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(54) **DEVICE AND METHOD FOR BUILDING A SILO**

(57) The invention generally relates to an alignment device for aligning arced silo panels to form a silo wall during construction of a silo. The invention may also relate to a lifting device for lifting silo panels during the construction of a silo. The invention may further relate to an arced silo panel for the construction of a silo, in particular to be used in combination with the alignment device and the lifting device for the construction of a silo. The invention may further relate to a method for constructing a silo, preferably using the alignment device, the lifting device, and/or the arced silo panels.

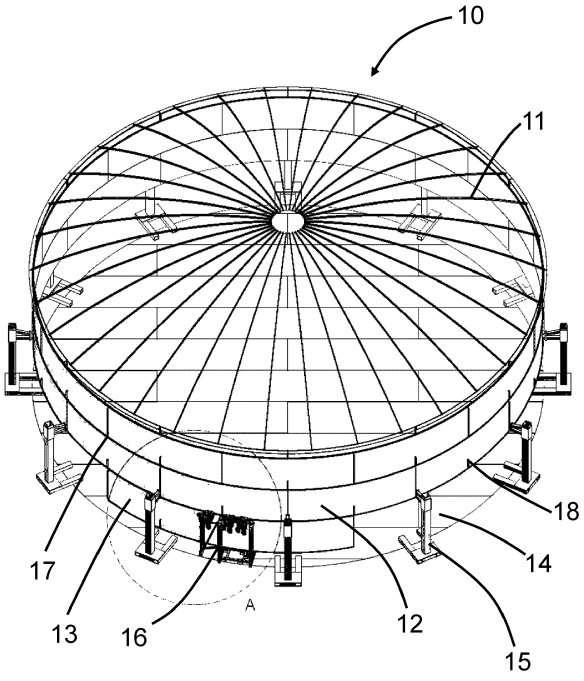


FIG. 1

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## Description

### BACKGROUND OF THE INVENTION

**[0001]** The invention generally relates to an alignment device for aligning arced silo panels to form a silo wall during construction of a silo. The invention may also relate to a lifting device for lifting silo panels during the construction of a silo, and an arced silo panel for the construction of a silo. The invention may further relate to a method for constructing a silo. A silo may be understood to encompass storage tanks, in particular large storage tanks.

**[0002]** Mass production of increasing amounts of goods of varied nature makes it necessary to build storage structures of a proportionally growing capacity for storing materials. Industries such as the petrochemical, biodiesel, oil and the dairy industry, as well as wastewater treatment plants, water purification plants and, in general, every industry requiring the storage of large quantities of fuel, liquids, grains and other products, need large size silos in order to achieve competitive prices in the purchase of raw materials as well as in large-scale production.

**[0003]** The construction of large size silos presents a number of technological challenges which are hard to address. A silo is generally constructed using a multiplicity of stacked cylindrical rings to achieve the desired height. The traditional construction system starts from the base of the silo. The walls are built up from below, using cylindrical rings, starting from the lowest ring welded to the base and ending with the construction of the roof and the subsequent attachment of all fittings (ladders, piping, telemetry and control systems, etc.). This approach to the construction of silos brings about difficulties with regards to, amongst others, required equipment, safety, alignment, and quality of welding.

**[0004]** Attempts have been made to overcome the problems associated with the traditional methods of silo construction. For example, to ensure that the equipment necessary to join the cylindrical rings is not required to be raised, the silo under construction may be raised so that a new cylindrical ring may be provided under the part of the silo which is already constructed. As such, the silo under construction is raised, rather than all the materials necessary to form a new cylindrical ring. In this manner, e.g. welding equipment and/or alignment equipment, as well as the parts forming the new cylindrical rings, may be kept on the ground, which improves safety and efficiency.

**[0005]** A known method of constructing silos is to provide a multiplicity of separate silo panels, which are joined to form a cylindrical ring. These separate silo panels are generally pre-bent and often comprise outwardly projecting flanges around the periphery of the silo panel. Such separate silo panels are shown in WO00/49249. Even in such systems, the alignment of the silo panels provides significant challenges.

**[0006]** It is therefore desirable to provide an alignment device for the construction of a silo that has benefits and/or overcomes one or more disadvantages of silo construction devices/methods of the prior art. Exemplary benefits may be achievement of improved efficiency, lowered safety-risks, lowered production costs, and/or higher quality of the silo construction.

**[0007]** In the below relative positions will be mentioned, such as upper and lower. In the below, those positions refer mostly to the respective positions in the under construction silo. It will clear however that those positions can be generalized. Upper and lower generally refers to a first and a second at a distance. The invention is not limited to the specific in use positions.

