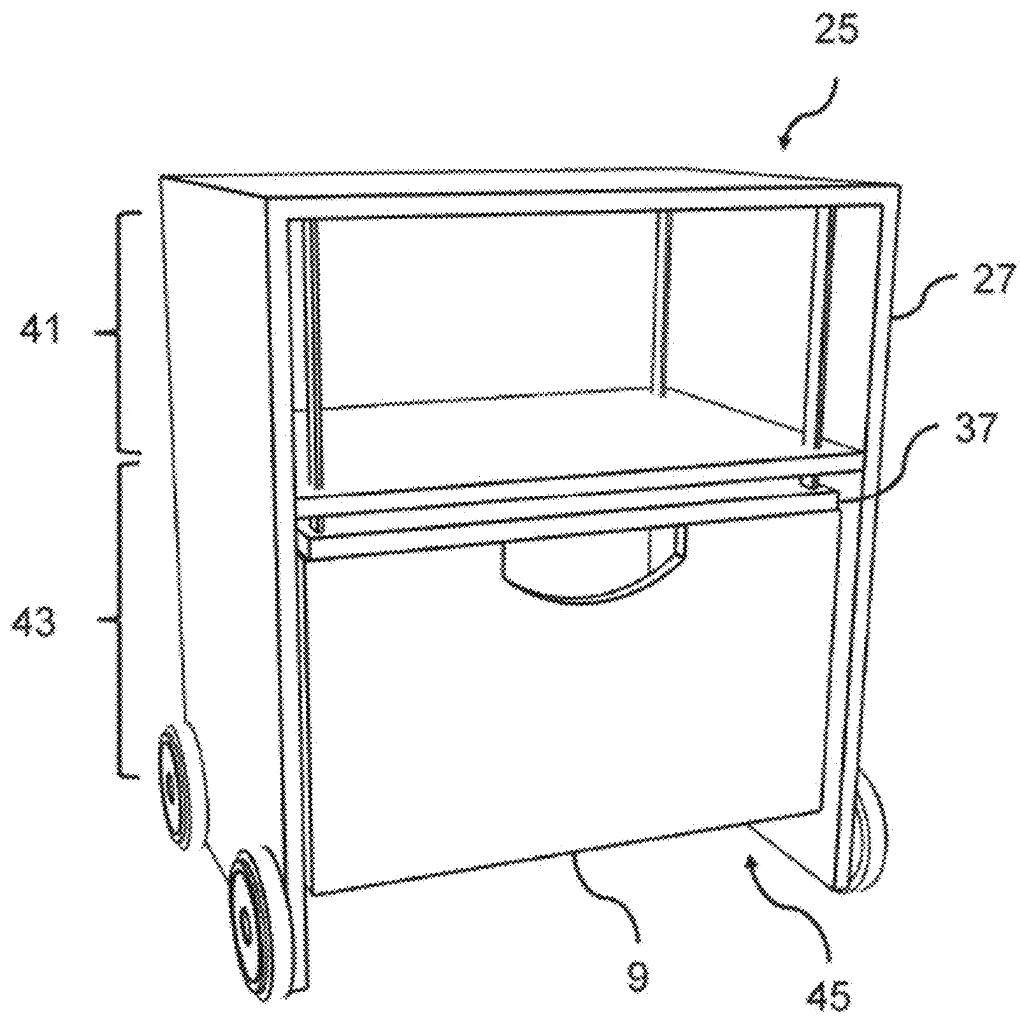


FIG. 6

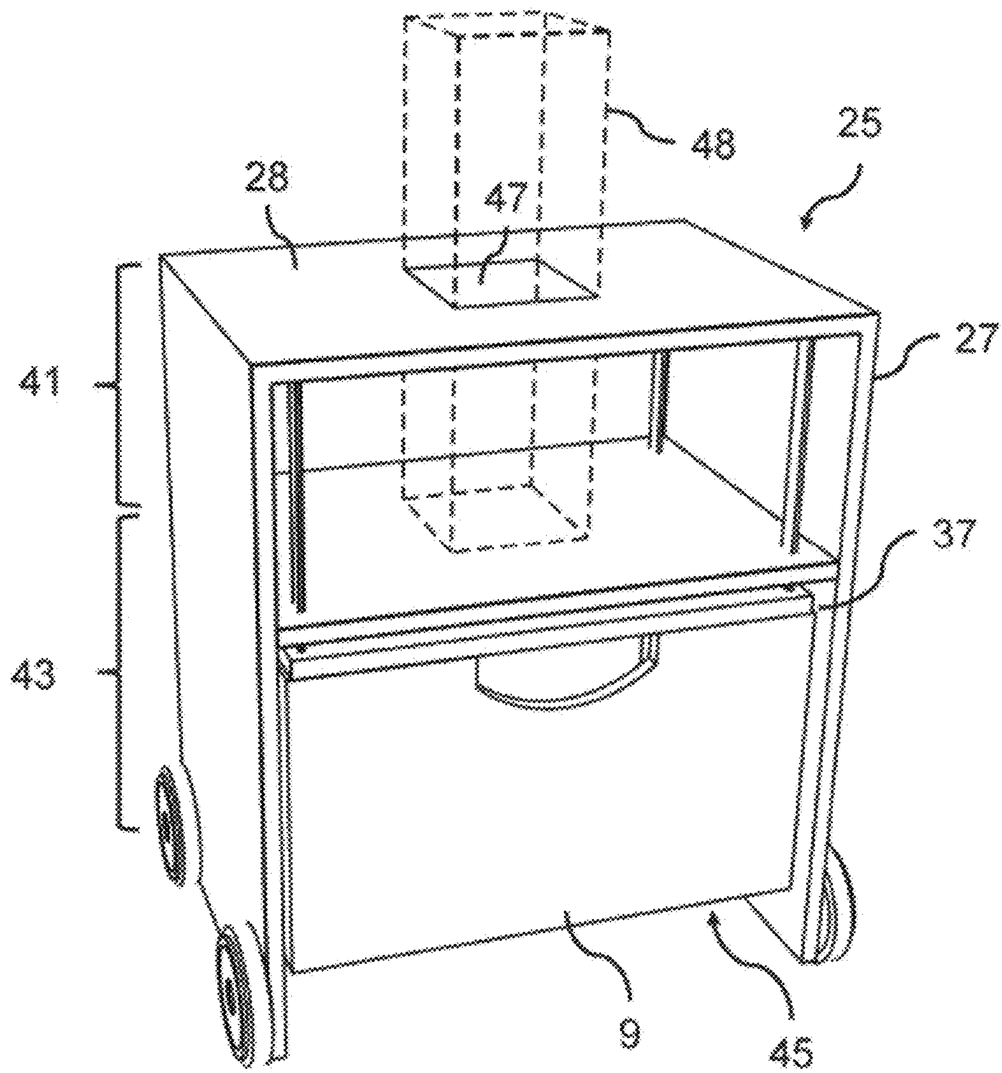


FIG. 7

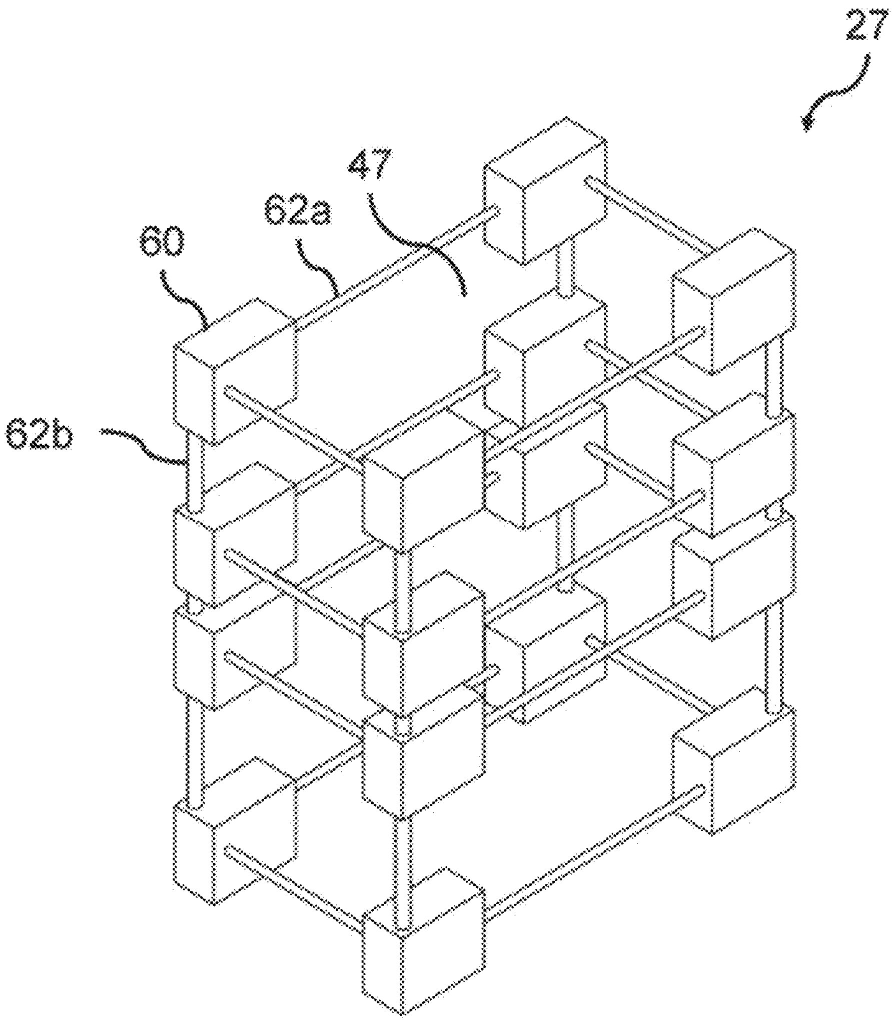


FIG. 8

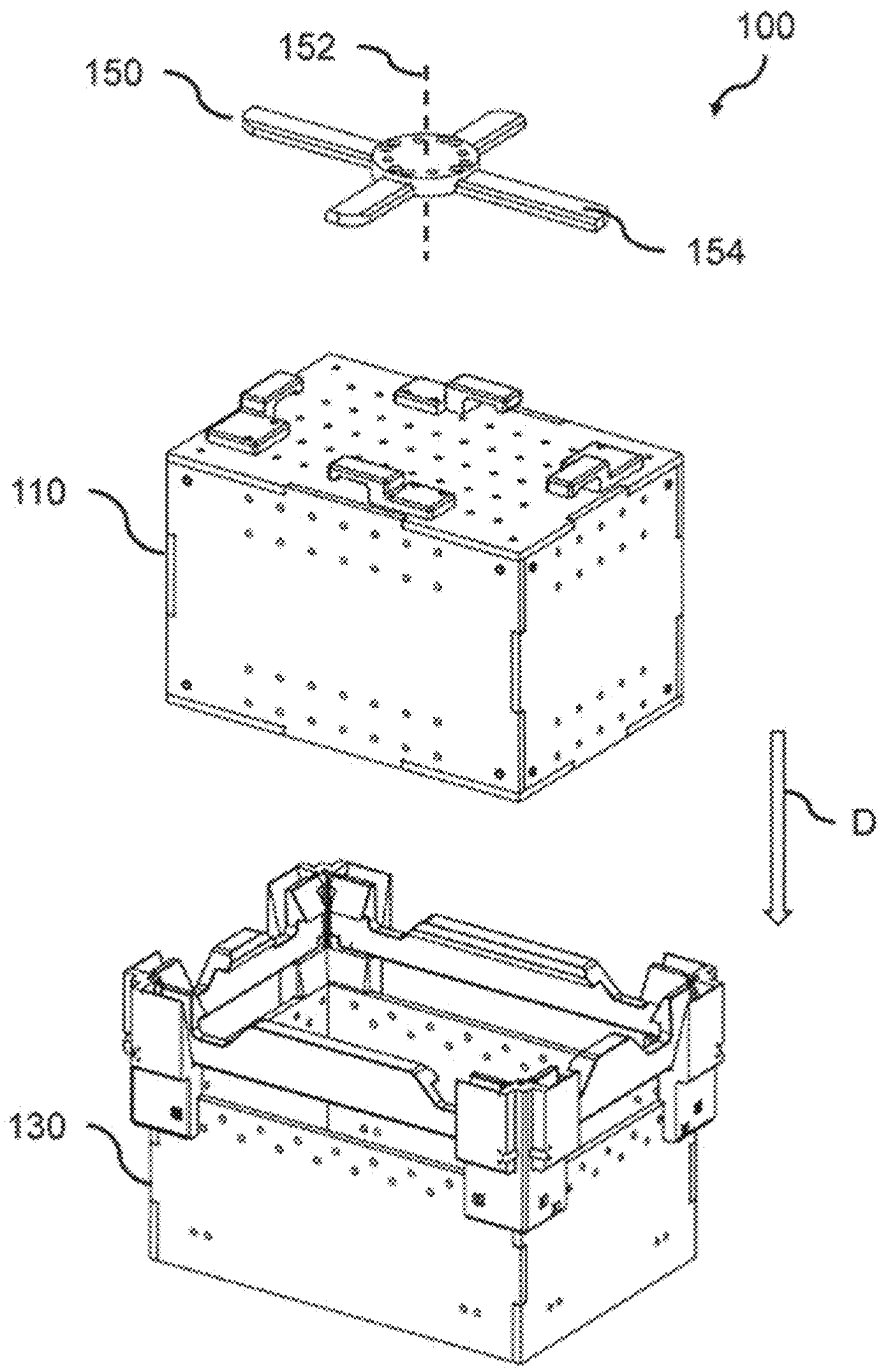


FIG. 9

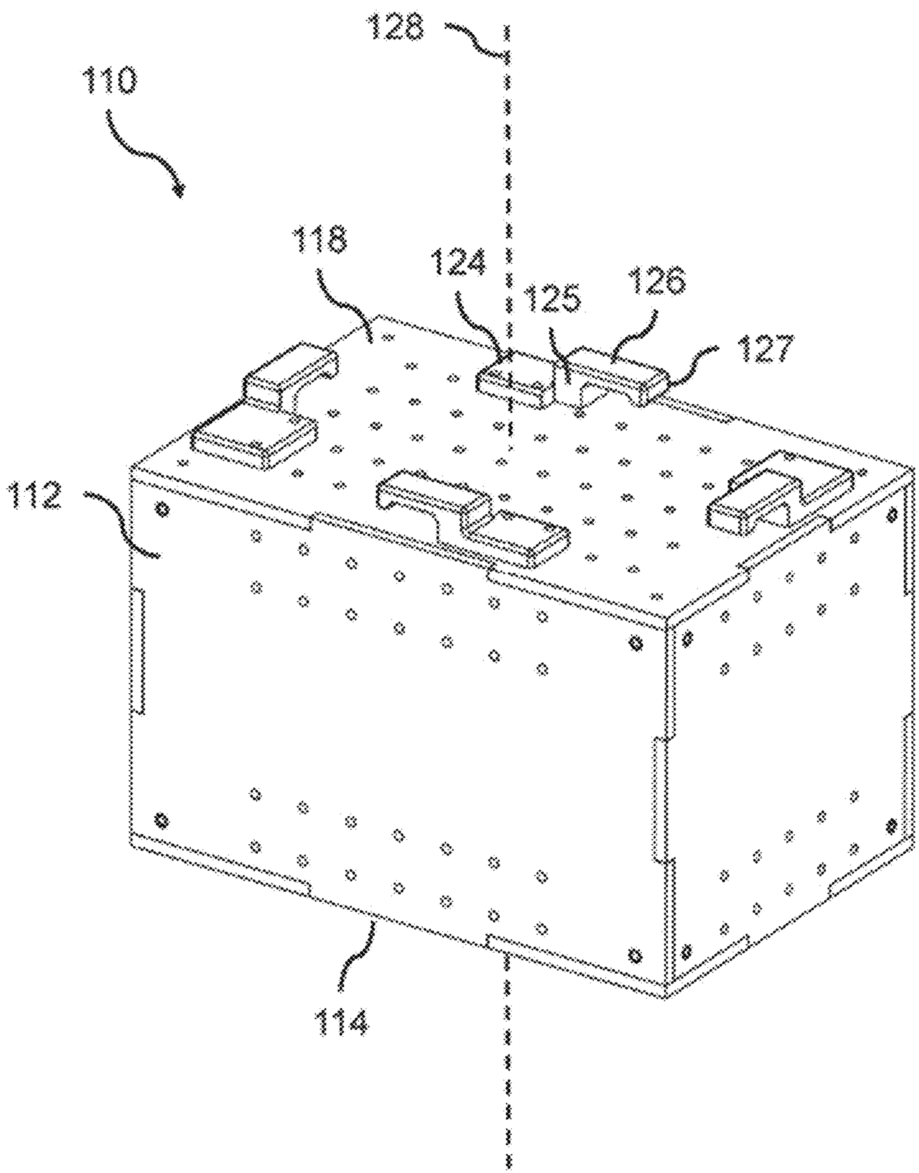


FIG. 10

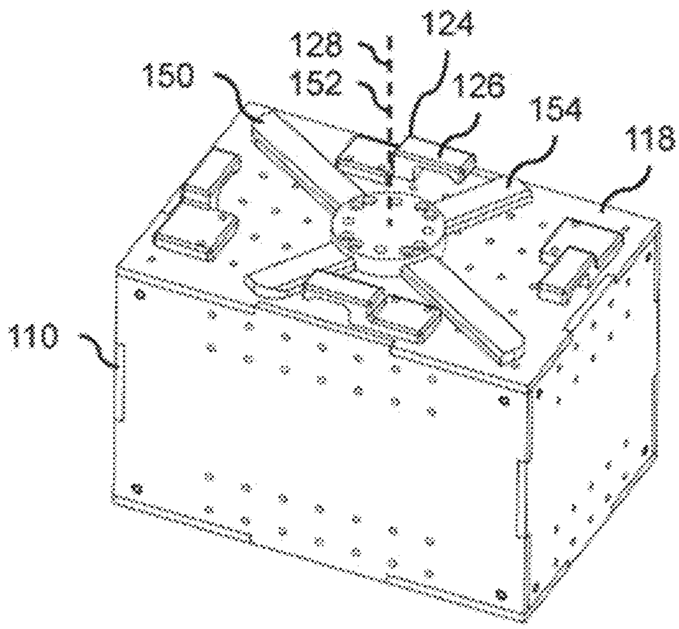


FIG. 11A

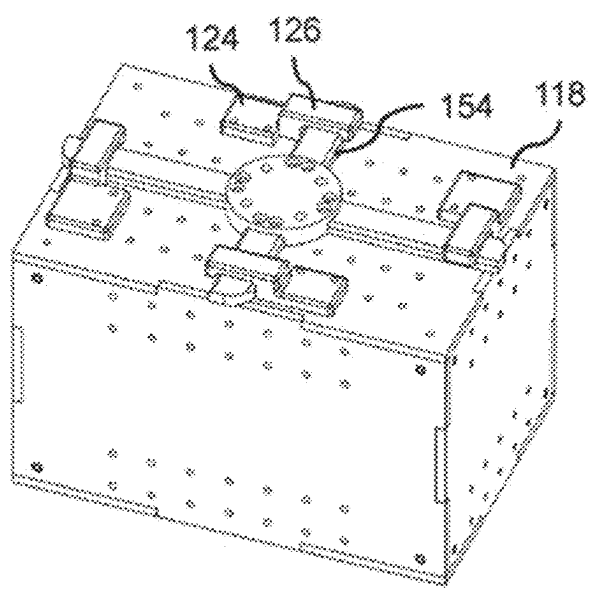


FIG. 11B

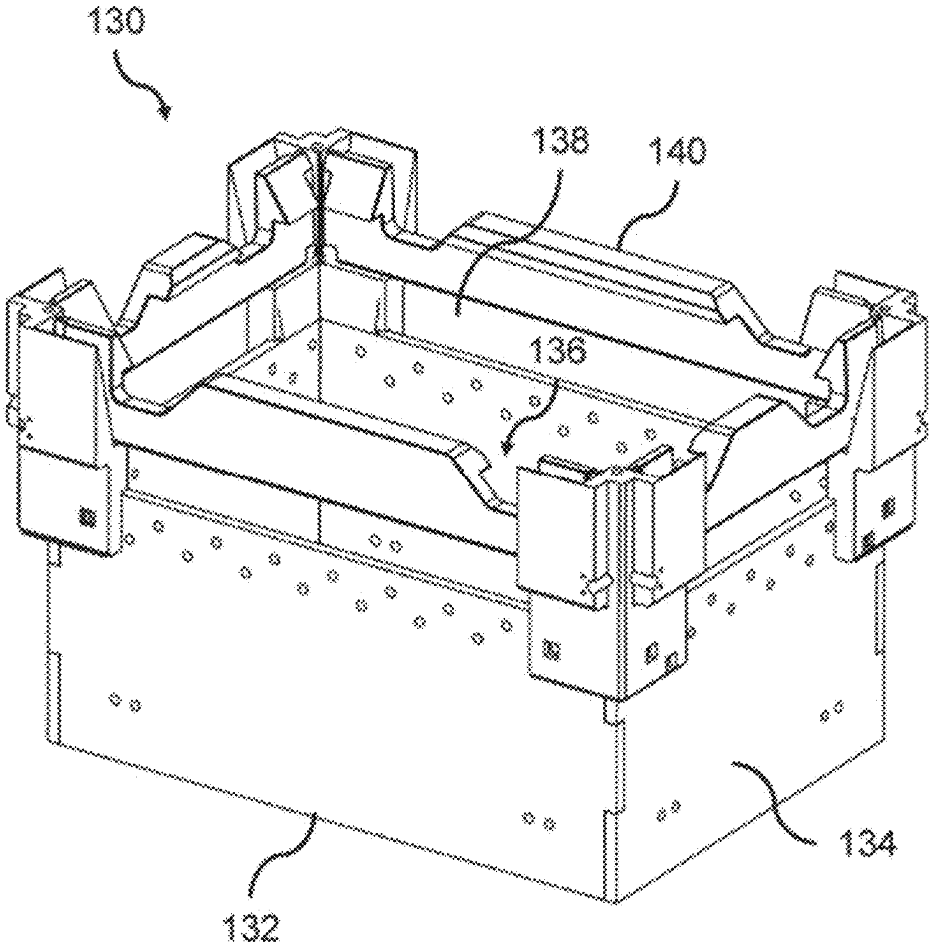


FIG. 12

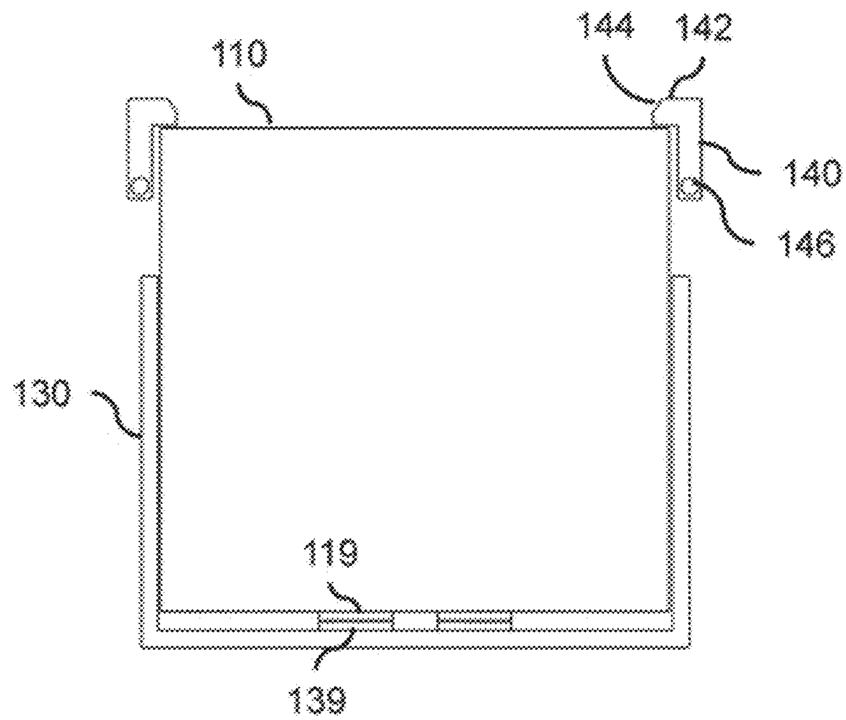


FIG. 13A

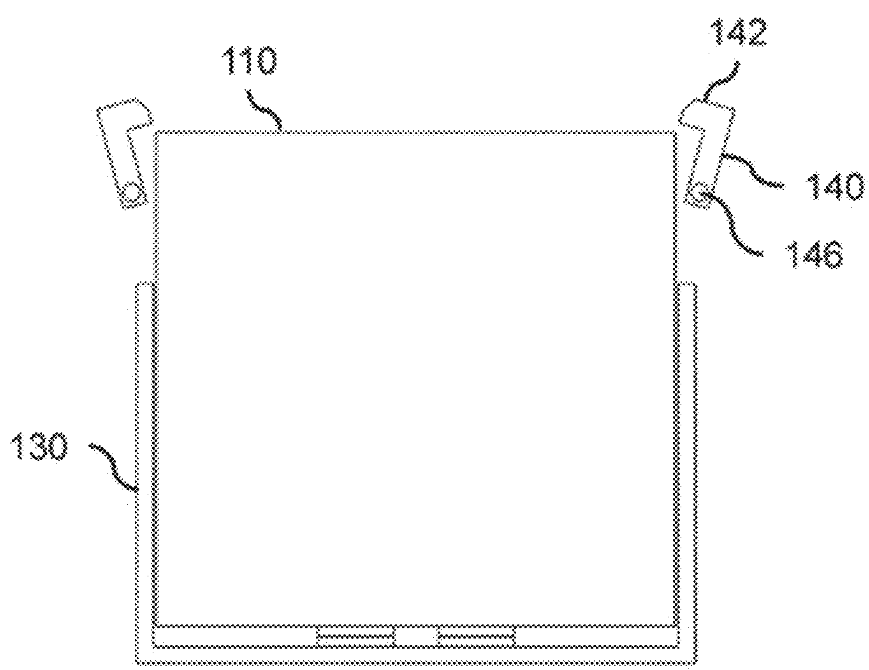


FIG. 13B

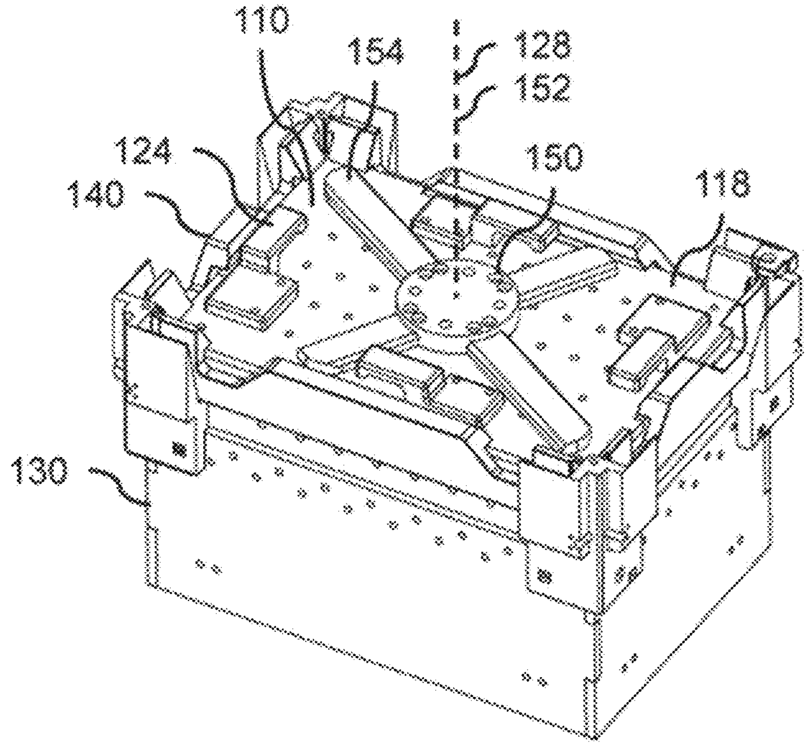


