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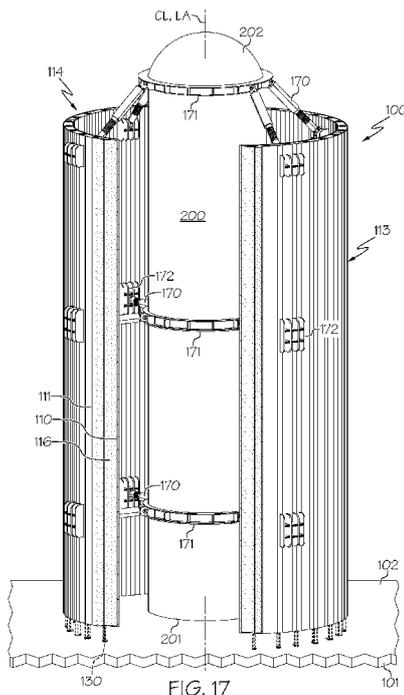
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(54) Title: STEAM GENERATOR ENCLOSURE STRUCTURE FOR NUCLEAR POWER GENERATION PLANT



(57) Abstract: A steam generator enclosure system for a nuclear power generation plant includes a concrete slab defining an operating deck and an enclosure disposed on the slab. The enclosure is formed by a double-walled sidewall comprising an inner and outer shell spaced radially apart defining an annular space therebetween filled with concrete for radiation shielding. Vertically-extending rib plates in the annular space couple the inner and outer shells together. Downward extensions of the rib plates from the sidewall form anchors embedded in the concrete slab. A steam generator vessel seated on the slab is disposed inside an internal cavity formed by the sidewall. Seismic restraints provided at multiple elevations couple the vessel to the sidewall in a manner which accommodates thermal expansion/contraction of the vessel. In one embodiment, the enclosure may have a modular construction formed by an assemblage of shop-fabricated wall section modules erected on site and filled with concrete.



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**STEAM GENERATOR ENCLOSURE STRUCTURE FOR NUCLEAR POWER  
GENERATION PLANT**

**CROSS-REFERENCE TO RELATED APPLICATIONS**

[0001] This application claims the benefit of U.S. Provisional Application No. 63/615,883 filed December 29, 2023, which is incorporated herein by reference in its entirety.

**BACKGROUND**

[0002] The present invention relates generally to a nuclear power generation plant, and more particularly to an enclosure structure for housing a steam generator associated with a small modular reactor (SMR).

[0003] The steam generator in a nuclear power generation plant may be a tall vertical heat exchanger which receives heated primary coolant from the reactor pressure vessel (RPV) containing the nuclear fuel core which heats the primary coolant. The steam generator includes a tube bundle which conveys a secondary working fluid such as water inside the tubes which is converted to steam via absorbing heat from the primary coolant. The steam can be used to operate the turbogenerator associated with a Rankine power generation cycle to produce electricity in a well known manner. The primary coolant flows on the shell side inside the steam generator outside of the tubes and is therefore fluidly isolated from the working fluid water.

[0004] However, because the reactor coolant water (i.e. primary coolant) which inevitably contains small amounts of radionuclides picked up in the reactor circulates through the steam generator along side the secondary working fluid inside the tubes, the radiation emanating from the primary coolant necessitates that the steam generator be sequestered from the environment to protect plant workers from radiation exposure.

[0005] In the present state-of-the-art, the steam generator is typically enclosed inside a large rectangular enclosure structure with walls made of reinforced concrete alone which occupy a considerable amount of space and area inside the reactor containment building, thereby requiring expensive on-site only construction of the concrete structure. The containment needs of the steam generator concomitantly drives the size of the reactor containment building up also. This is contrary to the general goals of small modular reactors (SMRs) one of which is to minimize the footprint and land area required to install and operate a nuclear power generation facility.

[0006] Improvements in radiation containment enclosures for steam generators of a SMR powered nuclear power generation plant is needed.

#### BRIEF SUMMARY

[0007] The present application discloses a modular steam generator enclosure structure (SGES) which can be substantially shop manufactured in segments or sections shipped to the nuclear generation plant for assembly and erection on site, occupies a much smaller floor surface area inside the reactor containment building, serves to efficiently shield the surrounding environment and workers from the radiation emitted by the primary coolant inside the steam generator, and finally increases the steam generator's "beam-frequency" to better resist seismic events (earthquakes). The SGES laterally encloses the steam generator.

[0008] In one embodiment, the individual SGES sections may be stacked and coupled together at the installation site to erect a vertically tall enclosure substantially commensurate for the most part with the height of the steam generator vessel. A majority of the height of the steam generator vessel may be enclosed within the walls of the SGES (e.g., 80% or more) starting at the concrete slab that forms the plant operating deck below and extending upwards to a height enclosing all of the steam generator vessel except for its very upper portion in some embodiments. This ensures that the operating deck which may be occasionally occupied by plant workers are shielded from radiation exposure. In other possible embodiments, the entire height of the steam generator may be surrounded by the SGES. The bottom end of the SGES is founded on and fixedly anchored in the concrete operating deck. The top end of the SGES may be open for access to the steam generator inside and to allow air within the SGES which may be heated by the steam generator to rise and escape the enclosure.

[0009] The SGES may have a non-polygonal cross-section shape such as circular, or in a preferred embodiment oblong such as elliptical. The SGES is sufficiently larger in diameter compared to the steam generator to enable workers to perform preventive or remedial maintenance work on the steam generator without undue space restriction. The elliptical configuration in particular provides additional enlarged space at its ends on two opposite sides of the steam generator inside the SGES to easily accommodate routing primary coolant piping from the reactor pressure vessel, seismic lateral restraints for the steam generator to stabilize the vessel against a seismic event, and increased personnel access to the steam generator for maintenance and repairs. In addition, the elliptical cross-section SGES which forms a three-dimensional ellipsoid advantageously is

narrower in the short transverse direction which saves room on the operating deck of the plant to accommodate other equipment, yet still provides sufficient access to the steam generating vessel.

**[0010]** In one embodiment, the SGES may be a double-walled structure having composite walls formed by two spaced apart concentric steel shells including inner and outer shells defining an annular space therebetween filled with high density concrete on site as the enclosure is gradually built from the bottom up by stacking and coupling individually fabricated wall segments together in tiers. The two shells are joined and coupled to each other by a plurality of vertically elongated radial connector rib plates. The plates extend both radially perpendicular to the shells and axially in the vertical direction. In the vertical direction, the rib plates may be formed either intermittently and spaced vertically apart, or continuously from the top to bottom of SGES.

**[0011]** In one embodiment, the SGES may have a modular construction formed by an assembly comprising a plurality of both curved and straight wall sections or modules for erecting an elliptical enclosure in cross-section (i.e. ellipsoidal three-dimensional structure). Each wall section module comprises an inner shell and outer shell coupled together by at least two vertical radial connector rib plates. For an SGES with circular cross-sectional shape, all wall section modules are curved. For an SGES with polygonal cross-sectional shape (e.g., square or rectangular), all wall section modules are straight. The wall section modules advantageously are prefabricated in the shop and then shipped to the plant site for assembly and coupling together such as via welding and/or bolting. The wall section modules may be shop fabricated to maximum permissible shipping dimensions depending on the mode of transport which permits shipment to the site via rail car, truck bed, barge/ship, etc. for assembly by methods such as welding and/or bolting. The concrete liner in the annular space of each wall section module is added later at the plant installation site.

**[0012]** The SGES may be constructed on site at the nuclear power generation plant from a plurality of vertically stacked tiers of the wall section modules to gradually erect the SGES to the required preselected height; each tier including a coupled ring of wall section module forming a continuous ring structure for a non-polygonal shaped SGES (e.g., circular or elliptical). Advantageously, each tier when completed by coupling the wall section modules together forms a complete annular space which can then be filled with concrete before moving on to assembling the next successive tier up and so forth. Each ring of wall section modules is coupled to the next vertically adjacent ring of modules. This method of construction provides cost and installation advantages in contrast

to complete site fabrication of the SGES. By filling the wall section modules on site, their overall weight is lessened making them more amenable to shipment in a cost-efficient manner.

**[0013]** The steam generator may be laterally supported and stabilized within the internal cavity of the SGES by a plurality of lateral restraint members such as without limitation snubbers and sway braces or struts which couple the steam generator to the inner shell of the SGES at multiple elevations and circumferential locations as further described herein. This provides protection against excessive lateral movement of the steam generator relative to the SGES during a seismic event to prevent damaging the steam generator.

**[0014]** The steam generator may be any steam generating vessel which is a shell and tube heat exchanger circulating heated primary coolant for the nuclear reactor pressure vessel containing the nuclear fuel core on the shell side inside the vessel, and a working fluid such as water circulating inside the tubes on the tube side heated by the primary coolant to generate steam. The steam may be used in a nuclear power generation plant in one embodiment which includes a turbogenerator and associated auxiliary equipment associated with a Rankine power cycle to generate electricity.

**[0015]** In one aspect, the invention may be an enclosure structure for a vertically elongated steam generator of a nuclear power generation plant, the enclosure structure comprising: a vertical longitudinal axis; an elongated double-walled sidewall extending vertically along the longitudinal axis, the sidewall including top and bottom ends; the sidewall comprising a metallic inner shell and a metallic outer shell in a concentric arrangement spaced radially apart from each other to define an annular space therebetween; the sidewall defining a laterally enclosed internal cavity extending vertically along the longitudinal axis, the internal cavity configured for housing the steam generator therein; a plurality of vertically-extending rib plates disposed in the annular space coupling the inner and outer shells together, the rib plates being circumferentially spaced apart and extending radially between the inner and outer shells; a concrete liner disposed in the annular space; and a plurality of circumferentially spaced apart anchors projecting vertically downwards from the bottom end of the sidewall, the anchors being configured for embedment in concrete

**[0016]** In another aspect, the invention may be a steam generator enclosure system for a nuclear power generation plant comprising: a concrete slab defining an operating deck; an enclosure disposed on the slab and defining a vertical longitudinal axis, the enclosure comprising: an elongated double-walled sidewall extending vertically along the longitudinal axis, the sidewall including top and bottom ends; the sidewall comprising a metallic inner shell and a metallic outer

shell in a concentric arrangement spaced radially apart from each other to define an annular space therebetween; the sidewall defining a laterally enclosed internal cavity extending vertically along the longitudinal axis; a plurality of vertically-extending rib plates disposed in the annular space coupling the inner and outer shells together, the rib plates being circumferentially spaced apart and extending radially between the inner and outer shells; a concrete liner disposed in the annular space; a plurality of anchors projecting vertically downwards from the bottom end of the sidewall, the anchors being embedded in the concrete slab. A steam generator vessel is disposed in the internal cavity and seated on the slab.

### BRIEF DESCRIPTION OF THE DRAWINGS

[0017] The present invention will become more fully understood from the detailed description and the accompanying drawings, wherein like elements are labeled similarly and in which:

[0018] FIG. 1 is a top perspective view of a modular steam generator enclosure structure (SGES) for housing a steam generating vessel associated with a nuclear power generation system in accordance with an embodiment of the present invention;

[0019] FIG. 2 is an enlarged view of the upper portion of the SGES in FIG. 1;

[0020] FIG. 3 is a bottom perspective view of the SGES;

[0021] FIG. 4 is an enlarged view of the lower portion of the SGES in FIG. 3;

[0022] FIG. 5 is a side view of the long side of the SGES;

[0023] FIG. 6 is a side view of the short side of the SGES;

[0024] FIG. 7 is a top view of the SGES;

[0025] FIG. 8 is a bottom view of the SGES;

[0026] FIG. 9 is a transverse cross-section taken along line 9-9 in FIG. 6 proximate to the bottom of the SGES;

[0027] FIG. 10 is a transverse cross-section taken along line 10-10 in FIG. 6 in an intermediate portion of the SGES;

[0028] FIG. 11 is a transverse cross-section taken along line 11-11 in FIG. 6 proximate to the top of the SGES;

[0029] FIG. 12 is side perspective view of the SGES;

[0030] FIG. 13 is a transverse cross-sectional view of a portion of the sidewall of the SGES showing one of the seismic restraint anchorage plate assemblies;

[0031] FIG. 14 is an end view thereof looking inward toward the SGES;

[0032] FIG. 15 is a top view of the SGES showing the seismic restraint system for the steam generating vessel;

[0033] FIG. 16 is a top perspective view thereof;

[0034] FIG. 17 is a side perspective view thereof showing the steam generating vessel coupled to the seismic restraint system;

[0035] FIG. 18 is a perspective view of a straight wall section module used to erect the SGES of FIG. 1 in a modular construction method;

[0036] FIG. 19 is a perspective view of a curved wall section module used to erect the SGES of FIG. 1;

[0037] FIG. 20 is an enlarged partial bottom perspective view of a portion of the SGES showing details of anchors use for embedment in concrete to support the SGES; and

[0038] FIG. 21 is side cross-sectional view of the lower portion of the SGES showing the double walled construction of the sidewall thereof.

[0039] All drawings are schematic and not necessarily to scale. Features shown numbered in certain figures which may appear un-numbered in other figures are the same features unless noted otherwise herein.

#### **DETAILED DESCRIPTION**

[0040] The features and benefits of the invention are illustrated and described herein by reference to non-limiting exemplary embodiments. This description of exemplary embodiments is intended to be read in connection with the accompanying drawings, which are to be considered part of the entire written description. Accordingly, the disclosure expressly should not be limited to such exemplary embodiments illustrating some possible non-limiting combination of features that may exist alone or in other combinations of features.

[0041] In the description of embodiments disclosed herein, any reference to direction or orientation is merely intended for convenience of description and is not intended in any way to limit the scope of the present invention. Relative terms such as “lower,” “upper,” “horizontal,” “vertical,” “above,” “below,” “up,” “down,” “top” and “bottom” as well as derivatives thereof (e.g., “horizontally,” “downwardly,” “upwardly,” etc.) should be construed to refer to the orientation as then described or as shown in the drawing under discussion. These relative terms are for convenience of description only and do not require that the apparatus be constructed or operated in a particular orientation. Terms such as “attached,” “affixed,” “connected,” “coupled,”

“interconnected,” and similar refer to a relationship wherein structures are secured or attached to one another either directly or indirectly through intervening structures, as well as both movable or rigid attachments or relationships, unless expressly described otherwise.

**[0042]** As used throughout, any ranges disclosed herein are used as shorthand for describing each and every value that is within the range. Any value within the range can be selected as the terminus of the range. In addition, any references cited herein are hereby incorporated by reference in their entireties. In the event of a conflict in a definition in the present disclosure and that of a cited reference, the present disclosure controls.

**[0043]** As used herein, the terms “seal weld or welding” shall be construed according to its conventional meaning in the art to be a continuous weld which forms a gas-tight joint between the parts joined by the weld.

**[0044]** FIGS. 1-21 depict one embodiment of a steam generator enclosure structure (SGES) 100 and features thereof according to the present disclosure which is configured to house and laterally enclose at least a majority of the steam generator such as steam generating vessel 200 substantially therein. Both the SGES and steam generating vessel are founded on a reinforced concrete slab 101 that forms part of the nuclear power generation plant’s operating deck 102.

**[0045]** The steam generator vessel 200 is a vertically elongated and upright shell and tube heat exchanger which circulates primary coolant on the shell side from the nuclear reactor and a working fluid such as water on the tube side to generate steam as previously described herein. Such steam generating vessels are well known in the art for use in nuclear power generation plants including those powered by small modular reactors (SMRs). Steam generating vessel 200 generally includes a bottom head 201, top head 202, and cylindrical shell 203 extending between the heads. Internals of the steam generating vessel including the tube bundles which convey the working fluid, associated tube sheets which support the tubes, and other features are not shown but are well known in the art.

**[0046]** The SGES 100 is a vertically tall and elongated structure which laterally surrounds the steam generating vessel 200 from the operating deck 102 upwards to shield workers from radiation emitted by the steam generating vessel. The SGES may be a double-walled structure having a composite sidewall 113 formed of metal and concrete defining a vertical longitudinal axis extending through the geometric center of the enclosure. Sidewall 113 includes a top end 114 and opposite bottom end 115 seated on the operating deck concrete slab 101. The sidewall is formed

by two radially spaced apart concentric and coaxially aligned steel shells including inner shell 110 and outer shell 111 defining an annular space 112 therebetween. The annular space is filled with a preferably high density concrete (e.g., 200 pcf/pounds per cubic foot) forming a concrete liner 116 when hardened which is the primary barrier for blocking radiation emitted by the steam generating vessel 200. The steel shells also provide an additional degree of radiation blocking since a representative thicknesses for the inner and outer shell plates is about 3/4 inches or more in some embodiments.

**[0047]** Sidewall 113 further includes an annular top closure plate 121 welded to the top end 114 of the sidewall which covers and encloses annular space 112 at the top of SGES 100. A plurality of circumferentially spaced apart holes 121A may be provided in plate 121. The holes facilitate pouring concrete into the annular 112 of the SGES sidewall 113 and allows air and heat to escape during the pour and while the concrete cures (which emits heat as the concrete dries and dehydrates). An annular bottom closure plate 122 is provided to cover the annular space on the bottom of the SGES. Bottom closure plate 122 is welded to bottom end 115 of sidewall 113. Each closure plate may be flat and formed of steel.

**[0048]** Sidewall 113 defines an internal cavity 120 configured to house steam generating vessel 200 therein. Cavity 120 extends from top end 114 to bottom end 115 of the sidewall 114. The internal cavity 120 may be open at top and bottom in one embodiment as shown. The open bottom end 115 exposes the concrete slab 101 of operating deck 102 on which steam generating vessel 200 is seated inside the cavity. The vertical centerline axis CL of the steam generating vessel may be coaxially aligned with the longitudinal axis LA of the SGES 100 when positioned in the cavity (see, e.g., FIG. 17). The steam generating vessel and SGES are independently supported from the operating deck. The only physical ties between the steam generating vessel and SGES are a plurality of seismic restraints for earthquake protection, as further described herein.

