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(54) HORIZONTAL STORAGE MODULE, LIFTING ASSEMBLY, AND CANISTER TRANSFER ASSEMBLIES

(57) A horizontal storage module (HSM) includes a body defining a plurality of compartments configured for receiving canisters, wherein the compartments are arranged in a first row at a first elevation and a second row at a second elevation higher than the first elevation, and wherein at least a portion of one compartment in the first row is in the same horizontal axis location as at least a portion of one compartment in the second row. A method of manufacturing the HSM includes positioning adjacent segments. A lifting assembly for the HSM includes a frame and an actuation means for lifting a cask containing a canister. A method of lifting includes receiving a cask and lifting a cask for delivery of the canister to the HSM.

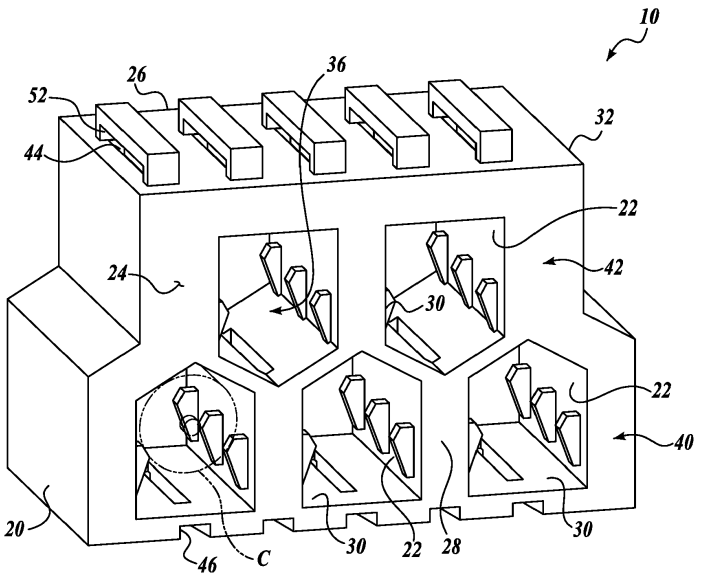


FIG. 1

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Description

BACKGROUND

[0001] Horizontal storage modules (HSMs) are typically used for the dry storage and containment of radioactive materials as ventilated canister storage systems at reactor or other storage sites. Previously designed HSMs are generally manufactured from reinforced concrete as a single body unit with an attachable lid or a roof atop. These HSMs may have dimensions of about 16-20 feet in height, by about 8-10 feet in width and about 20-22 feet in length. The weight of these single body unit HSMs can be around 300,000 lbs (145,000 kgs) (unloaded, i.e., without the canister). The footprint limits storage facility capabilities.

[0002] HSM units are typically constructed at a manufacturing site in two pieces (base and lid or roof). The pieces are then shipped to a reactor or storage site for use. Due to shipping regulations, single body unit HSMs must be shipped by rail or barge. In view of the size and weight, the shipping costs for such large, heavy unit HSMs have become very high and, in some cases, cost prohibitive.

[0003] There exists a need for an improved HSM design having a smaller footprint to expand storage facility capabilities. In addition, there exists a need for a modular HSM that can be constructed on site. Further, there exists a need for improved access and handling of canisters being transferred to and from HSMs. Embodiments of the present disclosure are directed to fulfilling these and other needs.

SUMMARY

[0004] This summary is provided to introduce a selection of concepts in a simplified form that are further described below in the Detailed Description. This summary is not intended to identify key features of the claimed subject matter, nor is it intended to be used as an aid in determining the scope of the claimed subject matter.

[0005] In accordance with one embodiment of the present disclosure, a horizontal storage module (HSM) is provided. The HSM includes a body defining a plurality of compartments configured for receiving canisters, wherein the compartments are arranged in a first row at a first elevation and a second row at a second elevation higher than the first elevation, and wherein at least a portion of one compartment in the first row is in the same horizontal axis location as at least a portion of one compartment in the second row.

[0006] In accordance with another embodiment of the present disclosure, a method of constructing an HSM assembly is provided. The method includes forming a plurality of segments for the body portion of the HSM assembly; and positioning adjacent segments.

[0007] In accordance with another embodiment of the present disclosure, a lift assembly for a high-density horizontal storage module (HSM) is provided. The HSM includes a body defining a plurality of compartments configured for receiving canisters, wherein the compartments are arranged in a first row at a first elevation and a second row at a second elevation higher than the first elevation, and wherein at least a portion of one compartment in the first row is in the same horizontal axis location as at least a portion of one compartment in the second row. The lift assembly includes a frame assembly, and actuation means for lifting a cask containing a canister for delivery to the second row at the second elevation.

[0008] In accordance with another embodiment of the present disclosure, a method of loading a canister in a high-density horizontal storage module (HSM) is provided. The HSM includes a body defining a plurality of compartments configured for receiving canisters, wherein the compartments are arranged in a first row at a first elevation and a second row at a second elevation higher than the first elevation, and wherein at least a portion of one compartment in the first row is in the same horizontal axis location as at least a portion of one compartment in the second row. The method includes receiving a cask containing a canister in a frame assembly of a lifting assembly at the first elevation, and lifting the cask containing the canister for delivery of the canister to the second row at the second elevation.

[0009] In any of the embodiments described herein, the HSM may further include ventilation means in each of the plurality of compartments including vent paths having substantially vertical pathways.

[0010] In any of the embodiments described herein, each compartment may be adjacent at least two other compartments, preferably adjacent to at least three other compartments, and preferably adjacent to at least four other compartments.

[0011] In any of the embodiments described herein, each compartment may be polygonal in cross-sectional shape.

[0012] In any of the embodiments described herein, at least some of the compartments may be hexagonal in cross-sectional shape.

[0013] In any of the embodiments described herein, the plurality of compartments may be arranged in a staggered configuration

[0014] In any of the embodiments described herein, the HSM may further include a roof on the body.

[0015] In any of the embodiments described herein, the roof may have impact resistance means, preferably including one or more of the following elements: an impact resistant polymer blanket; a reinforced concrete slab supported by pre-deformed steel pipes; half pipes; a pretensioned concrete slab.

[0016] In any of the embodiments described herein, the roof may be supported only by the front and back walls.

[0017] In any of the embodiments described herein, at least a first vertical pathway may extend from each inlet vents to each compartment and at least a second vertical

pathway may extend from each compartment to each outlet vent.

[0018] In any of the embodiments described herein, the HSM may further include a lift assembly for lifting the canister to the second elevation.

[0019] In any of the embodiments described herein, the body portion may be modularized and made from a plurality of segments.

[0020] In any of the embodiments described herein, the plurality of segments may be vertically layered on top of each other.

[0021] In any of the embodiments described herein, adjacent segments may be attached to one another using only a vertical attachment system.

[0022] In any of the embodiments described herein, the vertical attachment system may include a plurality of vertically oriented holes in the walls of adjacent segments, and ties connecting such holes.

[0023] In any of the embodiments described herein, the plurality of segments may be made from reinforced concrete.

[0024] In any of the embodiments described herein, a method of construction may further include vertically attaching adjacent segments.

[0025] In any of the embodiments described herein, the frame assembly may be folded to a traveling configuration and expanding to a lifting configuration.

DESCRIPTION OF THE DRAWINGS

[0026] The foregoing aspects and many of the attendant advantages of this disclosure will become more readily appreciated as the same become better understood by reference to the following detailed description, when taken in conjunction with the accompanying drawings, wherein:

FIGURE 1 is an isometric view of a high-density horizontal storage module (HSM) in accordance with one embodiment of the present disclosure;

FIGURE 2 is a cutaway front view of the high-density HSM of FIGURE 1;

FIGURE 3 shows comparative front views of two systems: a previously designed HSM arrangement and the high-density HSM of FIGURE 1;

FIGURE 4 shows comparative front and top views of a previously designed HSM arrangement and another arrangement in accordance with embodiments of the present disclosure;

FIGURE 5 is an isometric view of a high-density HSM in accordance with yet another embodiment of the present disclosure;

FIGURES 6-8 are isometric views of various roof designs for high-density HSMs in accordance with embodiments of the present disclosure;

FIGURES 9 to 11 are isometric views illustrating one method of manufacture of a high-density HSM in accordance with one embodiment of the present disclosure; and

FIGURES 12-18 are isometric view showing a lifting assembly and the sequence steps of lifting a canister for loading into the top row of compartments of a high density HSM in accordance with one embodiment of the present disclosure.

DETAILED DESCRIPTION

[0027] The detailed description set forth below in connection with the appended drawings, where like numerals reference like elements, is intended as a description of various embodiments of the disclosed subject matter and is not intended to represent the only embodiments. Each embodiment described in this disclosure is provided merely as an example or illustration and should not be construed as preferred or advantageous over other embodiments. The illustrative examples provided herein are not intended to be exhaustive or to limit the disclosure to the precise forms disclosed. Similarly, any steps described herein may be interchangeable with other steps, or combinations of steps, in order to achieve the same or substantially similar result.

[0028] In the following description, numerous specific details are set forth in order to provide a thorough understanding of exemplary embodiments of the present disclosure. It will be apparent to one skilled in the art, however, that many embodiments of the present disclosure may be practiced without some or all of the specific details. In some instances, well-known process steps have not been described in detail in order not to unnecessarily obscure various aspects of the present disclosure. Further, it will be appreciated that embodiments of the present disclosure may employ any combination of the features described herein.

[0029] Embodiments of the present disclosure are directed to horizontal storage modules (HSMs), for example, used for the dry storage and containment of radioactive materials as ventilated canister storage systems having modular constructions, and methods of manufacturing the same. Methods of manufacturing may include manufacture, construction, and/or fabrication. Referring to FIGURES 1 and 2, a high density HSM assembly 10 constructed in accordance with one embodiment of the present disclosure is provided.

[0030] The HSM 10 in the illustrated embodiment of FIGURES 1 and 2 includes a body 20 defining a plurality of compartments 22 configured for receiving canisters C that may contain radioactive materials. The body 20 includes a front face 24, a rear wall 26, and a plurality of interior dividing walls 28 defining the plurality of compartments 22.

[0031] The HSM 10 includes a plurality of front entry holes 30 leading to each of the plurality of compartments 22 for supporting individual canisters C. Shielding doors (not shown) can be used to close the front entry holes 30 of the HSM 10 after the canisters C have been received. A roof or lid 32 can be constructed integrally with

the dividing walls 28 or can be manufactured separately from the body 20 and placed on top of the body 20 when the HSM 10 is assembled on site for use, as described in greater detail below.

[0032] Inside the compartments 22, the canisters C may rest on suitable resting devices 34, such as pillow blocks, bearing blocks, or rails (see also, pillow blocks 234 in FIGURE 5). The canisters C can be inserted by being pushed into the entry holes 30, for example, along rails or bearing blocks, or by being set down on the support pillow blocks, as described in greater detail below. The sizing of the entry holes 30 along with the configuration and/or sizing or rails, pillow blocks, or bearing blocks can be used to accommodate canisters C having different diameters.

[0033] The HSM includes provisions in the front and back of the cavities for retaining the canister C in horizontal orientation (in case of a seismic event). In one embodiment, the canister C may be free to slide in the compartment cavity 36 to some degree. In one embodiment, the canister C may be anchored to the pillow blocks to prevent significant sliding.

[0034] In one embodiment of the present disclosure, each compartment 22 shares a common dividing wall 28 with at least one other compartment 22. In another embodiment, each compartment 22 shares a common dividing wall 28 with at least two other compartments 22.

[0035] In the illustrated embodiment of FIGURES 1 and 2, the HSM 10 includes five compartments 22 for receiving five separate canisters C. The five compartments 22 are arranged in a staggered configuration having a bottom row 40 and a top row 42. An exemplary staggered configuration is shown in the illustrated embodiment, such that the compartments are arranged in a first row at a first elevation and a second row at a second elevation higher than the first elevation, and wherein at least a portion of one compartment in the first row is in the same horizontal axis location as at least a portion of one compartment in the second row. In that regard, the compartment in the second row may not be directly positioned on top of the compartment in the first row. Instead, the compartments may be staggered and only have some overlap on point along a horizontal axis.