FIG. 14A

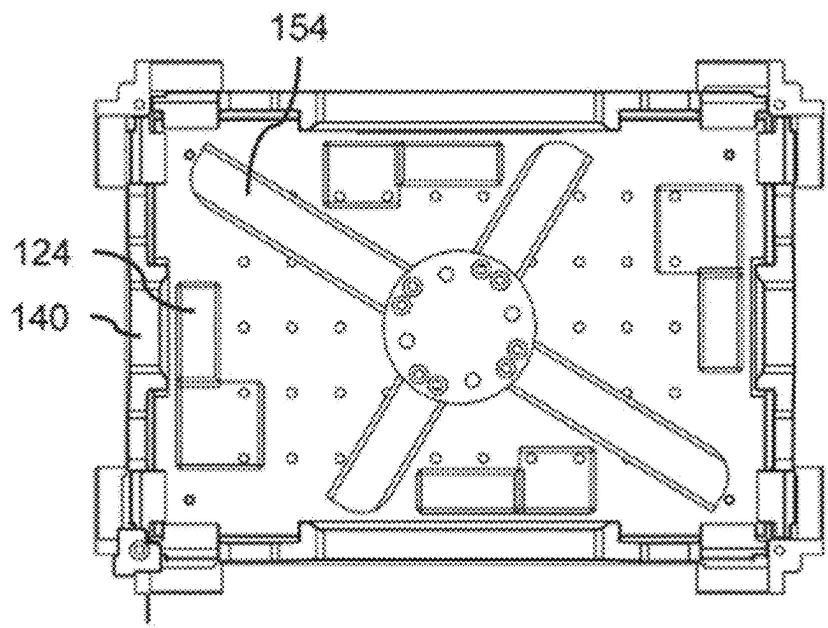


FIG. 14B

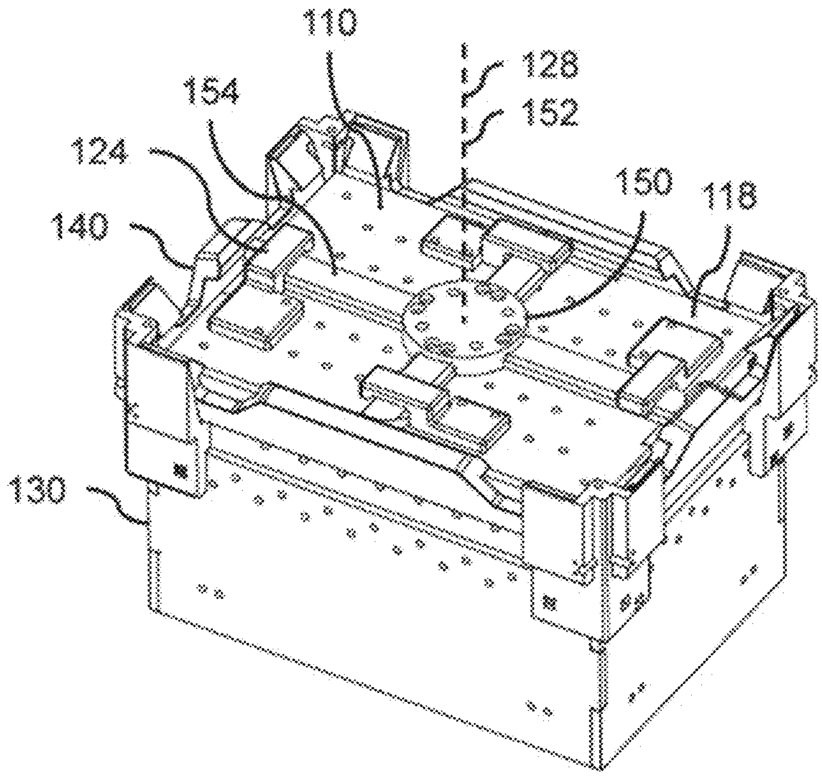


FIG. 15A

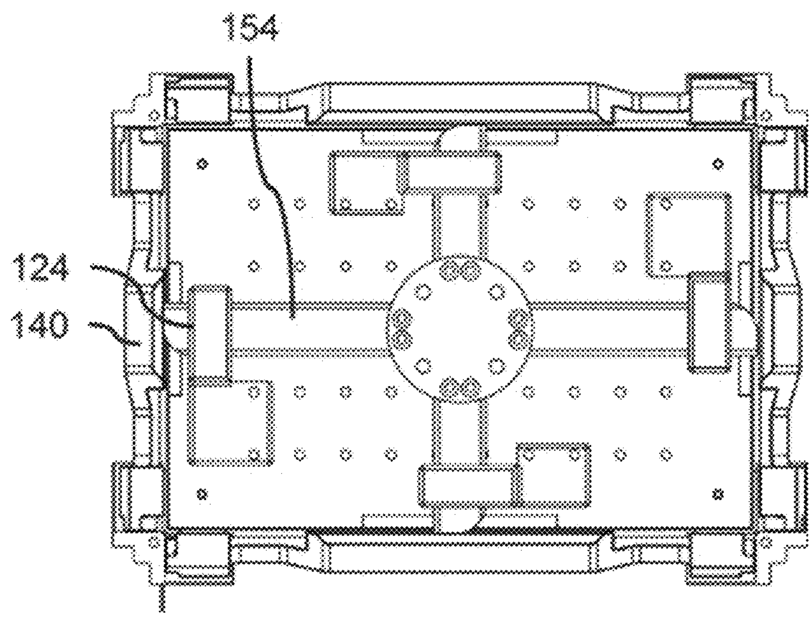


FIG. 15B

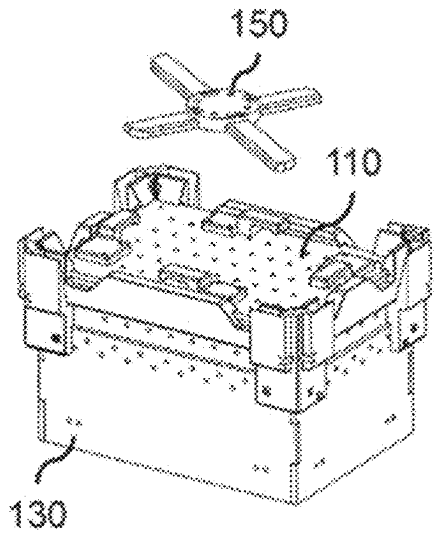


FIG. 16A

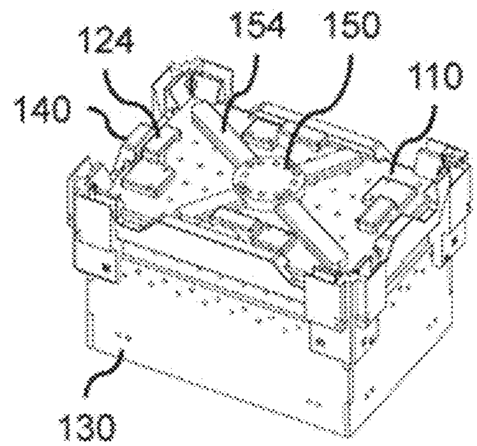


FIG. 16B

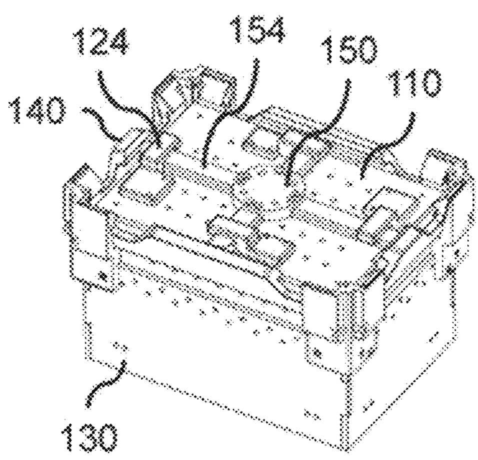


FIG. 16C

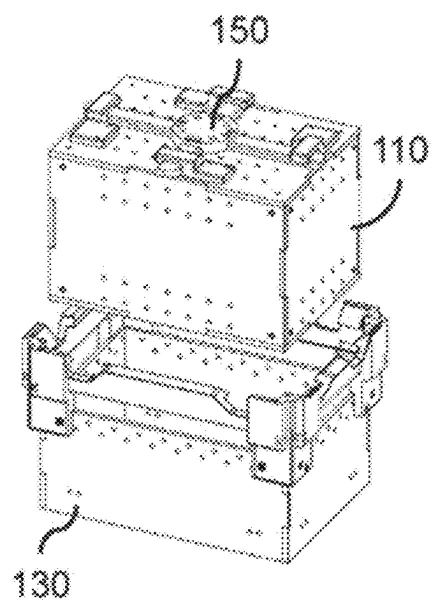


FIG. 16D

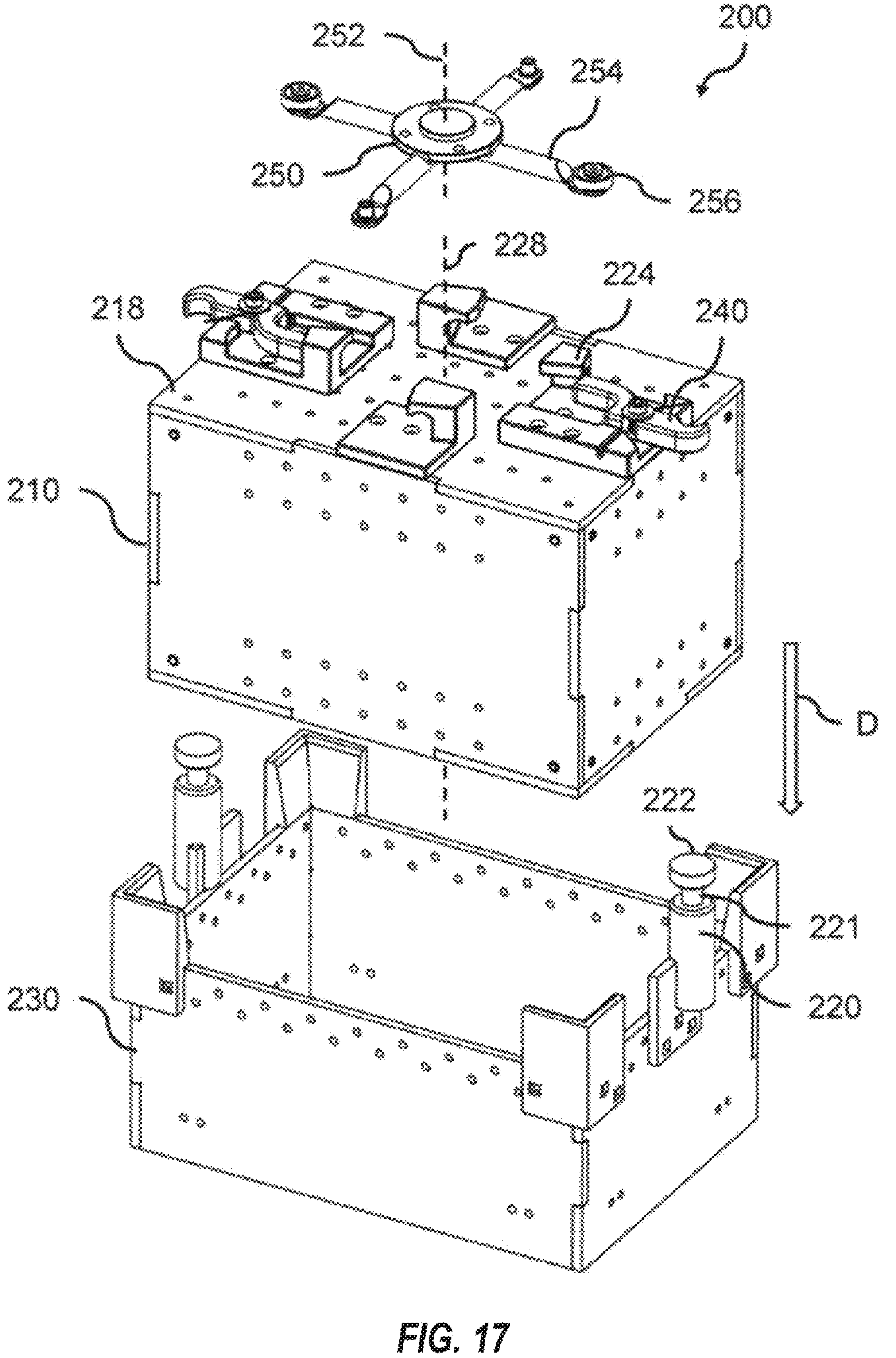


FIG. 17

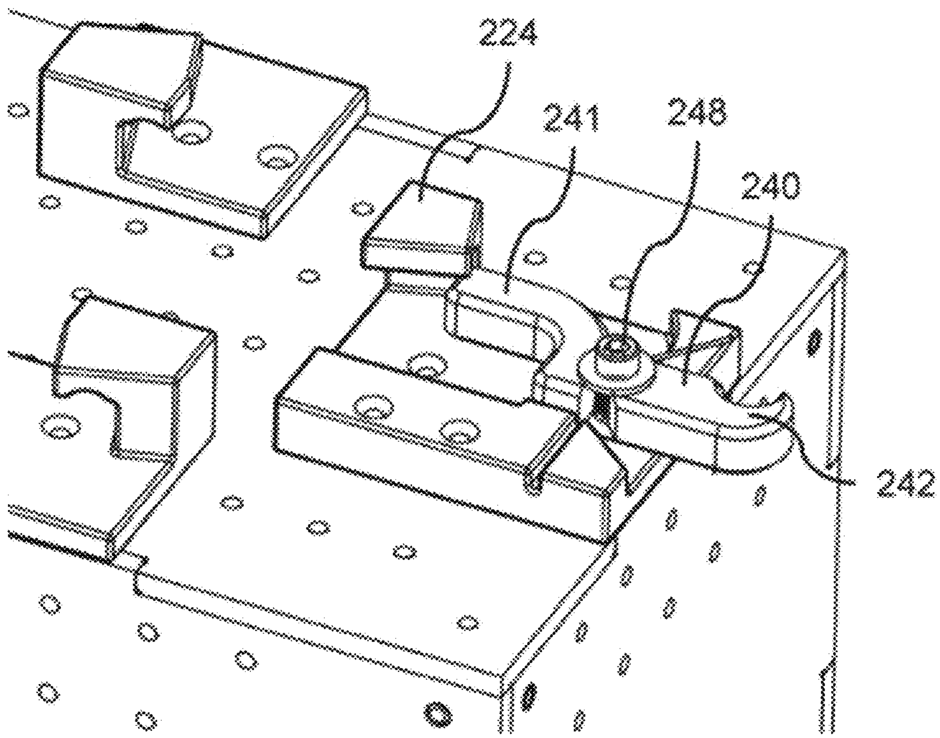


FIG. 18

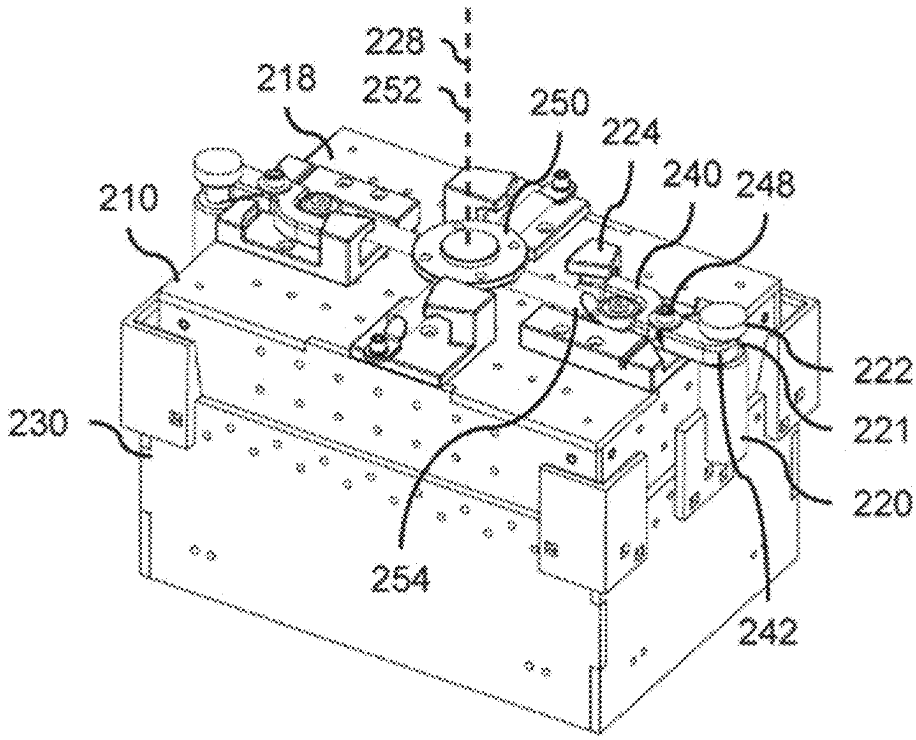