### BRIEF SUMMARY OF THE INVENTION

**[0008]** The present invention addresses these problems by providing an alignment device for aligning panels, in particular arced silo panels, to form a silo wall during construction of a silo. The alignment device may comprise a base frame supporting an outer side and an inner side. The base frame with inner and outer side may form a U-shape having a space for receiving an arced silo panel in between the outer and inner side. Such an arrangement allows engaging the arced silo from multiple sides. The open side of the U-shape allows connecting a new arced panel to an existing arced part, e.g. an arced silo panel that is already part of the silo under construction.

**[0009]** The alignment device may further comprise at least one clamping unit provided on the outer side of the base frame, the clamping unit being arranged to clamp two flanges of a lower arced silo panel and upper arced silo panel together. In other or additional embodiments, the clamping unit may be on the inner side, or on both inner and outer side, of the base frame for clamping flanges that are part of an inner periphery of a lower and upper arced silo panel.

**[0010]** The alignment device may further comprise at least one pressing unit, comprising an inner panel aligner provided on the innerside and an outer panel aligner provided on the outer side. The pressing unit may be arranged to engage the lower arced silo panel and the upper arced silo panel, wherein the pressing unit is arranged to provide opposing alignment forces on inner and an outer sides of lower and upper arced silo panels.

**[0011]** Preferably, the pressing unit and the clamping unit are arranged to align the lower arced silo panel and the upper arced silo panel radially and vertically. The pressing an clamping units can position and align a new arced panel with an existing arced part, e.g. an arced silo panel that is already part of the silo under construction. To manipulate the position of the new arced silo panel with respect to the existing part, the clamping and pressing unit engage the new arced silo panel and the existing silo part. For constructing a silo, a new arced silo panel is added to the already constructed part of the silo that

comprises other arced silo panels. The new part is to be held in position and is to be aligned with an arced silo panel that is already part of the partially constructed silo. To that end the pressing and clamping units engage on inner and outer sides of the arced silo panels during construction for positioning and aligning.

**[0012]** Further, the alignment device may have a drive arranged to move along a existing part of the silo under construction, that existing part being a stationary part. This allows to move the alignment device in a circumferential direction along arced panels, along the wall region of the silo under construction. As a result, the silo under construction can remain stationary, while the alignment device travels around its periphery. This is highly advantageous as it mitigates the need for rotating the entire silo during construction. Driving the alignment device allows moving the alignment device to a position that allows aligning the new arced silo panel into position with reduced lever. The alignment device can be driven to positions that allow engaging closer to misaligned regions. The alignment device can also be driven, after positioning and aligning and preferably fixing a new arced panel to the silo under construction, to a further position where it can receive the next new arced silo panel and start with positioning and aligning that next arced silo panel.

**[0013]** To mount the pressing and clamping units in a suitable position for alignment of the arced silo panels, the base frame has an outer and an inner side. The pressing and clamping units can then engage on inner and outer side of the received arced silo panel. In addition, the use of such a U-shape ensures that forces exerted on either side of the arced silo panels are communicated, thus providing opposing alignment forces. In an embodiment, the base frame, the outer side, and the inner side, are formed from a single frame defining U-shape, the frame defining the outer and the inner side. This is advantageous since the forces that need to be transferred between the outer side and the inner side are large, requiring high structural loads to be transferred through the U-shape. Preferably, these loads are transferred with low deformation of the U-shape. In an another embodiment, the base frame, the outer side, and the inner side are separately joined components, which act together to form the U-shape.

**[0014]** The clamping unit can generally exert a force in a vertical direction, resulting in bringing the new arced silo panel in a desired vertical position with respect to the arced silo panel of the under-construction-silo. In embodiments, the clamping unit is arranged to clamp two flanges of two arced silo panels together. In particular, when a new arced silo panel is provided into the system, underneath an existing cylindrical ring, the new arced silo panel is aligned with the existing cylindrical ring by clamping the top flange of the new arced silo panel together with the bottom flange of the arced silo panel above, which forms a part of the existing cylindrical ring. In this manner, the height of the new arced silo panel, and thus its height alignment with respect to the existing cylindrical ring, is set.

**[0015]** In embodiments, the silo is built from prefabricated pieces, in particular arced silo panels. In embodiments the arced silo panels are formed and shaped at the work location. The invention will be described with reference to arced silo panels, the silo can be formed from other pieces. Preferably the arced silo panels have a horizontal flange when the arced silo panel is part of the silo. The flange preferably extends in the radially outward direction, along a periphery of the arced silo panel. A horizontal flange of an arced silo panel already part of the silo can be engaged by the clamping unit and allows positioning the alignment device with respect to the already-partially constructed silo. A new arced silo panel having a similar horizonal flange can be aligned with the horizontal flange of an arced silo panel already part of the silo. The flanges will abut, which also allows connecting the flanges. The clamping unit can clamp on the top side of one flange and on the bottom side of the other flange, clamping the flanges together, resulting in alignment in the vertical direction.