**[0049]** The two concentric inner and outer shells 110, 112 of the sidewall 113 are structurally joined and coupled together in the radial direction by a plurality of vertically elongated radial connector rib plates 118. The rib plates 118 may be flat in non-limiting configurations and internal to the sidewall structure being disposed inside the annular space 112 between the shells. The rib plates 118 are circumferentially spaced apart inside annular space 112. The rib plates preferably are formed of steel for strength similar to the shells 110, 111. Rib plates 118 extend both perpendicularly to and between the shells in the radial direction, and axially in the vertical direction

along the longitudinal axis LA from the top end 114 to bottom end 115 of sidewall 113. The rib plates 118 may be formed either intermittently spaced vertically apart along the height of the sidewall inside annular space 112, or preferably extend continuously in a contiguous uninterrupted structure from the top to bottom of sidewall being formed of multiple vertical sections of flat plate welded end-to-end inside the annular space 112. In the modular construction of the SGES 100 further described elsewhere herein, the rib plates 118 in the stacked vertical tiers 184 of wall section modules 180 may be welded together end to end as the SGES is erected on site to form the contiguous vertical structure of the rib plates in one embodiment from the top to bottom of the SGES.

**[0050]** The SGES 100 further includes a plurality of anchors 130 configured for embedment in concrete slab 101 of the operating deck 102. The anchors project vertically downwards from the bottom end 115 of the sidewall 113 and are circumferentially spaced apart preferably around the entire circumference of the SGES as shown for secure anchorage to the concrete. Anchors 130 maximize the floor slab's anchorage capacity using rebar or other connecting ties.

**[0051]** In one embodiment, the anchors are preferably formed by exposed downward extensions of the rib plates 118 from inside the annular space 112; the anchors being contiguous unitary portions of the rib plates of the lowermost ring of wall section modules. Because the rib plates are welded along their vertical lengths to both the inner and outer shells 110, 111, the rib plates and their anchor extensions are advantageously very stiff structurally and resistant to bending moments which may be imparted on the tall SGES 100 structure induced by vibrational loads imposed on the structure from a seismic event (i.e. earthquake). The SGES is anchored to the operating deck concrete slab 101 (e.g., floor slab) at the bottom via the embedded anchors 130, but may be unsupported along its height making it a vertically cantilevered structure. A representative height for the SGES may be about 50 feet as a non-limiting example. The non-polygonal cross-sectional shape of the SGES 100 forming a structure which may be an ellipsoid or cylinder is further advantageously strong to resist seismic bending loads.

**[0052]** In one embodiment, each anchor 130 comprises an exposed flat vertical extension of a rib plate 118 as noted above, a flat horizontal bottom flange 119A welded to a bottom end of the exposed rib plate portion, and a pair of flat vertical gusset plates 119B oriented perpendicularly to the exposed rib plate portion and bottom flange. One gusset plate 119B each is disposed on

opposite sides of the exposed portion of the vertical rib plate. Flange 119A and gusset plates 119B are welded to the exposed portion of the rib plate 118 and to each other in the configuration shown.

**[0053]** The bottom end of the sidewall 130 includes annular bottom closure plate 122 as previously described herein welded between the inner and outer shells which closes the bottom of the annular space. The exposed downward extensions of the rib plates 118 which form the SGES anchors 130 protrude through the bottom closure plate from inside the annular space 112 of sidewall 113, and therefore the extensions do not terminate at the bottom closure plate for improved strength and stiffness thereby providing a superior anchorage system for the SGES as noted above.

**[0054]** According to another aspect of the invention, a seismic restraint system for the SGES 100 is provided to protect and stabilize the steam generating vessel 200 inside the SGES during a seismic event (e.g., earthquake). A plurality of vertically spaced apart and circumferentially spaced apart seismic restraint members 170 are provided which span laterally across the gap between the SGES sidewall 113 and steam generating vessel inside internal cavity 120 thereby coupling the steam generator vessel to the sidewall. The seismic restraint members are operable to arrest lateral movement of the steam generator vessel during a seismic event. Suitable commercially-available piping supports such as linearly elongated piping struts or pipe snubbers may be used for the seismic restraint members in some embodiments.

**[0055]** An array of seismic restraint members 170 may be provided at several vertical support elevations SEL along the height of the steam generating vessel 200 to stabilize the vessel during a seismic event. In the non-limiting illustrated embodiment, three support elevations may be provided; however, more or less support elevations may be used depending on the height of the steam generating vessel 200 and SGES 100. The seismic restraint members are circumferentially spaced apart at each support elevation. At least three seismic restraint members are provided at each support elevation which are circumferentially spaced apart around the steam generating vessel at each support elevation. Preferably, four seismic restraint members 170 may be provided as shown at each support elevation to stabilize each quadrant of the steam generating vessel 200.

**[0056]** To couple the seismic restraint members to the steam generating vessel 200 and SGES sidewall 113, specialized support apparatuses are provided. The seismic restraint system includes a plurality of ring-shaped seismic restraint collars 171. One collar is provided at each support elevation SEL along the height of the steam generating vessel. Seismic restraint collars 171 each defining a central opening 171A which slideably receives the steam generating vessel therein to

allow the steam generating vessel to vertically grow or contract via thermal expansion when heated during operation of the reactor or cool down during outages, respectively. The collars are therefore preferably not fixedly attached to the steam generating vessel. One end of each seismic restraint member 170 is coupled to a seismic restraint collar at each support elevation SEL. A pinned connection 175 formed by a pin preferably may be used in some embodiments to allow the seismic restraint members to adjust for thermal growth/shrinkage of the steam generating vessel 200 to avoid introducing thermal stresses into the vessel at the seismic restraint coupling points thereby potentially resulting in thermal stress cracking over time.

**[0057]** The opposite end of each seismic restraint member 170 is coupled to one of a plurality of structurally rigid seismic restraint anchorage plate assemblies 172 each having a portion embedded in and attached to structure of the SGES sidewall 113 for strength. The sidewall thus includes a plurality of anchorage plate assemblies at each of the support elevations SEL; one anchorage plate assembly 172 on the SGES sidewall for each corresponding seismic restraint member 170. The anchorage plate assemblies are therefore circumferentially spaced apart at each support elevation SEL as shown. A pinned connection 175 preferably may also be used to couple each seismic restraint member to its corresponding anchorage plate assembly 172 to allow the seismic restraint members to adjust for thermal growth/shrinkage of the steam generating vessel 200.

**[0058]** Each seismic restraint anchorage plate assembly 172 in one embodiment includes an internal portion 172A which projects radially inwards from the SGES sidewall 113 into the internal cavity 120, an external portion 172B which projects radially outwards from sidewall, and an intermediate portion 172C embedded in the concrete liner 116 in the annular space 112 for strength. Accordingly, each anchorage plate assembly is an assemblage of structural members that has the foregoing portions 172A-C which act in concert to provide strong anchorage points for the seismic restraint members 170 at various locations of the sidewall 113.

**[0059]** Each anchorage plate assembly 172 further comprises a plurality of circumferentially spaced apart vertical connection plates 173 welded to at least one horizontal connection plate 174 oriented perpendicularly to the vertical connection plates at both the internal and external portions 172A, 172B inside and outside the SGES sidewall 113. For example, the uppermost support elevation SEL of the SGES as shown in FIG. 17 includes a single horizontal connection plate 174. In some embodiments and support elevations SEL, a pair of horizontal connection plates spaced

vertically apart may be provided. For example, the lowermost and intermediate support elevations SEL as shown in FIG. 17 include two horizontal connection plates each.

[0060] The vertical connection plates 173 of the anchorage plate assemblies 172 include vertical connection plates located outside the annular space 112 of the SGES sidewall 113 which are welded to the inner and outer shells 110, 111 forming the internal and external portions 172A, 172B of the assemblies 172, respectively. Four circumferentially spaced apart vertical connection plates 173 may be provided for the internal and external portions 172A, 172B of the anchorage plate assemblies 172 as shown. Some of the vertical connection plates 173 are also disposed inside the sidewall annular space 112 and welded to the inner and outer shells 110, 111 therein which form the intermediate portion 172C of each anchorage plate assembly 172. In one embodiment, two circumferentially spaced part vertical connection plates 173 may be located between a pair of internal rib plates 118 within the annular space 112 as shown. These connection plates inside the annular space help structurally stiffen the sidewall 113 of the SGES 100 at the anchorage plate assembly locations for the seismic restraints 170.

[0061] The vertical connection plates 173 inside the internal cavity 120 of SGES 100 at the surface of the inner shell 110 and those at the outer/exterior surface of the outer shell 111 are each radially aligned with either one of the vertical connection plates 173 inside the annular space 112 or one of the rib plates 118 inside the annular space as shown in the sidewall cross-section FIG. 13. In the non-limiting illustrated embodiment, a vertical connection plate 173 is radially aligned with each of a pair of rib plates 118 inside internal cavity 120 and at the exterior surface of the outer shell. Also as shown, a vertical connection plate 173 is radially aligned with each of a pair of vertical connection plates located inside the annular space 112 lying between the pair of rib plates 118 plates both inside internal cavity 120 and at the exterior surface of the outer shell 111. These radially aligned plate structure advantageously increase the stiffness of the sidewall 113 at the anchorage plate assembly locations in the sidewall to resist tensile or compressive forces imparted to the anchorage plate assemblies by the seismic restraints 170 during a seismic event.

[0062] The horizontal connection plates 174 of the anchorage plate assemblies 172 in one embodiment are welded to the vertical connection plates 173 of both the internal and external portions 172A, 172B of the anchorage plate assemblies. Horizontal connection plates 174 in turn may also be welded to the inner surface of the inner shell 110 and the outer surface of the outer shell 111 also forming part of the internal and external portions 172A, 172B of each anchorage

plate assembly. In such a construction, no horizontal connection plates are disposed inside the sidewall 113 of the SGES 100. Other variations of the seismic restraint anchorage plate assemblies 170 are possible so long a final structurally stiffened structure results which is rigidly attached to the sidewall 113 of the SGES.

**[0063]** The vertical connection plates 173 and horizontal connection plates 174 are flat plates formed of steel of suitable thickness.

**[0064]** As previously described herein, the SGES 100 may have a modular construction formed by assembling a plurality of modular wall section modules 180 having a shape selected to match the desired and preselected cross-sectional shape of SGES. Each wall section module 180 in essence is a section or segment of the sidewall 113 of the SGES; multiple modules being coupled together by welding and/or bolting to form the SGES to a preselected height based on the height of the steam generating vessel 200. Note that the steam generating vessel may have a height greater than the SGES as shown in the illustrated embodiment. Preferably, the SGES has a height selected to be sufficient to shield workers who may access the operating deck 102 of the nuclear power generation plant from unacceptable levels of radiation emitting from the steam generating vessel.

**[0065]** To form the SGES 100 in the illustrated embodiment having a oblong elliptical cross-sectional configured, a plurality of both arcuately curved wall section modules 181 and straight wall section modules 182 are provided which are coupled together to collectively form the ellipsoidal sidewall 113 of the SGES. Portions of the SGES 100 in the figures provided with shading lines represent the curved portions of the sidewall 113 formed by the curved modules 181 whereas unshaded portions represent the straight sections of the sidewall formed by the straight modules 182. In the present embodiment, the curved wall section modules 181 may form a quarter of a circle each (see, e.g., FIG. 7).

**[0066]** Referring to FIGS. 18-19, each wall section module comprises an inner shell 110 and an outer shell section 111 coupled together in the radial direction by at least two vertical radial connector rib plates 118. Each module may have a rib plate 118 on each vertical end forming end walls 118A to enclose the ends of the modules for shipping. In a similar vane to sidewall 113, shell sections 110 and 111 are radially spaced apart to form part of an annular space portion 112A therebetween which will be filled with concrete to form the sidewall liner 116 of the SGES. Lifting lugs (not shown) may be welded to each module to facilitate lifting and transporting the modules to the installation site at the nuclear power generation plant.

**[0067]** The SGES 100 is erected on concrete slab 101, which in one embodiment forms part of the plant operating deck 102. The SGES sidewall 113 may be formed by assembling and successively vertically stacking and coupling multiple rings 183 of wall section modules 180 on top of each other together in tiers 184. Rings 183 and tiers 184 of wall section modules are delineated in FIG. 5 by dashed lines. Each ring of modules may have the same or different heights depending on the height of the SGES 100 and locations of the anchorage plate assemblies 172 for the seismic restraints 170. The wall section modules in each ring 183 for forming an ellipsoidal SGES of the non-limiting illustrated embodiment include a plurality of curved wall section modules 181 and straight wall section modules 182. The straight wall section modules are located along the long sides of the SGES sidewall 113 whereas the curved wall section modules are located along the short sides and wrap around onto the long sides.

**[0068]** The wall section modules 180 in each ring 183 are formed by coupling the modules 180 together end-to-end to form a continuous ring of modules. After a continuous ring is formed in one tier 184, the next succeeding tier up may be formed in a similar manner on top of the preceding ring of modules. The modules of the rings in each tier are coupled to modules in each vertically adjacent ring of modules. Accordingly, the modules 180 in each tier are coupled together to form a ring, and the modules in each tier 184 are coupled to the modules above and/or below in adjacent rings to form a strong structure capable of withstanding seismic events without sustaining damage or failing. All modules 180 may be coupled together via welding and/or bolting. The vertically and radially extending internal rib plates 118 inside each wall section module 180 may be welded together end-to-end during erection of the sidewall 113. In other embodiments where added structural strength of the sidewall is not needed, the rib plates need not be coupled together in adjacent rings of modules.

**[0069]** An example process or method for erecting a modular enclosure for a steam generator vessel of a nuclear power generation plant will be briefly described and summarized.

**[0070]** In one embodiment, the method includes: providing a concrete slab 101 and plurality of wall section modules 180, each wall section module including an inner shell, an outer shell spaced apart from the inner shell, and a plurality of vertical rib plates extending between the inner and outer shells forming an annular space portion therebetween; coupling a first plurality of the wall section modules together end to end to form a continuous lowermost first ring of wall section modules collectively defining a first tier, the first ring of wall section modules being seated on the

concrete slab; filling the annular space portions in the wall section modules of the first tier with concrete; coupling a second plurality of wall section modules together end to end on top of the first ring of wall section modules to form a continuous second ring of the wall section modules collectively defining a second tier; filling the annular space portions in the wall section modules of the second tier with concrete; and coupling multiple successive rings of concrete-filled wall section modules together end to end on top of the second tier to form additional tiers to a preselected height of the enclosure.

[0071] As noted above, the wall section modules may include a combination of arcuately curved modules 181 and straight modules 182 to form an ellipsoidal-shaped SGES 100. For such a construction in one non-limiting embodiment as an example, two pairs of curved wall section modules may be provided (one pair for each end) and two straight wall section modules on the sides coupled to the end pairs of curved wall section modules in each ring 183 of each tier 184. The SGES may comprise 5 tiers of module rings in one non-limiting example to form an enclosure about 50 feet in height. Other variations of module shapes and numbers of tiers may be used in other embodiments.

[0072] The wall section modules can thus be advantageously prefabricated accurately to dimension in the shop without the concrete liner, and then shipped to the plant site for coupling together such as via welding and/or bolting followed by filling the modules with concrete to form the sidewall liner. This modular construction approach provides a cost effective manner for providing and erecting a large concrete filled structure such as the SGES 100 from multiple modules.

[0073] The same foregoing basic process and method may be used for forming steam generator enclosure structures (SGES) of other cross-sectional shapes including circular and polygonal (e.g., square or rectangular).

[0074] The SGES may be equipped with access hatches, platforms, and/or manways as needed to enable plant personnel/workers to gain access to the steam generating vessel inside for maintenance.

[0075] Example Embodiments

[0076] 1. An enclosure structure for a vertically elongated steam generator of a nuclear power generation plant, the enclosure structure comprising:

a vertical longitudinal axis;

an elongated double-walled sidewall extending vertically along the longitudinal axis, the sidewall including top and bottom ends;

the sidewall comprising a metallic inner shell and a metallic outer shell in a concentric arrangement spaced radially apart from each other to define an annular space therebetween;

the sidewall defining a laterally enclosed internal cavity extending vertically along the longitudinal axis, the internal cavity configured for housing the steam generator therein;

a plurality of vertically-extending rib plates disposed in the annular space coupling the inner and outer shells together, the rib plates being circumferentially spaced apart and extending radially between the inner and outer shells;

a concrete liner disposed in the annular space; and

a plurality of circumferentially spaced apart anchors projecting vertically downwards from the bottom end of the sidewall, the anchors being configured for embedment in concrete.

[0077] 2. The enclosure structure according to example 1, wherein the sidewall is formed of a plurality of individual wall section modules coupled together.

[0078] 3. The enclosure structure according to example 2, wherein the wall section modules are arranged in vertically stacked tiers each formed by a ring of wall section modules coupled together, each ring of wall section modules being coupled to a vertically adjacent ring of walls sections in adjacent tiers.

[0079] 4. The enclosure structure according to examples 2 or 3, wherein the wall section modules include a combination of straight wall section modules and curved wall section modules to form an elliptically-shaped sidewall of the enclosure.

[0080] 5. The enclosure structure according to example 4, wherein the anchors are circumferentially spaced apart on a lowermost tier of the straight and curved wall section modules.

[0081] 6. The enclosure structure according to example 1, wherein the rib plates are flat and welded to the inner and outer shells.

[0082] 7. The enclosure structure according to any one of examples 1-6, wherein the anchors are formed by exposed downward extensions of the rib plates inside the annular space of the sidewall, the anchors being contiguous unitary portions of the rib plates inside the annular space.