FIG. 19A

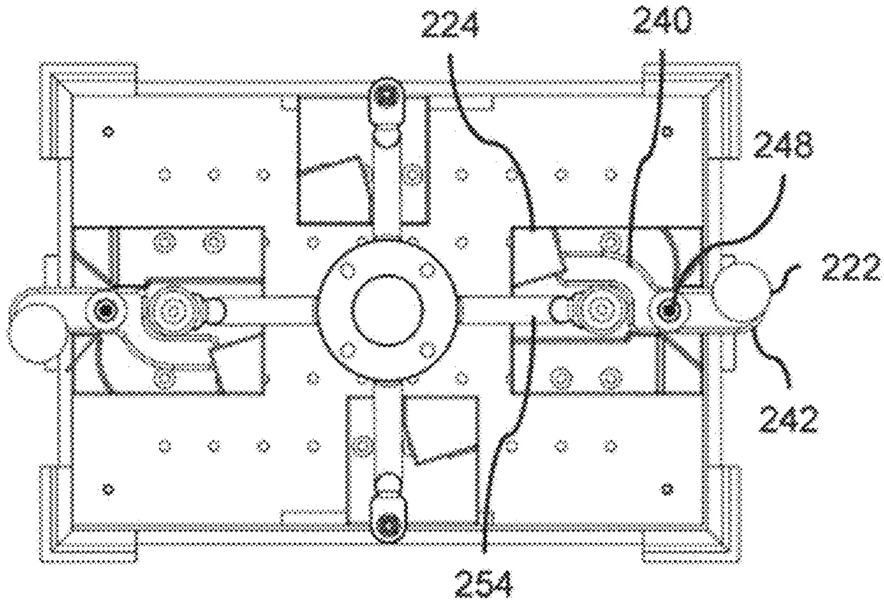


FIG. 19B

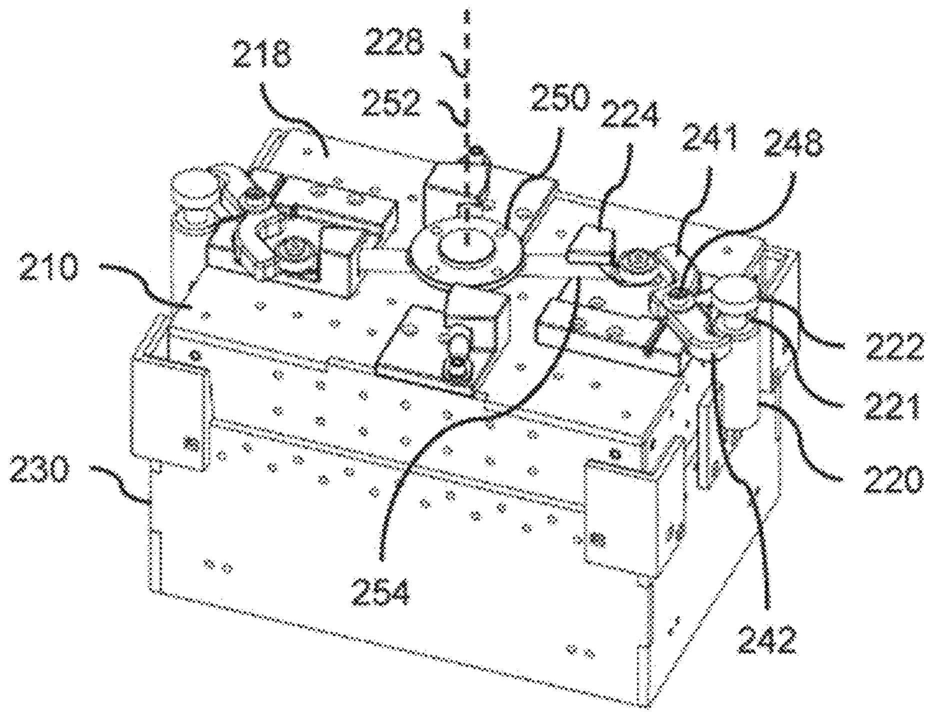


FIG. 20A

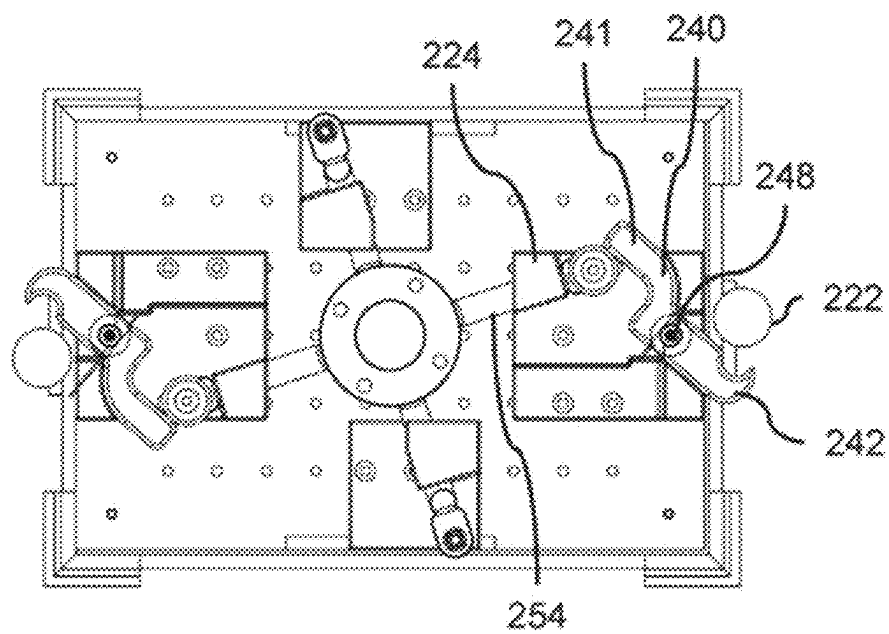


FIG. 20B

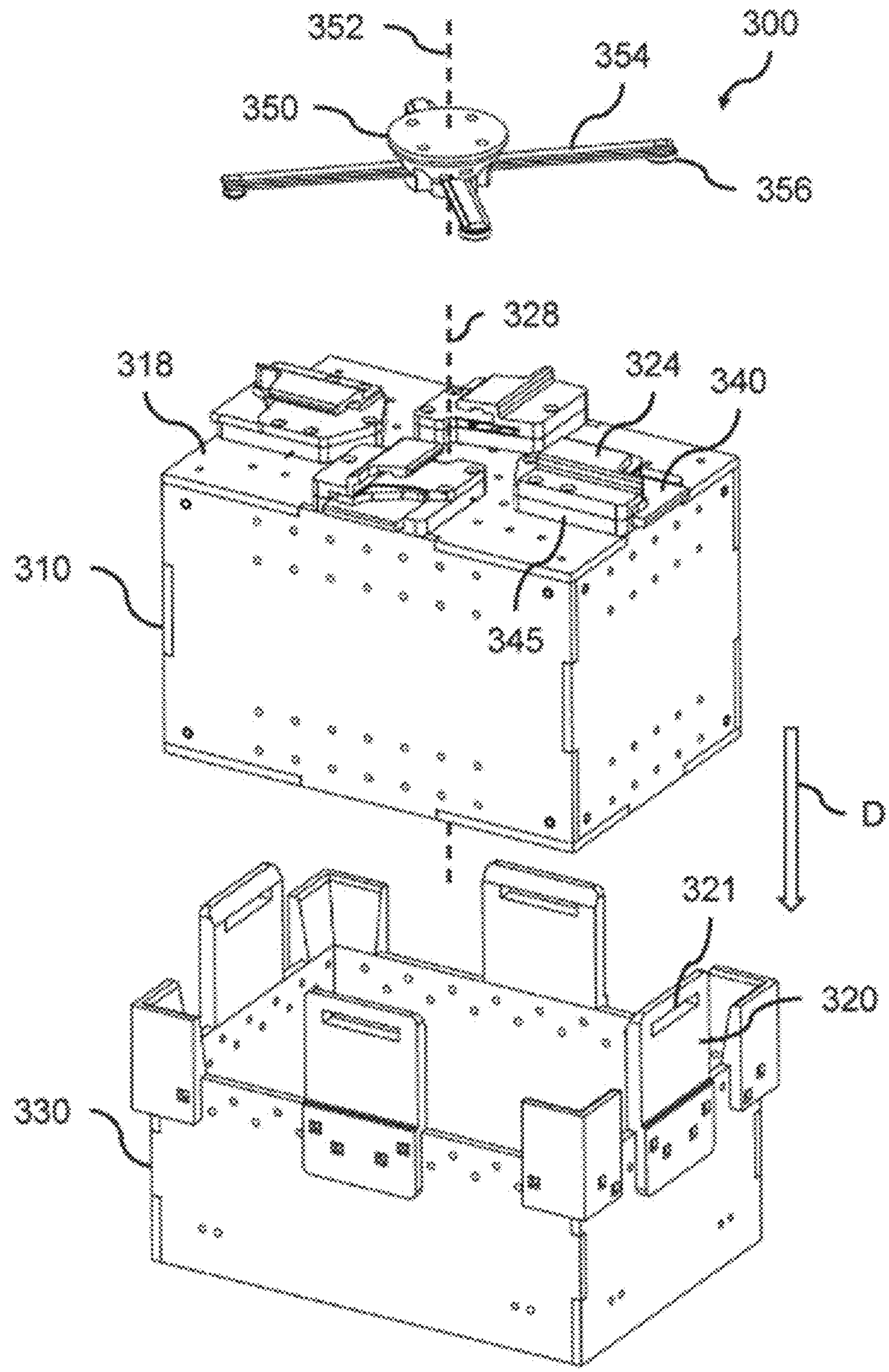


FIG. 21

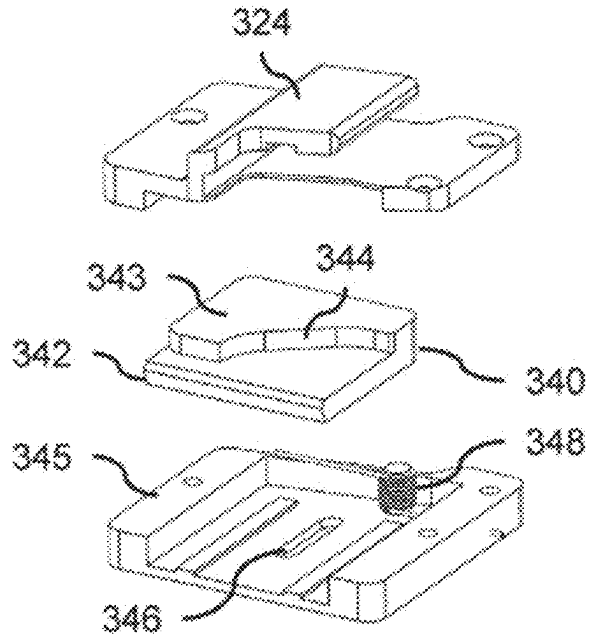


FIG. 22A

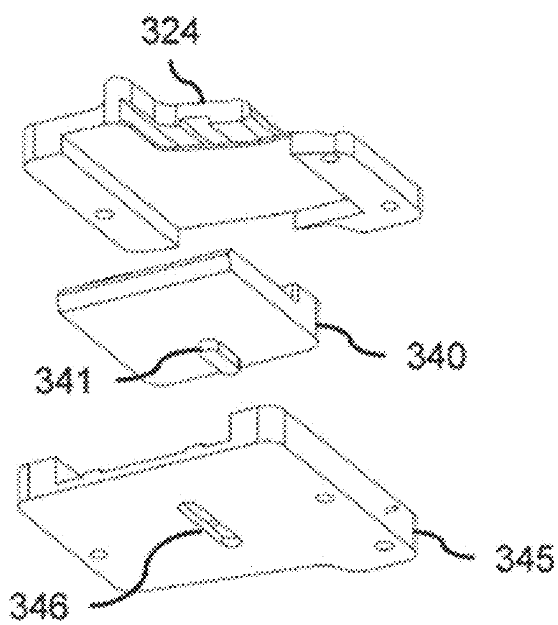


FIG. 22B

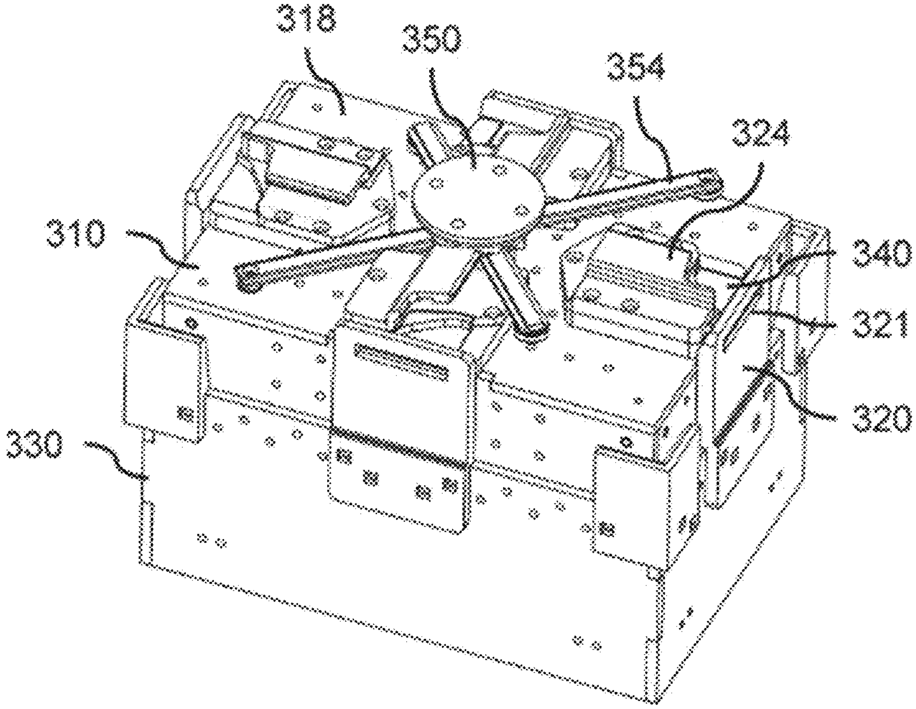


FIG. 23A

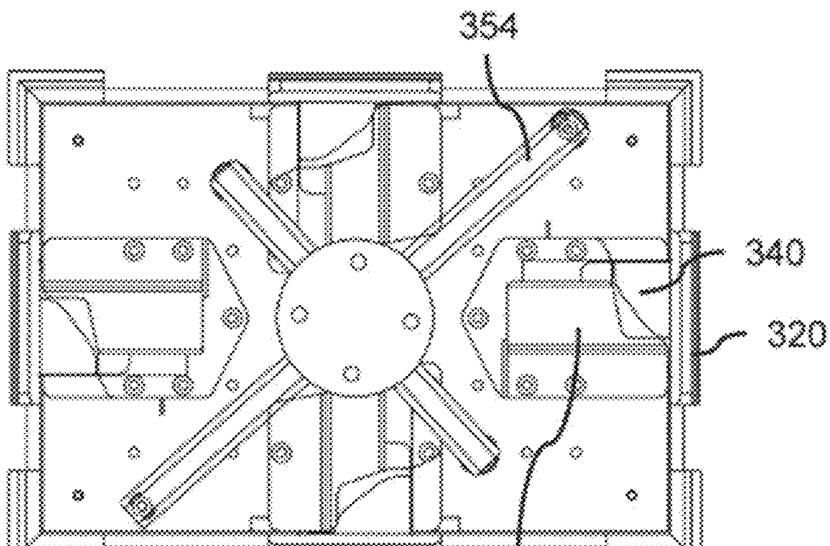


FIG. 23B

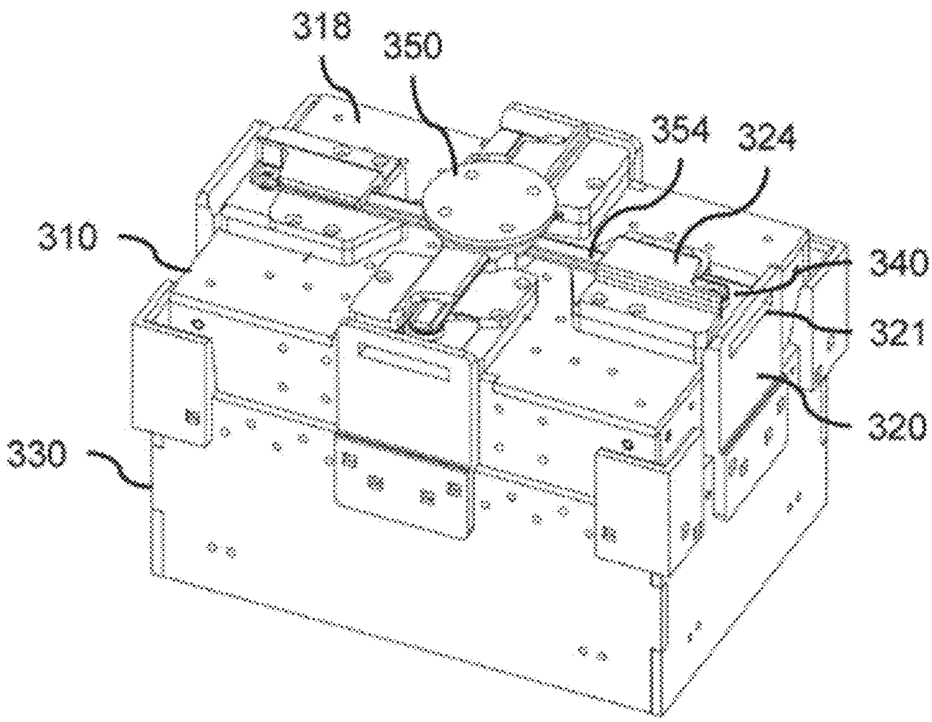


FIG. 24A

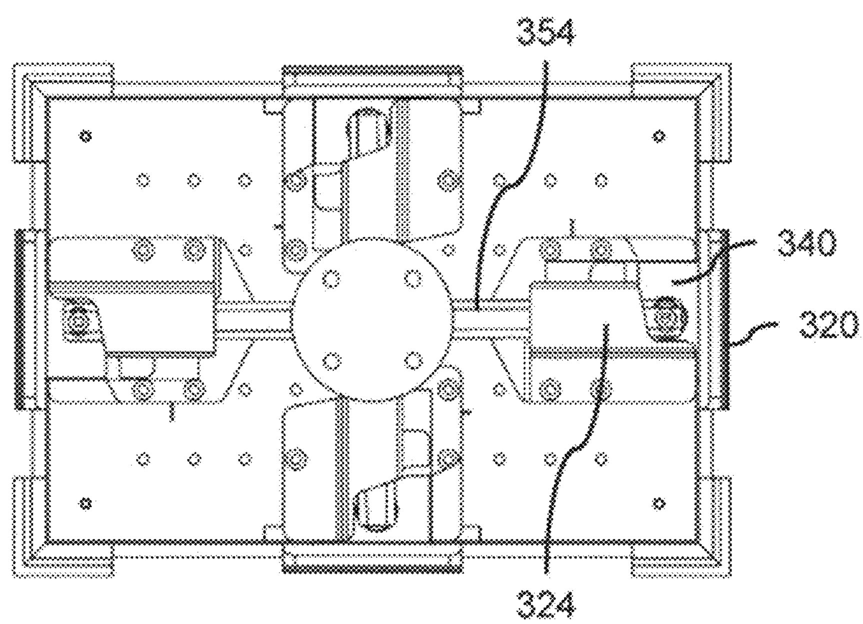


FIG. 24B