**[0016]** The pressing unit can generally exert force on the new arced silo panel in a radial direction. To that end, the pressing unit can have an inner and an outer panel aligner. The new arced silo panel can be engaged at multiple spots. The silo-under-construction can be engaged at multiple spots. The pressing unit can be controlled to bring the new arced silo panel aligned with the already existing silo part in the circumferential direction. The pressing unit can provide opposing radial forces against both the newly provided arced silo panel and the existing cylindrical ring. As a result, the inner surface of the new arced silo panel and the inner surface of the existing cylindrical ring align, to radially align the new arced silo panel with the existing structure. Simultaneously, the outwardly extending peripheral flange of the new arced silo panel is aligned with the flange of the existing cylindrical ring.

**[0017]** In a preferred embodiment, the clamping unit comprises two opposing clamping wheels. These wheels may be provided on two substantially parallel and substantially horizontal axes, said axes being vertically spaced from one another. The clamping wheels are preferably arranged to clamp two flanges of two arced silo panels together. The wheels are mounted on rotatable shafts that e.g. are connected to the frame via one or more bearings.

**[0018]** In embodiments the clamping unit comprises two opposing clamping wheels. The wheels can roll over the flange of the silo, in particular a flange of the silo panel. This allows the alignment device to move along the wall region of the silo under construction. As a result, the silo under construction can remain stationary, while the alignment device travels around its periphery. This is highly advantageous as it mitigates the need for rotating the entire silo during construction.

**[0019]** In a preferred embodiment, at least one of the clamping wheels is driven to move the alignment device

along the silo wall. In an alternative or additional embodiment, an external drive system may be provided to move the alignment device along the stationary silo wall. In an embodiment, at least one of the horizontal axes of the clamping wheels is driven by a drive unit. In a preferred embodiment, the drive unit is an electromotor. Preferably, a single drive unit is arranged to drive multiple axes, by a drive chain, provided over two or more axes. That way, if one axis is driven, it will translate rotational force to a second axis.

**[0020]** In a preferred embodiment, the clamping wheels are made of a hard material, preferably a metal, more preferably of steel. Since the coefficient of friction between the material of the arced silo panels and such wheels is generally low, it is preferred to have more than one wheel being driven to prevent the wheels from spinning on the surface of the flange or on the surface of the arced silo panel. That way, more control is provided over the alignment device due to improved traction between the arced silo panels and the wheels.

**[0021]** In a preferred embodiment, the clamping unit is arranged to suspend the alignment device from a flange of an arced silo panel. In such an embodiment, the alignment device is suspended from the silo under construction. As a result, the alignment device can freely move around the periphery of the silo without the need of additional guiding material, such as tracks, cables, carts, or the like. In addition, the friction required to move the alignment device is reduced, so that a drive unit needs less power to move the alignment device along the silo wall. The clamping unit provides the necessary force to clamp the alignment device onto the flange and to suspend the alignment device from the flange.

**[0022]** When a new arced silo panel is provided into the system, it is attached to the arced silo panel which was previously joined to the silo under construction. This is done by joining straight opposing side sections of the peripheral flange using e.g., bolts. The connected side sections extend generally in a vertical direction. The new arced silo panel is also grabbed by the clamping unit at the top flange that will generally extend in the horizontal direction. The top flange of the new arced silo panel is then clamped together with the bottom flange of the existing cylindrical ring, above the new arced silo panel. The new arced silo panel and the alignment device are then suspended from the bottom flange of the existing cylindrical ring.

**[0023]** As the alignment device is driven along the periphery of the silo, the silo being stationary, the seam between the new arced silo panel and the existing cylindrical ring is welded, thereby joining the new arced silo panel to the existing structure. In other embodiment a temporary connection is provided first before a permanent connection such as welding. As a result of this procedure, the weld is only provided as the new arced silo panel is aligned with the existing structure.

**[0024]** In an embodiment, the alignment device further comprises one or more wheels provided on the base frame, the wheel being arranged to support the alignment device on the ground, and to move the alignment device along the periphery of a silo under construction. In an embodiment, the alignment device further comprises a rail wheel provided on the base frame, the rail wheel being arranged to support the alignment device on a track.

**[0025]** Alternatively, or in addition to at least partial suspension of the alignment device, a rail wheel may be provided on the base frame, such that the alignment device can be moved along a track provided on the floor of the silo to be constructed. In such an embodiment, a track is provided in the shape of the silo to be constructed, and the alignment device travels along the track to build up the silo structure. Such an arrangement may aid in stability of the system and may reduce load on the flanges of the arced silo panels.