[0036] In one embodiment, each compartment 22 is adjacent to at least two other compartments 22. In another embodiment, adjacent compartments 22 may share a common dividing wall. The top compartments 22 are adjacent three other compartments 22. The bottom center compartment 22 is adjacent four other compartments 22.

[0037] In the illustrated embodiment, each compartment 22 is polygonal in cross-sectional shape. In other embodiments, the compartments 22 may have rounded walls instead of planar walls or a combination thereof (for example, a keyhole shape). In another embodiment, the structure may have a honeycomb configuration including a plurality of adjacent hexagonal cells.

[0038] In one non-limiting example, at least a portion of the compartments 22 may be hexagonal in cross-sectional shape. The compartment can also have other polygonal shapes such as triangular, rectangular, or pentagonal. In the illustrated embodiment of FIGURES 1 and 2, the compartments 22 in the bottom row 40 have a five-sided cross-sectional shape. The top row of compartments 22 have five sides, and are designed to interface with the five sided pattern of the bottom row.

[0039] Although illustrated as including five compartments arranged in a honeycomb configuration, other staggered configurations and arrangements are within the scope of the present disclosure. As non-limiting examples, the number of compartments, arrangement of compartments, number of rows, and/or cross-sectional shapes of the compartments may vary. As one example, the embodiment in FIGURE 4 is a staggered HSM having eleven compartments. As another example, an HSM may include compartments having non-hexagonal cross-sectional shapes that share a common dividing wall with at least one other compartment. In FIGURE 5, the HSM 210 includes key-hole shaped compartments 222. In another embodiment, an HSM may include three or more rows of compartments.

[0040] HSMs in accordance with embodiments of the present disclosure may be manufactured from reinforced concrete. For example, shielding walls can be made with steel fiber concrete. Other types of concrete such as reinforced with rebar, heavy duty, steel or other type of fibers.

[0041] Previously designed HSMs include enhanced radioactive shielding performance, seismic capabilities, heat rejection capabilities, and ruggedness for resisting acts of sabotage. Moreover, previously designed HSMs are fabricated off-site (or near site) so as to not require any major construction at the containment site. Embodiments of the present disclosure are also designed to meet these criteria

[0042] HSMs in accordance with the present disclosure are designed to have a reduced HSM footprint per canister as compared to previously designed HSMs to increase the storage capacity of a particular storage array. Referring to FIGURE 4, a previously designed HSM arrays are shown, including the HSM-H 2x11. Comparatively, a Staggered HSM 2x11 array in accordance with one embodiment of the present disclosure has a significantly reduced footprint area. In this example, the reduced Staggered HSM footprint is approximately 50% of the previously HSM-H arrays.

[0043] A side-by-side comparison of an HSM Model 102 array and a Staggered HSM array is shown in FIGURE 3.

[0044] The height of an HSM designed in accordance with embodiment of the present disclosure may be higher than the previously designed HSMs (see FIGURE 3), for example, a height increase of about 20 inches to about 40 inches (about 50 to about 100 cm). Despite the height increase, the staggered array of the high density HSM 10 allows for a reduction in reinforced concrete for HSM

construction in the range of about 30 to 45%.

[0045] The HSM is supported by a concrete pad that must meet requirements set forth by the Nuclear Regulatory Commission (NRC) or any other nuclear spent fuel management regulatory authority. The HSM reduced footprint also allows for a reduction in the costs and complexities associated with the concrete pad based on reduced requirements for concrete pad length, concrete hardness, soil stiffness, and other soil conditions. The HSM may be anchored to the pad or free to slide.

[0046] As can be seen in FIGURE 4, the HSMs 10 of the present disclosure may be arranged back-to-back in an array to maximize the use of space.

[0047] Referring to FIGURES 1 and 2, the HSM 10 includes a roof or lid 32 including a plurality of outlet vents 44 located above the compartments 22. Inlet vents 46 are located at the bottom of the HSM 10 under the compartments 22. To reduce the radiation dose from the inlet and outlet vents, theses vents may be included with dose reduction hardware such as pipes, plates, or any other suitable hardware. In addition or alternatively, dog leg inlet and/or outlet vents can be used to reduce dose. Outlet vent covers can also be used to reduce dose.

[0048] In the illustrated embodiment, each compartment 22 has its own substantially vertical airflow pathway. At least a first pathway 48 extends from each inlet vents 46 to each compartment 22 and at least a second pathway 50 extends from each compartment 22 to each outlet vent 44. As system including a bottom location for the inlet vents 46 and a top location for the outlet vents 44 is advantageous because it is unlikely there would be blockage of both the inlet vents 46 and the outlet vents 44 in a flood event depending on the flood water height.

[0049] In another embodiment, a top vent from a compartment 22 in the bottom row 40 may vent into another compartment 22 in the top row 42 before venting to ambient air.

[0050] The increase in height of the HSM 10 of the present disclosure, as compared to previously designed HSMs, compensates for heat removal from the bottom row 40 of compartments 22. In addition, the cavity 36 sizing for the compartments 22 may include spacing for heat shields between the compartment 22 interior surface and the canister C outer surface.

[0051] In addition, the HSM 10 may include additional vents in the back or side walls of the body 20 (see e.g., side lid vent 52 in FIGURE 1). Therefore, the HSM 10 may include more than one inlet vent and more than one outlet vent per module.

[0052] In addition to a common lid 32, the HSM 10 may further include an enhanced roof design for increased resistance for missile and aircraft crash or any other impact or explosion loads. In the illustrated embodiments of FIGURES 6-8, alternative roof designs are provided. These exemplary roof designs provide an impact spreader and may be used individually or together in combination with one another, and may be applied to roof and walls. In FIGURE 6, the HSM 210 includes a reinforced concrete slab 260 and pre-deformed steel pipes 262 on top of roof 232. In FIGURE 7, the HSM 210 includes a series of adjacent half pipes 270 on roof 232. In FIGURE 8, the HSM 210 includes a pre-tensioned concrete slab 272 on roof 232.

[0053] In some embodiments, the roof 232 may be lined with an impact resistant polymer blanket for missile protection and/or heavily reinforced to be resistant to aircraft crash. In one embodiment of the present disclosure, the roof 232 is supported fully on front and rear walls 24 and 26 of the HSM 10, without significant load being transmitted to interior dividing walls 28.

[0054] Advantageous effects of a staggered, high density HSM 10 include the following. The HSM 10 includes additional self-shielding as compared to previously designed HSMs, due at least in part to the monolith structure with no gaps. Further, the high-density HSM 10 has a reduction of about 50% of the skyshine and direct dose from the HSM array roof because there is no roof for the bottom row 40 of compartments 22. In addition, there is a significant reduction in the skyshine dose from the bottom HSM roof vents because of the long chimneys for those vents. The dose reduction hardware at the HSM bottom arrays reduces inlet vent dose rates.

[0055] Other advantageous effects of the HSM 10 according to the illustrated embodiment having at least some of the compartments 22 with a hexagonal cross-sectional shape include improved efficiency in the use of space and material, increased concrete surface area surrounding individual canisters for heat transfer, as compared to a rectangular array, and better weight distribution in a staggered structure, resulting in improved structural strength. In addition, adjacent modules self-shield each other similar to a rectangular array, with no indication of a compromise in the shielding effectiveness as compared to a rectangular array. Moreover, the hexagonal cross-sectional shape is a particularly efficient shape for compressive strength and tensile strength.

[0056] In addition to impact loads resistance due to explosives, missile or aircraft, the HSMs of the present disclosure are further designed for increased resistance to seismic events. The monolith array provides high seismic resistance. Increasing the size of the monolith array and the number of compartments can provide stronger seismic performance and a lower center of gravity. The monolith array may be free to slide on the pad with no need for a high seismic pad design. In addition, the compartments and vent flow paths are visible and easy to inspect for integrity after a seismic or other type of event, such as flood or tsunami

[0057] The HSMs 10 of the present disclosure may be manufactured as modular to simplify manufacture and shipment or cast in place monolithically, as described in greater detail below.

[0058] Referring to FIGURES 9-11, a monolithic cast in horizontal lifts method for an HSM 10 will now be described. The HSM assembly 10 includes a body portion 20 having a plurality of segments or layers 70, 72, 74

(see FIGURE 11) that can be constructed on top of one another.

[0059] Such cast in lifts employs a construction joint technique, as is described in greater detail below. In the illustrated embodiment, the body portion 20 is divided into three lifts; however, any number of body portion lifts is within the scope of the present disclosure.

[0060] In the illustrated embodiment of FIGURE 11, the three lifts 70, 72, and 74 of the body portion 20 have construction joints between lifts in horizontal planes occurring through the compartments 22. In one embodiment of the present disclosure, the segments 70, 72, and 74 are substantially similar in at least one of size, shape, and weight. The term "substantially" is used herein to be within an acceptable range of engineering tolerance in the industry. In other horizontal layering within the scope of the present disclosure, the segments 70, 72, and 74 are not substantially similar in at least one of size, shape, and weight.

[0061] In accordance with one embodiment of the present disclosure, a method of manufacturing the layered body portion 20 will now be described. The modular layer HSM assembly 10 may be constructed using reinforced concrete (or other types of concrete) that is poured in a metal and/or wood forms (as illustrated in FIGURE 9). The first lift 70 of the body portion 20 is poured into the forms, and allowed to harden. Thereafter, the second lift 72 of the body portion 20 is formed and poured into the forms on top of the hardened first lift 70 (as illustrated in FIGURE 10). Subsequently, the third lift 74 is poured into the forms on top of the hardened second lift 72 (as illustrated in FIGURE 11). The roof or lid 32 may be formed separately, or may be formed on top of or as part of the hardened third lift 74.

[0062] By casting subsequent layers against a hardened previous layer, the joints are almost invisible.

[0063] Because of casting in multiple layers 70, 72, and 74, the hydrostatic pressure in each lift is substantially decreased in a linear relation to the lift height, as compared to a single body unit HSM. As the hydrostatic pressure is reduced, the potential for dimensional deviation in the lift 70, 72, and 74 is significantly reduced. As a non-limiting example, for a three-lift concept, the hydrostatic pressure in each lift may be decreased in a linear relation to lift height to be approximately 1/3 of the hydrostatic pressure in a comparable single body unit HSM. Likewise, for a two-lift concept, the hydrostatic pressure in each lift may be decreased to be approximately 1/2 of the hydrostatic pressure in a comparable single body unit HSM.

[0064] Moreover, the forms for manufacturing the modular layer HSM assembly 10 are less expensive and more reliable because they are not required to be stiffened for handling the height requirements of a comparable single body unit HSM.

[0065] Although described as using a single form, it should be appreciated that the use of multiple forms for the various different segments of the body portion 20 is also within the scope of the present disclosure.

[0066] A suitable vertical attachment system may include using ties 76, such as rebar ties or rebar splicing technique. Vertical rebar is left exposed during forming and placement of lift 70. The rebar is then spliced and tied to rebar of lift 72. Similarly, vertical rebar is extended from lift 72 into lift 74 and spliced with matching rebar in lift 74. Other vertical attachment systems are also within the scope of the present disclosure.

[0067] Returning now to FIGURE 2, another method of manufacturing the segmented body portion 20 using a horizontal segment attachment method will now be described. The modular layer HSM assembly 10 may be constructed using reinforced concrete that is poured in a single form. The segments 80, 82, 84, 86, 88, and 90 are divided along the vent path lines. The lid 32 may be formed separately, or may be formed on top of the complete hardened body portion 20. A horizontal attachment system, such as a post tension system or any other suitable attachment system, may be used to attach the segments 80, 82, 84, 86, 88, and 90. A similar manufacturing method may be used for forming other vertical segments.