[0083] 8. The enclosure structure according to example 7, wherein the rib plates each form a vertically continuous structure in the sidewall which extend from the top end of the sidewall to a

point below the bottom end of the sidewall to form the exposed downward extension that defines the anchors.

[0084] 9. The enclosure structure according to examples 8, wherein each anchor further comprises an exposed flat vertical plate portion of the rib plate, a flat horizontal flange welded to a bottom end of the vertical plate portion, and a pair of vertical gusset plates oriented perpendicularly to the vertical plate portion of the rib plate and welded thereto and to the flange, one of the gusset plates each being disposed on opposite sides of the vertical plate portion of the rib plate.

[0085] 10. The enclosure structure according to examples 7 or 8, wherein the bottom end of the sidewall includes an annular bottom closure plate welded between the inner and outer shells which closes a bottom of the annular space, the downward extensions of the rib plates protruding through the bottom closure plate.

[0086] 11. The enclosure structure according to any one of examples 1-10, further comprising a plurality of seismic restraint anchorage plate assemblies embedded in the sidewall at a plurality of support elevations, the anchorage plate assemblies each comprising a weldment of structural members configured for coupling one end of a seismic restraint member thereto.

[0087] 12. The enclosure structure according to example 11, wherein the seismic restraint is coupled to the anchorage plate assembly via a pinned connection.

[0088] 13. The enclosure structure according to example 11, wherein each anchorage plate assembly includes an internal portion which projects radially inwards from the sidewall into the internal cavity, an external portion which projects radially outwards from sidewall, and an intermediate portion embedded in the concrete liner in the annular space.

[0089] 14. The enclosure structure according to example 13, wherein each anchorage plate assembly comprises a plurality of circumferentially spaced apart vertical connection plates welded to a plurality of vertically spaced apart horizontal connection plates oriented perpendicularly to the vertical connection plates.

[0090] 15. The enclosure structure according to example 14, wherein the vertical connection plates include vertical connection plates welded to the inner and outer shells inside the annular space of the sidewall, vertical connection plates welded to the inner shell inside the internal cavity of the enclosure structure, and vertical connection plates welded to an exterior surface of the outer shell.

[0091] 16. The enclosure structure according to example 15, wherein the vertical connection plates inside the internal cavity and at the exterior surface of the outer shell are each radially aligned with

either one of the vertical connection plates inside the annular space or one of the rib plates inside the annular space.

[0092] 17. The enclosure structure according to any one of examples 11-15, wherein at each support elevation including the anchorage plate assemblies, the anchorage plate assemblies are circumferentially spaced apart.

[0093] 18. The enclosure structure according to any one of examples 1-17, wherein the sidewall has a circular or elliptical cross-sectional configuration.

[0094] 19. The enclosure structure according to example 1, wherein the top end of the sidewall includes an annular top closure plate welded between the inner and outer shells over the annular space, the top closure plate including plurality of circumferentially spaced apart holes around an entirety of the top closure plate.

[0095] 20. A steam generator enclosure system for a nuclear power generation plant, the system comprising:

- a concrete slab defining an operating deck;

- an enclosure disposed on the slab and defining a vertical longitudinal axis, the enclosure comprising:

- an elongated double-walled sidewall extending vertically along the longitudinal axis, the sidewall including top and bottom ends;

- the sidewall comprising a metallic inner shell and a metallic outer shell in a concentric arrangement spaced radially apart from each other to define an annular space therebetween;

- the sidewall defining a laterally enclosed internal cavity extending vertically along the longitudinal axis;

- a plurality of vertically-extending rib plates disposed in the annular space coupling the inner and outer shells together, the rib plates being circumferentially spaced apart and extending radially between the inner and outer shells;

- a concrete liner disposed in the annular space;

- a plurality of anchors projecting vertically downwards from the bottom end of the sidewall, the anchors being embedded in the concrete slab;

- a steam generator vessel disposed in the internal cavity and seated on the slab.

[0096] 21. The system according to example 20, wherein the steam generator vessel is a shell and tube heat exchanger which is vertically elongated.

[0097] 22. The system according to example 21, wherein the sidewall has a non-polygonal shape formed by a plurality of individual wall section modules coupled together.

[0098] 23. The system according to example 21, wherein the wall section modules are arranged in vertically stacked tiers each formed by a ring of wall section modules being coupled together, each ring of wall section modules being coupled to a vertically adjacent ring of walls section modules in adjacent tiers.

[0099] 24. The system according to example 23, wherein the wall section modules include straight wall section modules and curved wall section modules forming an elliptically-shaped sidewall of the enclosure.

[0100] 25. The system according to example 21, wherein the anchors are circumferentially spaced apart.

[0101] 26. The system according to example 21, wherein the rib plates are flat and welded to the inner and outer shells within the annular space of the sidewall.

[0102] 27. The system according to any one of examples 21-26, wherein the anchors are formed by exposed downward extensions of the rib plates inside the annular space, the anchors being contiguous unitary portions of the rib plates.

[0103] 28. The system according to example 27, wherein each anchor comprises an exposed flat vertical plate portion of the rib plate, a flat horizontal flange welded to a bottom end of the vertical plate portion, and a pair of vertical gusset plates oriented perpendicularly to the vertical plate portion of the rib plate and welded thereto and to the flange, one of the gusset plates being disposed on opposite sides of the vertical plate portion of the rib plate.

[0104] 29. The system according to examples 27 or 28, wherein the bottom end of the sidewall includes an annular bottom closure plate welded between the inner and outer shells which closes a bottom of the annular space of the sidewall, the downward extensions of the rib plates protruding through the bottom closure plate.

[0105] 30. The system according to example 27, wherein the rib plates each form a vertically continuous structure in the sidewall which extend from the top end of the sidewall to a point below the bottom end of the sidewall to form the exposed downward extension that defines the anchors.

[0106] 31. The system according to any one of examples 20-30, further comprising a plurality of vertically spaced apart and circumferentially spaced apart seismic restraint members coupling the steam generator vessel to the sidewall of the enclosure, the seismic restraint members being operable to arrest lateral movement of the steam generator vessel during a seismic event.

[0107] 32. The system according to example 31, wherein the enclosure further comprises a plurality of circumferentially spaced apart anchorage plate assemblies embedded in the sidewall at a plurality of support elevations, each seismic restraint member including a first end coupled to one of the anchorage plate assemblies via a pinned connection and a second end coupled to the steam generating vessel.

[0108] 33. The system according to examples 32, further comprising:

a plurality of ring-shaped seismic restraint collars coupled to the steam generating vessel at a plurality of elevations, the seismic restraint collars each defining a central opening slideably receiving the steam generating vessel therein to allow the steam generating vessel to vertically grow or contract via thermal expansion;

wherein the second end of each seismic restraint member is coupled to one of the seismic restraint collars via a pinned connection.

[0109] 34. The system according to examples 32 or 33, wherein the seismic restraint members are linearly elongated struts or pipe snubbers.

[0110] 35. The system according to example 32, wherein each anchorage plate assembly includes an internal portion which projects radially inwards from the sidewall into the internal cavity, an external portion which projects radially outwards from sidewall, and an intermediate portion embedded in the concrete liner in the annular space.

[0111] 36. The system according to example 35, wherein each anchorage plate assembly comprises a plurality of circumferentially spaced apart vertical connection plates welded to a plurality of vertically spaced apart horizontal connection plates oriented perpendicularly to the vertical plates.

[0112] 37. The system according to example 14, wherein the vertical connection plates include vertical connection plates welded to the inner and outer shells inside the annular space of the sidewall, vertical connection plates welded to the inner shell inside the internal cavity of the enclosure structure, and vertical connection plates welded to an exterior surface of the outer shell.

[0113] 38. The system according to example 37, wherein the vertical connection plates inside the internal cavity and at the exterior surface of the outer shell are each radially aligned with either one of the vertical connection plates inside the annular space or one of the rib plates inside the annular space.

[0114] 39. The system according to example 32, wherein at each support elevation including the anchorage plate assemblies, at least three anchorage plate assemblies are provided.

[0115] 40. The system according to any one of examples 20-39, wherein the sidewall of the enclosure has a circular or elliptical cross-sectional configuration.

[0116] 41. The system according to example 40, wherein the top end of the sidewall includes an annular top closure plate welded between the inner and outer shells over the annular space, the top closure plate including plurality of holes.

[0117] 42. A method for erecting a modular enclosure for a steam generator vessel of a nuclear power generation plant, the method comprising:

- providing a concrete slab and plurality of wall section modules, each wall section module including an inner shell, an outer shell spaced apart from the inner shell, and a plurality of vertical rib plates extending between the inner and outer shells forming an annular space portion therebetween;

- coupling a plurality of the wall section modules together end to end to form a continuous lowermost first ring of wall section modules collectively defining a first tier, the first ring of wall section modules being seated on the concrete slab;

- filling the annular space portion in the wall section modules of the first tier with concrete;

- coupling a plurality of wall section modules together end to end on top of the first ring of wall section modules to form a continuous second ring of wall section modules collectively defining a second tier;

- filling the annular space in the wall section modules of the second tier with concrete; and

- coupling multiple successive rings of concrete-filled wall section modules together end to end on top of the second tier to form additional tiers to a preselected height of the enclosure.

[0118] 43. The method according to example 42, wherein the wall section modules in each ring of wall section modules in each tier are coupled to the wall section modules of the vertically adjacent rings of wall section modules.

[0119] 44. The method according to examples 42 or 43, wherein the vertical rib plates in the first ring of wall section modules extend downwards from a bottom end of the first wall section modules to form a plurality of circumferentially spaced apart anchors.

[0120] 45. The method according to example 44, further comprising a step of embedding the anchors in the concrete slab.

[0121] 46. The method according to example 45, wherein the wall section modules define a sidewall of the enclosure having a non-polygonal cross-sectional shape defining an internal cavity.

[0122] 47. The method according to any one of examples 42-46, further comprising before or after erecting the enclosure, locating the steam generating vessel on the concrete slab inside the internal cavity.

[0123] 48. The method according to example 47, wherein the enclosure further comprises a plurality of anchorage plate assemblies embedded in the sidewall at a plurality of elevations and circumferential locations.

[0124] 49. The method according to examples 48, further comprising:

locating a plurality of ring-shaped seismic restraint collars on the steam generating vessel at a plurality of support elevations, the seismic restraint collars each defining a central opening slideably receiving the steam generating vessel therein to allow the steam generating vessel to thermally expand or contract in length;

coupling a first end of a plurality of seismic restraint members to each of the seismic restraint collars at each support elevation; and

coupling a second end of the seismic restraint members to each of the anchorage plate assemblies at each support elevation;

wherein each of the seismic restraint members extends radially between the collars and anchorage plate assemblies.

[0125] 50. The method according to example 49, wherein the seismic restraint members are coupled to the restraint collars and closure plate assemblies via pinned connections to accommodate thermal expansion or contraction of the steam generating vessel.

[0126] 51. The method according to examples 49 or 50, wherein the seismic restraint members are linearly elongated struts or pipe snubbers.

[0127] 52. The method according to any one of examples 48-51, wherein each anchorage plate assembly comprises a weldment of structural members, the anchorage plate assemblies including

an internal portion which projects radially inwards from the sidewall into the internal cavity, an external portion which projects radially outwards from sidewall, and an intermediate portion embedded in the concrete liner in the annular space.

**[0128]** 53. The method according to any one of examples 46-52, wherein the sidewall of the enclosure has a circular or elliptical cross-sectional configuration.

**[0129]** While the foregoing description and drawings represent some example systems, it will be understood that various additions, modifications and substitutions may be made therein without departing from the spirit and scope and range of equivalents of the accompanying claims. In particular, it will be clear to those skilled in the art that the present invention may be embodied in other forms, structures, arrangements, proportions, sizes, and with other elements, materials, and components, without departing from the spirit or essential characteristics thereof. In addition, numerous variations in the methods/processes described herein may be made. One skilled in the art will further appreciate that the invention may be used with many modifications of structure, arrangement, proportions, sizes, materials, and components and otherwise, used in the practice of the invention, which are particularly adapted to specific environments and operative requirements without departing from the principles of the present invention. The presently disclosed embodiments are therefore to be considered in all respects as illustrative and not restrictive, the scope of the invention being defined by the appended claims and equivalents thereof, and not limited to the foregoing description or embodiments. Rather, the appended claims should be construed broadly, to include other variants and embodiments of the invention, which may be made by those skilled in the art without departing from the scope and range of equivalents of the invention.

## CLAIMS

What is claimed is:

1. An enclosure structure for a vertically elongated steam generator of a nuclear power generation plant, the enclosure structure comprising:
  - a vertical longitudinal axis;
  - an elongated double-walled sidewall extending vertically along the longitudinal axis, the sidewall including top and bottom ends;
    - the sidewall comprising a metallic inner shell and a metallic outer shell in a concentric arrangement spaced radially apart from each other to define an annular space therebetween;
    - the sidewall defining a laterally enclosed internal cavity extending vertically along the longitudinal axis, the internal cavity configured for housing the steam generator therein;
    - a plurality of vertically-extending rib plates disposed in the annular space coupling the inner and outer shells together, the rib plates being circumferentially spaced apart and extending radially between the inner and outer shells;
    - a concrete liner disposed in the annular space; and
    - a plurality of circumferentially spaced apart anchors projecting vertically downwards from the bottom end of the sidewall, the anchors being configured for embedment in concrete.
2. The enclosure structure according to claim 1, wherein the sidewall is formed of a plurality of individual wall section modules coupled together.
3. The enclosure structure according to claim 2, wherein the wall section modules are arranged in vertically stacked tiers each formed by a ring of wall section modules coupled together, each ring of wall section modules being coupled to a vertically adjacent ring of wall sections in adjacent tiers.
4. The enclosure structure according to claims 2 or 3, wherein the wall section modules include a combination of straight wall section modules and curved wall section modules to form an elliptically-shaped sidewall of the enclosure.
5. The enclosure structure according to claim 4, wherein the anchors are circumferentially spaced apart on a lowermost tier of the straight and curved wall section modules.

6. The enclosure structure according to claim 1, wherein the rib plates are flat and welded to the inner and outer shells.
7. The enclosure structure according to any one of claims 1-6, wherein the anchors are formed by exposed downward extensions of the rib plates inside the annular space of the sidewall, the anchors being contiguous unitary portions of the rib plates inside the annular space.
8. The enclosure structure according to claim 7, wherein the rib plates each form a vertically continuous structure in the sidewall which extend from the top end of the sidewall to a point below the bottom end of the sidewall to form the exposed downward extension that defines the anchors.
9. The enclosure structure according to claims 8, wherein each anchor further comprises an exposed flat vertical plate portion of the rib plate, a flat horizontal flange welded to a bottom end of the vertical plate portion, and a pair of vertical gusset plates oriented perpendicularly to the vertical plate portion of the rib plate and welded thereto and to the flange, one of the gusset plates each being disposed on opposite sides of the vertical plate portion of the rib plate.
10. The enclosure structure according to claims 7 or 8, wherein the bottom end of the sidewall includes an annular bottom closure plate welded between the inner and outer shells which closes a bottom of the annular space, the downward extensions of the rib plates protruding through the bottom closure plate.
11. The enclosure structure according to any one of claims 1-10, further comprising a plurality of seismic restraint anchorage plate assemblies embedded in the sidewall at a plurality of support elevations, the anchorage plate assemblies each comprising a weldment of structural members configured for coupling one end of a seismic restraint member thereto.
12. The enclosure structure according to claim 11, wherein the seismic restraint is coupled to the anchorage plate assembly via a pinned connection.
13. The enclosure structure according to claim 11, wherein each anchorage plate assembly includes an internal portion which projects radially inwards from the sidewall into the internal cavity, an external portion which projects radially outwards from sidewall, and an intermediate portion embedded in the concrete liner in the annular space.

14. The enclosure structure according to claim 13, wherein each anchorage plate assembly comprises a plurality of circumferentially spaced apart vertical connection plates welded to a plurality of vertically spaced apart horizontal connection plates oriented perpendicularly to the vertical connection plates.

15. The enclosure structure according to claim 14, wherein the vertical connection plates include vertical connection plates welded to the inner and outer shells inside the annular space of the sidewall, vertical connection plates welded to the inner shell inside the internal cavity of the enclosure structure, and vertical connection plates welded to an exterior surface of the outer shell.

16. The enclosure structure according to claim 15, wherein the vertical connection plates inside the internal cavity and at the exterior surface of the outer shell are each radially aligned with either one of the vertical connection plates inside the annular space or one of the rib plates inside the annular space.

17. The enclosure structure according to any one of claims 11-15, wherein at each support elevation including the anchorage plate assemblies, the anchorage plate assemblies are circumferentially spaced apart.

18. The enclosure structure according to any one of claims 1-17, wherein the sidewall has a circular or elliptical cross-sectional configuration.

19. The enclosure structure according to claim 1, wherein the top end of the sidewall includes an annular top closure plate welded between the inner and outer shells over the annular space, the top closure plate including plurality of circumferentially spaced apart holes around an entirety of the top closure plate.

20. A steam generator enclosure system for a nuclear power generation plant, the system comprising:

- a concrete slab defining an operating deck;

- an enclosure disposed on the slab and defining a vertical longitudinal axis, the enclosure comprising:

- an elongated double-walled sidewall extending vertically along the longitudinal axis, the sidewall including top and bottom ends;

the sidewall comprising a metallic inner shell and a metallic outer shell in a concentric arrangement spaced radially apart from each other to define an annular space therebetween;

the sidewall defining a laterally enclosed internal cavity extending vertically along the longitudinal axis;

a plurality of vertically-extending rib plates disposed in the annular space coupling the inner and outer shells together, the rib plates being circumferentially spaced apart and extending radially between the inner and outer shells;

a concrete liner disposed in the annular space;

a plurality of anchors projecting vertically downwards from the bottom end of the sidewall, the anchors being embedded in the concrete slab;

a steam generator vessel disposed in the internal cavity and seated on the slab.