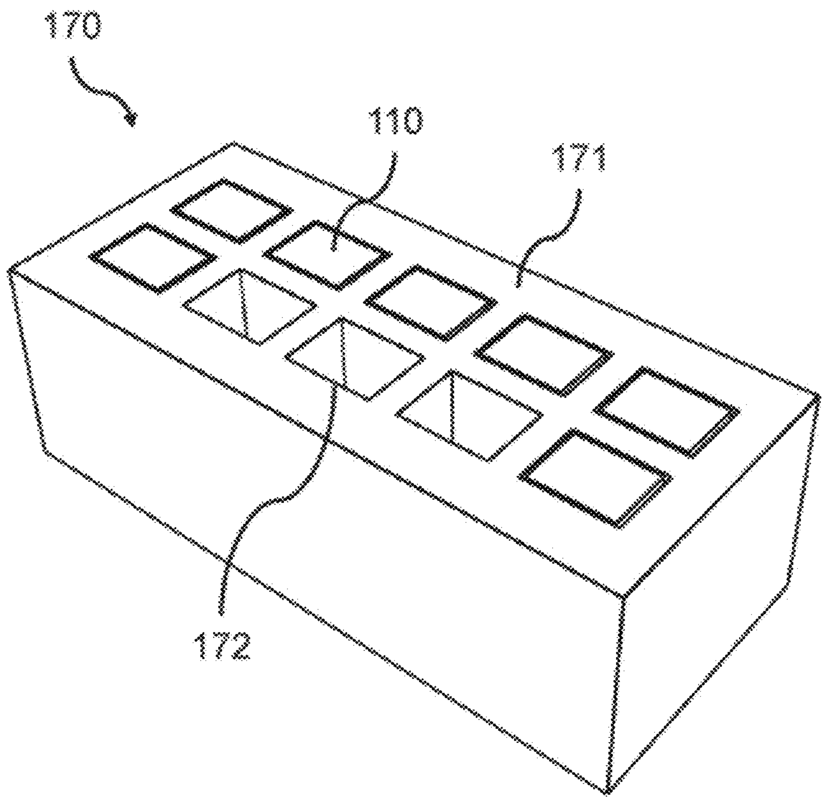


FIG. 25

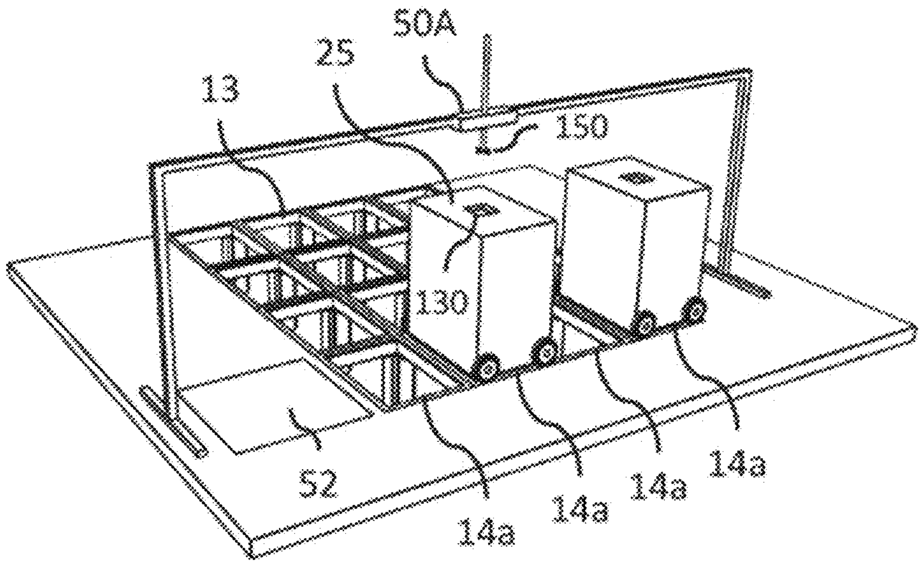


FIG. 26

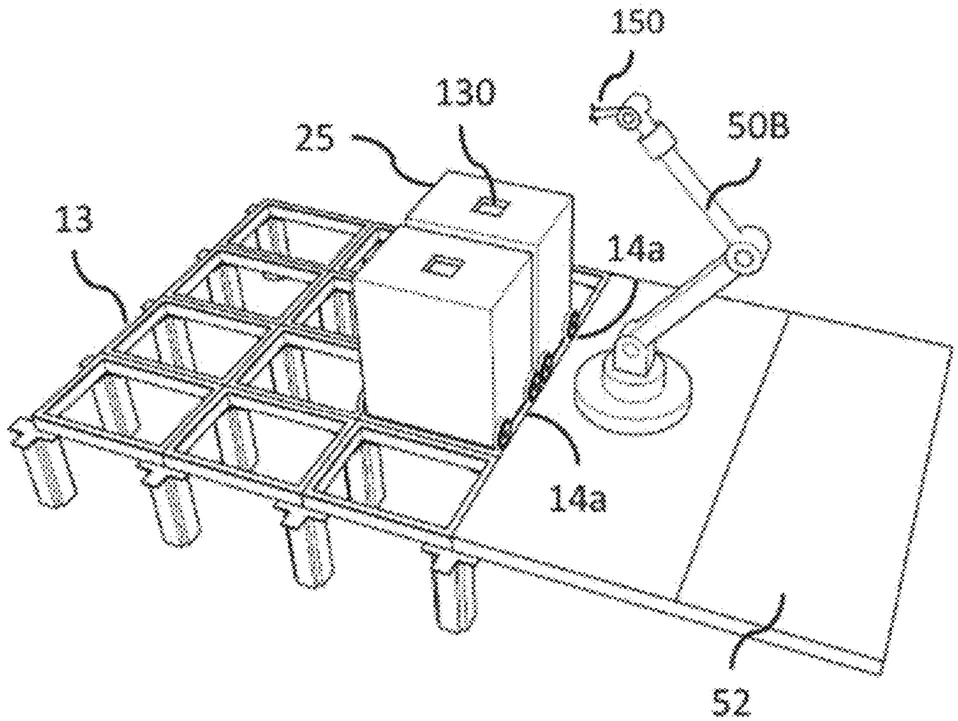


FIG. 27

POWER SOURCE EXCHANGE SYSTEM AND METHOD OF EXCHANGING A POWER SOURCE

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This Application is a continuation of PCT International Patent Application No. PCT/EP2023/081199, filed on Nov. 8, 2023, which claims priority to UK Patent Application No. GB2216843.9, filed Nov. 11, 2022, the entire contents of each of which are hereby incorporated by reference.