LIFT ASSEMBLY

[0068] Referring now to FIGURES 12-18, a lift assembly 120 and method for lifting a canister C for transfer from a cask K into an entry hole 30 in the top row 42 of an HSM 10 will now be described. The lift assembly 120 includes a frame assembly 122 having first and second frame portions 124 and 126 for receiving a cask K containing a canister C. The first and second frame portions 124 and 126 are connected to one another by a joinder arm 128 (which is shown in a folded position in FIGURE 12 and an extended position in FIGURE 13).

[0069] The lift assembly 120 is supported by a means for conveyance, shown as a plurality of wheels 130, such that the lift assembly 120 can be positioned at numerous positions along the HSM 10 or in the storage facility. Referring to FIGURES 12 and 13, the wheels 130 may pivot relative to the frame assembly 122 to allow for multidirectional travel.

[0070] The means for conveyance may also include other suitable types of conveyances besides wheels, such as tracks, rollers, bearing pads, bearing surfaces, air skids, and combinations thereof. In the illustrated embodiment, the wheels 130 are configured for sideways travel for positioning the lift assembly 120 at the HSM 10 and also for foldability and expansion (compare configuration of lift assembly 120 in FIGURES 12 and 13).

[0071] As can be seen in comparing FIGURES 12 and 13, the lifting assembly 120 may be foldable for compact storage and movement in the storage facility. Upon arrival at a position for lifting, the lift assembly 120 can be expanded to its lifting configuration (see FIGURE 13). As seen in FIGURE 13, width expansion is achieved by moving the first and second frame portions 124 and 126 outwardly away from each other. Joinder arm 128 includes

first and second arms portions 140 and 142 and an elbow coupling 144. The arm portions 140 and 142 rotate relative to the first and second frame portions 124 and 126 and the elbow coupling 144 for arm extension. When the joinder arm 128 is extended, the first and second frame portions 124 and 126 are distanced from each other an appropriate distance to receive a cask K for lifting (see FIGURE 15). Comparing FIGURES 13 and 14, when the elbow coupling 144 is in its fully extended position, a locking portion 146 can be moved to a locking position to cover the elbow coupling 144 and prevent it from bending during use. Other locking configurations for the joinder arm 128 are also within the scope of the present disclosure.

[0072] As seen in FIGURE 14, the lift assembly 120 has been expanded to its receiving and lifting configuration and moved to couple with the HSM 10. The lift assembly 120 includes a stabilization system for stabilizing the lift assembly 120 and/or securing the lift assembly 120 to the HSM 10 to prevent movement during a seismic event that may occur during the transfer process. The stabilization system includes a ground anchor or outrigger system 150 shown as first and second anchors 152 and 154 deployed from a first unengaged position (see FIGURE 12) to a second engaged position (see FIGURE 14) are used to stabilize the lift assembly 120 when it is received in a transfer position. Any suitable number of anchors or outriggers in the ground anchor system (such as one or more than two) is within the scope of the present disclosure.

[0073] The stabilization system further includes an HSM anchor system 160. In the illustrated embodiment, the HSM anchor system 160 includes first and second vertical arms 162 and 164 configured to engage with the front surface of the HSM 10. The arms 162 and 164 are respectively attached to the front of the first and second frame portions 124 and 126. Each of the arms 162 and 164 includes a respective extension portion 166 and 168 for engaging with the top horizontal surface of the HSM 10. As the lift assembly 120 travels toward and approaches the HSM 10, the arms 162 and 164 are lifted upwardly relative to the frame assembly 122 with the extension portions 166 and 168 positioned above the top surface of the HSM 10 (see FIGURE 13). When the lift assembly 120 is secured in its transfer position, the arms 162 and 164 are retracted downwardly relative to the frame assembly 122 to engage the arms 162 and 164 with the front substantially vertical surface of the HSM 10 and to engage the extension portions 166 and 168 with the top substantially horizontal surface of the HSM 10 (see FIGURE 14).

[0074] At the same time, the ground anchor or outrigger system 150 may be deployed such that the means for conveyance is inactivated. As seen in FIGURE 14, with the ground anchor system 150 deployed wheels 130 are raised off the ground and free to pivot relative to the frame assembly 122.

[0075] Referring now to FIGURE 15, a trailer T including a skid S holding a cask K containing a canister C approaches the lift assembly 120. The trailer T supporting the skid S and cask K rolls toward the HSM 10 and is received between the first and second frame portions 124 and 126 of the lift assembly 120.

[0076] Referring to FIGURE 16, gripping devices 170 from the lift assembly 120 engage with the skid S to secure the skid S within the lift assembly 120 and prevent movement during lifting.

[0077] Referring to FIGURES 17 and 18, lifting features of the lift assembly 120 will now be described. The lift assembly 120 includes a plurality of lifting actuators or impact limiters 172 for use in moving the skid S and cask K from a first elevation position (see FIGURE 17) to a second elevation position (see FIGURE 18). The lifting mechanism for moving the skid S and cask K from a first elevation position to a second elevation position includes multiple fail safe mechanisms which may include shock absorbers, impact limiters, rack and pinion ratchet and friction brake, hydraulic load holding and safety circuitry Other lifting systems are also within the scope of the present disclosure.

[0078] Comparing FIGURES 17 and 18, the lift assembly 120 lifts the skid S holding a cask K containing a canister C from a first ground level elevation position to a second elevation position. In the second elevation position, a canister C is transferred from a cask K into an entry hole 30 in the top row 42 of an HSM 10. When the skid S and cask K are in the second elevation position, a linear actuator, shown as a telescoping ram device R extends and pushes the canister C out of the cask K and into the entry hole 30 in the top row 42 of an HSM 10.

[0079] Although shown and illustrated in a loading sequence for loading a canister C into an entry hole 30 in the top row 42 of an HSM 10, the lift assembly 120 can also be used in an unloading sequence for removing a canister C from an entry hole 30 in the top row 42 of an HSM 10. In that regard, the telescoping ram device R may also be used to retrieve the canister from the cavity 36 in the top row 42 of the HSM 10 and pull it into the cask K. After being retrieved, the lift assembly 120 lowers the skid S holding a cask K containing a canister C from the second elevation position to the first ground level elevation position.

[0080] As an alternative to sliding rails in the HSM 10 for sliding transfer of the canister to and from the compartment 22 of the HSM 10, a reduced-friction horizontal transfer device 220 described below may be used to transfer the canister C to and from the compartment 30 of the HSM 10.

[0081] Although shown as lifting to a second elevation position, embodiments of the present disclosure may also be configured to lift to higher elevation positions, for example, in HSMs 10 having more than two rows of compartments.

[0082] The principles, representative embodiments, and modes of operation of the present disclosure have been described in the foregoing description. However,

aspects of the present disclosure which are intended to be protected are not to be construed as limited to the particular embodiments disclosed. Further, the embodiments described herein are to be regarded as illustrative rather than restrictive. It will be appreciated that variations and changes may be made by others, and equivalents employed, without departing from the spirit of the present disclosure. Accordingly, it is expressly intended that all such variations, changes, and equivalents fall within the spirit and scope of the present disclosure, as claimed.

Claims

1. A horizontal storage module (HSM), comprising:

a body defining a plurality of compartments configured for receiving canisters, wherein the compartments are arranged in a first row at a first elevation and a second row at a second elevation higher than the first elevation, and wherein at least a portion of one compartment in the first row is in the same horizontal axis location as at least a portion of one compartment in the second row.

2. The HSM of Claim 1, further comprising ventilation means in each of the plurality of compartments including vent paths having substantially vertical pathways.

3. The HSM of Claim 1 or 2, wherein each compartment is adjacent at least two other compartments, preferably adjacent to at least three other compartments, and preferably adjacent to at least four other compartments.

4. The HSM of any of Claims 1 to 3, wherein each compartment is polygonal in cross-sectional shape and/or wherein at least some of the compartments are hexagonal in cross-sectional shape.

5. The HSM of any one of Claims 1 to 4, wherein the plurality of compartments are arranged in a staggered configuration

6. The HSM of any one of Claims 1 to 5, further comprising a roof on the body, namely a roof supported only by the front and back walls.

7. The HSM of Claim 6, wherein the roof has impact resistance means, preferably including one or more of the following elements: an impact resistant polymer blanket; a reinforced concrete slab supported by pre-deformed steel pipes; half pipes; a pre-tensioned concrete slab.

8. The HSM of any of Claims 1 to 7, wherein at least a first vertical pathway extends from each inlet vents to each compartment and at least a second vertical pathway extends from each compartment to each outlet vent.

9. The HSM of any of Claims 1 to 8, further comprising a lift assembly for lifting the canister to the second elevation.

10. The HSM assembly of any one of Claims 1 to 9, wherein the body portion is modularized and made from a plurality of segments, namely a plurality of segments which are made from reinforced concrete.

11. The HSM assembly of Claim 10, wherein the plurality of segments are vertically layered on top of each other.

12. The HSM assembly of Claim 11, wherein adjacent segments are attached to one another using only a vertical attachment system, namely a vertical attachment system includes a plurality of vertically oriented holes in the walls of adjacent segments, and ties connecting such holes.

13. A method of constructing an HSM assembly, the method comprising:

(a) forming a plurality of segments for the body portion of the HSM assembly; and
(b) positioning adjacent segments.

14. The method of Claim 13, further comprising vertically attaching adjacent segments.

15. A lift assembly for a high-density horizontal storage module (HSM), the HSM including a body defining a plurality of compartments configured for receiving canisters, wherein the compartments are arranged in a first row at a first elevation and a second row at a second elevation higher than the first elevation, and wherein at least a portion of one compartment in the first row is in the same horizontal axis location as at least a portion of one compartment in the second row, the lift assembly comprising:

a frame assembly; and
actuation means for lifting a cask containing a canister for delivery to the second row at the second elevation.

16. The lift assembly of Claim 15, wherein the frame assembly can be folded to a traveling configuration and expanding to a lifting configuration.

17. A method of loading a canister in a high-density horizontal storage module (HSM), the HSM including a

body defining a plurality of compartments configured for receiving canisters, wherein the compartments are arranged in a first row at a first elevation and a second row at a second elevation higher than the first elevation, and wherein at least a portion of one compartment in the first row is in the same horizontal axis location as at least a portion of one compartment in the second row, the method comprising:

receiving a cask containing a canister in a frame assembly of a lifting assembly at the first elevation; and

lifting the cask containing the canister for delivery of the canister to the second row at the second elevation.