**[0026]** In an embodiment, the inner panel aligner may comprise at least one inner pressing unit. The inner pressing unit may comprise at least one inner pressing wheel. The inner pressing wheel may be provided on a substantially vertical axis and preferably being arranged to engage with two arced silo panels and to provide an outwardly directed pressing force on the two arced silo panels.

**[0027]** In an embodiment, the outer panel aligner may comprise at least one outer pressing unit. The outer pressing unit may comprise at least one outer pressing wheel. The outer pressing wheel may be provided on a substantially vertical axis and preferably being arranged to engage with two arced silo panels and to provide an inwardly directed pressing force on the two arced silo panels.

**[0028]** The use of an inner and/or an outer pressing unit having at least one inner and outer pressing wheel, respectively, allows the alignment device to travel along the arced silo panels, while reducing friction. As a result, a high pressing force can be exerted, without a high friction while the alignment device travels along the silo wall. As such, the alignment device can be moved along the wall of the stationary silo under construction, while allowing for large alignment forces to be applied by the pressing unit.

**[0029]** In a preferred embodiment, the inner panel aligner comprises at least two inner pressing wheels provided on a substantially vertical axis. In an embodiment, the inner pressing wheels may be provided on separate substantially vertical axes. By providing at least two pressing wheels, the inner panel aligner can provide pressing forces on two arced silo panels without providing a force to the seam between the two arced silo panels. This is advantageous since the seam is preferably welded, the generated heat of which may lead to increased malleability.

**[0030]** In addition, the provision of two vertically spaced inner pressing wheels that are arranged to engage a lower and a upper arced silo panel respectively, allows for access to the seam between the new silo arced silo panel and the existing cylindrical ring. As a result,

the welding may occur closer to the point where the arced silo panel is best aligned.

**[0031]** Similarly, in an embodiment, the outer panel aligner comprises at least two outer pressing wheels, which are arranged to provide a pressing force to two arced silo panels without engaging the flanges in the seam area of the two arced silo panels.

**[0032]** In an embodiment, the alignment device may further comprise a pre-alignment unit comprising a further clamping unit and/or a further pressing unit, said pre-alignment unit being arranged at a lateral distance such that the pre-alignment unit is arranged to engage with an arced silo panel to pre-align the arced silo panel. The pre-alignment unit is positioned upstream, so in the driving direction, from the main alignment units

**[0033]** The pre-alignment unit is preferably positioned at a lateral distance such that it is the first point of contact for a new arced silo panel. The pre-alignment unit can then bring the arced silo panel in a position such that it can be engaged by the rest of the alignment device. This allows the tolerances of the rest of the alignment unit to be lowered, since the pre-alignment unit can bring the new arced silo panel in such a position that it already closely conforms to its eventual position. The engagement points of the alignment device on a first side are provided by the pre-alignment unit, while the engagement points on a second side are defined by the last clamping unit and/or pressing unit of the alignment device. These engagement points define a distance therebetween. In a preferred embodiment, the pre-alignment unit is provided at a lateral distance such that the ultimate distance between the engagement points is more than the length of an arced silo panel, preferably of about the length of two arced silo panels. In an embodiment, the distance between the engagement points between about 1 and 8 meters, preferably between about 2 and 6 meters.

**[0034]** In an embodiment, the alignment device may further comprise a welding unit. The welding unit preferably comprises a welding torch mounted on the inner side of the base frame. In a preferred embodiment, the welding torch is mounted adjacent to the inner panel aligner. The welding torch is preferably arranged to provide an elongated weld along two arced silo panels as the alignment device travels along the arced silo panels.

**[0035]** In a preferred embodiment, a welding unit is integrated in the alignment device so that the aligned panels are automatically welded upon placement. As a result, the weld is integral with the alignment procedure and risks associated with manual welding are lowered.

**[0036]** In an embodiment, the alignment device further may comprise at least two laterally positioned clamping units, preferably at least four laterally positioned clamping units, more preferably six laterally positioned clamping units. By providing multiple laterally positioned clamping units, the new arced silo panels are better aligned and balanced in the alignment device. In addition, a multiplicity of clamping units can also divide a driving force better, preventing the wheels to slip on the flanges.

**[0037]** In embodiments, multiple clamping units, each with wheels are provided, each engaging on the flange of the silo. This allows welding at a position in between two clamping units. This makes sure that the flanges are correctly clamped and held in aligned positions during welding.

**[0038]** In an embodiment, the alignment device may comprise at least two laterally positioned pressing units, preferably comprising at least three laterally positioned pressing units, more preferably comprising at least four laterally positioned pressing units.