TECHNICAL FIELD

[0002] The present invention relates to a power source exchange system and a method for exchanging a power source.

BACKGROUND

[0003] 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 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.

[0004] 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.

[0005] 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.

[0006] A load handling device may encounter bumps, vibrations or even crashes when operating on the tracks of the grid storage structure. For a load handling device powered by an exchangeable battery, it is desirable for the battery to be securely held within the load handling device. It is also desirable to provide an efficient and automated system for exchanging a battery in the load handling device.

SUMMARY

[0007] The invention is defined in the accompanying claims.

[0008] The invention provides a power source exchange system comprising: a compartment configured to removably receive a power source; an end effector rotatable between an engaged position for engagement with the power source in order to move the power source into and out of the compartment, and a release position; and a locking assembly comprising a locking member movable between a locked position for blocking removal of the power source from the compartment and an unlocked position for enabling removal of the power source from the compartment, wherein the end effector and locking assembly are configured such that rotation of the end effector from the release position to the engaged position causes the end effector to move the locking member from the locked position to the unlocked position.

[0009] The invention thus provides a system in which an exchangeable power source can be securely locked in a compartment and in which an end effector can be used to unlock and remove power source in an efficient and automated manner. The end effector is only required to perform a simple rotational movement to simultaneously unlock the power source and be in a position for engaging the power source to remove the power source from the compartment.

[0010] In the release position, the end effector may be disengaged from the power source to allow the end effector to move away from the power source, e.g. in a direction parallel to an insertion direction in which the power source is inserted into the compartment.

[0011] The compartment may comprise the locking member. The compartment may define a power-source-receiving space for receiving the power source and the locking member may be configured to overhang the power-source-receiving space in the locked position in order to block removal of the power source from the compartment. In other words, when the power source is within the compartment, the locking member protrudes over the power source to block removal of the power source. The end effector may be configured such that when the end effector is in the engaged position, the end effector extends past the power-source-receiving space to enable the end effector to move the locking member to the unlocked position. The locking member may comprise a tapered surface configured such that movement of the power source into the compartment moves the locking member from the locked position to the unlocked position to allow the power source to be received into the compartment.

[0012] The power source exchange system may further comprise a power source.

[0013] The power source may comprise the locking member. The compartment may be configured to engage with the locking member when the locking member is in the locked position in order to block removal of the power source from the compartment. For example, the compartment may comprise a blocking member configured to engage with the locking member when the locking member is in the locked position in order to block removal of the power source from the compartment. The power source may comprise an end wall exposed to the end effector when the power source is within the compartment. The end wall may be oriented perpendicular to an insertion direction in which the power source is received into the compartment. The locking member may be mounted on the end wall.

[0014] The power source may comprise one or more handling members. Each handling member may be configured to receive a respective portion of the end effector when the end effector is rotated from the release position to the engaged position. The respective portions of the end effector may be received by each handling member in a circumferential direction. Each handling member may be further configured to engage the respective portion of the end effector to enable the end effector to move the power source into and out of the compartment. Each handling member may engage the respective portion of the end effector in a direction parallel to an insertion direction in which the power source is received into the compartment. In the release position, the respective portions of the end effector may exit the handling members (move away from the handling members in a circumferential direction) such that the end effector can no longer engage the handing members in a direction parallel to an insertion direction in which the power source is received into the compartment. The power source may comprise an end wall exposed to the end effector when the power source is within the compartment. The end wall may be oriented perpendicular to the insertion direction. The one or more handling members may be mounted on the end wall.

[0015] The power source may comprise a plurality of handling members and the plurality of handling members may be arranged at different angular positions about a longitudinal axis, i.e. they are spaced in the circumferential direction about a longitudinal axis. The longitudinal axis may be an axis orientated parallel to the insertion direction when the power source is received into the compartment. The plurality of handling members may be spaced at substantially equal angular intervals about the longitudinal axis, i.e. the interval between the angular positions of the handling members may be substantially equal. The handling members may be arranged in substantially the same plane. The plane may be orientated substantially perpendicular to the longitudinal axis. The handling members may be configured to receive respective portions of the end effector in the same circumferential direction. The power source may comprise at least one pair of handling members diametrically opposed about the longitudinal axis. The power source may comprise four handling members arranged at 90 degree intervals about the longitudinal axis.

[0016] The power source may be a battery. The battery may be a rechargeable battery.

[0017] The power source compartment may be configured to electrically couple to the power source (automatically) when the power source is received in the compartment. The power source may comprise an electrical connector and the compartment may comprise a corresponding electrical connector. The electrical connector of the power source and the corresponding electrical connector of the compartment may be configured to electrically couple (automatically) when the power source is received into the compartment.

[0018] The locking assembly may further comprise biasing means configured to apply a biasing force for biasing the locking member to the locked position. The end effector and the locking assembly may be further configured such that rotation of the end effector from the engaged position to the release position allows the biasing force to return the locking member to the locked position. The end effector may be disengaged from the locking member in the release position. The biasing means may be a spring, e.g. a torsion spring, a compression spring or an extension spring. The end effector is therefore only required to perform a simple rotational movement to simultaneously release and lock the power source in the compartment.

[0019] The end effector and the locking assembly may be configured such that when the end effector is in the engaged position, the locking member is held in the unlocked position by the end effector.

[0020] The locking member may be linearly movable between the locked position and the unlocked position. The locking member may be linearly movable between the locked position and the unlocked position in a direction substantially perpendicular to an insertion direction in which the power source is received into the compartment. Alternatively, the locking member may be pivotally mounted for rotation between the locked position and the unlocked position. The pivot axis may be orientated parallel to the insertion direction. The pivot axis may be orientated perpendicular to the insertion direction.

[0021] The locking assembly may comprise a plurality of locking members. The locking assembly and the end effector may be configured such that rotation of the end effector from the release position to the engaged position causes the end effector to move each locking member from the locked position to the unlocked position.

[0022] The plurality of locking members may be arranged at different angular positions about a longitudinal axis, i.e. they are spaced in the circumferential direction about a longitudinal axis. The longitudinal axis may be an axis orientated parallel to the insertion direction when the power source is received into the compartment. The plurality of locking members may be spaced at substantially equal angular intervals about the longitudinal axis, i.e. the interval between the angular positions of the locking members may be substantially equal. The locking members may be arranged in substantially the same plane. The plane may be orientated substantially perpendicular to the longitudinal axis. The longitudinal axis may be an axis orientated parallel to the insertion direction when the power source is received into the compartment. The locking assembly may comprise at least one pair of locking members diametrically opposed about the longitudinal axis. The locking assembly may comprise four locking members arranged at 90 degree intervals about the longitudinal axis. In the case where the power source also comprises a plurality of handling members, the angular positions of at least a subset of the handling members and the angular positions of at least a subset of the locking members may be substantially the same with respect to a common longitudinal axis.

[0023] The end effector may comprise a plurality of engagement members. In the case where the locking assembly comprises a plurality of locking members, the engagement members may be arranged such that when the end effector is rotated from the release position to the engaged position about a rotational axis, each particular engagement member moves to a position for engagement with the power source and/or moves one of the locking members from the locked position to the unlocked position. In the case where the power source comprises a plurality of handling members and a plurality of locking members, the engagement members may be arranged such that when the end effector is rotated from the release position to the engaged position, each particular engagement member is received by one of the handling members and/or moves one of the locking members from the locked position to the unlocked position. When the end effector is in the release position, the angular positions of the engagement members may be between the angular positions of the locking members and between the angular positions of the handling members with respect to a common longitudinal axis. Put another way, the engagement members may lie between the handling members and between the locking members in a circumferential direction with respect to a common longitudinal axis.

[0024] The engagement members may be positionally fixed with respect to each other. In other words, the engagement members may not be movable relative to each other. The engagement members may extend in a radial direction with respect to the rotational axis. The engagement members may be arranged substantially in a plane orientated perpendicular to the rotational axis. The engagement members may be arranged at different angular positions about the rotational axis, i.e. they are spaced in the circumferential direction about a longitudinal axis. The engagement members may be spaced at substantially equal angular intervals about the rotational axis, i.e. the interval between the angular positions of the engagement members may be substantially equal. The end effector may comprise at least one pair of engagement members extending in opposite radial directions with respect to the rotational axis. The end effector may comprise four engagement members arranged at 90 degree intervals about the rotational axis to form a substantially cruciform shape. In this case, the power source may comprise four handling members arranged at 90 degree intervals about a longitudinal axis and/or the locking assembly may comprise four locking members arranged at 90 degree intervals about a longitudinal axis. In another example, the power source may comprise four handling members arranged at 90 degree intervals about a longitudinal axis and the locking assembly may comprise a pair of locking members diametrically opposed about a longitudinal axis. In another example, the power source may comprise a pair of handling members diametrically opposed about a longitudinal axis and the locking assembly may comprise four locking members arranged at 90 degree intervals about a longitudinal axis.

[0025] The end effector may be configured such that a rotational axis of the end effector is orientated parallel to the insertion direction of the power source when rotating between the engaged and release positions. The rotational axis may be concentric with the longitudinal axis about which the handling members and/or the locking members are arranged when rotating between the engaged and release positions.

[0026] The compartment may be configured to receive the power source in a downwards direction.

[0027] The compartment may be configured to receive the power source in a horizontal direction.

[0028] The end effector may be mounted on a robotic arm configured to move and rotate the end effector between the engaged position and the release position. The robotic arm may, for example, be a gantry robot, a Cartesian robot or an articulated robot.

[0029] The power source exchange system may further comprise a power source station. The power source station may comprise a plurality of power source bays, each power source bay being configured to receive the power source. The end effector may be further configured to move the power source between the compartment and any of the power source bays of the power source station. Each power source bay may be configured to charge the power source once received in the power source bay.

[0030] The power source exchange system may further comprise a device. The device may comprise the compartment and one or more electrical and/or electronic components. The compartment may be configured to deliver power from the power source to the one or more electrical and/or electronic components once the power source is received into the compartment.

[0031] The power source exchange system may further comprise a load handling device for lifting and moving containers arranged in stacks in a storage structure. The storage structure may comprise a track structure. The track structure may comprise a first set of tracks and a second set of tracks. The first set of tracks may extend in a first direction and the second set of tracks may extend in a second direction. The second direction may be 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 may comprise: a driving assembly configured to move the load handling device on the track structure; a container-holding device configured to releasably hold a container from above; and a lifting mechanism configured to raise and lower the container-holding device.

[0032] The load handling device may further comprise the compartment. The compartment may be configured to deliver electrical power to one or more electrical or electronic components of the load handling device once the power source is received into the compartment. The one or more electrical and/or electronic components may include one or more of: the driving assembly, the container-holding device and the lifting mechanism.

[0033] The compartment may be externally exposed such that the compartment is externally accessible to the end effector to allow the end effector to move the power source into and out of the compartment. The compartment may be located at least partially within an external body of the load handling device. The compartment may extend out of the external body of the load handling device.

[0034] The present invention also provides 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; and a plurality of upright members configured to support the track structure from below to define a storage area below the track structure for storing a plurality of stacks of containers below each grid cell; and wherein the storage and retrieval system further comprises the power source exchange system as defined above.

[0035] The end effector may be mounted on a robotic arm located on, or above, or adjacent to the track structure such that the end effector can move a power source into and out of the compartment of a load handling device located on the track structure.

[0036] The present invention also provides a method of inserting the power source into the compartment of the power source exchange system or storage and retrieval system defined above. The method comprises the steps of: moving the power source into the compartment using the end effector in the engaged position; and rotating the end effector from the engaged position to the release position.

[0037] The present invention also provides a method of removing the power source from the compartment of the power source exchange system or storage and retrieval system defined above. The method comprises the steps of:

rotating the end effector from the release position to the engaged position; and moving the power source out of the compartment using the end effector.

[0038] The present invention also provides a method of exchanging a first power source for a second power source in the compartment of the power source exchange system as defined above. The method comprises the steps of: rotating the end effector from the release position to the engaged position; moving the first power source out of the compartment using the end effector; inserting the second power source into the compartment using the end effector in the engaged position; and rotating the end effector from the engaged position to the release position.

[0039] The second power source may have a higher charge level than the first power source at the point when the first power source is moved out of the compartment.

DESCRIPTION OF THE DRAWINGS

[0040] The present invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

[0041] FIG. **1** is a schematic perspective view of a grid storage structure and containers arranged within the grid storage structure.

[0042] FIG. **2** is a schematic plan view of a track structure on top of the storage structure of FIG. **1**.

[0043] FIG. **3** shows load handling devices on top of the track structure of the storage structure of FIG. **1**.

[0044] FIG. **4** is a schematic perspective view of a load handling device with a container-holding device in a position below the bottom of the load handling device.

[0045] FIG. **5** is a schematic perspective view of the load handling device of FIG. **4** with a side panel removed to show a container-receiving space.

[0046] FIG. **6** is a schematic perspective view of the load handling device of FIG. **5** with a container occupying the container-receiving space.

[0047] FIG. **7** is a schematic perspective view of the load handling device of FIG. **6** showing an example location for a power source compartment.

[0048] FIG. **8** is a schematic perspective view of an alternative external body for the load handling device of FIG. **4**, comprising corner blocks together connected by connecting elements to form an open frame structure.

[0049] FIG. **9** is an exploded view of a first power source exchange system comprising a power source compartment, a power source and an end effector.

[0050] FIG. **10** is a perspective view of the power source of the first power source exchange system.

[0051] FIG. **11**A is a perspective view of the power source and the end effector of the first power source exchange system showing the end effector in a release position. FIG. **11**B shows the end effector in an engaged position.

[0052] FIG. **12** is a perspective view of the power source compartment of the first power source exchange system.

[0053] FIG. **13**A is a schematic cross-sectional view of the power source and the power source compartment of the first power source exchange system showing the power source in the power source compartment with locking members in a locked position.

[0054] FIG. **13**B shows the locking members in an unlocked position.

[0055] FIG. **14**A is a perspective view of the power source, power source compartment and end effector of the first power source exchange system showing the power source in the power source compartment with the locking members in the locked position and the end effector in the release position.

[0056] FIG. **14**B is a top view of the system shown in FIG. **14**A.

[0057] FIG. **15**A is a perspective view of the power source, power source compartment and end effector of the first power source exchange system showing the power source in the power source compartment with the locking members in the unlocked position and the end effector in the engaged position.

[0058] FIG. **15**B is a top view of the system shown in FIG. **15**A.

[0059] FIGS. **16**A-**16**D is a sequence showing how the power source is unlocked and removed from the power source compartment using the end effector in the first power source exchange system.

[0060] FIG. **17** is an exploded view of a second power source exchange system comprising a power source compartment, a power source and an end effector.

[0061] FIG. **18** is a close-up view of a locking member of the second power source exchange system.

[0062] FIG. **19**A is a perspective view of the power source, power source compartment and end effector of the second power source exchange system showing the power source in the power source compartment with the locking members in a locked position and the end effector in a release position.

[0063] FIG. **19**B is a top view of the system shown in FIG. **19**A.

[0064] FIG. **20**A is a perspective view of the power source, power source compartment and end effector of the second power source exchange system showing the power source in the power source compartment with the locking members in an unlocked position and the end effector in an engaged position.

[0065] FIG. **20**B is a top view of the system shown in FIG. **20**A.

[0066] FIG. **21** is an exploded view of a third power source exchange system comprising a power source compartment, a power source and an end effector.

[0067] FIG. **22**A is an exploded view of an assembly comprising a handling member, a locking member and a guide.

[0068] FIG. **22**B shows the exploded assembly of FIG. **22**A from below.

[0069] FIG. **23**A is a perspective view of the power source, power source compartment and end effector of the second power source exchange system showing the power source in the power source compartment with the locking members in a locked position and the end effector in a release position.

[0070] FIG. **23**B is a top view of the system shown in FIG. **23**A.

[0071] FIG. **24**A is a perspective view of the power source, power source compartment and end effector of the second power source exchange system showing the power source in the power source compartment with the locking members in an unlocked position and the end effector in an engaged position.