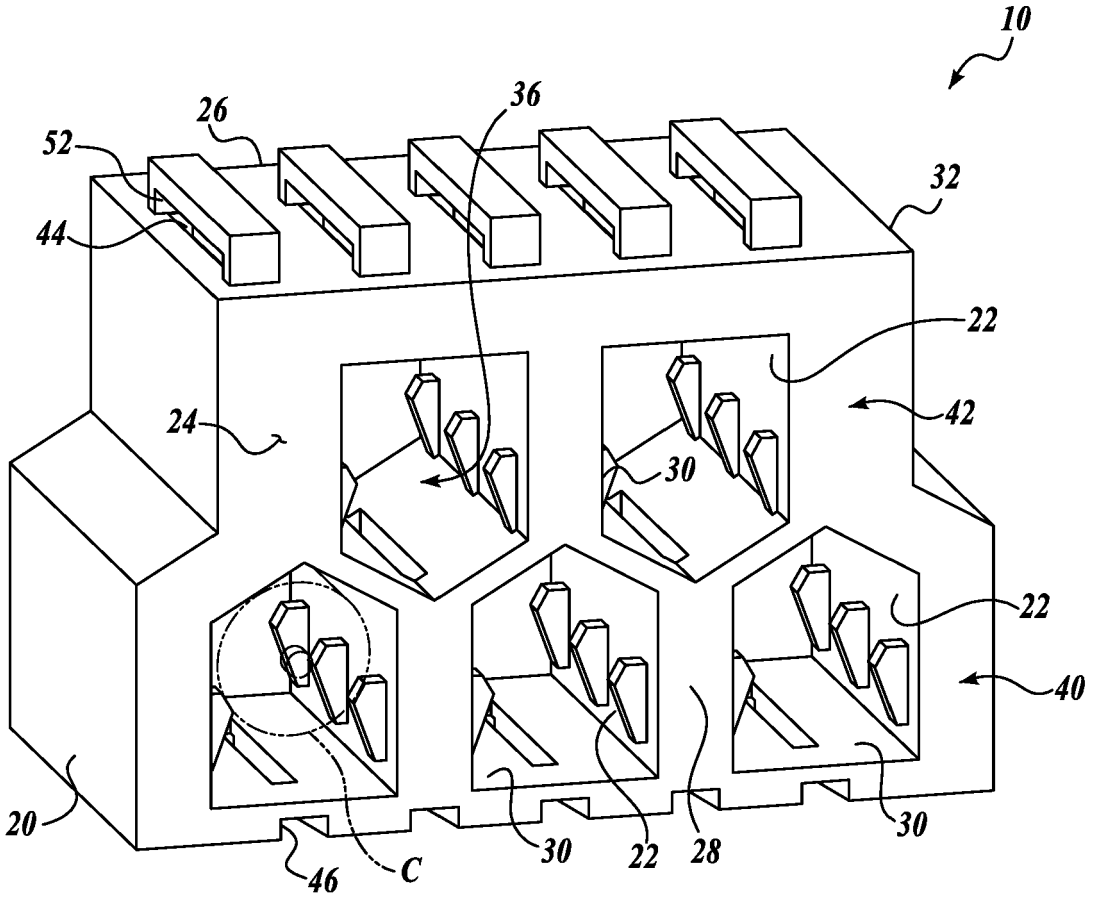


FIG. 1

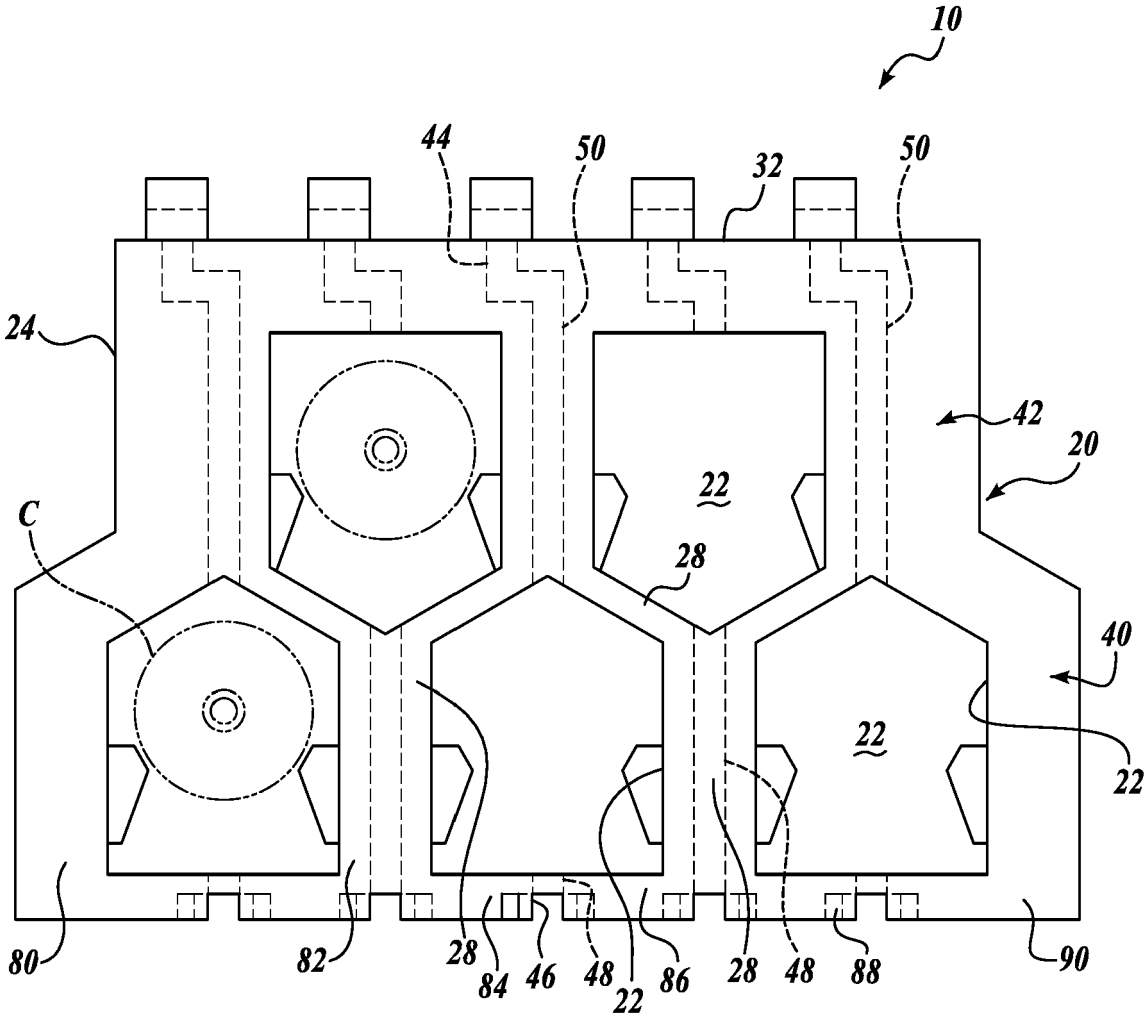
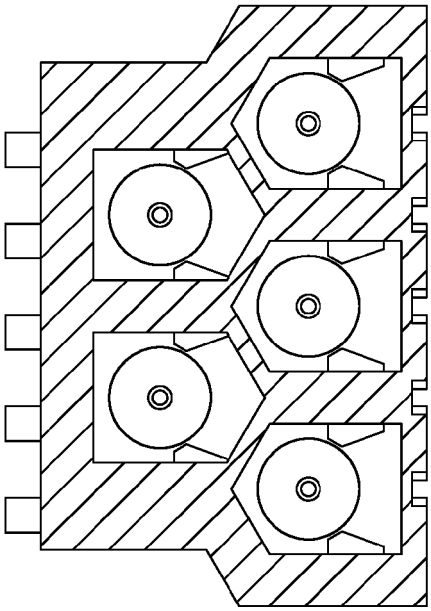

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FIG. 2



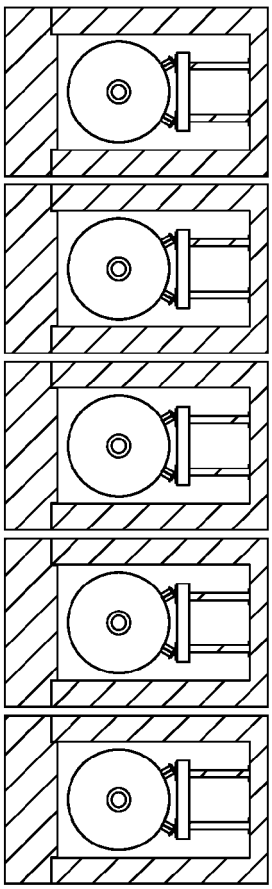
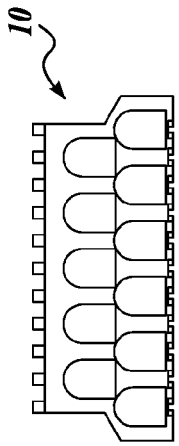
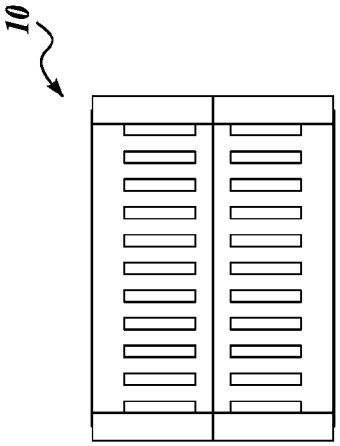