**[0039]** In an aspect of the invention, there is provided an arced silo panel for the construction of a silo. In an embodiment, the arced silo panel comprises an arced wall defining a section of a cylindrical shape to form a silo panel body being arced in a first angular direction, and substantially straight in a second direction defining a height, perpendicular to the first angular direction. As a result, a multiplicity of laterally positioned panel bodies defines a cylinder. Further, the arced panel body defines a convex outer surface.

**[0040]** In an embodiment, the arced silo panel may comprise a circumferential flange provided around the periphery of the arced panel body, said flange extending outwardly, in the direction of the convex outer surface. The flange may define arced top and bottom sections, and straight opposing side sections. The flange may be interrupted at the ends of the opposing side sections. This allows a wheel to pass over the arced top and bottom sections, between adjacent arced silo panels. Advantageously, such an arced silo panel allows the continuous movement of the alignment device having clamping units with wheels. That is, the clamping wheels can continuously move over the flanges of arced silo panels forming the silo, without being interrupted by a side flange. The opening provided in the opposing side sections by interrupting the flange thus allows for a continuous movement of the alignment device.

**[0041]** In an embodiment, the arced silo panel may comprise a lifting clamp extending outwardly from the outer surface. In a preferred embodiment, the lifting clamp is provided at a distance of about a quarter along the first angular direction of the arced silo panel, said lifting clamp comprising an engagement element to communicate with a lifting device. Preferably, the lifting clamp extends substantially parallel to the straight opposing side sections.

**[0042]** The provision of a lifting clamp allows a lifting device to engage with the silo panel to lift the silo once a cylindrical ring has been formed from the arced silo panels. By lifting the silo using such lifting devices, the silo is raised for the formation of a new cylindrical ring.

**[0043]** In an embodiment, the lifting clamp is provided centrally along the arced wall. In such an embodiment, the central lifting clamp is provided substantially in the middle of the first angular direction.

**[0044]** The use of a central lifting clamp a lifting device to raise the silo even if the subsequent panels are pro-

vided in a staggered manner with respect to the previous cylindrical ring. In particular, the use of a central lifting clamp ensures that the lifting device can either engage with the combination of two opposed side flanges of lateral panels, or engage with the central lifting clamp. Either way, a staggered pattern of silo panels can be used without the need to shift the lifting devices to lift the silo to the next level.

**[0045]** In an embodiment, the central lifting clamp extends upwards over between about 5% and 80% of the height, preferably to between about 5% and 60% of the height, more preferably to between about 5% and 50% of the height. A lower central lifting clamp ensures that the panel can be grasped with less height of the lifting device required. The same holds for a lifting clamp being provided on the silo panel.

**[0046]** In an aspect of the invention, there is provided a lifting device for lifting arced silo panels during the construction of a silo. The lifting apparatus may comprise a base, a vertical frame, connected to the base, and a lifting jack, arranged to travel along the vertical frame.

**[0047]** In an embodiment, the lifting jack may comprise an engagement unit, preferably a hook. Preferably, said engagement unit is moveable in a direction substantially perpendicular to the vertical frame, so that the engagement unit can move outwardly and inwardly to engage and disengage with an engagement element of the lifting clamp on an arced silo panel.

**[0048]** The use of such a lifting device ensures that the silo may be raised during construction without the need for a lifting device being the height of the silo. Rather, the lifting device can lift the silo so that a new cylindrical ring can be provided underneath. The silo can then be placed on the ground or on blocks by the lifting device. The lifting device will then engage with the engaging element of the silo panels of the newly formed cylindrical ring, and raise the silo to provide a space for new arced silo panels for the formation of a ring. The lifting device can then lift the silo again, to form a space sufficient for the formation of a subsequent cylindrical ring.

**[0049]** In a preferred embodiment, the engagement unit is a parallelogram hook.

**[0050]** In an embodiment, the lifting jack may be arranged to engage with the engagement element of the lifting clamp of the arced silo panel according to any of the embodiments discussed hereinbefore.

**[0051]** In an aspect according to the invention, there is provided a method for constructing a silo. The method comprises the steps of providing a plurality of arced silo panels, preferably according to any of the embodiments discussed hereinbefore, providing an alignment device, preferably according to any of the embodiments described hereinbefore, laterally joining arced silo panels to construct a first cylindrical ring, providing a lifting device, preferably according to any of the embodiments described hereinbefore, raising the silo with the lifting device to provide space for a next cylindrical ring, aligning and joining arced silo panels with the alignment device to form the next cylindrical ring, and repeating these steps to form the silo.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0052]** The features and advantages of the invention will be appreciated upon reference to the following drawings, in which:

FIG. 1 is a three-dimensional view according to an embodiment of the invention, showing silo under construction;

FIG. 2 is a top view according to an embodiment of to the invention, showing the silo under construction;