21. The system according to claim 20, wherein the steam generator vessel is a shell and tube heat exchanger which is vertically elongated.

22. The system according to claim 21, wherein the sidewall has a non-polygonal shape formed by a plurality of individual wall section modules coupled together.

23. The system according to claim 21, wherein the wall section modules are arranged in vertically stacked tiers each formed by a ring of wall section modules being coupled together, each ring of wall section modules being coupled to a vertically adjacent ring of wall section modules in adjacent tiers.

24. The system according to claim 23, wherein the wall section modules include straight wall section modules and curved wall section modules forming an elliptically-shaped sidewall of the enclosure.

25. The system according to claim 21, wherein the anchors are circumferentially spaced apart.

26. The system according to claim 21, wherein the rib plates are flat and welded to the inner and outer shells within the annular space of the sidewall.

27. The system according to any one of claims 21-26, wherein the anchors are formed by exposed downward extensions of the rib plates inside the annular space, the anchors being contiguous unitary portions of the rib plates.

28. The system according to claim 27, wherein each anchor comprises an exposed flat vertical plate portion of the rib plate, a flat horizontal flange welded to a bottom end of the vertical plate portion, and a pair of vertical gusset plates oriented perpendicularly to the vertical plate portion of the rib plate and welded thereto and to the flange, one of the gusset plates being disposed on opposite sides of the vertical plate portion of the rib plate.

29. The system according to claims 27 or 28, wherein the bottom end of the sidewall includes an annular bottom closure plate welded between the inner and outer shells which closes a bottom of the annular space of the sidewall, the downward extensions of the rib plates protruding through the bottom closure plate.

30. The system according to claim 27, wherein the rib plates each form a vertically continuous structure in the sidewall which extend from the top end of the sidewall to a point below the bottom end of the sidewall to form the exposed downward extension that defines the anchors.

31. The system according to any one of claims 20-30, further comprising a plurality of vertically spaced apart and circumferentially spaced apart seismic restraint members coupling the steam generator vessel to the sidewall of the enclosure, the seismic restraint members being operable to arrest lateral movement of the steam generator vessel during a seismic event.

32. The system according to claim 31, wherein the enclosure further comprises a plurality of circumferentially spaced apart anchorage plate assemblies embedded in the sidewall at a plurality of support elevations, each seismic restraint member including a first end coupled to one of the anchorage plate assemblies via a pinned connection and a second end coupled to the steam generating vessel.

33. The system according to claims 32, further comprising:

a plurality of ring-shaped seismic restraint collars coupled to the steam generating vessel at a plurality of elevations, the seismic restraint collars each defining a central opening slideably

receiving the steam generating vessel therein to allow the steam generating vessel to vertically grow or contract via thermal expansion;

wherein the second end of each seismic restraint member is coupled to one of the seismic restraint collars via a pinned connection.

34. The system according to claims 32 or 33, wherein the seismic restraint members are linearly elongated struts or pipe snubbers.

35. The system according to claim 32, wherein each anchorage plate assembly includes an internal portion which projects radially inwards from the sidewall into the internal cavity, an external portion which projects radially outwards from sidewall, and an intermediate portion embedded in the concrete liner in the annular space.

36. The system according to claim 35, wherein each anchorage plate assembly comprises a plurality of circumferentially spaced apart vertical connection plates welded to a plurality of vertically spaced apart horizontal connection plates oriented perpendicularly to the vertical plates.

37. The system according to claim 14, wherein the vertical connection plates include vertical connection plates welded to the inner and outer shells inside the annular space of the sidewall, vertical connection plates welded to the inner shell inside the internal cavity of the enclosure structure, and vertical connection plates welded to an exterior surface of the outer shell.

38. The system according to claim 37, wherein the vertical connection plates inside the internal cavity and at the exterior surface of the outer shell are each radially aligned with either one of the vertical connection plates inside the annular space or one of the rib plates inside the annular space.

39. The system according to claim 32, wherein at each support elevation including the anchorage plate assemblies, at least three anchorage plate assemblies are provided.

40. The system according to any one of claims 20-39, wherein the sidewall of the enclosure has a circular or elliptical cross-sectional configuration.

41. The system according to claim 40, wherein the top end of the sidewall includes an annular top closure plate welded between the inner and outer shells over the annular space, the top closure plate including plurality of holes.

42. A method for erecting a modular enclosure for a steam generator vessel of a nuclear power generation plant, the method comprising:

providing a concrete slab and plurality of wall section modules, each wall section module including an inner shell, an outer shell spaced apart from the inner shell, and a plurality of vertical rib plates extending between the inner and outer shells forming an annular space portion therebetween;

coupling a plurality of the wall section modules together end to end to form a continuous lowermost first ring of wall section modules collectively defining a first tier, the first ring of wall section modules being seated on the concrete slab;

filling the annular space portion in the wall section modules of the first tier with concrete;

coupling a plurality of wall section modules together end to end on top of the first ring of wall section modules to form a continuous second ring of wall section modules collectively defining a second tier;

filling the annular space in the wall section modules of the second tier with concrete; and

coupling multiple successive rings of concrete-filled wall section modules together end to end on top of the second tier to form additional tiers to a preselected height of the enclosure.

43. The method according to claim 42, wherein the wall section modules in each ring of wall section modules in each tier are coupled to the wall section modules of the vertically adjacent rings of wall section modules.

44. The method according to claims 42 or 43, wherein the vertical rib plates in the first ring of wall section modules extend downwards from a bottom end of the first wall section modules to form a plurality of circumferentially spaced apart anchors.

45. The method according to claim 44, further comprising a step of embedding the anchors in the concrete slab.

46. The method according to claim 45, wherein the wall section modules define a sidewall of the enclosure having a non-polygonal cross-sectional shape defining an internal cavity.

47. The method according to any one of claims 42-46, further comprising before or after erecting the enclosure, locating the steam generating vessel on the concrete slab inside the internal cavity.

48. The method according to claim 47, wherein the enclosure further comprises a plurality of anchorage plate assemblies embedded in the sidewall at a plurality of elevations and circumferential locations.

49. The method according to claims 48, further comprising:

locating a plurality of ring-shaped seismic restraint collars on the steam generating vessel at a plurality of support elevations, the seismic restraint collars each defining a central opening slideably receiving the steam generating vessel therein to allow the steam generating vessel to thermally expand or contract in length;

coupling a first end of a plurality of seismic restraint members to each of the seismic restraint collars at each support elevation; and

coupling a second end of the seismic restraint members to each of the anchorage plate assemblies at each support elevation;

wherein each of the seismic restraint members extends radially between the collars and anchorage plate assemblies.

50. The method according to claim 49, wherein the seismic restraint members are coupled to the restraint collars and closure plate assemblies via pinned connections to accommodate thermal expansion or contraction of the steam generating vessel.

51. The method according to claims 49 or 50, wherein the seismic restraint members are linearly elongated struts or pipe snubbers.

52. The method according to any one of claims 48-51, wherein each anchorage plate assembly comprises a weldment of structural members, the anchorage plate assemblies including an internal portion which projects radially inwards from the sidewall into the internal cavity, an external portion which projects radially outwards from sidewall, and an intermediate portion embedded in the concrete liner in the annular space.

53. The method according to any one of claims 46-52, wherein the sidewall of the enclosure has a circular or elliptical cross-sectional configuration.