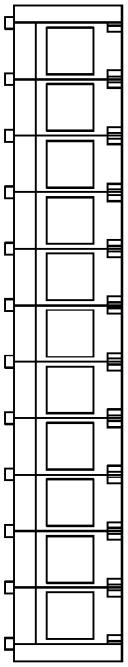
FIG. 3

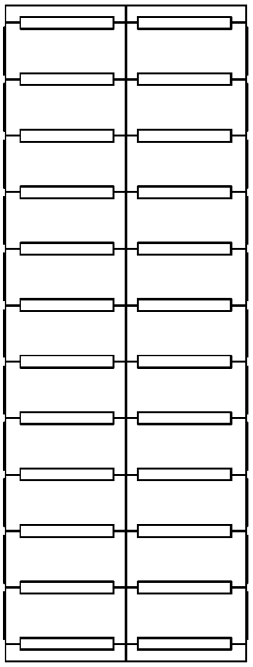




STAGGERED HSM
2 X 11 ARRAY

ELEVATION VIEW





HSM-H
2 X 11 ARRAY

PLAN VIEW

FIG. 4

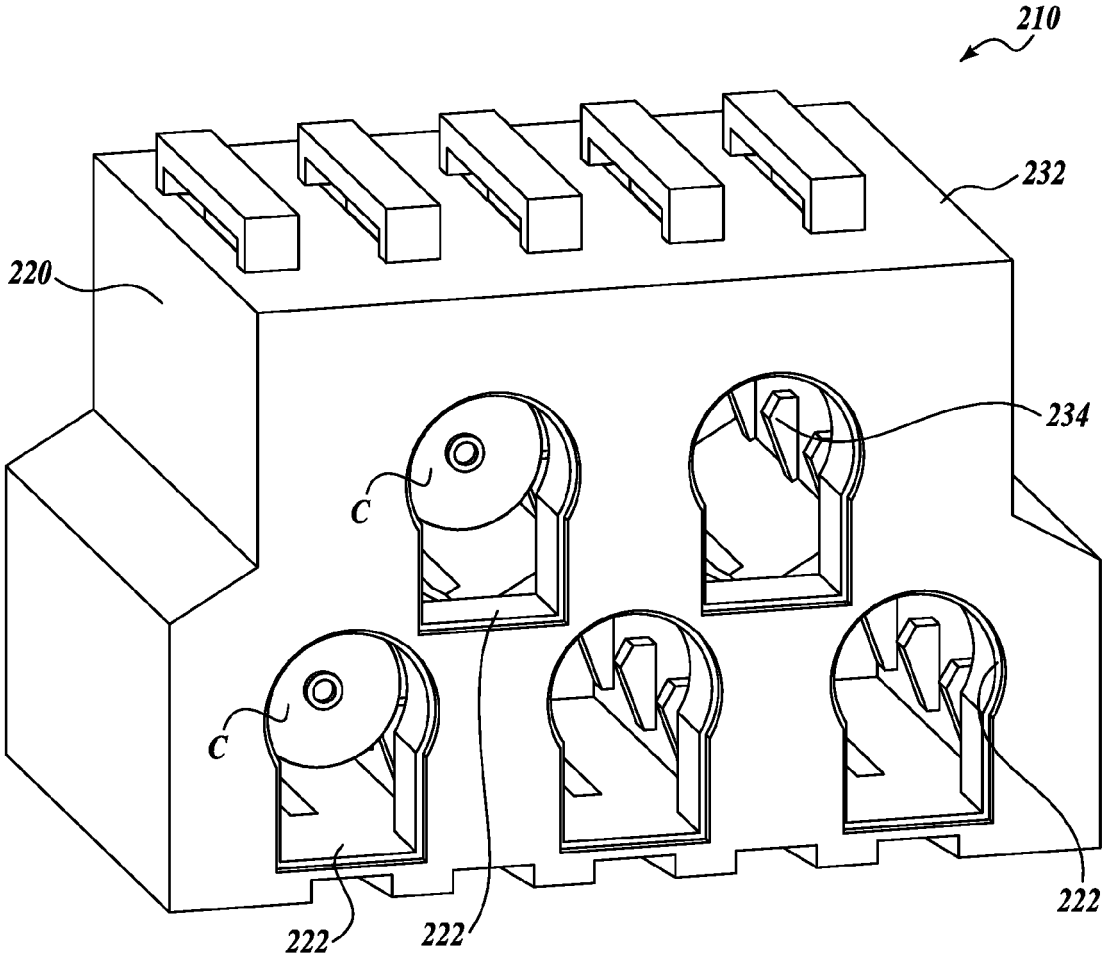