FIG. 3 is a side view of the alignment device according to an embodiment of to the invention, taken at section J-J of FIG. 2, showing the use of the alignment device during the construction of the silo;

FIG. 4 is a side view of the silo under construction according to an embodiment of to the invention, showing the use of the lifting device during the construction of the silo;

FIG. 5 is a side view of the silo under construction according to an embodiment of to the invention, showing the formation of a new cylindrical ring during the construction of the silo;

FIG. 6 is a three-dimensional view of the alignment device according to an embodiment of to the invention;

FIG. 7 is a detailed cross-sectional side view of the alignment device according to an embodiment of to the invention;

FIG. 8 is a top view of the alignment device according to an embodiment of to the invention;

FIG. 9 is a side view of the alignment device according to an embodiment of to the invention; and

FIG. 10 is a top view of the alignment device according to an embodiment of to the invention, during the construction of the silo.

## DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

**[0053]** The following is a description of certain embodiments of the invention, given by way of example only and with reference to the drawings. Relative positions will be mentioned, such as upper and lower. Those positions refer mostly to the respective positions in the under construction silo. It will clear however that those positions can be generalized. Upper and lower generally

refers to a first and a second at a distance. The invention is not limited to the specific in use positions.

**[0054]** Referring to FIG. 1, a three-dimensional view of a silo 10 under construction is shown. As shown, the silo is built from a plurality of arced silo panels 12, which are arced along a first angular direction. Such silo panels 12 comprise an arced wall defining a section of a cylindrical shape to form a silo panel body being arced in a first angular direction. In the illustrated embodiment the arced silo panels are substantially straight in a second direction. In FIG. 1, the first angular direction extends substantially horizontal, while the second direction is substantially vertical. During the construction of the silo 10, a multiplicity of laterally positioned panels define a cylindrical ring. The panels are formed by arced silo panels. The ring forms a level of the silo.

**[0055]** The silo panels 12 comprise a circumferential flange provided around a part of the periphery of the panel body. Here said flange extends outwardly. In the shown embodiment, the flange extends around a major part of the curved shape of the arced silo panel and defines arced top and bottom sections, and a flange extends along the straight (vertical) opposing side sections. The flange is preferably interrupted at the two ends of the opposing side sections close to the curved flange. The formed opening in the flange, of about 2-15cm, preferably 4-10cm, allows a wheel to pass over the arced top and bottom flange sections, between adjacent panels 12, during the construction of the silo 10. Preferably the arced silo panel has four openings in the circumferential flange. Preferably one or both arced flange extend from one to the other opposing end. The flange preferably extends generally perpendicular to the surface of the arced panel, extending about 1-12 cm, preferably about 2-10cm.

**[0056]** A silo 10 generally has a diameter of between about 5-50 meters, and a height of between about 5-40 meters. While the present invention is most advantageous for these sizes, it may also be utilized for smaller or larger silos.

**[0057]** The silo 10 further comprises a roof 11, which preferably defines a convex shape on top of the silo 10, forming a dome roof, allowing rain water and/or debris to flow off. The silo 10 further comprises a floor 14. In embodiments, the floor 14 is omitted, and the silo is provided directly on the ground, or on e.g. a concrete base.

**[0058]** As shown, during the construction of the silo 10, a multiplicity of arced silo panels 12 are combined to form the cylindrical shape of the silo 10. The silo panels are curved such that an integral number of silo panels forms a cylindrical ring of the silo. The silo panels 12 are provided to the lower end of the silo 10, during construction. Upon completion of an entire ring, the whole silo 10 is raised, to provide space to form the next ring. As shown, silo panel 13 is not yet part of the silo 10 and is provided in the opening defined between the floor 14 of the silo 10 and the next completed ring of silo panels 12.

**[0059]** To raise the silo 10 during construction, a plurality of lifting devices 15 is provided. In embodiments, the lifting device 15 is formed by a base from which a vertical pole extends upward. A (partial) sleeve over the pole can be moved upwards/downwards. The sleeve has a drive. The sleeve connects to a lifting arm that can engage panels of the silo under construction. In embodiments, the number of lifting devices corresponds with the number of silo panels that form a single ring of the silo.

**[0060]** The lifting devices 15 raise the under construction silo 10. The lift can take place once an entire ring of silo panels 12 is connected. The lifting devices 15 engage the arced silo panels 12. In embodiments, the vertical flange of the silo panels is engaged. The arced silo panels 12 can have an engagement device, such as a central lifting clamp 18 welded thereto, preferably on an outer circumference thereof.

**[0061]** By lifting a finished ring of silo panels, space is formed for positioning new panels to form a next ring of panels 12. Once an entire ring of panels 12 is provided, the lifting devices 15 may release the panels 12 and attach to a lower row of panels 12. This is only necessary when the reach of the lifting devices 15 is insufficient for the required height of the silo 10.