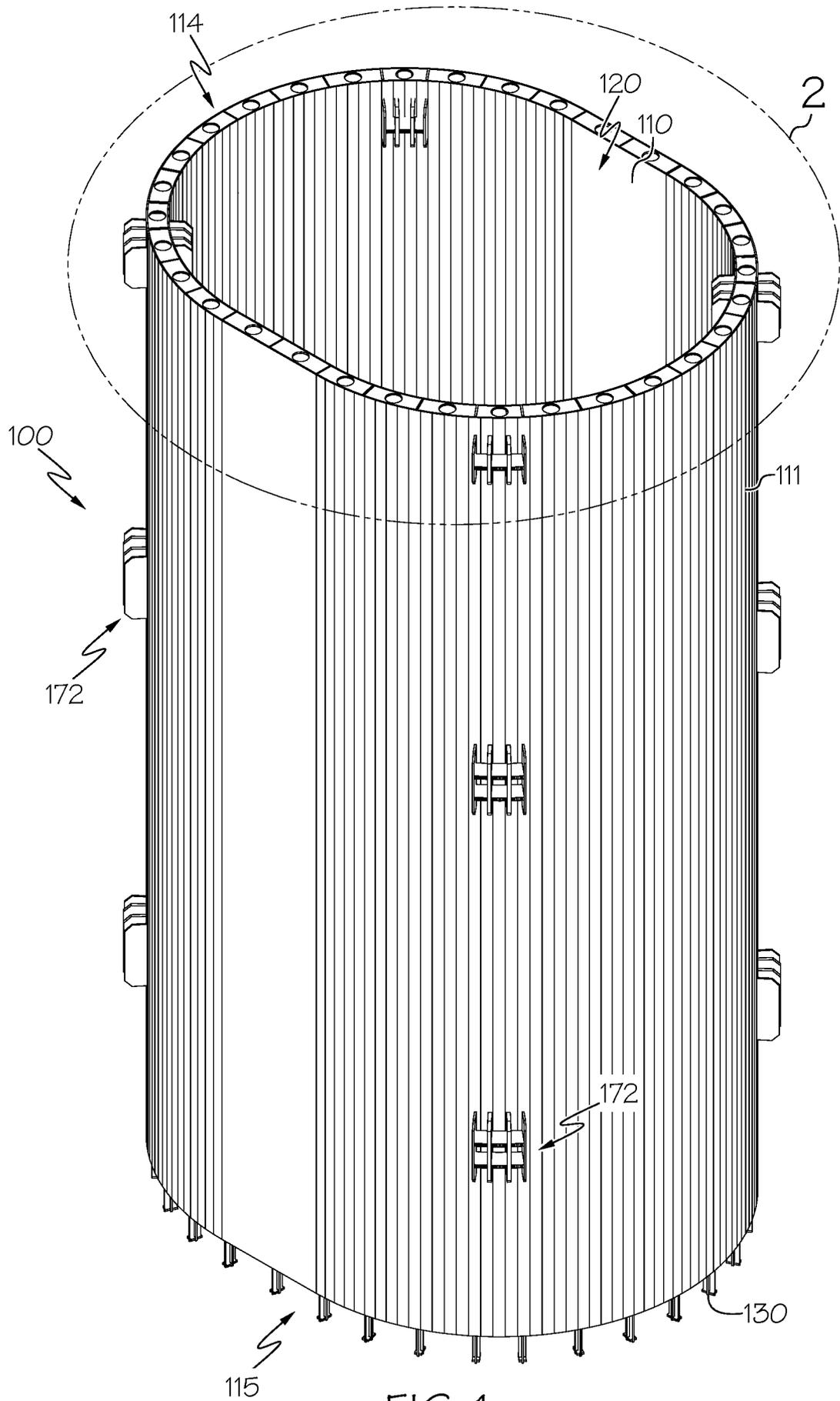


FIG. 1

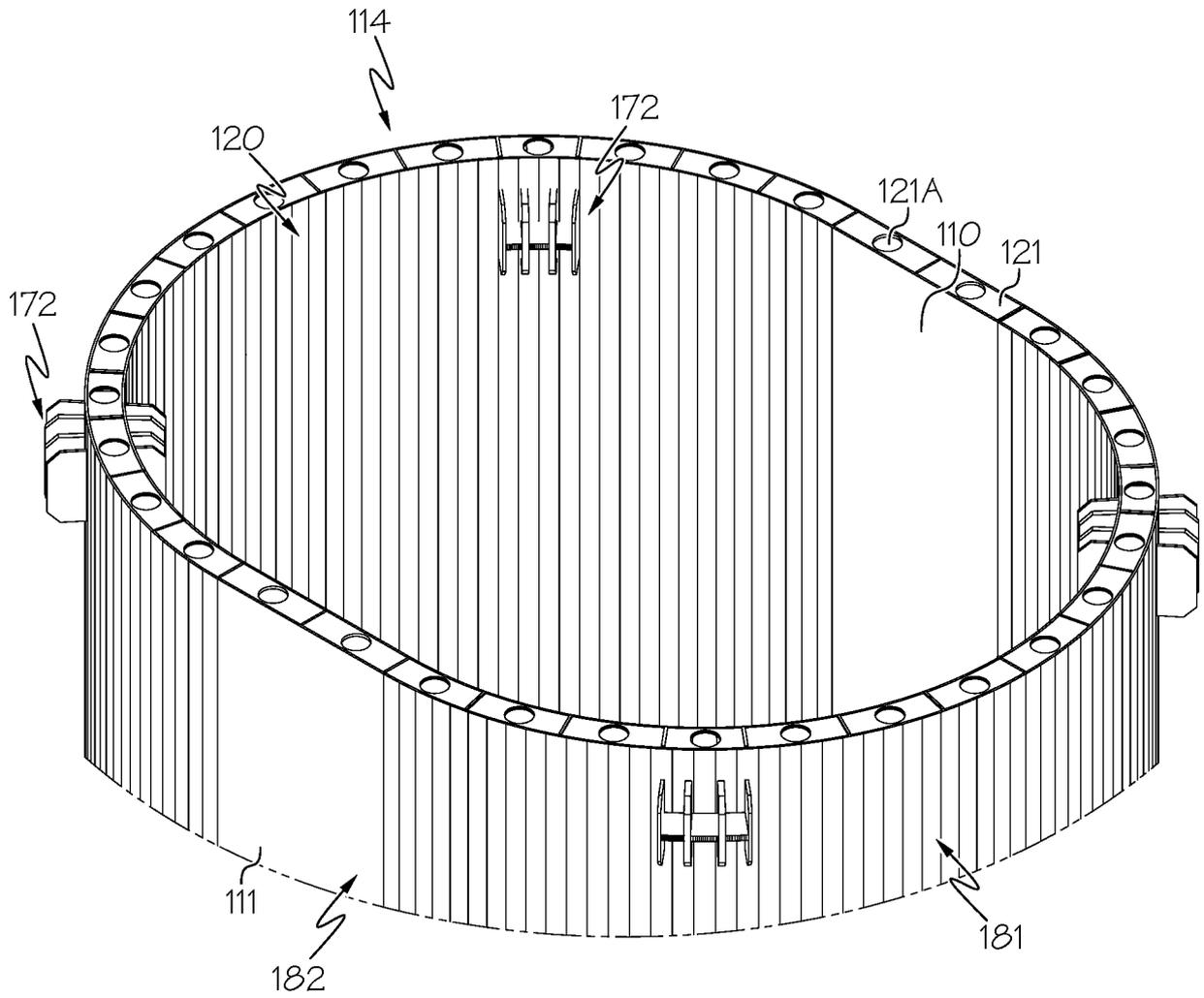


FIG. 2

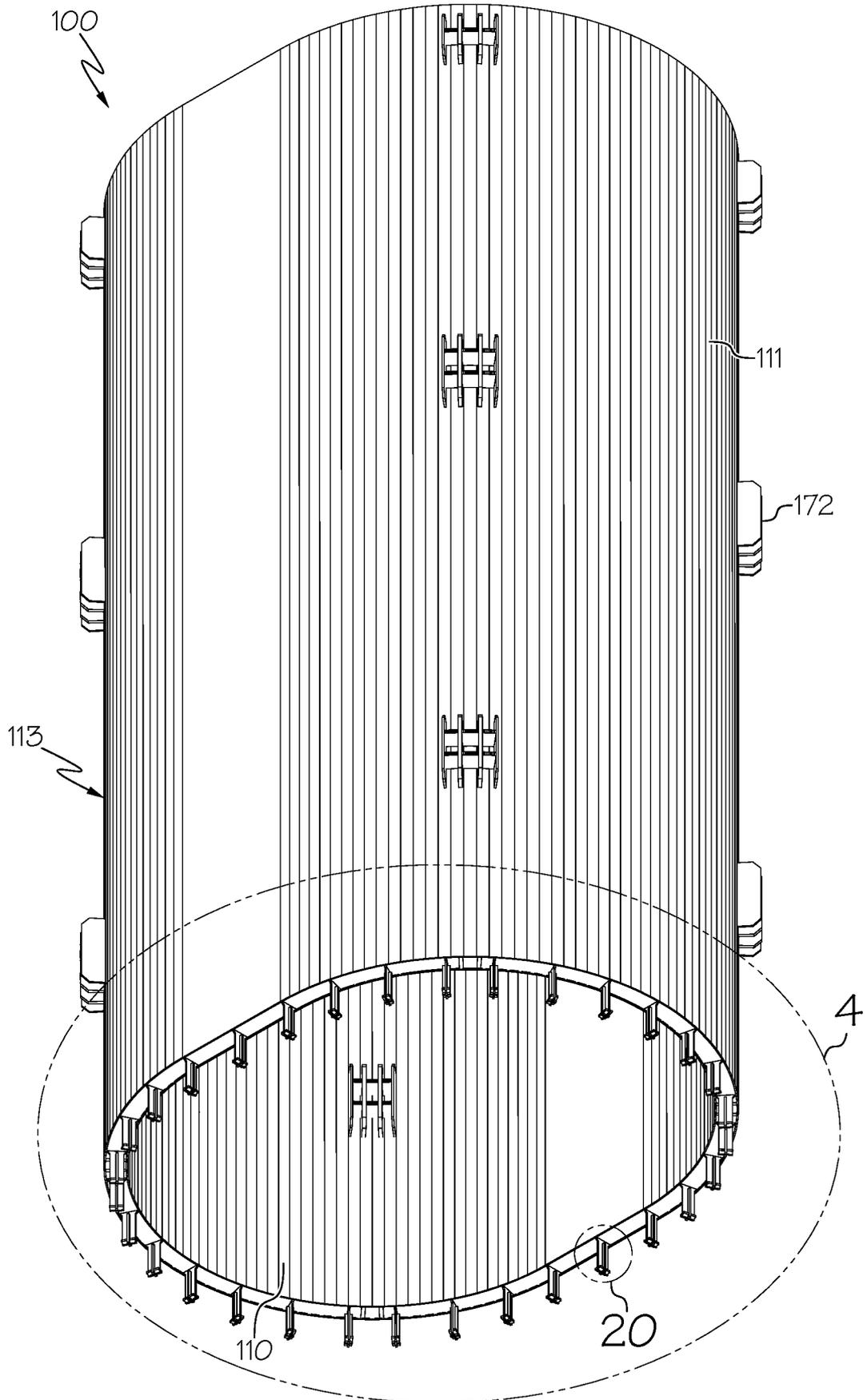


FIG. 3

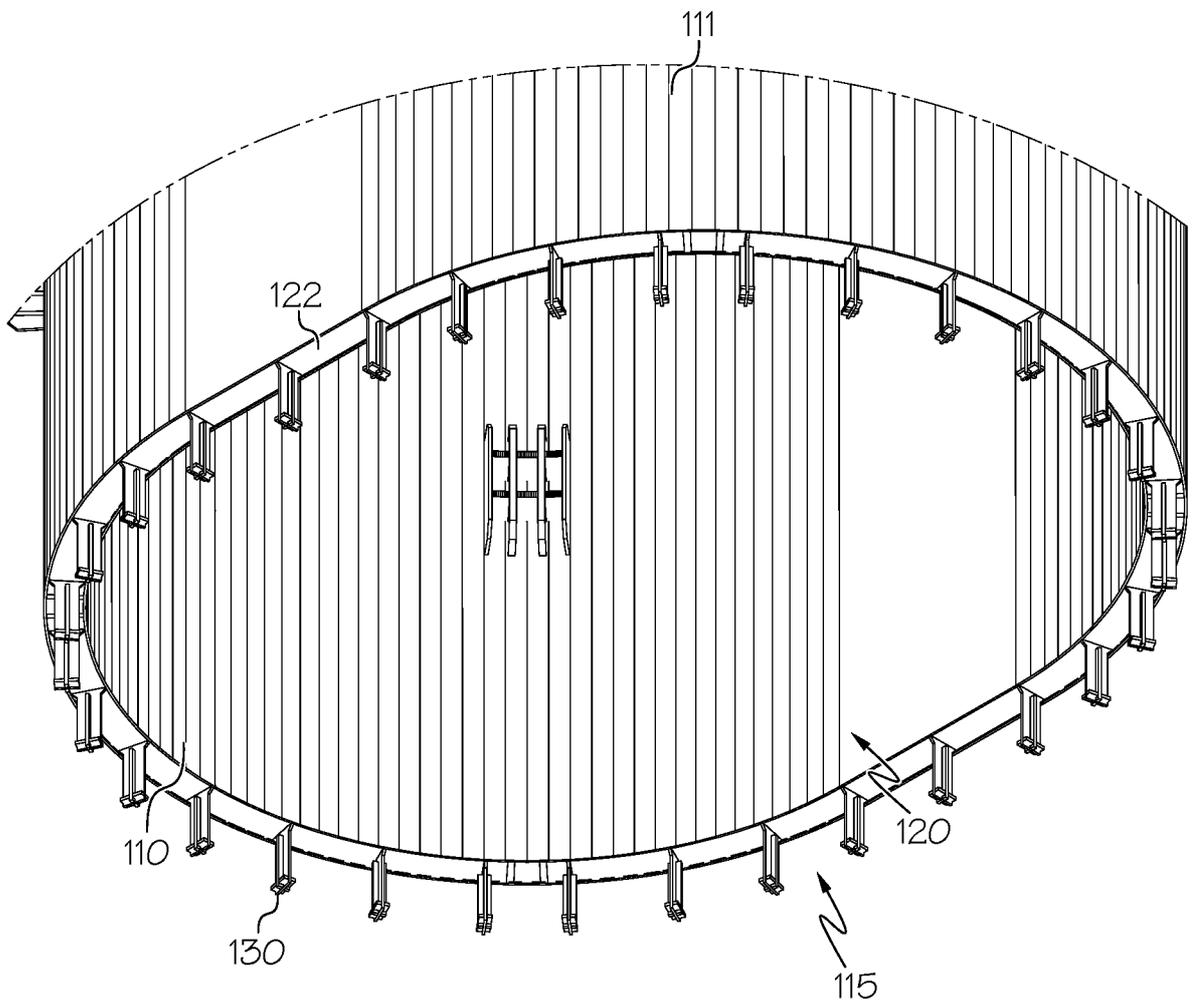
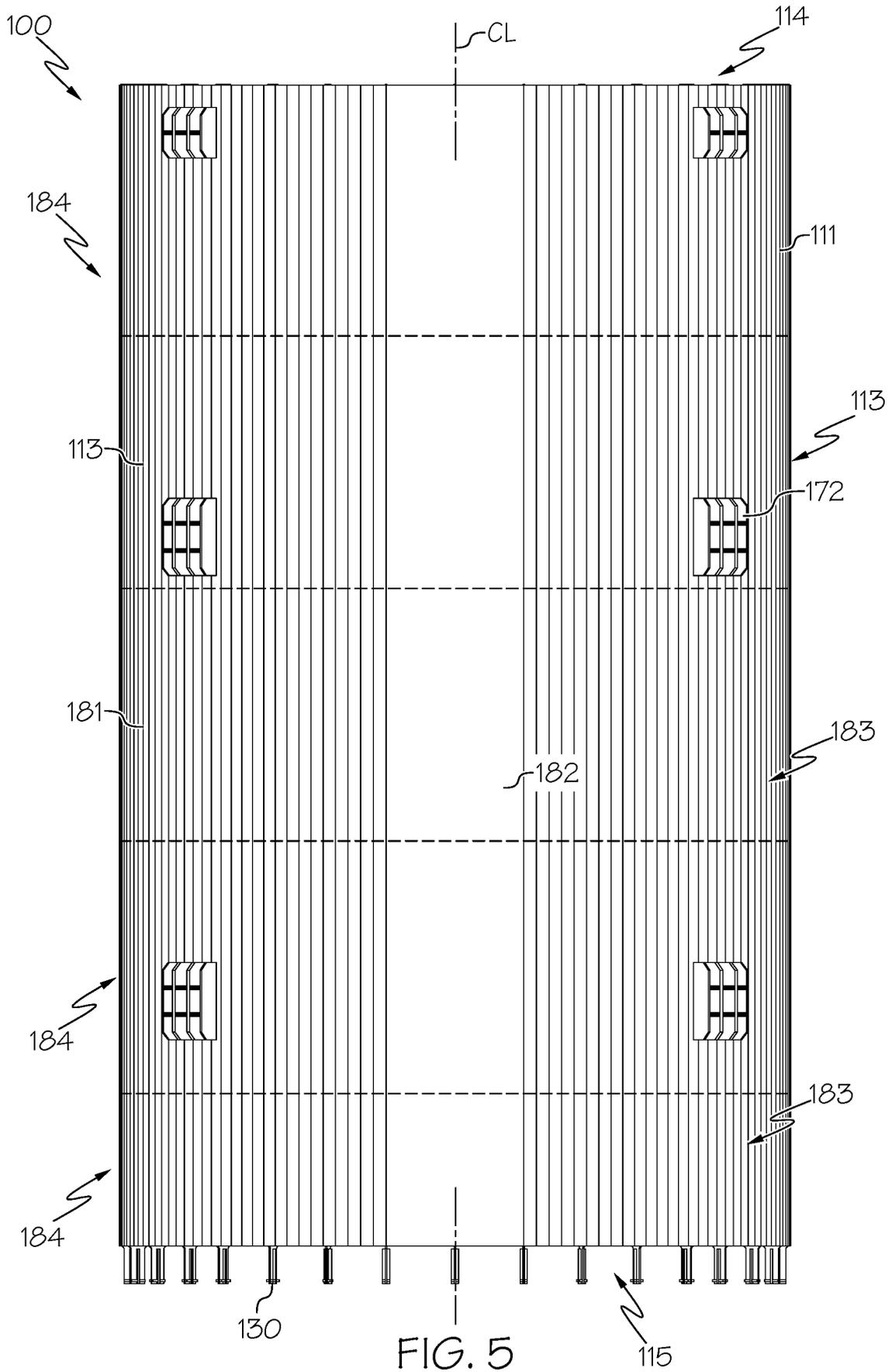


FIG. 4

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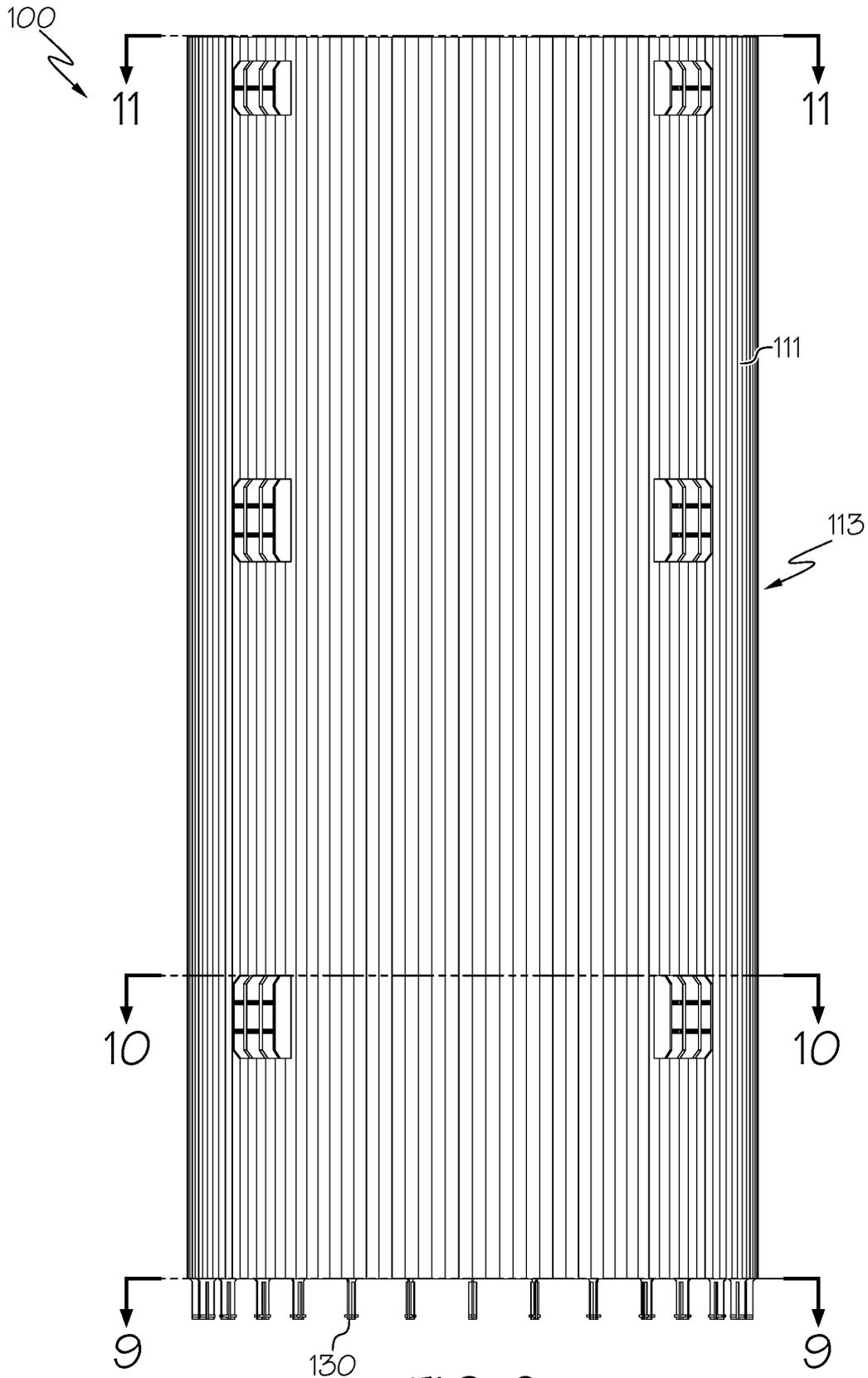
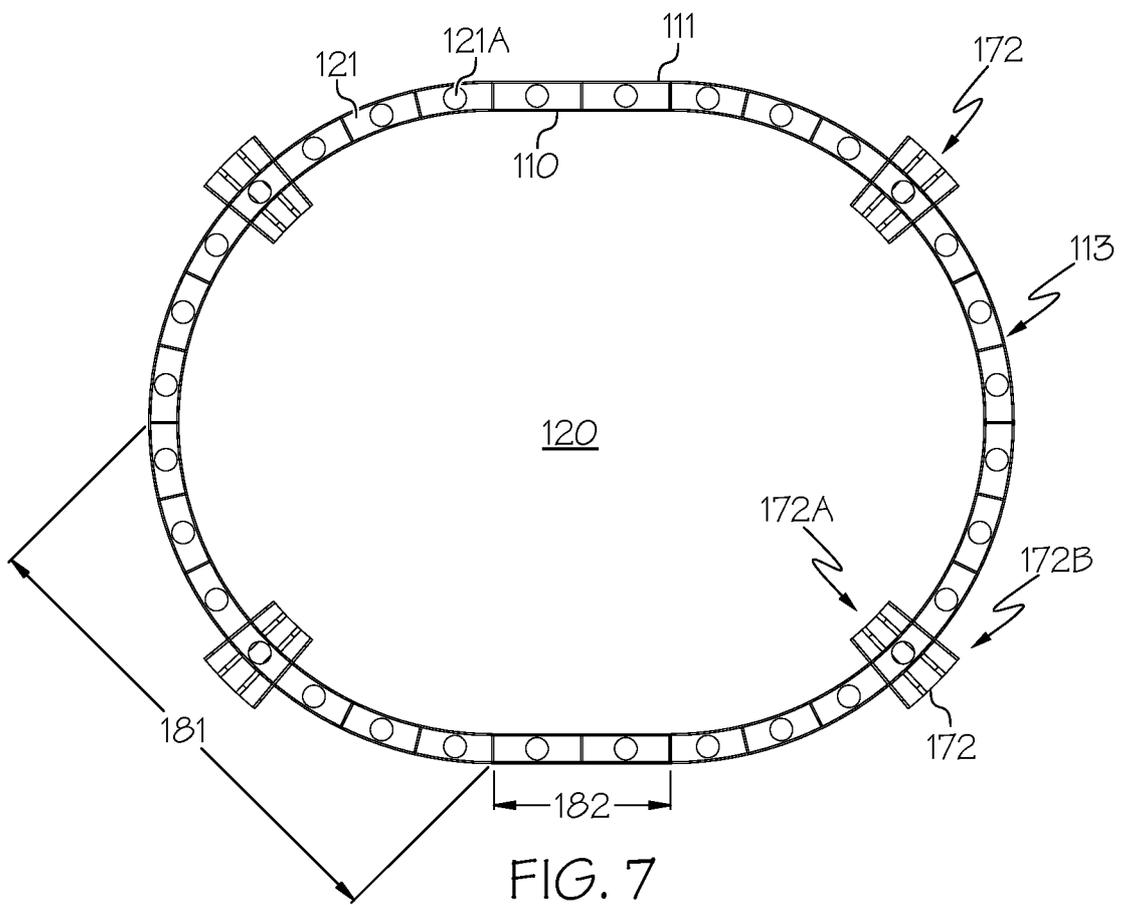