[0072] FIG. **24**B is a top view of the system shown in FIG. **24**A.

[0073] FIG. **25** is a schematic perspective view of a power source station.

[0074] FIG. **26** is a schematic perspective view of a first example robotic arm operating above the track structure of the grid storage structure shown in FIG. **1**.

[0075] FIG. **27** is a schematic perspective view of a second example robotic arm operating adjacent to the track structure of the grid storage structure shown in FIG. **1**.

DETAILED DESCRIPTION

[0076] FIG. **1** shows an example storage structure **1** that may be used in a storage and retrieval system to store storage containers **9**. 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 storage containers **9** per grid cell **14**.

[0077] FIG. **2** shows a large-scale plan view of a section of track structure **13** forming part of the storage structure **1** illustrated in FIG. **1** and located on top of the horizontal members **5**, **7** of the storage structure **1** illustrated in FIG. **18**. 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 centers of the grid cells **14**. The apertures **15** are sized to allow storage 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.

[0078] FIG. **3** shows a plurality of load handling devices **25** moving on top of the storage structure **1** illustrated in FIG. **18**. The load handling devices **25**, 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 **25** 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 **25** to occupy (or pass one another on) neighboring grid cells **14** without colliding with one another.

[0079] As illustrated in FIG. **4**, a bot **25** comprises an external body **27** in or on which are mounted one or more components which enable the bot **25** to perform its intended functions. These functions may include moving across the storage structure **1** on the track structure **13** and raising or lowering storage containers **9** (e.g. from or to stacks **11**) so that the bot **25** can retrieve or deposit storage containers **9** in specific locations defined by the grid pattern.

[0080] The illustrated bot **25** comprises a driving assembly comprising first and second sets of wheels **29**, **31** which are mounted on the external body **27** of the bot **25** and enable the bot **25** to move in the x-and y-directions along the tracks **17** and **19**, respectively. In particular, two wheels **29** are provided on the shorter side of the bot **25** visible in FIG. **4**, and a further two wheels **29** are provided on the opposite shorter side of the bot **25**. The wheels **29** engage with tracks **17** and are rotatably mounted on the external body **27** of the bot **25** to allow the bot **25** to move along the tracks **17**. Analogously, two wheels **31** are provided on the longer side of the bot **25** visible in FIG. **4**, and a further two wheels **31** are provided on the opposite longer side of the bot **25**. The wheels **31** engage with tracks **19** and are rotatably mounted on the external body **27** of the bot **25** to allow the bot **25** to move along the tracks **19**.

[0081] To enable the bot **25** to move on the different wheels **29**, **31** 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 **29** with the first set of tracks **17** or the second set of wheels **31** with the second set of tracks **19**. The wheel-positioning mechanism is configured to raise and lower the first set of wheels **29** and/or the second set of wheels **31** relative to the external body **27**, thereby enabling the load handling device **25** to selectively move in either the first direction or the second direction across the tracks **17**, **19** of the storage structure **1**.

[0082] 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 **29**, **31** relative to the external body **27** of the bot **25** to bring the at least one set of wheels **29**, **31** 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 external body **27** of the bot **25** stays substantially at the same height and therefore the weight of the external body **27** and the components mounted thereon does not need to be lifted and lowered by the wheel-positioning mechanism.

[0083] The bot **25** also comprises a lifting mechanism **33** and a container-holding device **37** configured to raise and lower storage containers **9**. The illustrated lifting mechanism **33** comprises four tethers **35** which are connected at their lower ends to the container-holding device **37**. The tethers **35** may be in the form of cables, ropes, tapes, or any other form of tether with the necessary physical properties to lift the storage containers **9**. The container-holding device **37** comprises a gripping mechanism **39** configured to engage with features of the storage containers **9** to releasably hold the containers **9** from above. In the illustrated example, the gripping mechanism **39** comprises legs that can be received in corresponding apertures **10** in the rim of the storage container **9** and then moved outwards to engage with the underside of the rim of the storage container **9**. The tethers **35** can be wound up or down to raise or lower the container-holding device **37** 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 **35**.

[0084] In FIG. **5** and FIG. **6**, a side portion of the external body **27** of the bot **25** has been omitted from view to allow the interior of the bot **25** to be seen. The external body **27** of the illustrated bot **25** has an upper portion **41** and a lower portion **43**. The upper portion **41** is configured to house or support one or more operation components (not shown), such as components of the lifting mechanism **33** (e.g. motors), wireless communication components, one or more processors for controlling operation of the bot **25**, etc. The lower portion **43** is arranged beneath the upper portion **41**. The lower portion **43** is externally open at the bottom and defines a container-receiving space **45** for accommodating at least part of a storage container **9** that has been raised into the container-receiving space **45** by the lifting mechanism **33**. FIG. **5** shows the container-receiving space **45** before it is occupied by a storage container **9** and FIG. **6** shows the container-receiving space **45** after it has been occupied by a storage container **9**. The container-receiving space **45** is sized such that enough of a storage container **9** can fit inside the space **45** to enable the bot **25** to move across the track structure **13** on top of storage structure **1** without the underside of the storage container **9** catching on the track structure **13** or another part of the storage structure **1**. When the bot **25** has reached its intended destination, the lifting mechanism **33** controls the tethers **35** to lower the container-holding device **37** and the corresponding storage container **9** out of the space **45** and into the intended position. The intended position may be a stack **11** of storage containers **9** or an egress point of the storage structure **1** (or an ingress point of the storage structure **1** if the bot **25** has moved to collect a storage container **9** for storage in the storage structure **1**). Although in the illustrated example the upper and lower portions **41**, **43** are separated by a physical divider, in other examples, the upper and lower portions **41**, **43** may not be physically divided by a specific component or part of the external body **27** of the bot **25**. The upper and lower configuration of the bot **25** allows the bot **25** to occupy only a single grid cell **14** on the track structure **13** of the storage system **1**.

[0085] In an alternative example, the container-receiving space **45** of the bot **25** may not be within the external body **27** of the bot **25**. For example, the container-receiving space **49** may instead be adjacent to the external body **27** of the bot **25**, e.g. in a cantilever arrangement with the weight of the external body **27** of the bot **25** counterbalancing the weight of the container **9** to be lifted. In such embodiments, a frame or arms of the lifting mechanism **33** may protrude horizontally from the external body **27** of the bot **25**, and the tethers **35** may be arranged at respective locations on the protruding frame/arms and configured to be raised and lowered from those locations to raise and lower a storage container **9** into the container-receiving space **45** adjacent to the external body **27**.

[0086] The bot **25** is powered by a power source (e.g. a battery) which is received into a power source compartment. The power source and power source compartment are configured to electrically couple to each other (e.g. by providing electrical connectors on the power source and in the power source compartment). Once coupled, electrical power is delivered from the power source to one or more electrical or electronic components of the bot **25**, such as the driving assembly, the lifting mechanism **33** and/or the container-holding device **37**.

[0087] FIG. **7** shows the bot **25** with a region **48** demarcated with dotted lines. The power source compartment may be located anywhere within the region **48**. For example, the power source compartment may be located fully within the external body **27** of the bot **25**, or the power source compartment may extend through the top side **28** of the external body **27** of the bot **25**, or the power source compartment may be fully located above the external body **27** of the bot **25**.

[0088] In this example, the power source compartment is configured to receive the power source in a downwards direction. The compartment is also externally exposed such that the power source compartment is externally accessible from a location above the external body **27** of the bot **25**. The top side **28** of the external body **27** of the bot **25** in FIG. **7** comprises an opening **47**. In the case where the compartment is fully within the external body **27** of the bot **25**, the opening **47** may be in communication a top opening of the power source compartment so that a power source can be directly inserted into the power source compartment via the opening **47** from a location above the top side **28** of the external body **27** of the bot **25**, and directly removed from the power source compartment via the opening **47** to a location above the top side **28** of the external body **27** of the bot **25**. In the case where the power source compartment extends through the top side **28** of the external body **27** of the bot **25**, the power source compartment may extend through the opening **47**. In the case where the power source compartment is fully located above the external body **27** of the bot **25**, the power source compartment may be mounted on top side **28** of the external body **27** of the bot **25** and the opening **47** may not be required.

[0089] The external body **27** of the bot **25** illustrated in FIG. **4** is defined by a top panel and side panels. FIG. **8** shows another example of the external body **27** of the bot **25** which is defined by corner blocks **60** connected by horizontal connecting elements **62*a*** and vertical connecting elements **62*b*** (e.g. rods) to form an open frame structure. The open frame structure can be used to house and/or support components of the bot **25**, such as the driving assembly and the lifting mechanism **33**. Due to the open frame structure of the external body, the top side of the external body **27** has an opening **47** formed by the corner blocks **60** and the horizontal connecting elements **62*a*** on the top side of the bot **25**. Similar to the bot **25** shown in FIG. **7**, the power source compartment can be fully located within the external body **27** of the bot **25** and communicate with the opening **47**, or can extend through of the opening **47** of the external body **27** of the bot **25**, or can be fully located above the external body **27** of the bot **25**.

[0090] The power source compartment of the bot **25** forms part of a power source exchange system in which the power source can be inserted into the power source compartment, removed from the power source compartment, or exchanged with another power source in an automated manner using an end effector. Several example power source exchange systems are described below. For conciseness, the power source compartment will be referred to simply as a "compartment" in the following description.

[0091] FIG. **9** shows an exploded view of a first power source exchange system **100** comprising a power source **110**, a compartment **130** configured to removably receive the power source **110**, and an end effector **150** for moving the power source **110** into and out of the compartment **130**. The compartment **130** is configured to receive the power source

110 in an insertion direction D, which in this example is a downwards direction. The power source **110** can therefore be removed from the compartment **130** in an upwards direction.

[0092] The power source **110** may be a battery or any other suitable form of encased power source for providing electrical power, e.g. a supercapacitor. The power source **110** may be a rechargeable power source, e.g. a rechargeable battery.

[0093] FIG. **10** shows the power source **110** in insolation. The power source **110** comprises an outer casing **112**. The outer casing **112** comprises a base **114** and an end wall **118** at opposite ends of the outer casing **112**, and sidewalls extending between the base **114** and the end wall **118** to define a substantially cuboidal shape. The base **114** refers to the wall of the outer casing **112** which faces the base **132** of the compartment **130** (i.e. faces downwards) when the power source **110** is orientated for insertion into the compartment **130** and the end wall **118** refers to the wall of the outer casing **112** which faces away from the base **132** of the compartment **130** (i.e. faces upwards) when the power source **110** is orientated for insertion into the compartment **130**. The end wall **118** is exposed to the end effector **150** when the power source **110** is within the compartment **130**.

[0094] The power source **110** further comprises one or more electrical connectors **119** configured to electrically couple to corresponding electrical connectors **139** of the compartment **130** such that electrical power from the power source **110** can be delivered to any electrical and/or electronic components connected (directly or indirectly) to the electrical connectors of the compartment **130**. The electrical connectors **119** of the power source **110** and the electrical connectors **139** of the compartment are arranged such that inserting the power source **110** into the compartment **130** causes the electrical connectors of the power source and the compartment **119**, **139** to electrically couple to each other automatically. For example, the electrical connectors **119** of the power source **110** and the corresponding electrical connectors of the compartment **130** may face in opposing directions when the power source **110** is orientated for insertion into the compartment **130** such that the electrical connectors **119**, **139** are coupled together when the power source **110** is fully inserted. The electrical connectors **119**, **139** may be in the form of any suitable connectors, e.g. male and female connectors (e.g. pins and sockets), electrical contacts, etc. An example arrangement of electrical connectors **119**, **139** is shown in FIG. **13**A in which a downwards-facing electrical connector **119** is provided on the base **114** of the power source **110** and an upwards-facing electrical connector **139** is provided on the base **132** of the compartment **130**.

[0095] The power source **110** further comprises handling members **124** mounted on the end wall **118** for engaging with the end effector **150** to allow the end effector **150** to move the power source **110** into and out of the compartment **130**. In this example, each handling member **140** comprises a support portion **125** extending upwards from the end wall **118** and a retention portion **126** extending perpendicular to the support portion **125** such that the retention portion **126** overhangs the end wall **118** of the power source **110** and defines a vertical space between the end wall **118** and the retention portion **126**. The handling members **140** are distributed evenly at 90 degree intervals about a longitudinal axis **128** extending through the end wall **118** and the base **114** of the power source **110**. Furthermore, the retention portions **126** all point (i.e. extend away from their respective support portions **125**) in the same circumferential direction with respect to the longitudinal axis **128** (i.e. the retention portions **126** all point clockwise or all point anti-clockwise).

[0096] Referring back to FIG. **9**, the end effector **150** comprises four engagement members **154** extending radially away from a rotational axis **152** about which the end effector **150** can rotate. The engagement members **154** lie in a plane perpendicular to the rotational axis **152** and are spaced evenly about the rotational axis **152** at 90 degree intervals to define a substantially cruciform shape.

[0097] FIG. **11**A shows the power source **110** and the end effector **150** when the end effector **150** is in a release position above the end wall **118** of the power source **110**. In this position, the longitudinal axis **128** of the power source **110** and the rotational axis **152** of the end effector **150** are concentric such that the engagement members **154** lie in a plane that is substantially parallel to the end wall **118**. In the release position, the engagement members **154** of the end effector **150** are located at angular positions between the angular positions of the handling members **124** with respect to the longitudinal axis **128**. Put another way, the engagement members **154** lie between the handling members **124** in a circumferential direction with respect to the longitudinal axis **128**. Thus, when the end effector **150** is in the release position, the engagement members **154** cannot engage with the handling members **124** when the end effector **150** is moved upwards or downwards relative to the power source **110** and therefore the end effector **150** is free to move upwards away from the power source **110**. For example, if the handling members **124** are located at angular positions 0, 90, 180 and 270 degrees with respect to the longitudinal axis **128**, then when the end effector **150** is in the release position, the engagement members **154** may be located at angular positions 45, 135, 210 and 315 degrees with respect to the longitudinal axis **128**.

[0098] FIG. **11**B shows the power source **110** and the end effector **150** when the end effector **150** is in an engaged position. In the engaged position, the end effector **150** is at an angular position with respect to the rotational axis **152** such that each engagement member **154** is received by a respective handling member **124**, in particular between the retention portion **126** of a respective handling member **124** and the end wall **118** of the power source **110**. In the engaged position, movement of the end effector **150** upwards will cause the engagement members **154** to engage with the retention portions **126**, which will cause the power source **110** to be lifted by the end effector **150**. The engagement between the engagement members **154** and the handling members **124** also allows the end effector **150** to support the weight of the power source **110** so that the end effector **150** can hold the power source **110** in the air and lower the power source **110**. The engagement members **154** are also long enough in the radial direction such that they protrude past the outer edge of the end wall **118** of the power source **110**.

[0099] To move from the release position to the engaged position, the end effector **150** is rotated in a first direction about its rotational axis **152**, and to move from the engaged position to the release position, the end effector **150** is rotated in a second, opposite direction about its rotational axis **152**. The first direction and the second direction will depend on the arrangement of the handling members **124**. For example, if the handling members **124** are configured and arranged to receive the engagement members **154** in an anti-clockwise direction, then the end effector **150** is rotated in an anti-clockwise direction to move from the release position to the engaged position, and the end effector **150** is rotated in a clockwise direction to move from the engaged position to the release position, and vice versa. In the example shown in FIGS. **11**A and **11**B, the end effector **150** is rotated anti-clockwise from the release position to the engaged position and rotated clockwise from the engaged position to the release position.

[0100] To mitigate the risk of the power source **110** slipping off the end effector **150** when being held in the air by the end effector **150**, a distal end of the retention portion **126** of each engagement member **154** (i.e. the end of the retention portion **126** opposite to the end which is attached to the support portion **125**) comprises a lip **127** extending towards the end wall **118**. When the engagement members **154** are engaged with the handling members **124**, each engagement member **154** is laterally contained between the support portion **125** and the lip **127** of a respective handling member **124**, which helps to prevent the engagement members **154** slipping relative to the power source **110** in a circumferential direction. The vertical distance between each lip **127** and the end wall **118** of the power source **110** may be large enough to allow the engagement members **154** to pass under the lips **127** when rotating between the release position and the engaged position. Alternatively, the vertical distance between each lip **127** and the end wall **118** may be less than the vertical thickness of the engagement members **154** such that the engagement members **154** are required to push past the lips **127** when moving between the release position and the engaged position. In this case, the retention portion **126** may have some resiliency such that the lips **127** are deflected upwards when a torque greater than a torque threshold is applied to the end effector **150** to rotate the engagement members **154** between the engaged position and the release position.

[0101] FIG. **12** shows the compartment **130** in insolation. The compartment **130** comprises a base **132** and sidewalls **134** extending from the base **132** define an approximately cuboidal power-source-receiving space **136** for receiving the power source **110** and a compartment opening **138** through which the power source **110** can be inserted into and removed from the compartment **130**. As mentioned above, the compartment **130** comprises one or more electrical connectors **139** configured to couple to corresponding electrical connectors **119** on the power source **110** when the power source **110** is inserted into the compartment **130**.

[0102] The system **100** further comprises a locking assembly for releasably locking the power source **110** in the compartment **130**. The locking assembly comprises four locking members **140**, each mounted adjacent to a respective side of the power-source¬-receiving space **136**. The locking members **140** may be directly or indirectly mounted on the sidewalls **134** of the compartment **130** or on a different supporting structure adjacent to the sidewalls **134**. In the illustrated example, the locking members **140** are mounted between corner brackets which are mounted to the sidewalls **134** of the compartment **130**. Each locking member **140** is pivotally mounted for rotation about a respective horizontal pivot axis that is parallel to a respective sidewall **134**. The locking members **140** are rotatable inwards about their respective pivot axes towards a locked position and outwards about their respective pivot axes towards an unlocked position.