FIG. 5

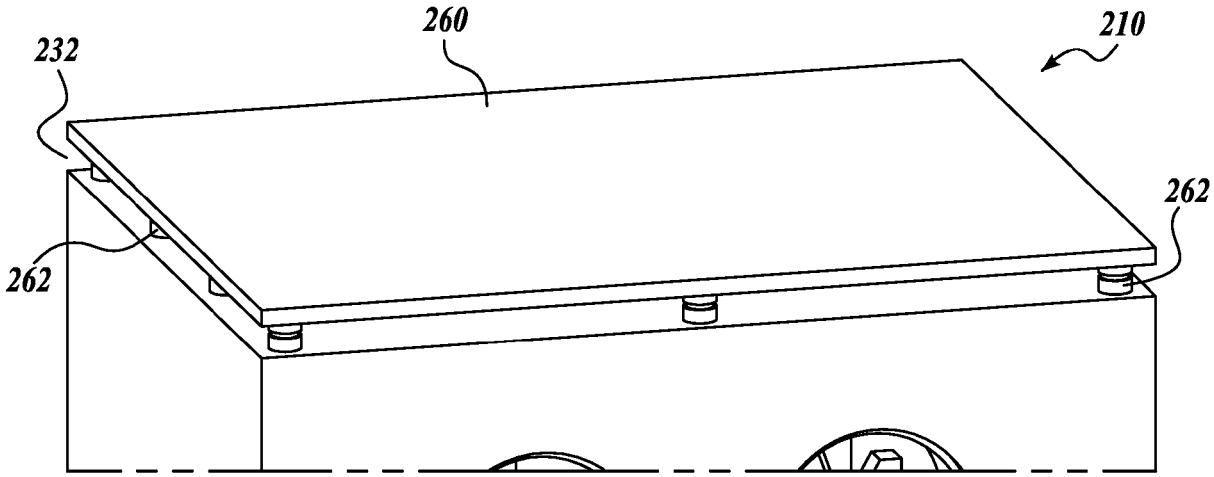


FIG. 6

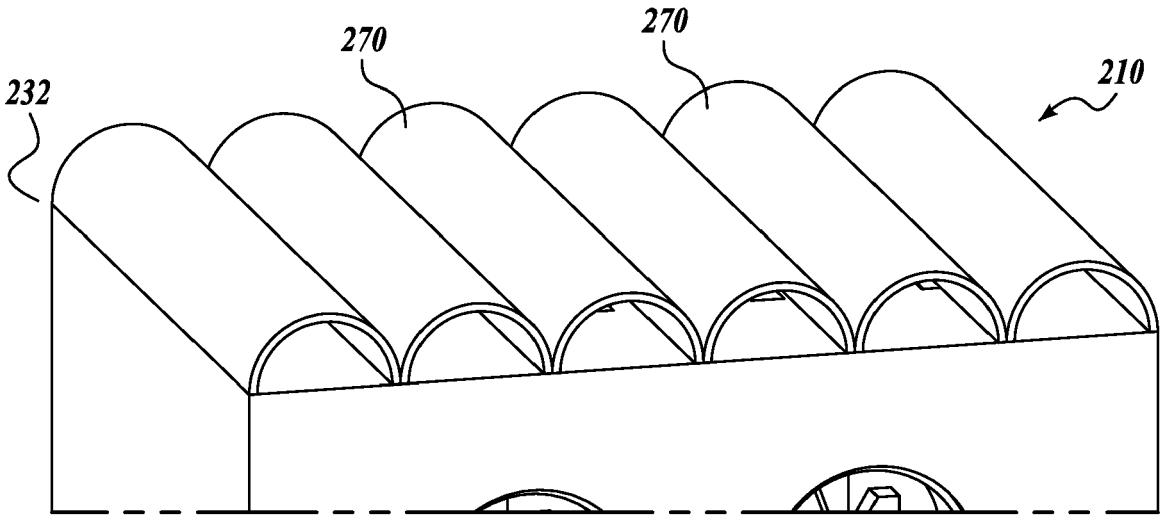


FIG. 7

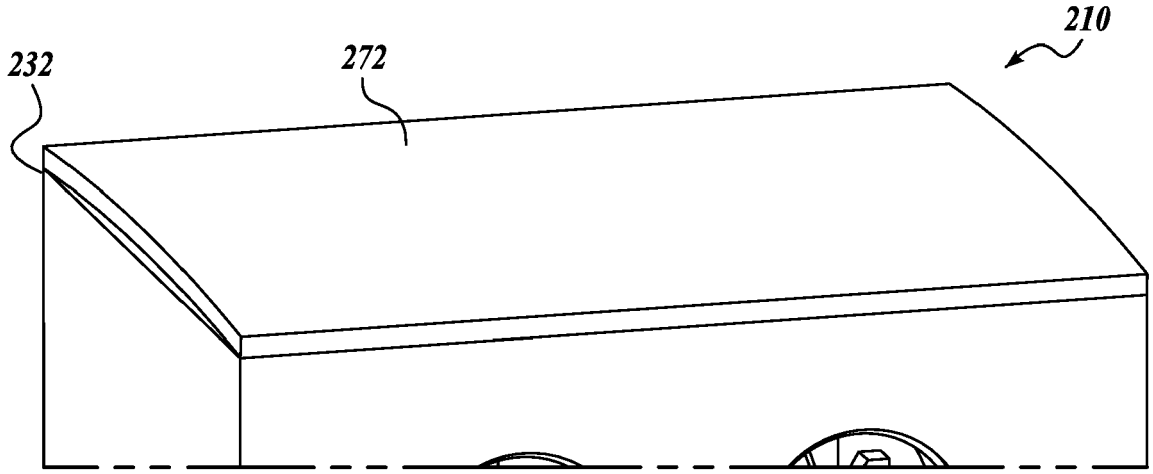


FIG. 8

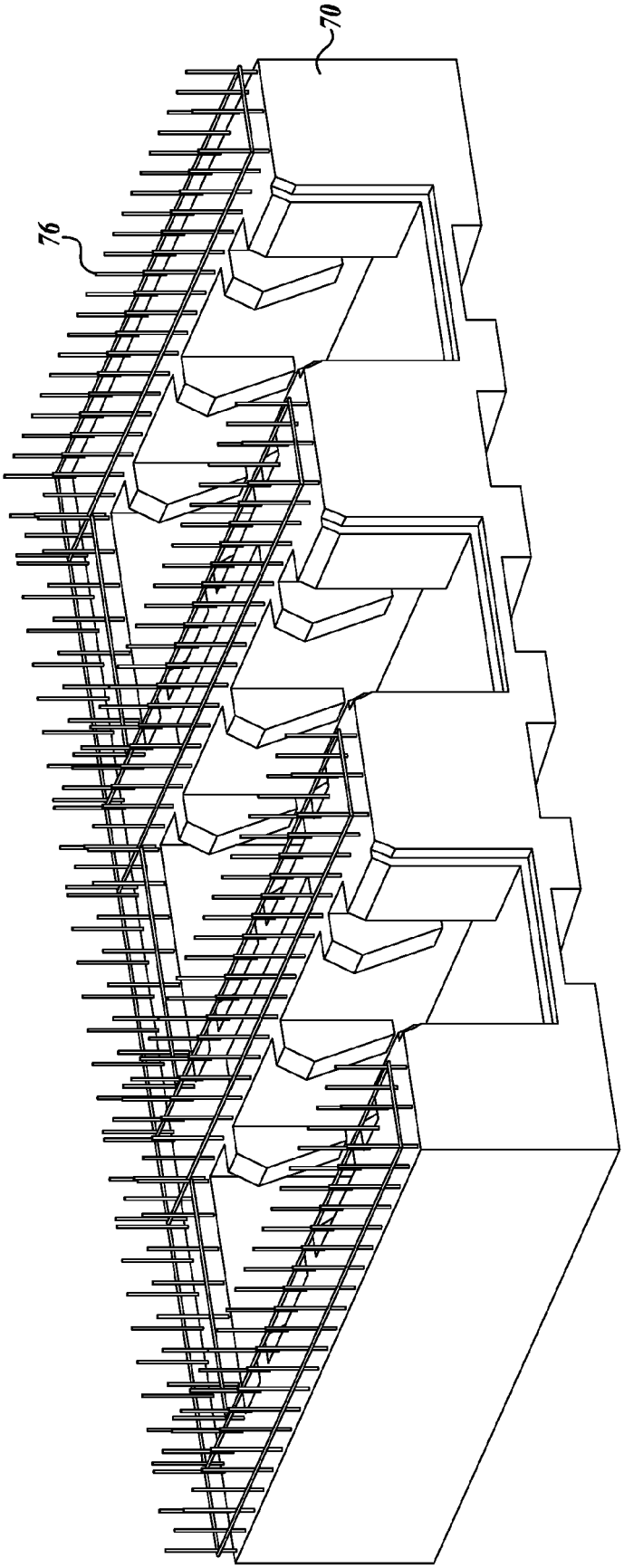


FIG. 9