FIG. 6



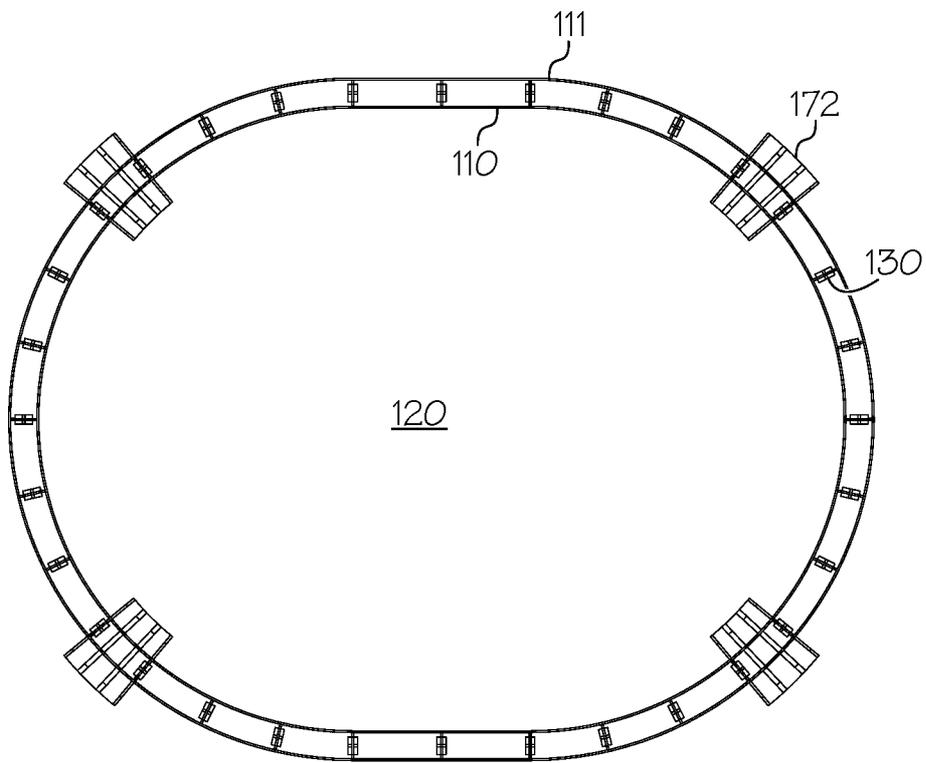


FIG. 8

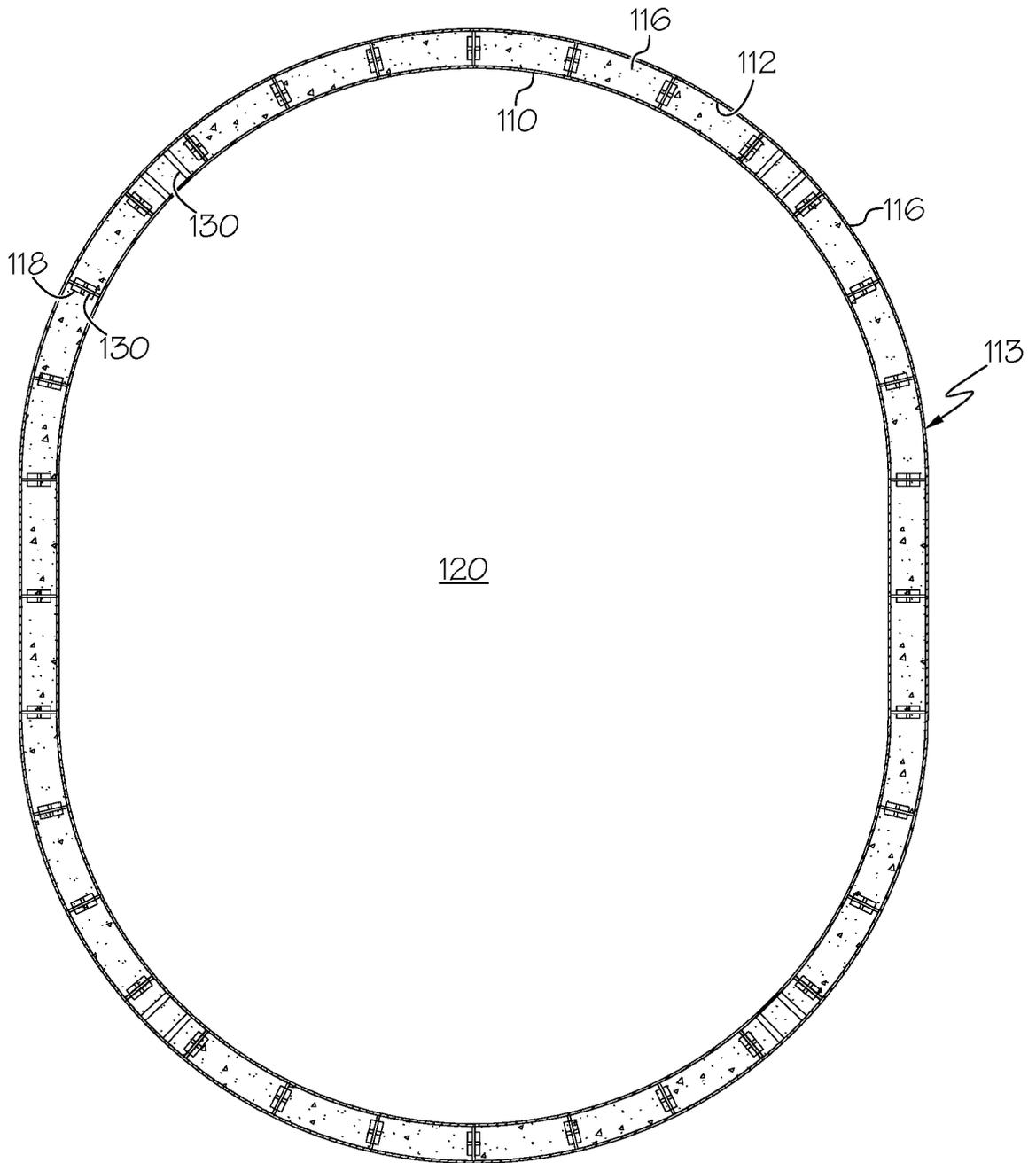


FIG. 9

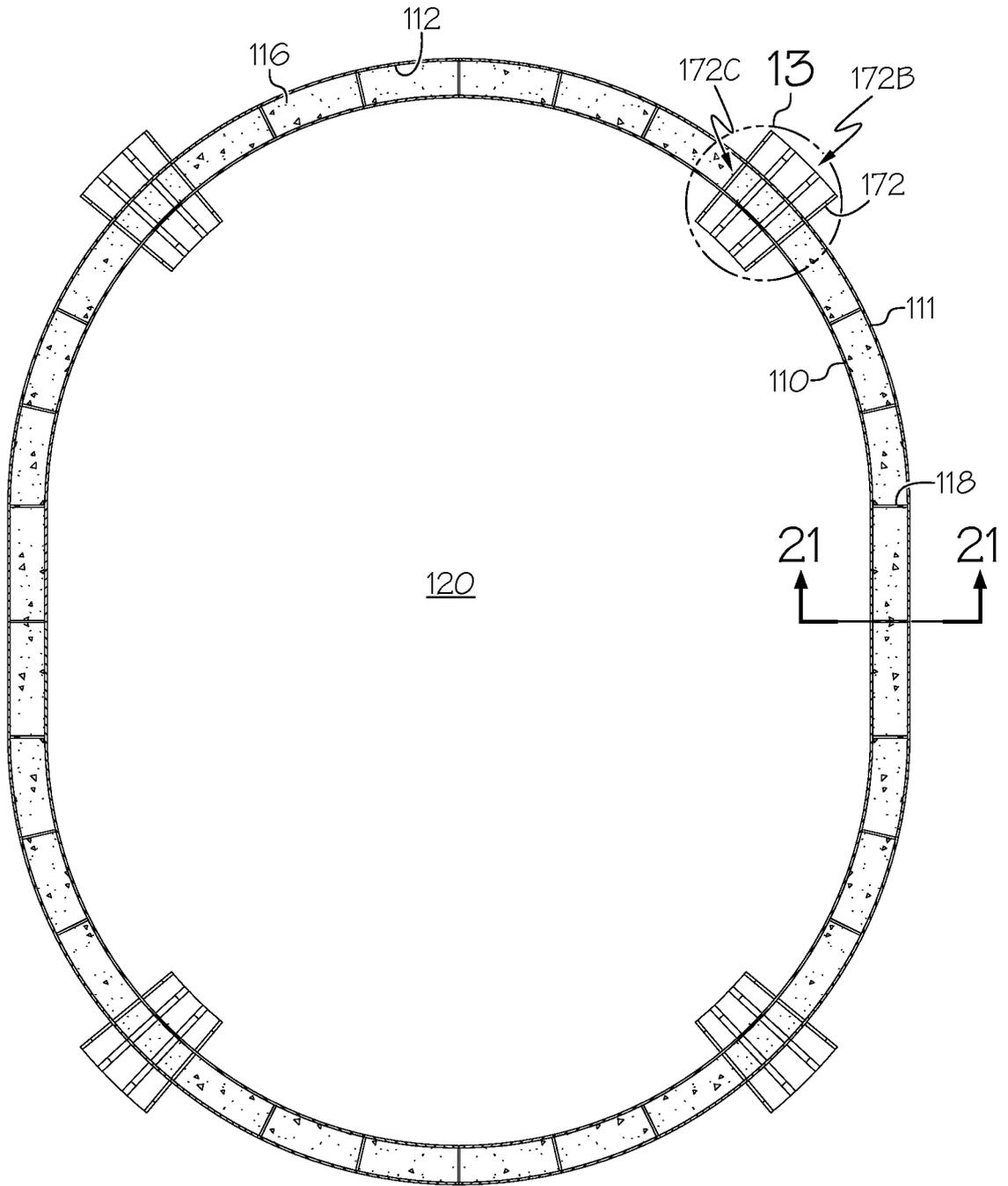


FIG. 10

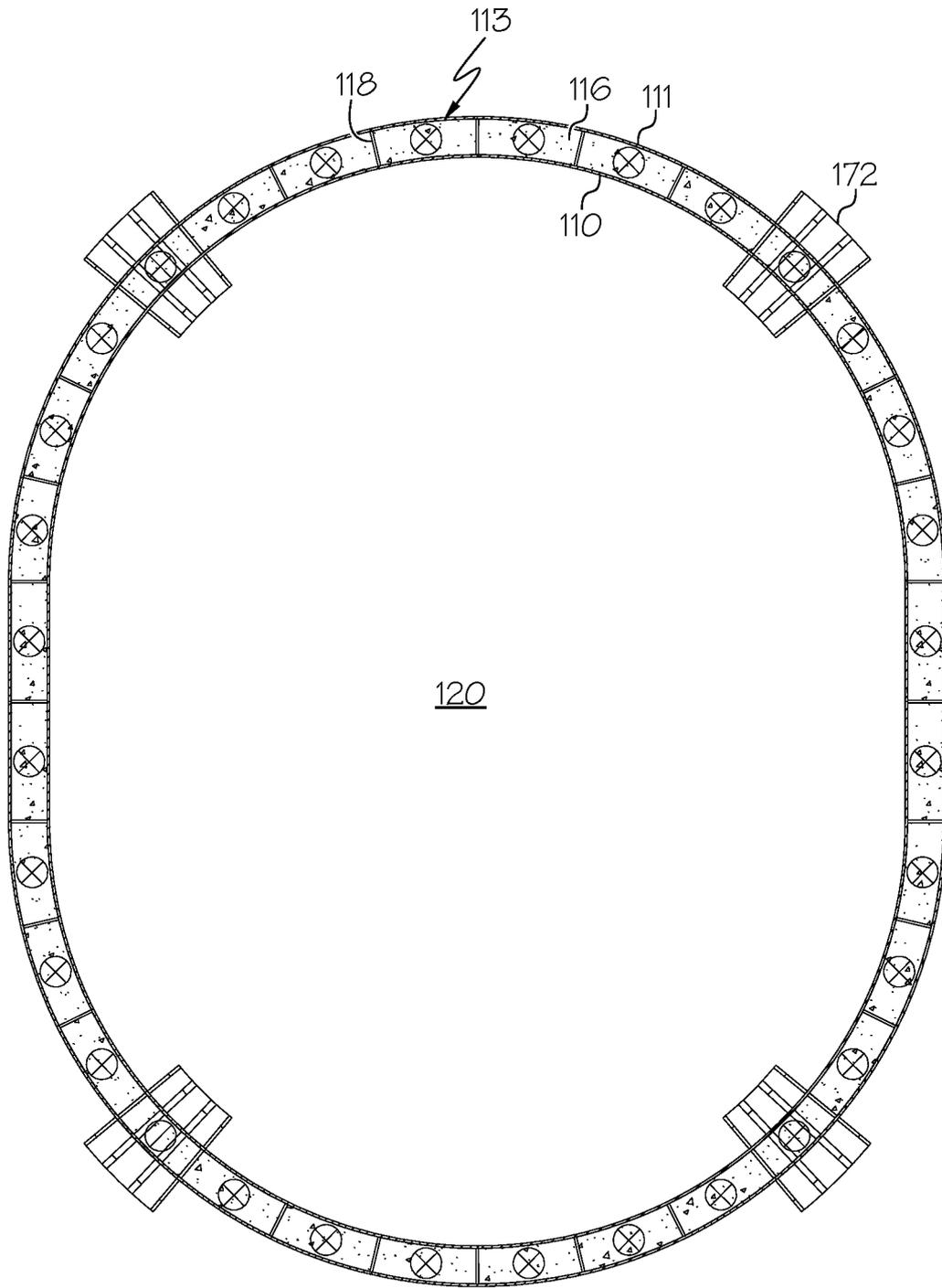


FIG. 11

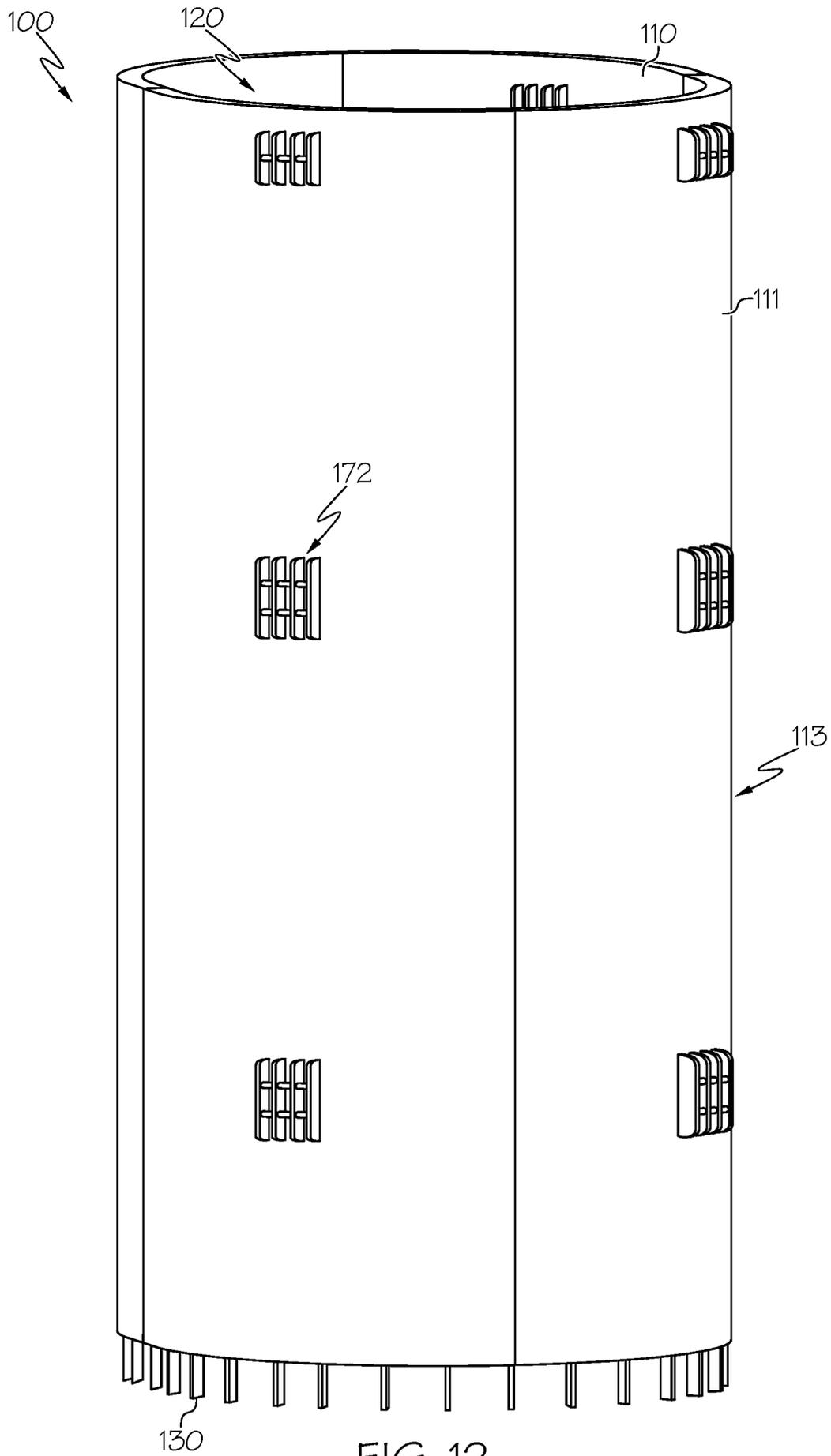