**[0062]** As shown in FIG. 1, the panels 12 are provided in a staggered manner 17. In the illustrated embodiment two laterally positioned side sections of the flange of two adjacent panels on a first ring coincides with the middle of the arced panel 12 on a higher ring. At that middle position along the arced panel 12 a central lifting clamp 18 is provided. In the staggered arrangement, the lifting devices 15 can engage with either the two laterally positioned flange sections of the panels 12 or with the central lifting clamp 18 of the panel above, or below. As a result, every ring can be engaged by the lifting devices 15, even though the panels 12 are provided in a staggered manner 17.

**[0063]** As further shown, an alignment device 16 is provided for aligning arced silo panels 12 to form a silo wall during construction of a silo 10. The alignment device 16 is arranged to efficiently position the panels 12 in such a way that they do not need to be manually aligned with earlier panels 12, thereby increasing the efficiency of the construction of the silo 10.

**[0064]** Now referring to FIG. 2, a top view of the silo 10 is shown, without roof 11. It is noted that features described in relation to this embodiment may be combined with any other embodiment described herein. As shown, the silo 10 comprises a floor 14, which in this embodiment is built up from staggered flat panels. The alignment device 16 is shown being engaged with the wall of the silo 10, which is built up from panels 12. The silo 10 is supported by a plurality of lifting devices 16. A cross-section taken on line J-J of the alignment device 16 is shown in FIG. 3, discussed below.

**[0065]** The alignment device 16 is arranged to travel along the periphery of the stationary silo 10 during construction, aligning panels 12 as it travels around the silo 10. In embodiments, the alignment device 16 suspends on a ring of the silo.

**[0066]** Now referring to FIG. 3, a side view of the alignment device according to an embodiment of to the invention is shown, taken at section J-J of FIG. 2, showing the use of the alignment device 16 during the construction of the silo. It is noted that features described in relation to this embodiment may be combined with any other embodiment described herein.

**[0067]** FIG.3 shows a side view of the silo panel 13. FIG.3 shows the silo panel 13 being aligned during construction with the existing structure of the silo. The alignment device 16 engages and is suspended by the existing panel 12 of the silo. The panel 12 of the existing structure is shown in cross-section, since the panels of the silo are provided in a staggered manner, with the middle of one panel coinciding with an edge region of a panel above, or below. The alignment device 16 further engages the panel 13 and clamps it together with the panel 12, which is located above the new panel 13.

**[0068]** As shown, the panels 12, 13 have a flange on their periphery. FIG.3 shows the cross-section of the arced panel at the position where two arced panels 13 sideward connect. As shown, panel 13 comprises a straight (vertical) side flange 22, and an arced bottom flange 24 and an arced top flange 25. Near the top and bottom of flange 22 openings 26 are formed. In embodiments, the straight side flange 22 is interrupted at its upper and lower regions, defining a gap through which the wheels of the alignment device 16 can travel while aligning the panels for the construction of the silo.

**[0069]** The top flange 25 is clamped together with the bottom flange of the top panel 12 by the alignment device 16. By clamping the flanges of panels 12 and 13 together, panels 13 is brought into position with respect to the already constructed silo. Panel 13 can then be connected, e.g. by welding, to the already formed silo.

**[0070]** In an embodiment, the bottom flange 24 is held by a bottom clamping unit. This may be advantageous to stop the bottom panel 13 from freely swinging while it is clamped together with the top panel 12.

**[0071]** Alignment device 16 comprises a base frame 27 supporting an outer side 28 and an inner side 29, forming a U-shape having a space for receiving an arced panel 13 in between the outer 28 and inner side 29. On an inner side 29 a platform for supporting a worker is formed. A ladder makes the platform accessible.

**[0072]** Now referring to FIG. 4, a side view of the silo under construction according to an embodiment of to the invention is shown, detailing the use of the lifting device during the construction of the silo. It is noted that features described in relation to this embodiment may be combined with any other embodiment described herein. The figures shows a silo 50 under construction, showing a roof 51 being built up using ring elements 52 and 52' to form a first ring supporting the roof 51. These ring elements 52, 52' at least have a radially outwardly directed flange on the lower side. This way, the alignment device can clamp the lower flange of the ring elements together with the upper arced flange of the silo panel underneath. Silo panels 53 and 54 are connected to the ring elements 52 and 52', as well as to each other. The silo panels 53, 54 have outwardly directed radial flanges, which are used to align the panels to each other and to the existing structure. The silo 50 under construction is carried by lifting devices 60, comprising a base 61, a vertical frame 62 acting as a guide and connected to the base 61, and a lifting jack 63, 64, arranged to travel along the vertical frame 62. The lifting jack 63, 64 preferably comprises a sleeve like element 63 comprising and/or being integrally formed with an engaging unit 64. Preferably, the engaging unit is a parallelogram hook.