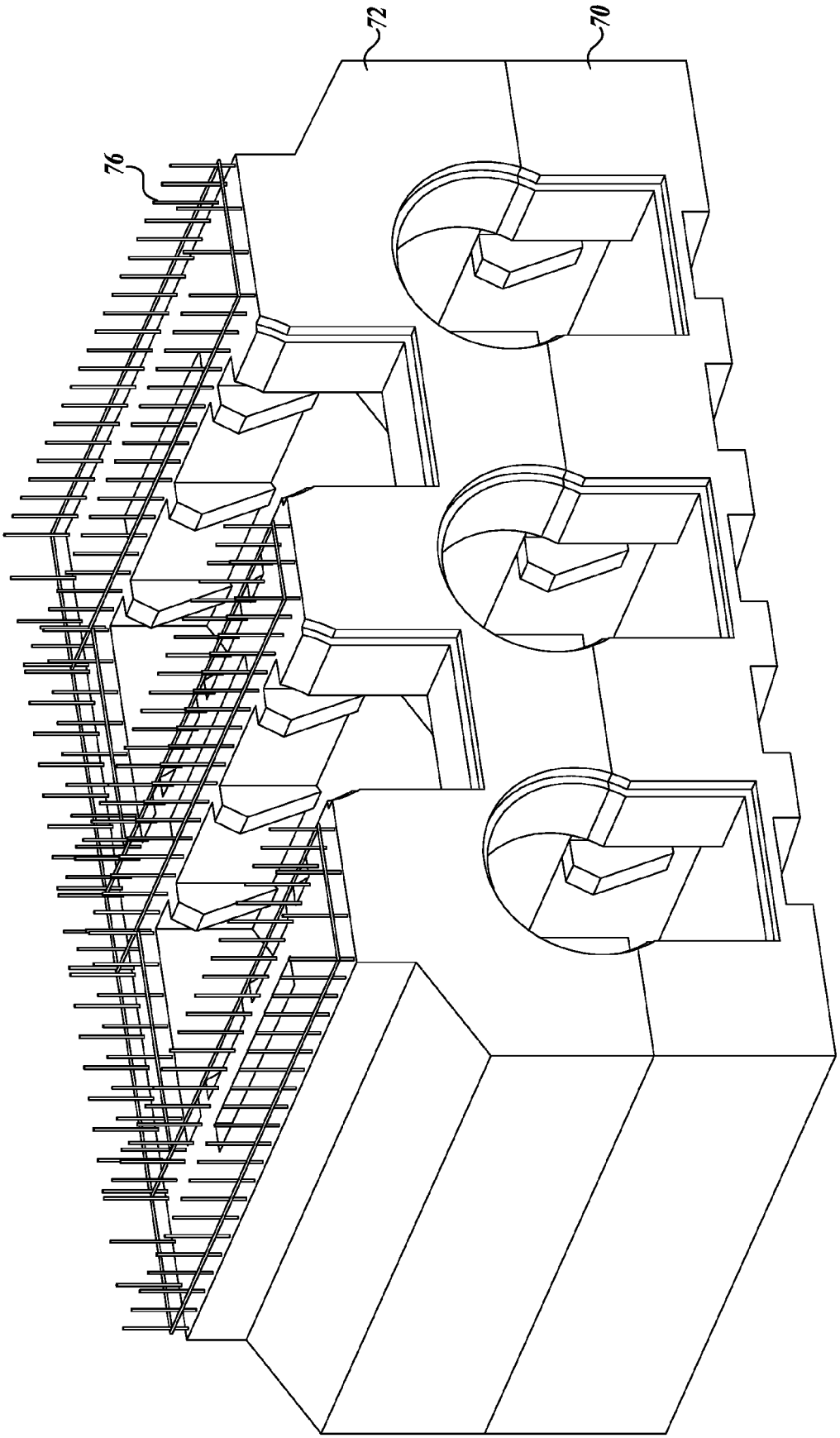


FIG. 10

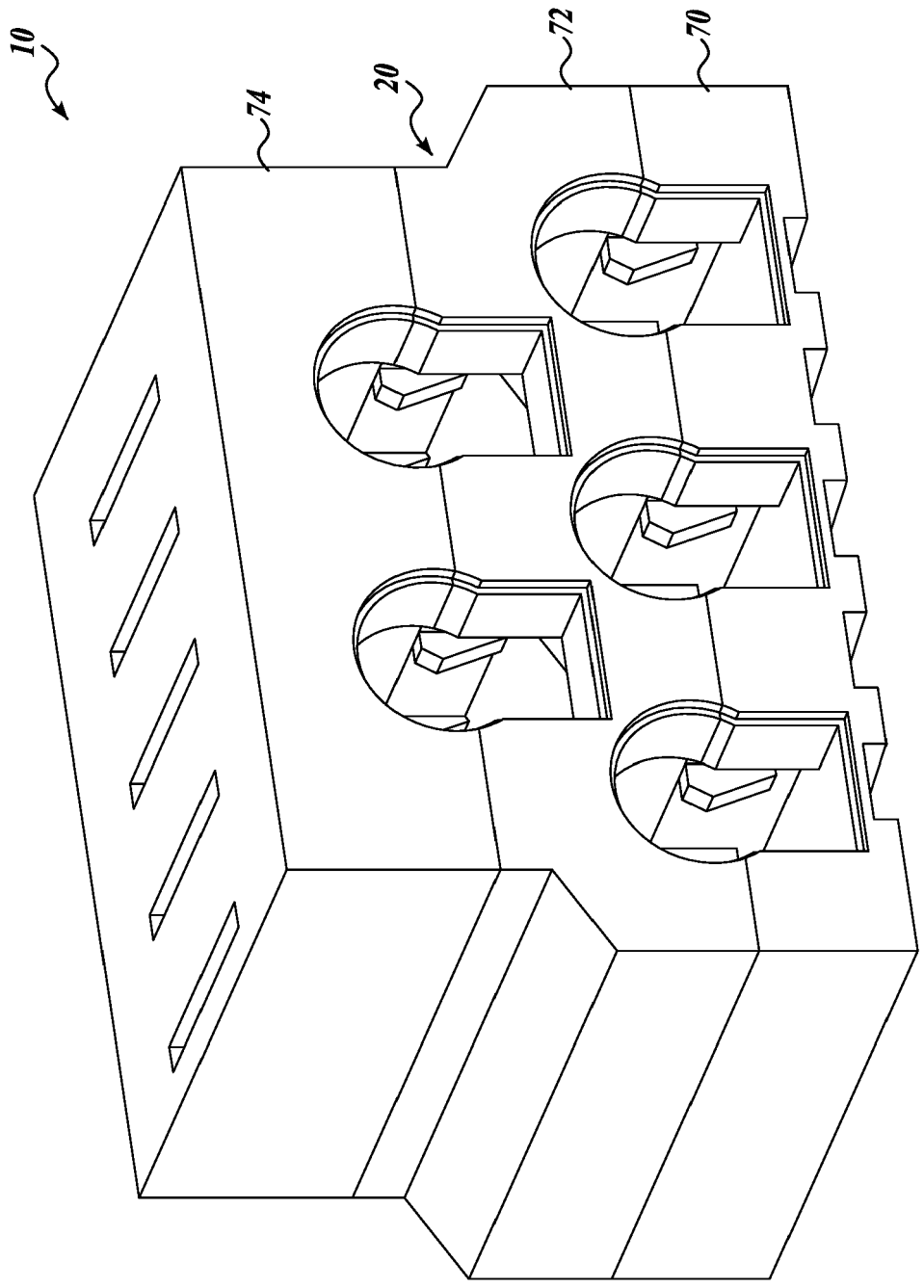


FIG. 11

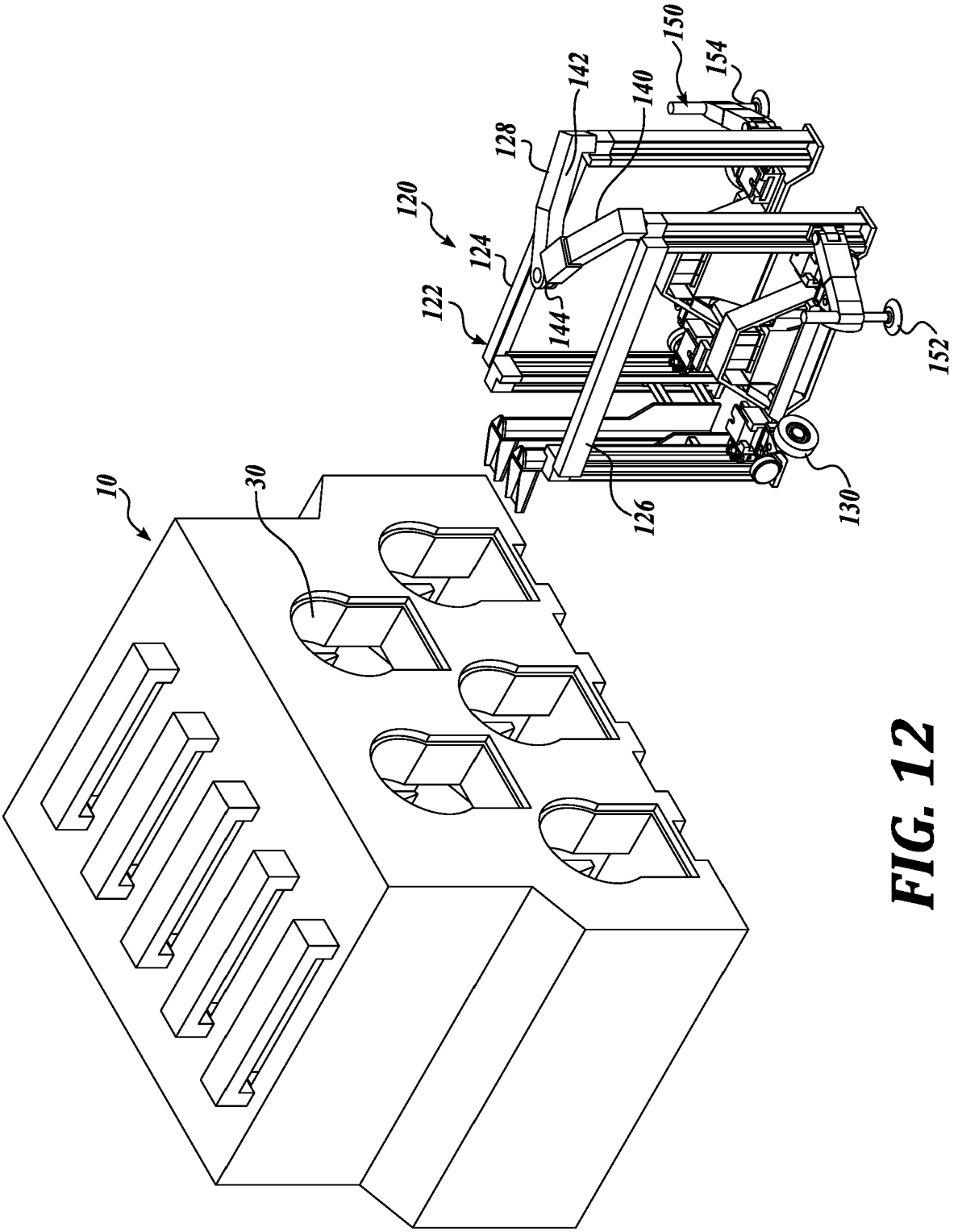


FIG. 12

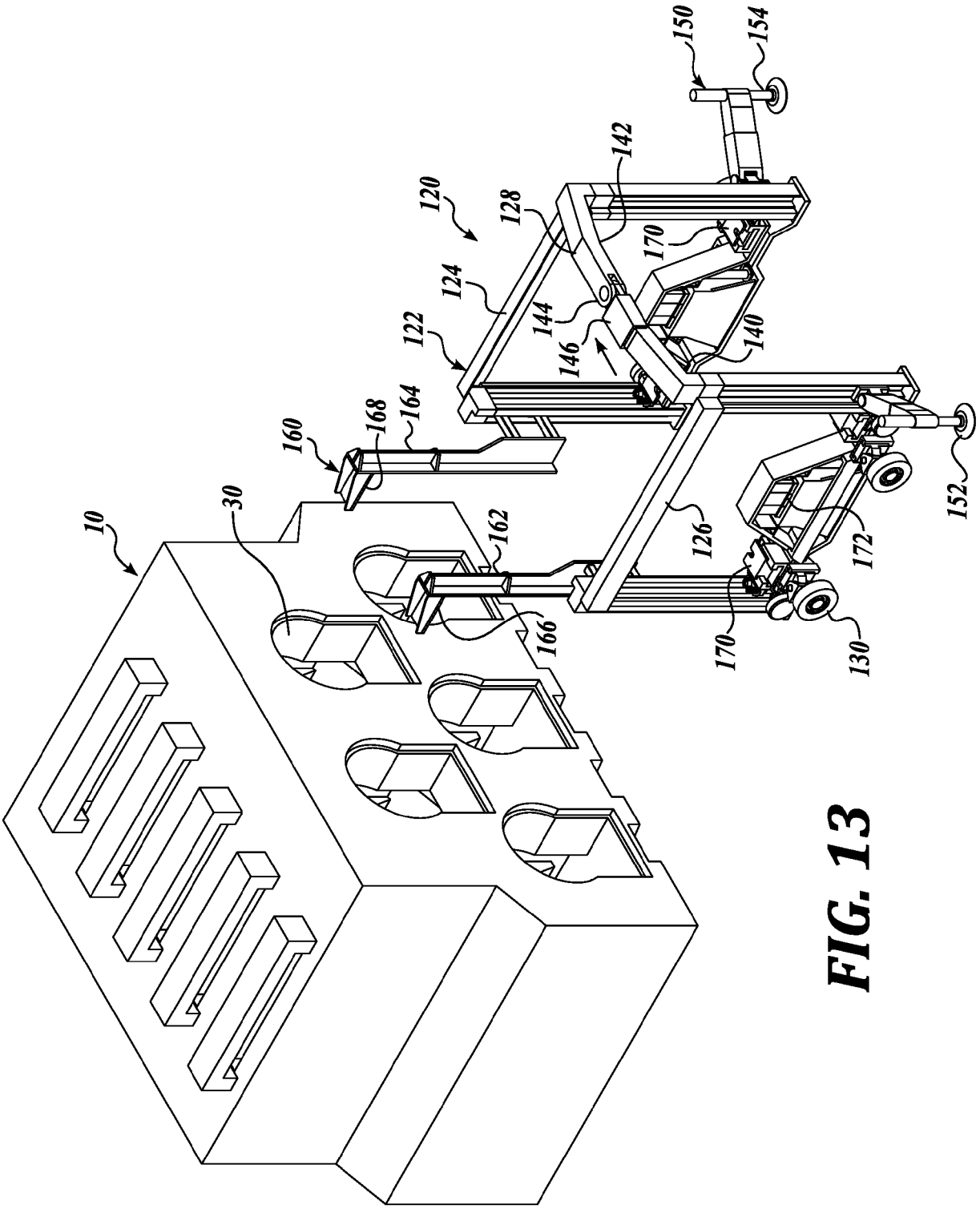
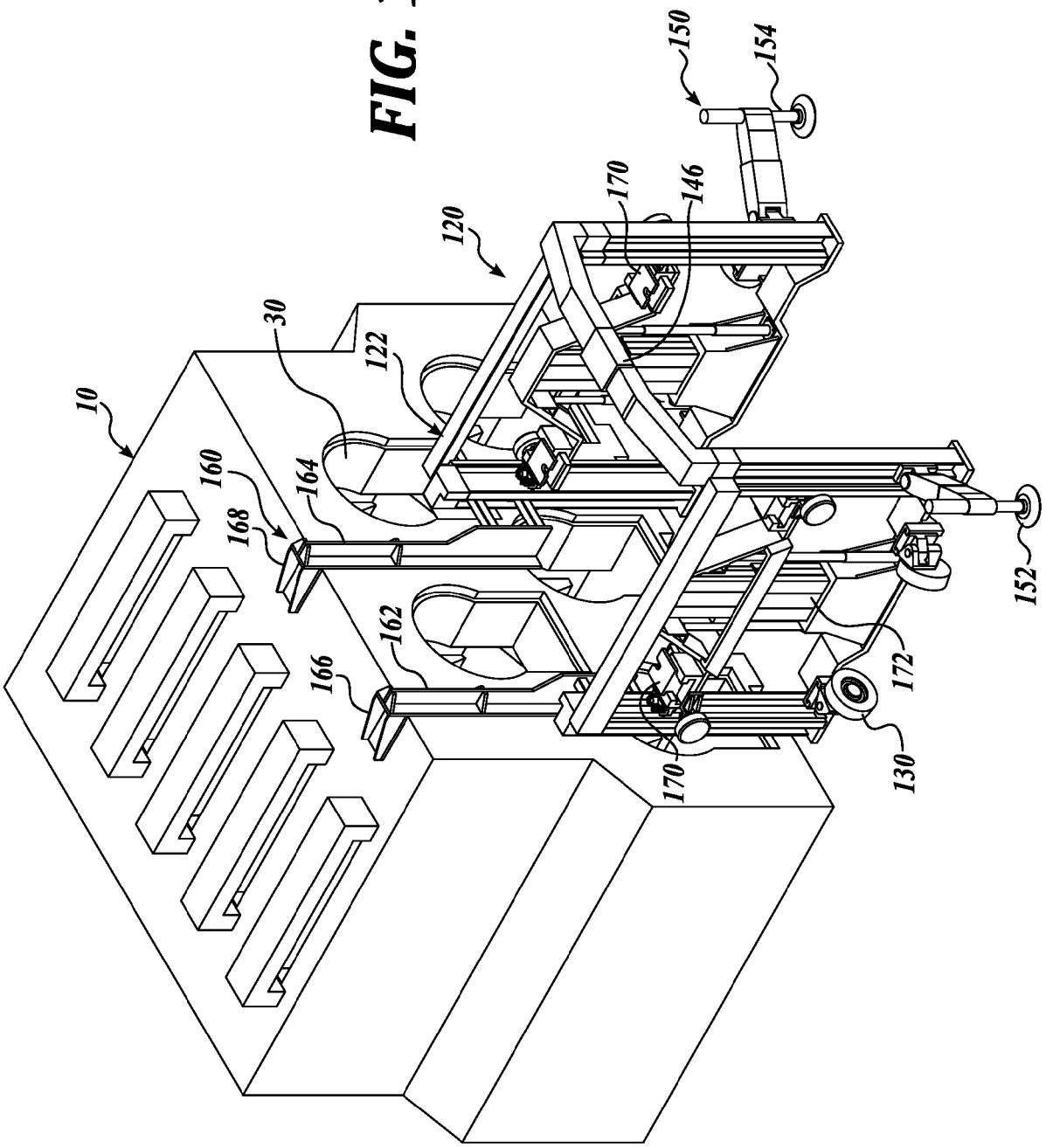