FIG. 12

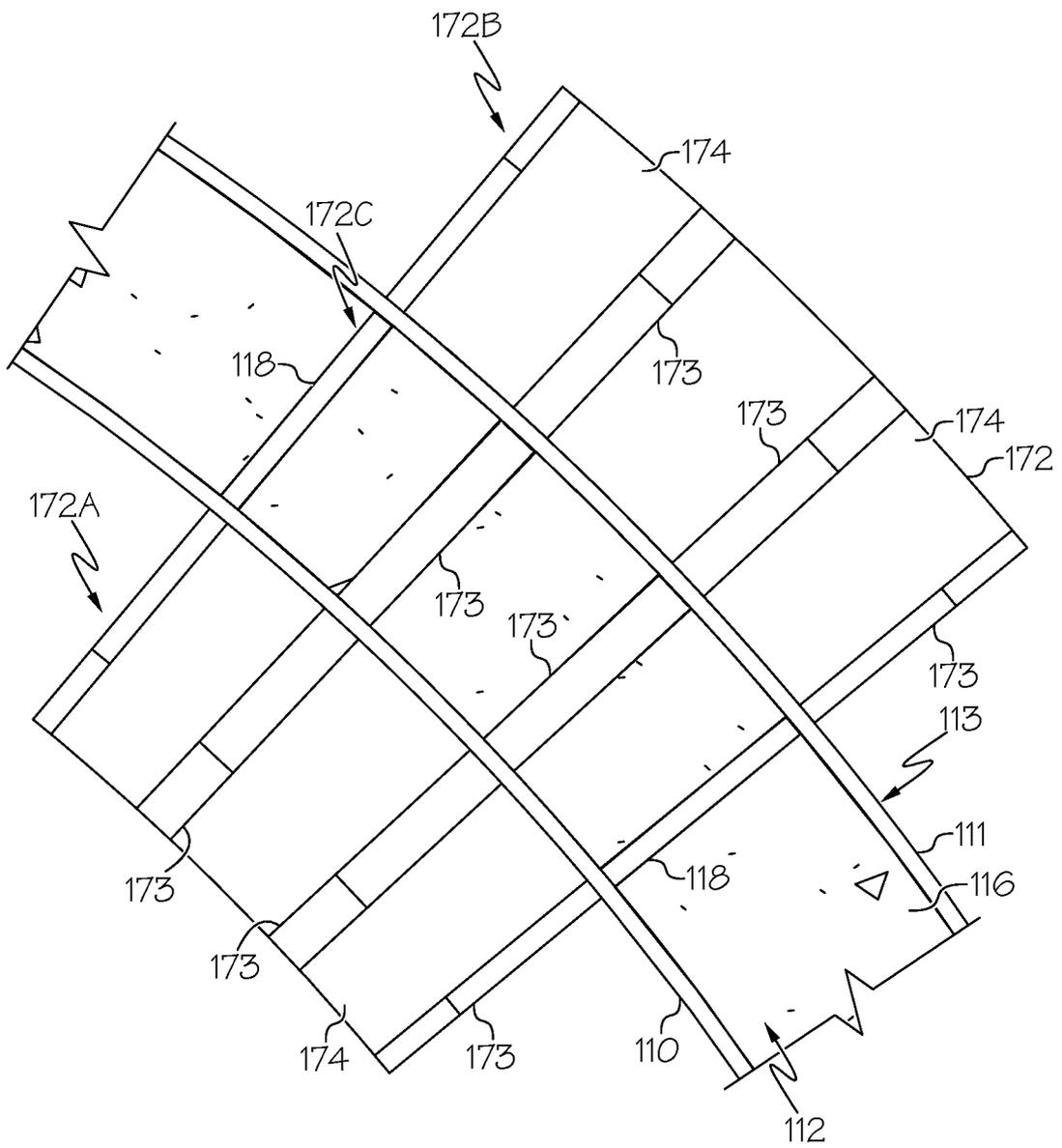


FIG. 13

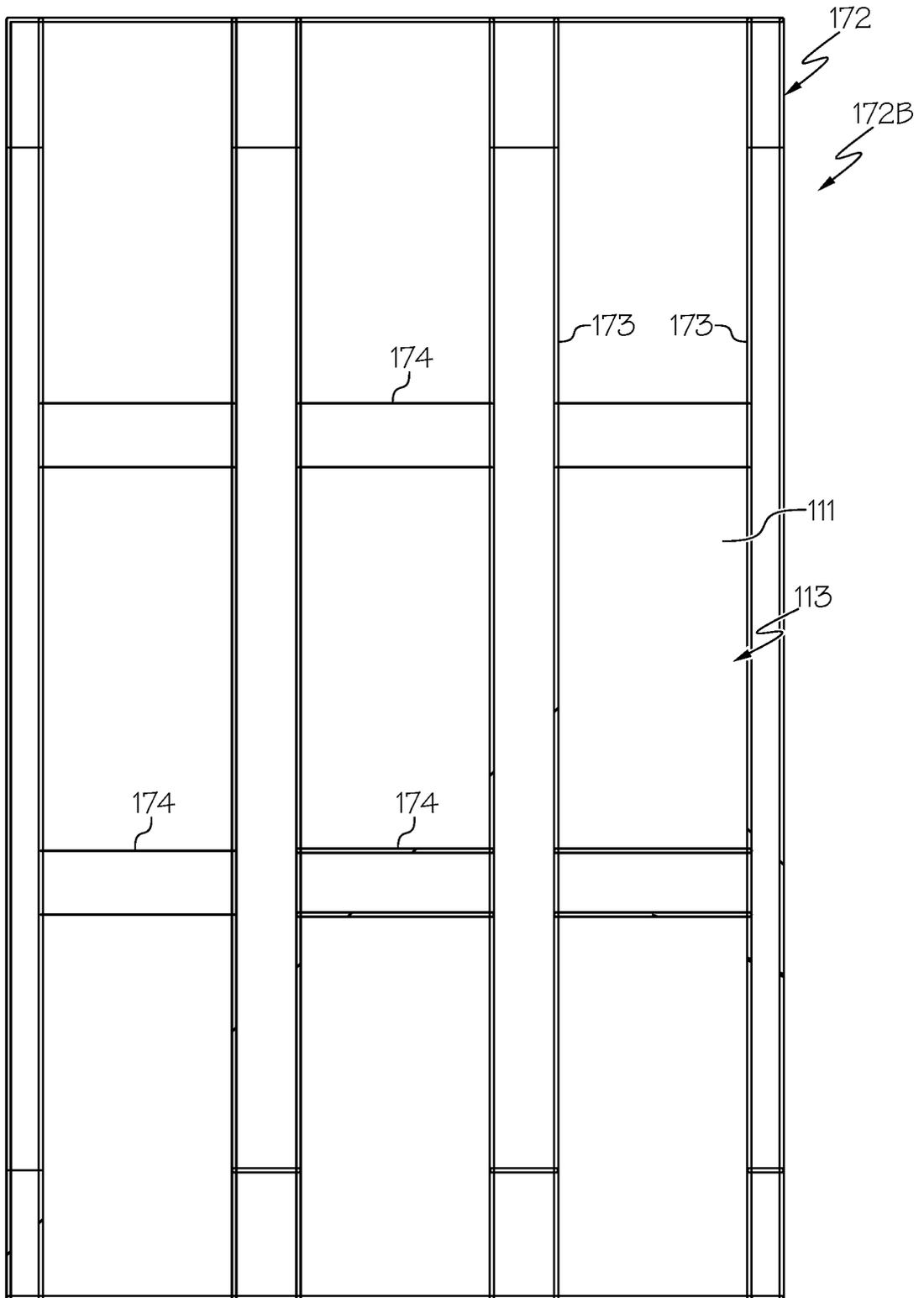


FIG. 14

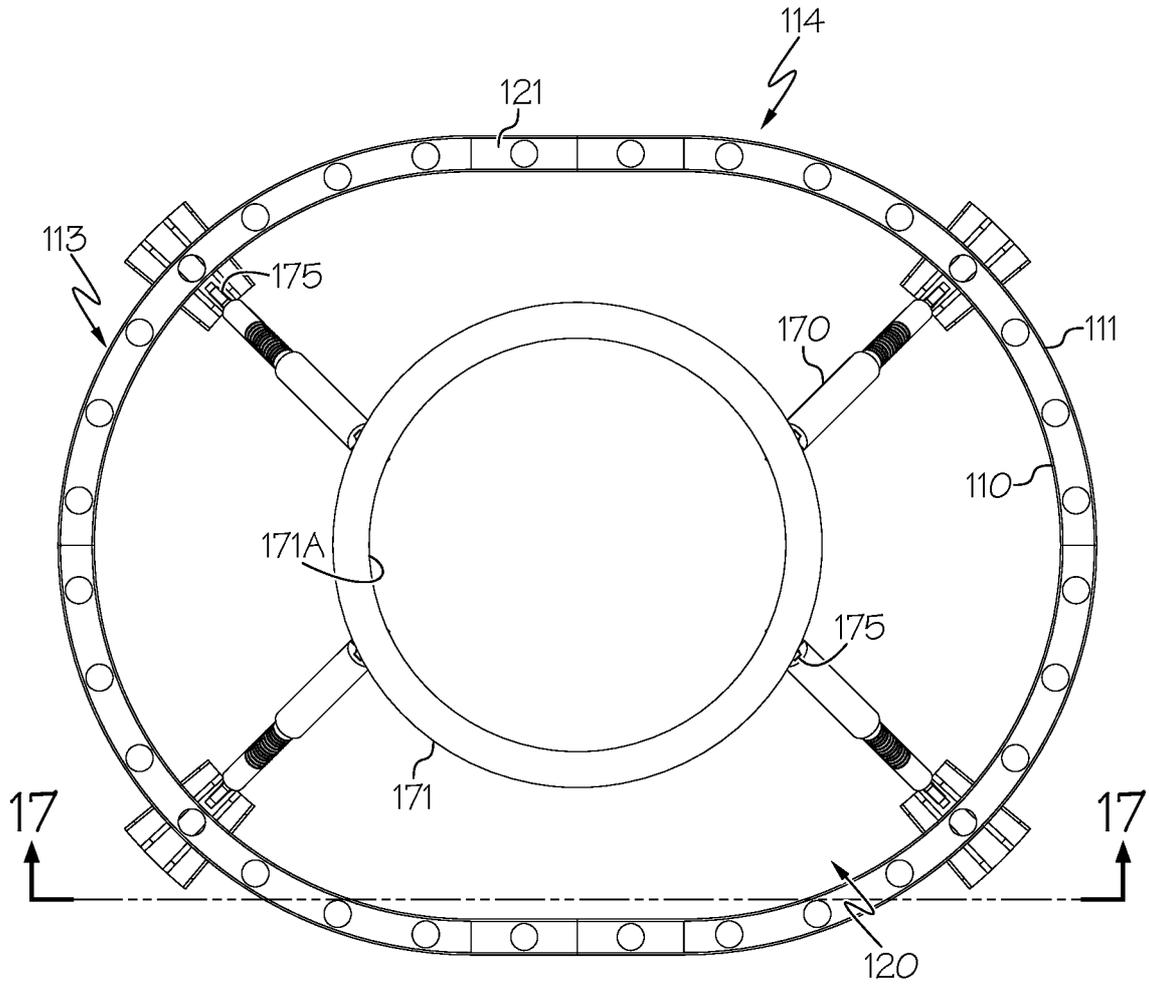


FIG. 15

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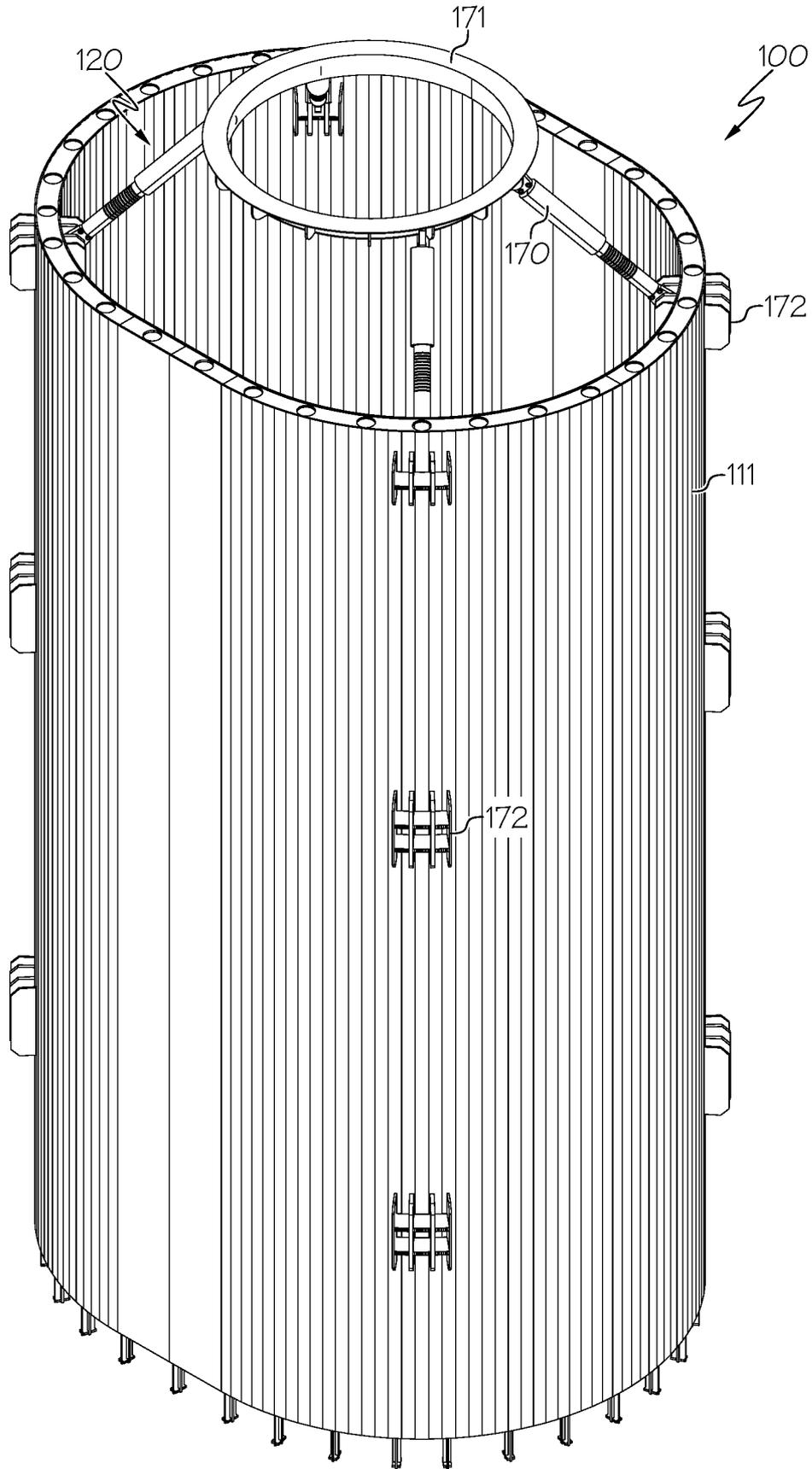