[0103] FIG. **13**A is a schematic cross-sectional view of the power source **110** within the compartment **130** when the locking members **140** in the locked position and FIG. **13**B shows the locking members in the unlocked position. Each locking member **140** comprises an overhang portion **142**. In the locked position, the overhang portions **142** overhang the power-source-receiving space **136** such that the power source **110** is blocked from moving upwards out of the compartment **130**. In the unlocked position, the overhang portions **142** are vertically clear of the power-source-receiving space **136** (i.e. they do not overhang the power-source-receiving space **136**) such that the power source **110** can be lifted out of the compartment **130**. Furthermore, each locking member **140** is biased towards the locked position by biasing means **146** such as a spring, e.g. a torsion spring.

[0104] Each overhang portion **142** further comprises a tapered surface **144** that slopes downwards towards the base of the compartment **130** such that when a power source **110** is being inserted into the compartment **130**, movement of the base **114** of the power source **110** against the tapered surfaces **144** causes the locking members **140** to be pushed outwards against their respective biasing means towards the unlocked position. Thus, the power source **110** can be inserted into the compartment even when the locking members **140** are in the locked position.

[0105] FIG. **14**A is a perspective view showing the state of the system **100** when the power source **110** is within the compartment **130** and the end effector **150** is in the release position, and FIG. **14**B shows a top view. As explained above, in the release position, the engagement members **154** are located at angular positions between the angular positions of the handling members **124** with respect to the longitudinal axis **128**. Furthermore, in the release position, the engagement members **154** are also located at angular positions between the angular positions of the locking members **140** with respect to the longitudinal axis **128** such that the engagement members **154** are not engaged with the locking members **140**. Therefore, when the end effector **150** is in the release position, the locking members **140** are in the locked position due to their respective biasing means.

[0106] FIG. **15**A is a perspective view showing the state of the system **100** after the end effector **150** has been rotated from the release position to the engaged position and FIG. **15**B is a top view. As explained above, in the engaged position, the engagement members **154** are received by the handling members **124** in a circumferential direction. Furthermore, in the engaged position, each engagement member **154** is also engaged with a respective locking member **140** such that the locking members **140** are held in the unlocked position against the biasing force of their respective biasing means. In particular, because each engagement member **154** protrudes past a respective outer edge of the end wall **118** in the engaged position, each locking member **140** is pushed outwards far enough so that the overhanging portions **142** no longer overhang the end wall **118** of the power source **110**. Therefore, when the end effector **150** is in the engaged position, the locking members **140** are held in the unlocked position and subsequent upwards movement of the end effector **150** will therefore result in the end effector **150** moving (pulling) the power source **110** out of the compartment **130**.

[0107] FIGS. **16**A-D are a sequence of figures showing how a power source **110** in the compartment **130** can be unlocked and removed using the end effector **150**.

[0108] In FIG. **16**A, the power source **110** is within the compartment **130** and the locking members **140** biased to locked position by the biasing means **146**.

[0109] In FIG. **16**B, the end effector **150** is moved to the release position.

[0110] In FIG. **16**C, the end effector **150** is rotated about its rotational axis **152** from the release position to the engaged position. This causes the engagement members **154** to simultaneously be received by the handling members **124** and move (push) the locking members **140** from the locked position to the unlocked position.

[0111] In FIG. **16**D, the end effector **150** is moved upwards to move the unlocked power source **110** out of the compartment **130**.

[0112] To insert the power source **110** into the compartment **130**, the above removal process can be carried out in reverse. In particular, the end effector **150** holds the power source **110** in the engaged position and moves the power source **110** downwards into the compartment **130**. Once the power source **110** has been fully inserted into the compartment **130**, the end effector **150** rotates from the engaged position to the release position. This causes the engagement members **154** to simultaneously disengage the locking members **140** and the handling members **124**, thereby allowing the biasing means to return the locking members **140** to the locked position and allowing the end effector **150** to move upwards away from the power source **110**.

[0113] To exchange a first power source **110** in the compartment **130** with a second power source **110**, the above removal process can be carried out to remove the first power source **110** from the compartment **130** and the above insertion processes can be carried out to insert the second power source in the empty compartment **130**. Between the removal the first power source **110** and inserting the second power source **110**, the end effector **150** can release the first power source **110** at a location outside the compartment **130** by setting the first power source **110** down and rotating from the engaged position to the release position. The end effector **150** can then pick up the second power source **110** by rotating from the release position to the engaged position with respect to the second power source **110**.

[0114] The first power source exchange system **100** described above is an example in which the locking members **140** are pivotally rotatable between the locked and unlocked positions. In a variation of the first power source exchange system **100**, the locking members **140** could instead be linearly movable between the locked and unlocked positions, together with biasing means (e.g. a spring) for biasing the locking members linearly towards the locked position. Such a variation would function in the same way as the first system **100** to insert, remove and exchange a power source.

[0115] The first power source exchange system **100** is also an example in which the compartment **130** comprises the locking members **140**, i.e. the moving parts of the locking assembly. In some situations, it may be advantageous for the locking members to be provided on the power source instead of the compartment, as it may be easier and/or cheaper to service the power source instead of the compartment when the locking members need to be serviced or replaced. Some example power source exchange systems in which the power source comprises the locking members will now be described.

[0116] FIG. **17** shows an exploded view of a second power source exchange system **200** comprising a power source **210**, a compartment **230** configured to removably receive the power source **210**, and an end effector **250** for moving the power source **210** into and out of the compartment **230**. The compartment **130** is configured to receive the power source **110** in an insertion direction D, which in this example is a downwards direction. The power source **110** can therefore be removed from the compartment **130** in an upwards direction.

[0117] These components of the second power source exchange system **200** are the same or similar to those of the first power source exchange system **100** and therefore, for conciseness, only notable similarities and differences between the two systems will be described below.

[0118] The end wall **218** of the power source **210** comprises four handling members **224** having a similar form and arrangement as the handling members **124** of the first system **100**, i.e. they are spaced at equal angular intervals about the longitudinal axis **228** of the power source **210**, and are configured to receive the engagement members **254** of the end effector **250** in the same circumferential direction.

[0119] The end effector **250** has four engagement members **254** arranged in the same way as the end effector **150** of the first example power source exchange system **100**, i.e. they are spaced at equal angular intervals about the rotational axis **252** to form a cruciform shape lying in a plane perpendicular to the rotational axis **252** of the end effector **250**. The engagement members **254** and the handling members **224** are configured to interact in the same way as the first system **100**, i.e. the end effector **250** is rotatable between an engaged position in which the engagement members **254** are received by the handling members **224** for engaging with the handling members **224** to allow the end effector **250** to move the power source **210** into and out of the compartment **230**, and a release position in which the engagement members **254** are disengaged from the handling members **224**.

[0120] The locking assembly comprises two locking members **240** mounted on the end wall **218** of the power source **210**. The locking members **240** are diametrically opposed about the longitudinal axis **228** of the power source **210**. FIG. **18** shows a close-up view of a locking member **240**. Each locking member **240** comprises a shank portion **241** and a hook portion **242** lying in a plane perpendicular to the longitudinal axis **228**. The locking members **240** are long enough in the radial direction with respect to the longitudinal axis **228** such that the hook portions **242** extend outwards past the outer perimeter of the end wall **218**. Each locking member **240** is pivotally mounted for rotation about a respective pivot axis extending parallel to the longitudinal axis **228**. The pivot axis of each locking member **240** is positioned between the end of the hook portion **242** and the end of the shank portion **241** such that the hook portion **242** can be rotated about the pivot axis by moving the end of the shank portion **241** about the pivot axis. The locking members **240** are rotatable in the same direction about their respective pivot axes between a locked position and an unlocked position (i.e. both locking members **240** rotate clockwise from the locked position to the unlocked position and anti-clockwise from the unlocked position to the locked position, or vice versa). Each locking member **240** further comprises biasing means **248** configured to bias the locking member **240** to the locked position. In the illustrated example, the biasing means **248** is in the form of a spring, in particular a torsion spring.

[0121] Referring back to FIG. **17**, the locking assembly further comprises blocking members **220** for engaging with the locking members **240** in the locked position in order to block the locking members **240**, and hence the power source **210**, from being moved out of the compartment **230**. In particular, the compartment **230** comprises two vertically extending posts **220** mounted adjacent to the power-source-receiving space **236**. In this example, the posts **220** are mounted on an opposing pair of sidewalls **234** of the compartment **230**; however, they could also be mounted on a structure adjacent to the sidewalls **234**. Each post **220** comprises a neck portion **221** and a head portion **222** located on top of the neck portion **221**, and the head portion **222** has a larger diameter than the neck portion **221**.

[0122] FIG. **19**A is a perspective view showing the state of the system **200** when the power source **210** is within the compartment **230** and the end effector **250** is in the release position, and FIG. **19**B shows a top view. In the release position, the engagement members **254** are located at angular positions between the angular positions of the handling members **224** and between the angular positions of the locking members **240** with respect to the longitudinal axis **228**, i.e. they are not engaged with the handling members **224** or the locking members **240**. The locking members **240** are therefore in the locked position due to the biasing means **248**. In the locked position, the hook portion **242** of each locking member **240** is engaged with (hooked around) the neck portion **221** of a respective post **220**. The diameter of the head portion **222** is large enough such that the head portion **222** blocks the hook portion **242** from moving upwards, which prevents the power source **210** from being moved upwards out of the compartment **230**. In particular, the diameter of the head portion **222** may be larger than the distance between two opposing points of the inner surface of the hook portion **242**.

[0123] FIG. **20**A is a perspective view showing the state of the system **200** after the end effector **250** has been rotated from the release position to the engaged position, and FIG. **20**B is a top view. In the engaged position, each engagement member **254** of the end effector **250** is received by a respective handling members **224**. Furthermore, in the engaged position, two of the engagement members **254** extending in opposing radial directions are engaged with the locking members **240** such that the locking members **240** are held in the unlocked position against the biasing force of the biasing means **248**. In particular, each of the two opposing engagement members **254** have moved (pushed) the shank portions **241** of the locking members **240** against the biasing force of the biasing means **248** such that the hook portions **242** have disengaged (rotated away) from the posts **220**. In the unlocked position, the hook portions **242** are vertically clear of the head portion **222** of the posts **220** such that they no longer block the hook portions **242** from moving upwards and therefore subsequent upwards movement of the end effector **250** will result in the end effector **250** moving (pulling) the power source **210** out of the compartment **230**.

[0124] To remove, insert and exchange a power source **210** using the end effector **250**, the same processes described above for the first power source exchange system **100** can be followed. In this example where the power source **210** comprises the locking member **240**, it will be appreciated that when the end effector **250** is holding the power source **210** in the engaged position outside the compartment **230**, the locking members **240** are held in the unlocked position by the engagement members **254**, which allows the end effector **250** to move the power source **210** into the compartment **230** without being obstructed by the posts **220**.

[0125] To assist the engagement members **254** in moving the shank portions **241** of the locking members **240**, each engagement member **254** for engaging a locking member **240** comprises a roller **256** (labelled in FIG. **17**) mounted for rotation about a roller axis that is parallel to the longitudinal axis **228**. The rollers **256** are configured to engage the shank portions **241** when the engagement members **254** are moving the locking members **240** to the unlocked position.

[0126] Although the locking members **240** of the second system **200** are in the form of a hook, the locking members **240** are not limited to this form and may have any shape that extends past the outer edge of the power source **210**. The blocking members **220** also do not need to be in the form of a post and may instead have any form which receives the locking members **240** in a circumferential direction with respect to the pivot axis and blocks the locking members **240** from moving upwards. The blocking members **220** could have a form similar to the handling members **224**, for example.

[0127] FIG. **21** shows an exploded view of a third power source exchange system **300** comprising a power source **310**, a compartment **330** configured to removably receive the power source **310**, and an end effector **350** for inserting and removing the power source **310** into and out of the compartment **330** respectively. The compartment **330** is configured to receive the power source **310** in an insertion direction D, which in this example is a downwards direction. The power source **310** can therefore be removed from the compartment **330** in an upwards direction.

[0128] These components of the third power source exchange system **300** are the same or similar to those of the first power source exchange system **100** and therefore, for conciseness, only notable similarities and differences between the two systems will be described below.

[0129] Whereas the second power source exchange system **200** was an example in which the locking members **240** on the power source **210** pivotally rotate between the locked and unlocked positions, the third power source exchange system **300** is an example in which locking members on the power source move linearly between the locked and unlocked positions.

[0130] The end wall **318** of the power source **310** comprises four handling members **324** which have a similar form and arrangement to the handling members **124** of the first system **100**, i.e. they are spaced at equal angular intervals about the longitudinal axis **328** of the power source **310**, and are configured to receive the engagement members **354** of the end effector **350** in the same circumferential direction

[0131] The end effector **350** has four engagement members **354** arranged in the same way as the end effector **150** of the first example power source exchange system **100**, i.e. spaced at equal angular intervals about the rotational axis **352** to form a cruciform shape lying in a plane perpendicular to the rotational axis **352**. The engagement members **354** and the handling members **224** are configured to interact in the same way as the first system **100**, i.e. the end effector **350** is rotatable between an engaged position in which the engagement members **354** are received by the handling members **324** in order to allow the end effector **350** to move the power source **310** into and out of the compartment **330**, and a release position in which the engagement members **354** are disengaged from the handling members **324**.

[0132] The locking assembly comprises four locking members **340** and four guides **345**, each locking member **340** and guide **345** being located on the end wall **318**, underneath a respective handling member **324**. In the illustrated example, the handling members **324** are mounted on the guides **345**, but the handling members **324** may alternatively be formed integrally with the guides **344**. The locking members **340** and guides **345** are spaced at equal angular intervals about the longitudinal axis **328** (i.e. at 90 degree intervals). The locking members **340** are linearly movable in a direction perpendicular to the longitudinal axis **328**. In particular, the locking members **340** are linearly moveable outwards towards a locked position and inwards towards an unlocked position. When a locking member **340** is in the locked position, a portion of the locking member **340** protrudes past a respective outer edge of the end wall **318**. When a locking member **340** is in the unlocked position, the locking member is retracted back from the outer edge of the end wall **318** such that it does not protrude past the outer edge.

[0133] FIG. **22**A and FIG. **22**B show an exploded view of a handling member **324**, a locking member **340** and a guide **345** from above and below respectively.

[0134] The handling member **324** and the guide **345** are shaped to define a space in which the locking member **340** sits. The locking member **340** is mounted for linear sliding movement within the guide **344** between a locked position and an unlocked position. The bottom of the locking member **340** comprises a protrusion **341** which is received within a linear slot **346** in the base of the guide **345**. The slot **347** and the protrusion **341** are configured to constrain the movement of the locking member **340** to linear movement only. The locking assembly further comprises biasing means **348** in the form of a torsion spring engaged between the locking member **340** and the guide **344**. The biasing means **348** applies a biasing force to the locking member **340** to biasing the locking member **340** towards the locked position.

[0135] The top of the locking member **340** comprises a raised portion **343** with a side surface **344** that is inclined with respect to the direction of travel of the locking member **340** between the locked and unlocked positions. The side surface **344** is configured to engage an engagement member **354** while the end effector **350** is being rotated from the release position to the engaged position such that the locking member **340** moves inwards to the unlocked position. To facilitate engagement between the engagement members **354** and the side surfaces **344** of the locking members **340**, each a roller **356** is mounted on the underside of each engagement member **354** for rotation about an axis parallel to the rotational axis **352**. When the end effector **350** is rotated from the release position to the engaged position, each roller **356** engages the side surface **344** of a respective locking member **340** to move the locking members **340** from the locked position to the unlocked position.

[0136] Referring back to FIG. **21** the locking assembly further comprises four brackets **320**, each mounted adjacent to a respective lateral side of the power-source-receiving space **336**. In this example, each bracket **320** is mounted on a respective sidewall **316** of the compartment **330**, but they could alternatively be mounted on structures adjacent to the sidewalls **316**. Each bracket **320** comprises a slot or recess **321** configured to receive a portion of a respective locking member **340** when the locking member **340** is in the locked position. Each bracket **320** is configured such that once a locking member **340** is within the slot or recess **321**, the locking member **340** is blocked from moving upwards, thereby blocking the power source **310** from moving upwards out of the compartment **330**. To mitigate any tolerance in the vertical positioning of the locking members **340** and the slots or recesses **321**, each locking member **340** comprises a double bevel edge **342** to help the locking member **340** self-locate into the slot or recess **321**.

[0137] FIG. **23**A is a perspective view showing the state of the system **300** when the power source **310** is within the compartment **330** and the end effector **350** is in the release position, and FIG. **23**B shows a top view. In the release position, the engagement members **354** are at angular positions between the angular positions of the handling members **324** and between the angular positions of the locking members **340** with respect to the longitudinal axis **328**, i.e. they are not engaged with the handling members **324** or the locking members **340**. The locking members **340** are therefore in the locked position due to the biasing means **348**. In the locked position, the brackets **320** block the locking members **340** from moving upwards, which prevents the power source **310** from being moved upwards out of the compartment **330**.