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FIG. 13

FIG. 14



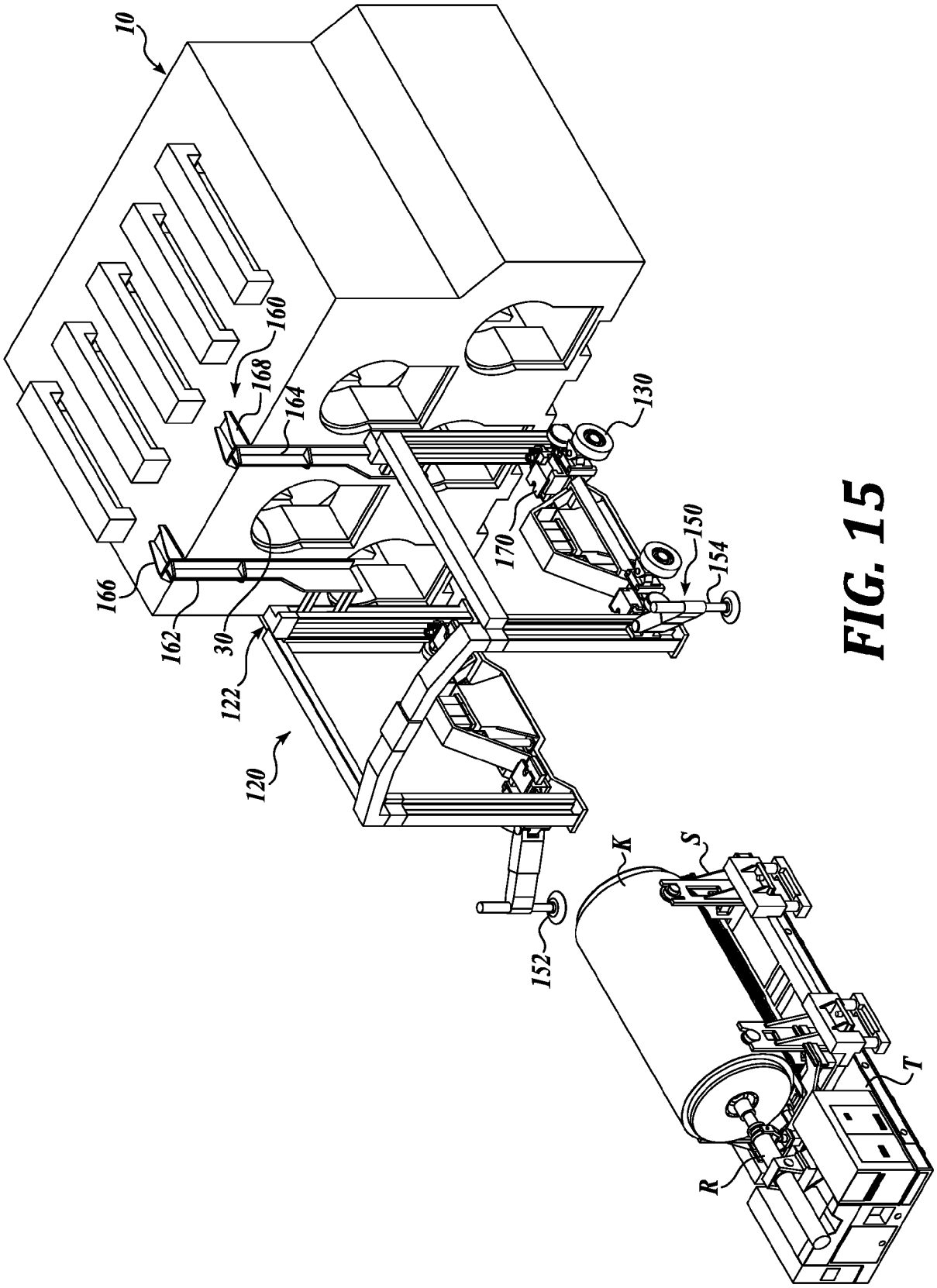


FIG. 15

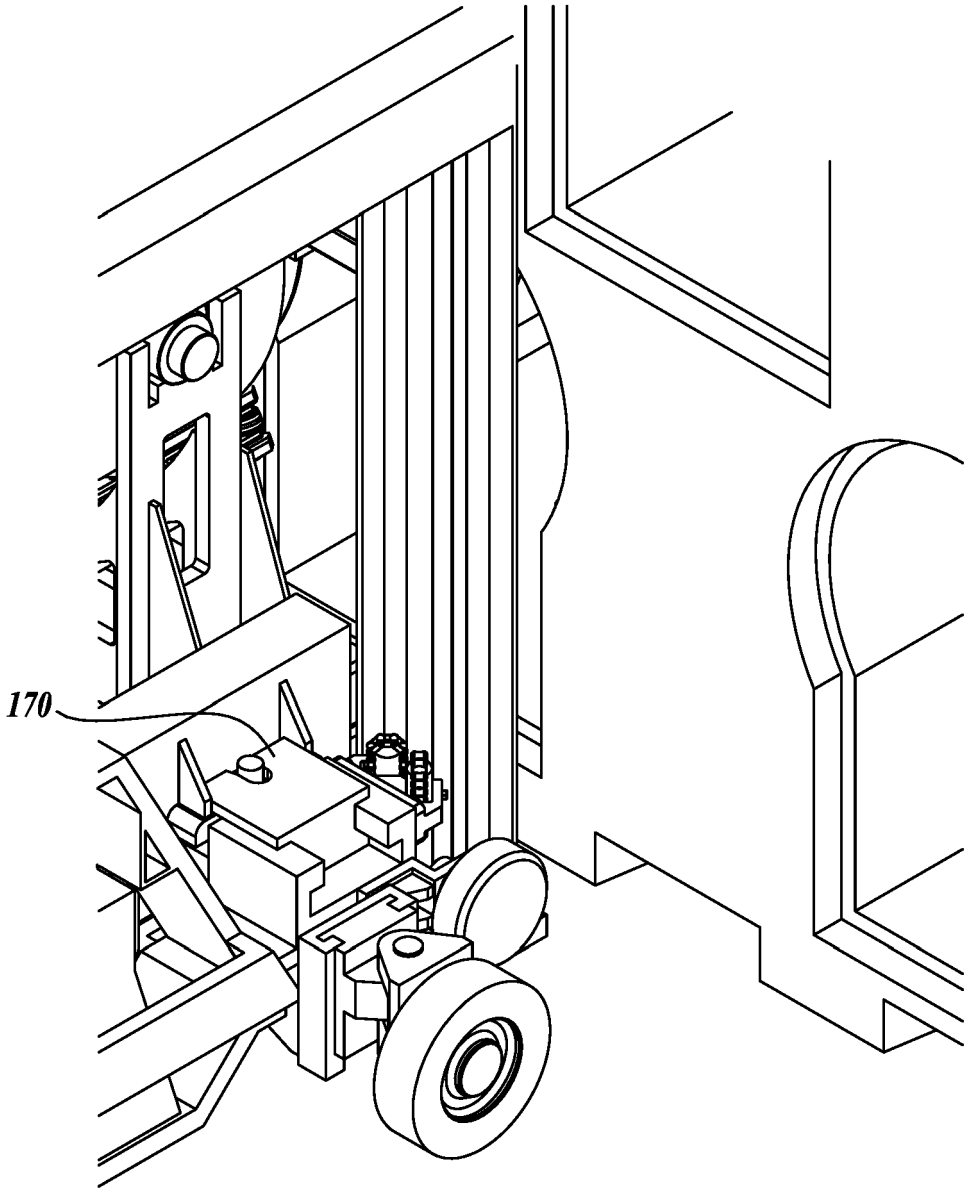


FIG. 16

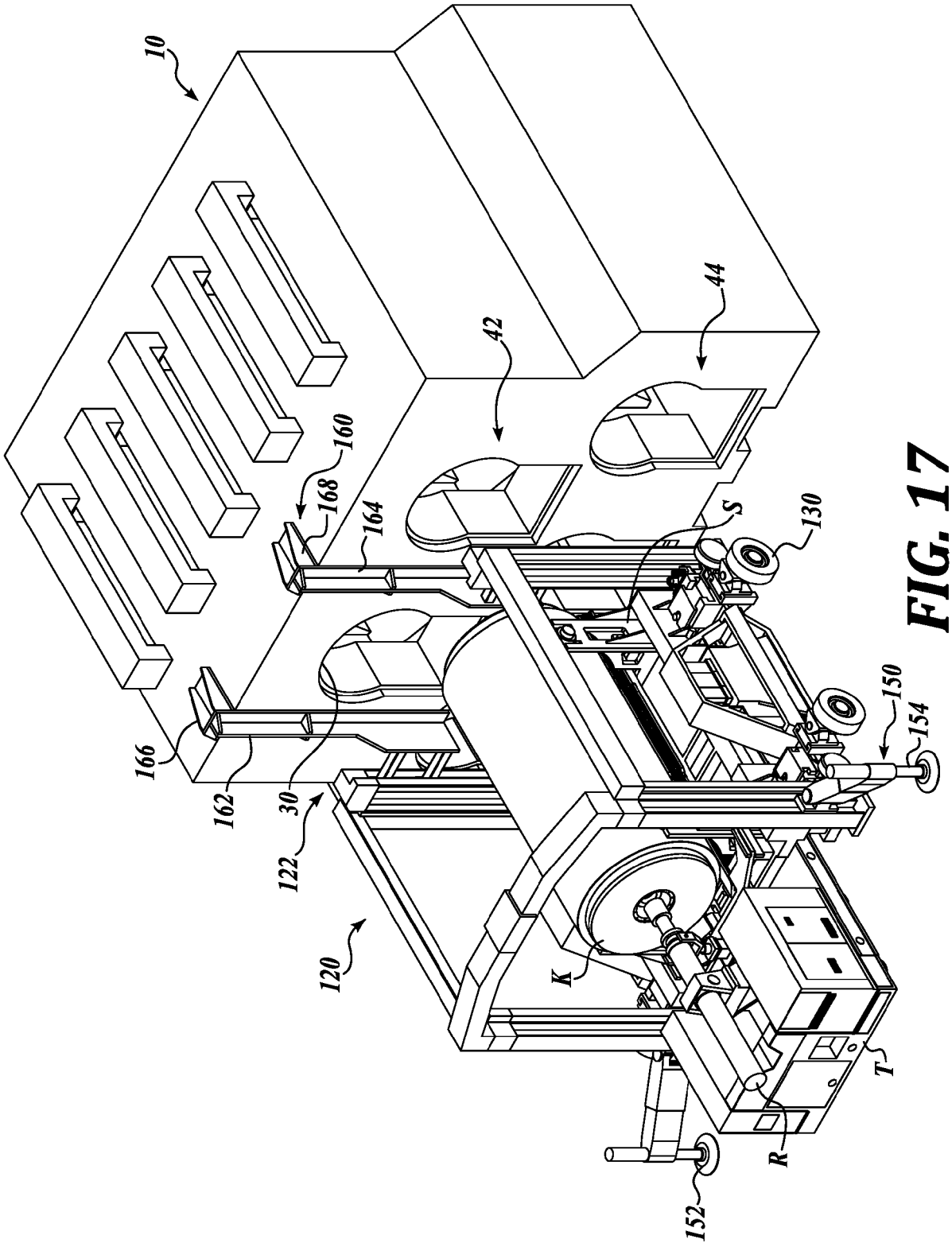


FIG. 17

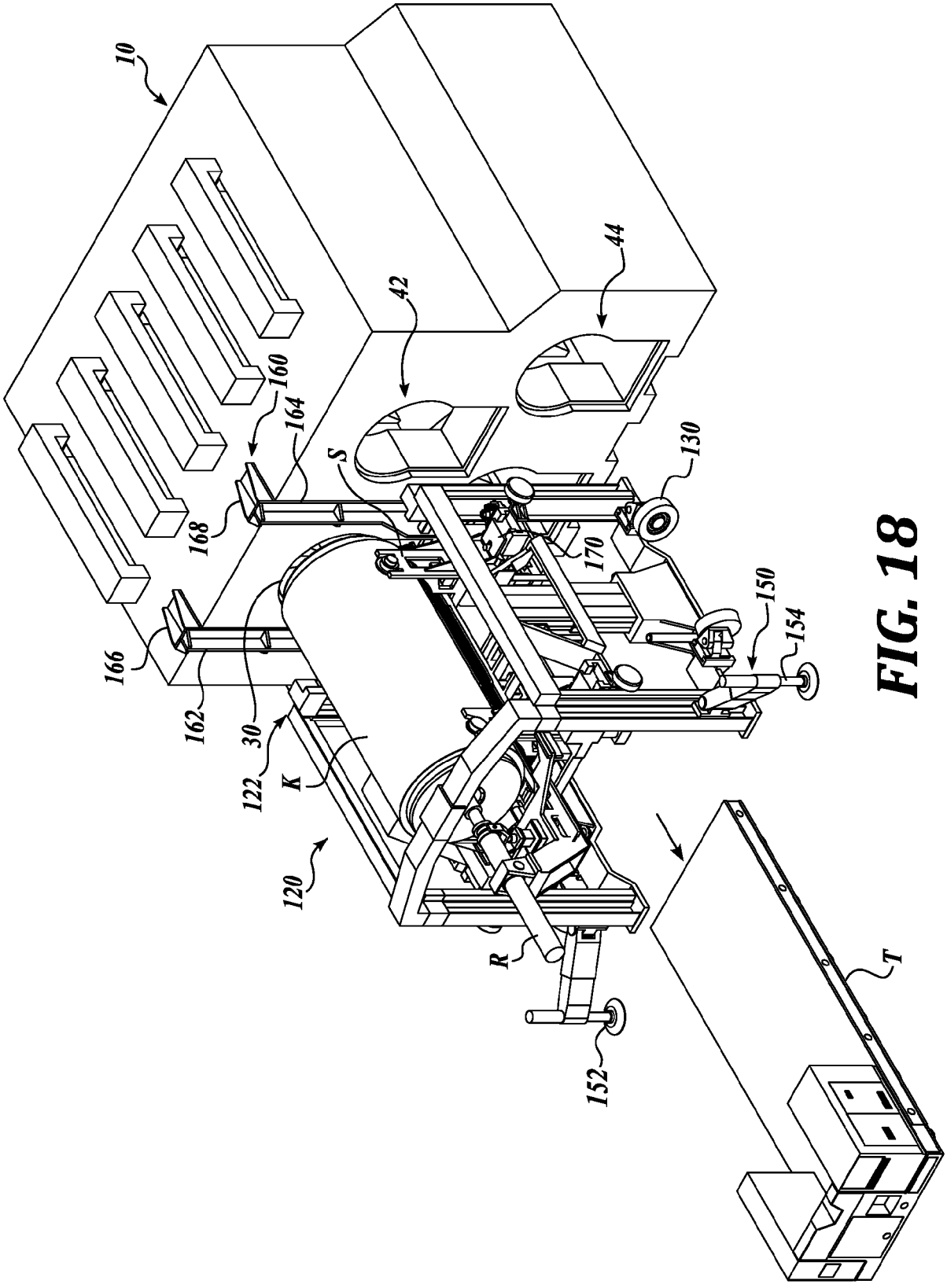


FIG. 18

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EUROPEAN SEARCH REPORT

Application Number
EP 15 19 7150

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	JP 2000 056071 A (KAWASAKI HEAVY IND LTD) 25 February 2000 (2000-02-25) * abstract; figures 7-11 * * paragraph [0012] *	1-4,8, 10,11,13	INV. G21C19/07 G21D1/02 G21F9/34
X	RU 2 069 395 C1 (ROSSIJSKIJ UNI DRUZHBY NARODOV [RU]) 20 November 1996 (1996-11-20) * abstract; figures *	1,3-5	
X	DE 43 36 421 A1 (HOETZELDT KLAUS PETER DR ING [DE]) 29 June 1995 (1995-06-29) * see fig. 1 and the description thereof *	1,6,7	
X	EP 0 072 356 A1 (ENEL ENTE NAZ EN ELETTRICA [IT]) 16 February 1983 (1983-02-16) * see fig. 1 - 3 and the description thereof * * see fig. 8-15 and the description thereof * * page 8, line 21 *	1,6,7,9, 15-17	
X	KR 101 569 874 B1 (HANSUNG WELLTECH CO LTD) 17 November 2015 (2015-11-17) * the whole document *	9,15-17	
X	US 2014/042159 A1 (SALIH AHMAD E [US]) 13 February 2014 (2014-02-13) * see fig 1 - 4 and the description thereof * * paragraphs [0002], [0014], [0020], [0034], [0044] *	1,10-14	

TECHNICAL FIELDS SEARCHED (IPC)
G21C
G21D
G21F

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	9 August 2016	Angloher, Godehard

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

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Application Number
EP 15 19 7150

CLAIMS INCURRING FEES

The present European patent application comprised at the time of filing claims for which payment was due.

☐ Only part of the claims have been paid within the prescribed time limit. The present European search report has been drawn up for those claims for which no payment was due and for those claims for which claims fees have been paid, namely claim(s):

☐ No claims fees have been paid within the prescribed time limit. The present European search report has been drawn up for those claims for which no payment was due.

LACK OF UNITY OF INVENTION

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

see sheet B

☒ All further search fees have been paid within the fixed time limit. The present European search report has been drawn up for all claims.

☐ As all searchable claims could be searched without effort justifying an additional fee, the Search Division did not invite payment of any additional fee.

☐ Only part of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the inventions in respect of which search fees have been paid, namely claims:

☐ None of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims, namely claims:

☐ The present supplementary European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims (Rule 164 (1) EPC).

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LACK OF UNITY OF INVENTION
SHEET B

Application Number
EP 15 19 7150

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

1. claims: 1-5, 8, 10, 11, 13

A horizontal storage module according to e.g. claim 1;
additional features of claim 5:
the plurality of compartments are arranged in a staggered configuration;

1.1. claims: 2-4, 8, 10, 11, 13

see the subject-matter of the corresponding claims;
---

2. claims: 6, 7

A horizontal storage module according to e.g. claim 1;
additional features common to claims 6 and 7:
a roof on the body, namely a roof supported only by the front and back walls;
---

3. claims: 9, 15-17

claims 9, 15, 16:
(An assembly comprising) a horizontal storage module according to (e.g.) claim 1;
additional features of claim 9:
a lift assembly for lifting the canister to the second elevation;
additional features common to claims 15, 16:
a frame assembly; and
actuation means for lifting a cask containing a canister for delivery to the second row at the second elevation
claim 17:
A method of loading a canister in a horizontal storage module according to claim 1;
additional features of claim 17:
receiving a cask containing a canister in a frame assembly of a lifting assembly at the first elevation; and
lifting the cask containing the canister for delivery of the canister to the second row at the second elevation;
---

4. claims: 12, 14

group 4 claims 12, 14;
claim 12:
A horizontal storage module according to claim 11;
additional features of claim 12:
adjacent segments are attached to one another using only a vertical attachment system, namely a vertical attachment system includes a plurality of vertically oriented holes in

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LACK OF UNITY OF INVENTION
SHEET B

Application Number
EP 15 19 7150

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

the walls of adjacent segments, and ties connecting such holes;
claim 14:
A method of constructing a horizontal storage module according to claim 13;
additional features of claim 14:
vertically attaching adjacent segments;

Please note that all inventions mentioned under item 1, although not necessarily linked by a common inventive concept, could be searched without effort justifying an additional fee.

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 15 19 7150

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

09-08-2016

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		WO 2014028402 A1	20-02-2014

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82