FIG. 16

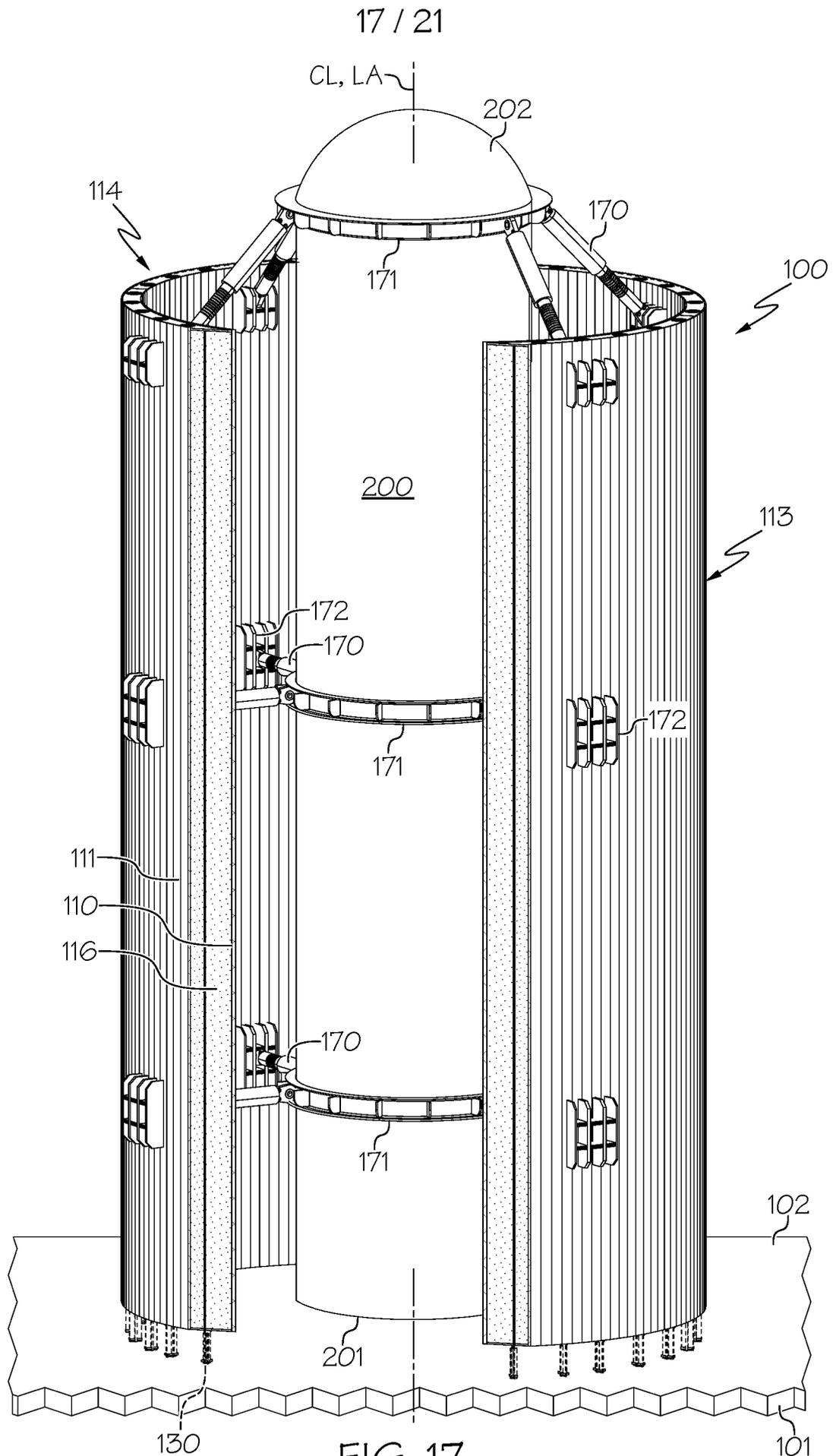


FIG. 17

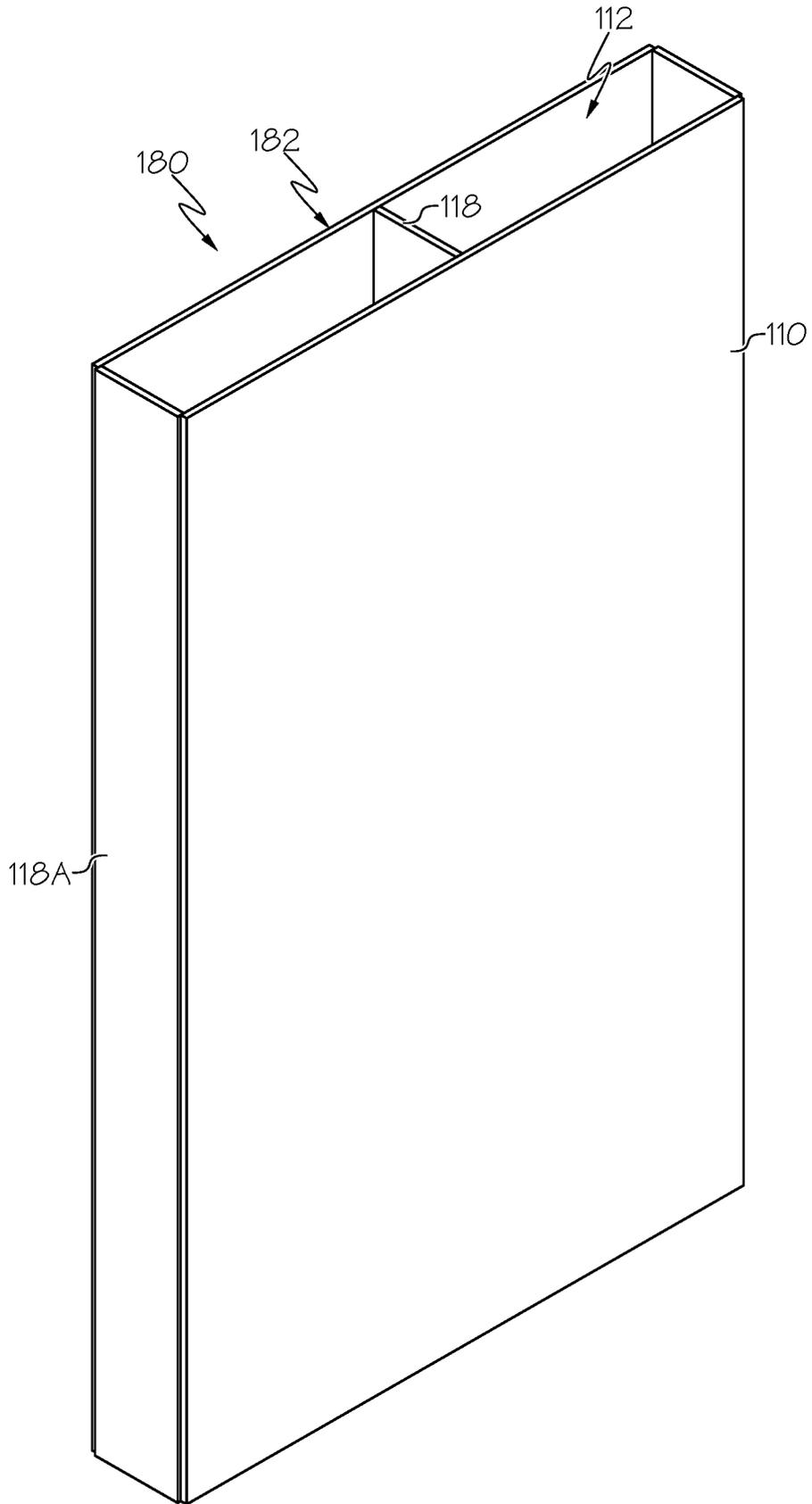


FIG. 18

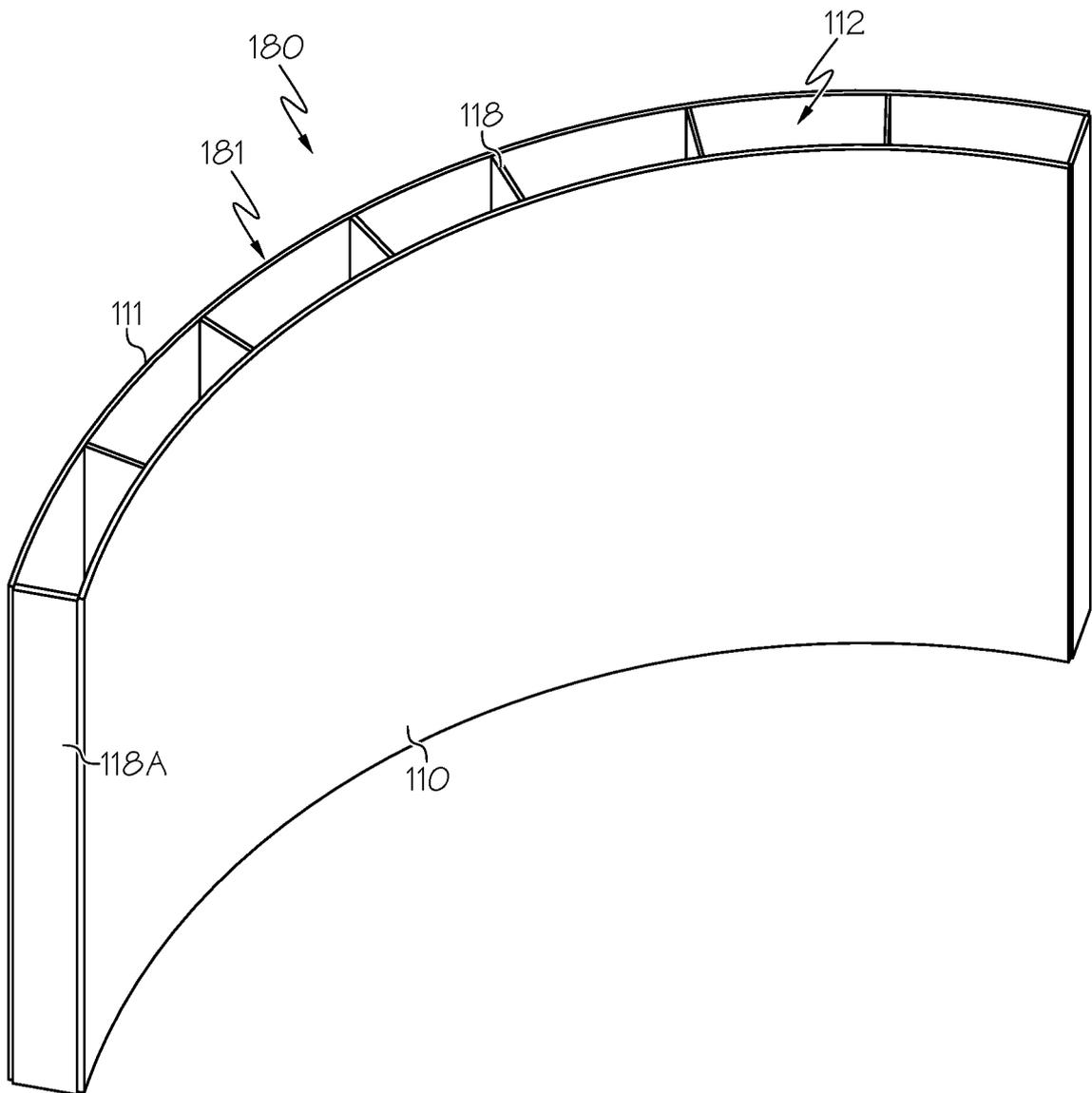


FIG. 19

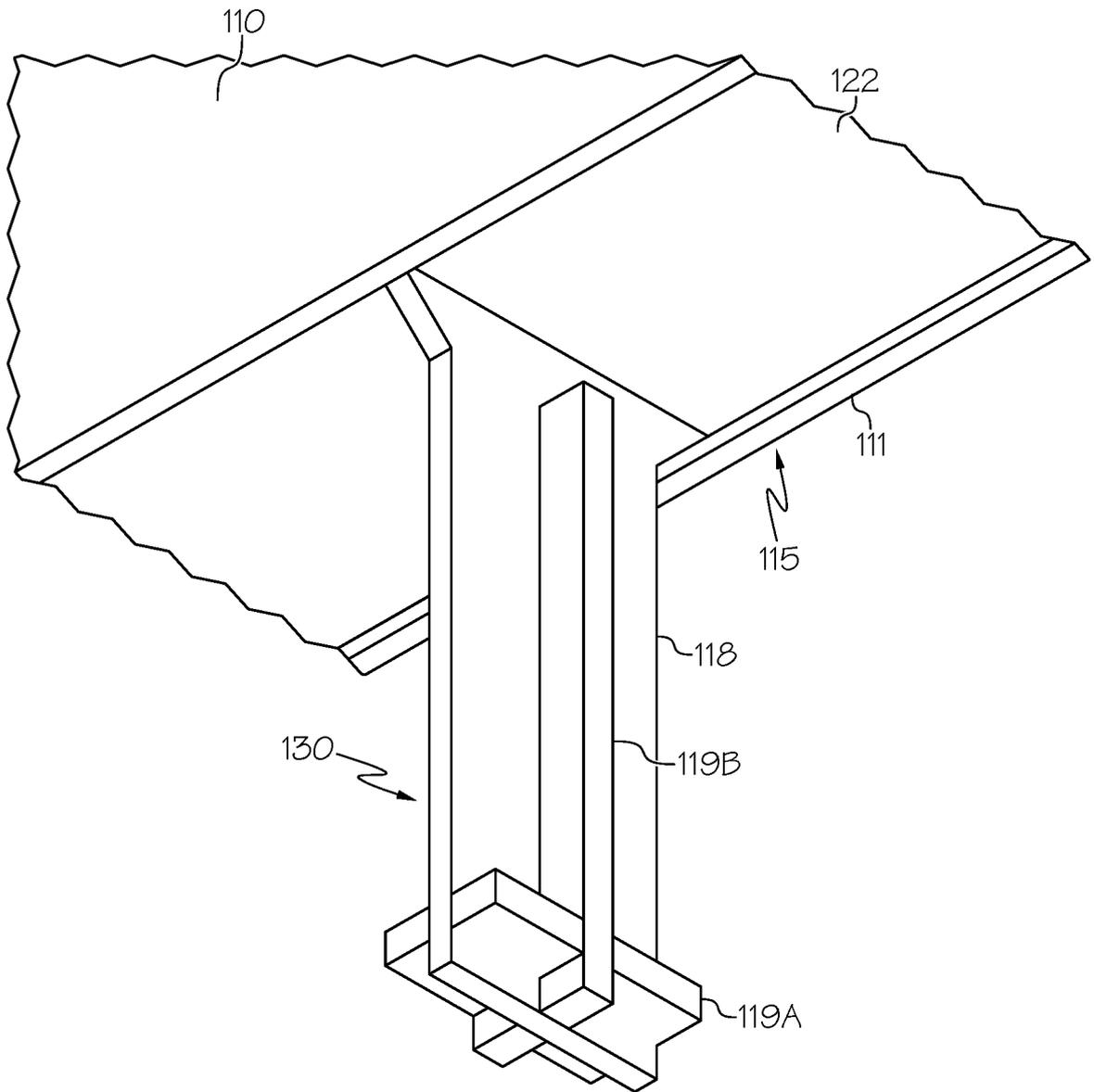


FIG. 20

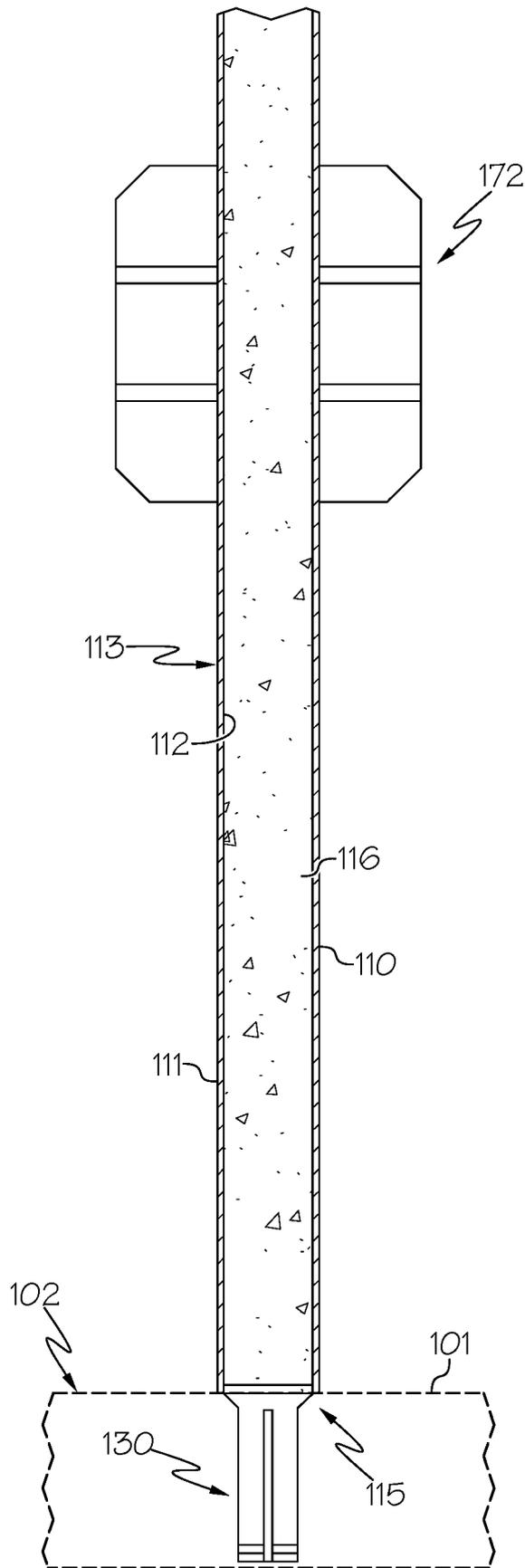


FIG. 21

## INTERNATIONAL SEARCH REPORT

International application No.

**PCT/US2024/061850**

<b>A. CLASSIFICATION OF SUBJECT MATTER</b>		
IPC: <b>F22B 37/24</b> (2025.01); <b>G21C 13/093</b> (2025.01); <b>G21C 15/12</b> (2025.01); <b>G21C 9/04</b> (2025.01); <b>G21C 13/04</b> (2025.01) CPC: <b>F22B 1/023</b> ; <b>F22B 37/007</b> ; <b>F22B 37/24</b> ; <b>G21D 1/006</b> ; <b>G21C 13/093</b> ; <b>G21C 15/12</b> ; <b>G21C 9/04</b> ; <b>G21C 13/04</b>		
According to International Patent Classification (IPC) or to both national classification and IPC		
<b>B. FIELDS SEARCHED</b>		
Minimum documentation searched (classification system followed by classification symbols) See Search History Document		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched See Search History Document		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) See Search History Document		
<b>C. DOCUMENTS CONSIDERED TO BE RELEVANT</b>		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y A	US 2003/0215047 A1 (KOBAYASHI et al.) 20 November 2003 (20.11.2003) Fig 1-5; para [0004], [0012], [0014], [0021], [0026], [0031], [0034]-[0036] Fig 1-5; para [0004], [0012], [0014], [0021], [0026], [0031], [0034]-[0036]	1-2, 6, 19 3-5
Y A	US 5,343,506 A (ARTNIK et al.) 30 August 1994 (30.08.1994) Fig 1-2B; col 9, ln 4-15, 27-34; col 10, ln 26-29; col 18, ln 42-51 Fig 1-2B; col 9, ln 4-15, 27-34; col 10, ln 26-29; col 18, ln 42-51	1-2, 6, 19 3-5
Y A	US 3,424,239 A (COUDRAY) 28 January 1969 (28.01.1969) Fig 2; col 4, ln 5-13, 31-34 Fig 2; col 4, ln 5-13, 31-34	2, 6 3-5
Y	US 2022/0406481 A1 (HOLTEC INTERNATIONAL) 22 December 2022 (22.12.2022) Fig 1-3, 6; para [0043], [0045]-[0046], [0059]	19
A	US 3,258,403 A (MALAY) 28 June 1966 (28.06.1966) entire document	1-6, 19
<input checked="" type="checkbox"/> Further documents are listed in the continuation of Box C. <input type="checkbox"/> See patent family annex.		
* Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "D" document cited by the applicant in the international application "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search <b>20 February 2025 (20.02.2025)</b>		Date of mailing of the international search report <b>18 April 2025 (18.04.2025)</b>
Name and mailing address of the ISA/US <b>COMMISSIONER FOR PATENTS MAIL STOP PCT, ATTN: ISA/US P.O. Box 1450 Alexandria, VA 22313-1450 UNITED STATES OF AMERICA</b>		Authorized officer  <b>KARI RODRIQUEZ</b>
Facsimile No. <b>571-273-8300</b>		Telephone No. <b>PCT Help Desk: 571-272-4300</b>

INTERNATIONAL SEARCH REPORT

International application No.

**PCT/US2024/061850**

<b>C. DOCUMENTS CONSIDERED TO BE RELEVANT</b>		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2014/0219410 A1 (MITSUBISHI HEAVY INDUSTRIES, LTD.) 07 August 2014 (07.08.2014) entire document	1-6, 19
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**Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)**

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1.  Claims Nos.:  
because they relate to subject matter not required to be searched by this Authority, namely:
  
2.  Claims Nos.:  
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
  
3.  Claims Nos.: **7-18, 29, 31-41, and 47-53**  
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

**Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)**

This International Searching Authority found multiple inventions in this international application, as follows:

This application contains the following inventions or groups of inventions which are not so linked as to form a single general inventive concept under PCT Rule 13.1.

Group I: Claims 1-6 and 19, directed to an enclosure structure for a vertically elongated steam generator of a nuclear power generation plant.

Group II: Claims 20-28 and 30, directed to a steam generator enclosure system for a nuclear power generation plant.

Group III: Claims 42-46, directed to a method for erecting a modular enclosure for a steam generator vessel of a nuclear power generation plant.

**Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)**

1.  As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2.  As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3.  As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4.  No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.: **1-6 and 19**

- Remark on Protest**
- The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
  - The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
  - No protest accompanied the payment of additional search fees.