[0138] FIG. **24**A is a perspective view showing the state of the system **300** after the end effector **350** has been rotated about its rotational axis **352** from the release position to the engaged position, and FIG. **24**B is a top view. In the engaged position, each engagement member **354** is received by a respective handling member **324**. Furthermore, each engagement members **354** has engaged the side surface **344** of a respective locking member **340** such that the locking members **340** have been moved (pushed) to the unlocked position against the biasing force of the biasing means **348**, and are being held at the unlocked position by the engagement members **354**. In the unlocked position, the locking members **340** have been retracted out of the slots or recesses **321** of the brackets **320** such that the locking members **340** are no longer blocked from moving in the upwards direction and therefore subsequent upwards movement of the end effector **350** will results in the end effector **350** moving (pulling) the power source **310** out of the compartment **230**.

[0139] To remove, insert and exchange a power source **310** using the end effector **350**, the same processes described above for the first power source exchange system **100** can be followed. In this example where the power source **310** comprises the locking member **340**, it will be appreciated that when the end effector **350** is holding the power source **310** in the engaged position outside the compartment **330**, the locking members **340** are held in the unlocked position by the engagement members **354**, which allows the end effector **350** to move the power source **210** into the compartment **230** without being obstructed by the brackets **320**.

[0140] The end effector **150**, **250**, **350** of the power source exchange systems **100**, **200**, **300** described above may be mounted at the end of a robotic arm for moving and rotating the end effector **150**, **250**, **350** such that the power source to be inserted, removed, or exchanged in an automated manner.

The robotic arm may be, for example, a gantry robot or Cartesian robot in which the end effector can be moved along two or three orthogonal directions (in addition being rotated), or the robotic arm may be an articulated robot comprising rotary joints which can provide greater degrees of freedom, e.g. three, four, five, or six degrees of freedom.

[0141] When a power source exchange is to be performed, the compartment **130**, **230**, **330** and the power source **110**, **210**, **310** inside or outside the compartment may be located at a predetermined position, or at any one of a plurality of predetermined positions, with respect to the robotic arm such that the robotic arm can be programmed to perform predetermined movements to move and orientate the end effector with respect to the power source to move the power source into or out of the compartment. Alternatively, or in addition, the robotic arm may comprise sensors or a machine vision system to allow the robotic arm to determine the location the power source and the compartment using methods known in the art.

[0142] The power source exchange system **100**, **200**, **300** may further comprise one or more power source stations **170** for storing power sources **110**, **210**, **310** that have been removed from the compartment **130**, **230**, **330** and for storing power sources to be inserted into the compartment. FIG. **25** shows an example power source station **170** comprising a plurality of bays **172**. Each bay **172** is open to a top surface **171** of the power source station **170** such that each bay **172** can receive a power source in a downwards direction. Each bay **172** may comprise the same locking assembly features as the compartment **130**, **230**, **330**, but given that the power source station **170** will typically be stationary in use, it is not essential for power sources **110**, **210**, **310** to be locked in the bays **172**. The power source station **170** preferably comprises a charging system configured to charge a power source **110**, **210**, **310** once it has been received in a bay **172**. For example, the bays **172** may comprise one or more electrical connectors configured to couple to the electrical connectors **119** on the power source **110**, **210**, **310** to deliver power from a power supply to charge the power source.

[0143] Once the end effector has moved a first power source **110**, **210**, **310** out of the compartment **130**, **230**, **330**, the end effector **150**, **250**, **350** may move and release the first power source into an empty bay **172** at the power source station **170**. The end effector **150**, **250**, **350** may then engage a second power source **110**, **210**, **310** from an occupied bay **172** and move it into the empty compartment **130**, **230**, **330**. In this way, a depleted power source **110**, **210**, **310** in the compartment **130**, **230**, **330** can be exchanged with a charged power source **110**, **210**, **310**. The depleted power source **110**, **210**, **310** can then be charged at the power source station **170** so that it can be used in a future exchange operation.

[0144] The use of the power source exchange system **100**, **200**, **300** in the storage and retrieval system described above allows the power source **110**, **210**, **310** of the bot **25** to be exchanged in an automated manner while the bot **25** remains on the track structure **13** of the storage structure **1**. In particular, one or more robotic arms **50** comprising the end effector **150**, **250**, **350** can be located on, over, or adjacent to the track structure **13** of the storage structure **1** such that the compartment **130**, **230**, **330** of one or more bots **25** on the track structure **13** is accessible to the end effector. The track structure **13** may have one or more designated grid cells **14***a* that are accessible to the end effector, which a bot **25** is required to move to in order to allow the end effector to perform a power source exchange. Once the bot **25** is on a designated grid cell **14***a*, the compartment may be at a predetermined position with respect to the robotic arm **50**, such that the robotic arm **50** can be configured to perform a set of predetermined movements of the end effector to perform the power source exchange.

[0145] FIG. **26** shows an example robotic arm in the form of a gantry robot **50**A in which the end effector is mounted on a gantry extending over a row of designated grid cells **14***a* of the track structure **13**. The illustrated gantry robot **50**A is configured to move the end effector in the vertical direction and a first horizontal direction parallel to the row of designated grid cells **14***a* of the track structure **13** such that the end effector **150**, **250**, **350** can reach a bot **25** on any one of the designated grid cells **14***a* in the row. The gantry robot **50**A could be further configured to move the end effector in a second horizontal direction perpendicular to the first horizontal direction to allow the end effector to move above a plurality of rows of designated grid cells **14***a*.

[0146] FIG. **27** shows an example robotic arm in the form of an articulated robot **50**B located adjacent to the track structure **13** from where the end effector **150**, **250**, **350** can reach the compartment **130**, **230**, **330** of a bot **25** on a designated grid cell **14***a* or one of a plurality of designated grid cells **14***a* at the edge of the track structure **13**. However, the articulated robot **50**B could also be located on the track structure **13** itself, e.g. on a grid cell **14**, to allow the end effector to reach the compartment of a bot **25** on a designated grid cell **14***a* or one of a plurality of designated grid cells **14***a* towards the middle of the track structure **13**.

[0147] The storage and retrieval system may further comprise one or more power source stations **170** as described above. Each power source storage station **170** may be located in the reachable vicinity of one or more robotic arms **50**. For example, a power source station **170** may be located in the region **52** marked in FIG. **26** and FIG. **27** near the track structure **13**. A robotic arm **50** may be mounted on the power source station **170** itself, e.g. on the top surface **171**.

[0148] The storage and retrieval system may comprise a central control system configured to control the movement and functions of the bots **25** on the track structure **13** and activation of the robotic arms **50** to perform power source exchanges. The bot **25** and/or the power source **110**, **210**, **310** may comprise a power source monitoring system for monitoring the charge level of the power source within the compartment **130**, **230**, **330**. The power source station **170** may also comprise a power source monitoring system to monitor the charge level of the power sources within the bays **172**. The control system may use this information to determine: when a bot **25** should move to a designated grid cell **14***a* to have its depleted power source exchanged; the empty bay **172** into which the robotic arm **50** should place the depleted power source **202**; and the occupied bay **172** from which the robotic arm **50** should pick up a charged power source for insertion into the bot **25**. When the power source monitoring system indicates that the charge level of the power source is below a predetermined charge level, a controller in the bot 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***a*. Once the bot **25** has arrived at the designated grid cell **14***a*, the bot can confirm its location to the central control system, which can then command a robotic arm **50** to perform a power source exchange. The bot **25** can then resume operation on the track structure **13**, while the depleted power source is recharged at the power source station **170**. The central control system may communicate wirelessly with the bots **25** and the robotic arms **50** via wireless transmitters and receivers using known wireless communication technologies such as 4G, 5G, Wi-Fi, etc.

[0149] The power source exchange system of the present invention is not limited to the precise forms described above and various modifications and variations will be apparent to the skilled person.

[0150] For example, the locking assembly is not limited to a particular number of locking members, provided that the power source is sufficiently prevented from moving out of the compartment for a particular use case. Having an opposing pair of locking members so that the power source is secured at two opposing sides (such as the locking assembly in the second system **200**) may be advantageous for securely locking the power source in the compartment. Having two pairs of opposing locking members arranged orthogonally to each other (such as the arrangements in the first system **100** and the third system **300**) may provide further security.

[0151] As shown by the second power source exchange system **200**, the number of locking members does not need to be equal to the number of handling members or to the number of engagement members. The number of handling members and the number of engagement members for engaging with the handling members may be chosen to provide sufficient handling stability when the end effector is moving the power source into and out of the compartment, whereas the number of locking members may be chosen to sufficiently secure the power source in the compartment. These different requirements may lead to different numbers of locking members, handling members and engagement members for a particular system. As a result, not all of the engagement members of the end effector may simultaneously be received by a handling member and move a locking member when the end effector is rotated from the release position to the engaged position. Each particular engagement member may be only received by a handling member, or may only move a locking member, or both. It is sufficient for the invention that the end effector as a whole can be received by the handling members and move the locking members when rotated from the release position to the engaged position.

[0152] The handling members do not need to be in the form described in the above examples and make take other forms that are suitable for receiving and engaging with a portion of the end effector such that the end effector can engage and move the power source into and out of the compartment. For example, the engagement member may comprise a protrusion and the handling member may comprise a recess that is configured to receive the protrusion in a circumferential direction with respect to the longitudinal axis of the power source when the end effector is rotated from the release position to the engaged position, and engage the protrusion in the vertical direction to allow the end effector to move the power source into and out of the compartment. Alternatively, the handling member may comprise the protrusion and the engagement member may comprise the recess.

[0153] The engagement members do not need to be in the form described and illustrated in the above examples and may have any suitable shape, configuration and arrangement for being received by a handling member and/or moving a locking member when the end effector is rotated from the release position to the engaged position.

[0154] Although the power-source-receiving space compartment in the above examples is defined by a base and sidewalls, the power-source-receiving space may be a simply be a reserved space within a larger region. The compartment may only be partially defined by a base and/or one or more sidewalls. Furthermore, the base and/or sidewalls do not need to be in the form of solid panels and the base and/or sidewalls of the compartment may instead be in the form of open frames made from corner blocks connected together by connecting elements (e.g. rods), similar to the example external bot body shown in FIG. **8**.

[0155] Although the example power source exchange systems have been described above with the compartment orientated such that the power source is received in a downwards direction, the power source exchange system is not limited to this orientation of the compartment. In general, the compartment is configured to receive the power source in an insertion direction and any particular directional and orientation terms used in the above description are not limiting, and should be understood as being with respect to the insertion direction. The compartment may be orientated such that the power source is received in a horizontal direction, for example. In this case, the power source would also be orientated such that the previously described end wall of the power source faces a horizontal direction and the rotational axis of the end effector is horizontally orientated for rotation between the engaged position and release position. A power source exchange system with horizontal insertion and removal of the power source may also be used with the bot **25** of the above-described storage and retrieval system. For example, the compartment may be configured to be externally exposed at a lateral side of the external body **27** of the bot **25** such that the compartment is externally accessible to an end effector for allowing the end effector to move the power source into and out of the compartment in a horizontal direction.

[0156] The power source exchange system is not limited to being used with the bot **25** described above and may be used with any device that can be powered by an exchangeable power source. The power source exchange system may be used with other forms of load handling devices, vehicles or robots, for example.

[0157] The invention thus provides a system in which an exchangeable power source can be securely locked in a compartment and in which an end effector can be used to unlock and remove power source in an efficient and automated manner. The end effector is only required to perform a simple rotational movement to simultaneously unlock the power source and be in a position for engaging the power source to remove the power source from the compartment. The end effector is also only required to perform a simple rotational movement to simultaneously release and lock the power source in the compartment. The end effector is therefore not required to perform any complex gripping movements for engaging and unlocking the power source and therefore a simple and cost-effective end effector can be used.

1. A power source exchange system, comprising:

a compartment configured to removably receive a power source;

an end effector rotatable between an engaged position for engagement with the power source in order to move the power source into and out of the compartment, and a release position; and

a locking assembly comprising a locking member movable between a locked position for blocking removal of the power source from the compartment and an unlocked position for enabling removal of the power source from the compartment,

wherein the end effector and locking assembly are configured such that rotation of the end effector from the release position to the engaged position causes the end effector to move the locking member from the locked position to the unlocked position, and

wherein the compartment defines a power-source-receiving space for receiving the power source and the locking member is configured to overhang the power-source-receiving space in the locked position in order to block removal of the power source from the compartment.

2. The power source exchange system according to claim **1**, wherein the compartment comprises the locking member.

3. The power source exchange system according to claim **2**, wherein the locking member comprises a tapered surface configured such that movement of the power source into the compartment moves the locking member from the locked position to the unlocked position to allow the power source to be received into the compartment.

4. The power source exchange system according to claim **1**, wherein the end effector is configured such that when the end effector is in the engaged position, the end effector extends past the power-source-receiving space to enable the end effector to move the locking member to the unlocked position.

5. The power source exchange system according to claim **1**, further comprising:

the power source comprising the locking member, and

wherein the compartment is configured to engage with the locking member when the locking member is in the locked position in order to block removal of the power source from the compartment.

6. The power source exchange system according to claim **5**, wherein:

the power source comprises one or more handling members,

each handling member is configured to receive a respective portion of the end effector when the end effector is rotated from the release position to the engaged position, and

the one or more handling members are further configured to engage the respective portion of the end effector to enable the end effector to move the power source into and out of the compartment.

7. The power source exchange system according to claim **1**, wherein the compartment is configured to electrically couple to the power source when the power source is received in the compartment.

8. The power source exchange system according to claim **1**, wherein:

the locking assembly further comprises biasing means configured to apply a biasing force for biasing the locking member to the locked position, and

the end effector and the locking assembly are further configured such that rotation of the end effector from the engaged position to the release position allows the biasing force to return the locking member to the locked position.

9. The power source exchange system according to claim **8**, wherein the end effector and the locking assembly are configured such that when the end effector is in the engaged position, the locking member is held in the unlocked position by the end effector.

10. The power source exchange system according to claim **1**, wherein:

the locking assembly comprises a plurality of locking members,

the locking assembly and the end effector are configured such that rotation of the end effector from the release position to the engaged position causes the end effector to move each locking member from the locked position to the unlocked position, and

the end effector comprises a plurality of engagement members arranged such that when the end effector is rotated from the release position to the engaged position about a rotational axis, each particular engagement member moves to a position for engagement with the power source and/or moves one of the locking members from the locked position to the unlocked position.

11. The power source exchange system according to claim **1**, wherein the end effector is mounted on a robotic arm configured to move the end effector and rotate the end effector between the engaged position and the release position.

12. The power source exchange system according to claim **1**, further comprising:

a power source station comprising a plurality of bays, each bay being configured to receive the power source,

wherein the end effector is further configured to move the power source between the compartment and any of the bays of the power source station,

wherein each bay is configured to charge the power source once received in the bay.

13. The power source exchange system according to claim **1**, further comprising:

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, the load handling device comprising:

a driving assembly configured to move the load handling device on the track structure;

a container-holding device configured to releasably hold a container from above; and

a lifting mechanism configured to raise and lower the container-holding device,

wherein the load handling device comprises the compartment and the compartment is configured to deliver electrical power to one or more electrical or electronic components of the load handling device once the power source is received into the compartment.

14. A power source exchange system comprising:

a compartment configured to removably receive a power source;

an end effector rotatable between an engaged position for engagement with the power source in order to move the power source into and out of the compartment and a release position;

a locking assembly comprising a locking member movable between a locked position for blocking removal of the power source from the compartment and an unlocked position for enabling removal of the power source from the compartment,

wherein the end effector and locking assembly are configured such that rotation of the end effector from the release position to the engaged position causes the end effector to move the locking member from the locked position to the unlocked position; and

the power source comprising the locking member,

wherein the compartment is configured to engage with the locking member when the locking member is in the locked position in order to block removal of the power source from the compartment,

wherein the power source comprises one or more handling members,

wherein each handling member is configured to receive a respective portion of the end effector when the end effector is rotated from the release position to the engaged position, and

wherein the one or more handling members are further configured to engage the respective portion of the end effector to enable the end effector to move the power source into and out of the compartment.

15. A power source exchange system comprising:

a compartment configured to removably receive a power source;

an end effector rotatable between an engaged position for engagement with the power source in order to move the power source into and out of the compartment, and a release position; and,

a locking assembly comprising a locking member movable between a locked position for blocking removal of the power source from the compartment and an unlocked position for enabling removal of the power source from the compartment; wherein the end effector and locking assembly are configured such that rotation of the end effector from the release position to the engaged position causes the end effector to move the locking member from the locked position to the unlocked position,

wherein the locking assembly comprises a plurality of locking members,

wherein the locking assembly and the end effector are configured such that rotation of the end effector from the release position to the engaged position causes the end effector to move each locking member from the locked position to the unlocked position, and

wherein the end effector comprises a plurality of engagement members arranged such that when the end effector is rotated from the release position to the engaged position about a rotational axis, each particular engagement member moves to a position for engagement with the power source and/or moves one of the locking members from the locked position to the unlocked position.

16. The power source exchange system according to claim **15**, wherein:

the power source comprises one or more handling members,

each handling member is configured to receive a respective portion of the end effector when the end effector is rotated from the release position to the engaged position,

the one or more handling members are further configured to engage the respective portion of the end effector to enable the end effector to move the power source into and out of the compartment, and

the plurality of engagement members are arranged such that when the end effector is rotated from the release position to the engaged position, each particular engagement member is received by one of the handling members and/or moves one of the plurality of locking members from the locked position to the unlocked position.

17-20. (canceled)

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