**[0073]** Vertical frame 62 is positioned at a distance from the panels to allow the alignment device 16 to move on an inner side thereof without colliding.

**[0074]** As shown in FIG.4, the hook 64 is not engaged with the engagement element 56 of the lifting clamp provided on the silo wall. If the hook is not engaged, the silo 50 rests on temporary supports 70, which may be folded away when not in use.

**[0075]** In embodiments, the arced silo panel is provided comprising an arced wall defining a section of a cylindrical shape to form a silo panel body being arced in a first angular direction defining a width, and substantially straight in a second direction defining a height, perpendicular to the first angular direction so that a multiplicity of laterally positioned panel bodies defines a cylinder and such that the arced panel body defines a convex outer surface. The arced silo panel can have a circumferential flange provided around the periphery of the arced panel body, said flange extending outwardly, in the direction of the convex outer surface. This can be a partial flange or a flange extending along the full length. In embodiments the silo panel has a flange along the arced top and bottom sections. In embodiments the silo panel has a flange extending along vertical side sections, preferably both opposite side sections. In embodiments the side flange is interrupted at the ends of the opposing side sections, to allow a wheel to pass over the arced top and bottom sections, between adjacent arced silo panels.

**[0076]** In embodiments the arced silo panel 53, 54 has a engagement element 56 for a lifting device. The engagement element is preferably mounted to an outer side of the arced silo panel. In embodiments that engagement element is adapted to be engaged by a hook like lifting device.

**[0077]** In embodiments the arced silo panels are rotationally symmetric, except for the engagement element of the lifting clamp. Preferably the engagement element is positioned at about ¼ and/or ¾ of periphery of the arced silo panel. In such an arrangement, the positions of the engagement elements are, even though the silo panels are staggered, at the same peripheral position, albeit vertically at a distance. This allows the lifting device to pick up the next level without having to make a peripheral movement, while providing only two kinds of silo panels. Moreover, the silo panel have only a single engagement element or lifting clamp. The silo panels can have

multiple engagement elements.

**[0078]** In an embodiment different from FIG.4, the engagement element extends and is positioned at similar distances from the top and bottom flange at ¼ of the periphery. The engagement element can be arranged to be engaged for lifting on both vertical sides. This embodiment then allows positioning the silo panel in a staggered manner, with the side panels of one ring positioned upside down with respect to the side panels of the next ring. In this embodiment only a single kind of arced panels is needed.

**[0079]** Now referring to FIG. 5, a side view of the silo under construction according to an embodiment of to the invention is shown, detailing the formation of a new cylindrical ring during the construction of the silo. As shown in FIG. 5, the silo 200 is raised using the lifting devices 205, which are engaged with the arced silo panels to lift the silo under construction to such an extent that new arced silo panels 204, 203 may be provided underneath for continued construction of the silo.

**[0080]** While the silo is raised by the lifting devices 205, the alignment device 201 is provided to the lower flange of the arced silo panels of the raised silo 200 such that the alignment device 201 is suspended from the arced silo panels. The suspended alignment device can move in the peripheral direction around the formed silo, without colliding with the lifting device. The lifting devices 205 are positioned at a distance further from the centre of the silo 200 then the outer most part of the suspended alignment device, although e.g. support legs of the lifting device can extend more inwardly. The lifting device is generally U-shaped, with the open end of the U receiving the alignment device.

**[0081]** A new arced silo panel 204 is provided to the space between the inner and outer side of the alignment device 201, while the alignment device is suspended from the lower arced flange of the top arced silo panel. Upon the provision of the new arced silo panel 204, the top flange of the new arced silo panel 204 is clamped together with the lower arced flange of the top arced silo panel. The alignment device 201 travels along the periphery of the silo to continuously clamp and align the two silo panels and to weld the new arced silo panel 204 to the existing silo structure.

**[0082]** A still further arced silo panel 203 is then provided to the system by raising it using panel lifting stands 206, provided underneath the new arced silo panel 203 to raise it so that it may be connected to the arced silo panel 204. The straight side flanges of the panels 204 and 203 are connected using e.g. bolts, after which the alignment device 201 travels along the arced flanges of panels 204 and 203 to align the new panels with the existing structure and to weld the panels to the existing structure, thereby creating a further cylindrical ring 202 for the formation of the silo.

**[0083]** Many different methods and method steps can be used to form the silo using the alignment device of the invention. The invention is in no way limited to the shown method steps.

**[0084]** Now referring to FIG. 6, a three-dimensional view of the alignment device 800 according to an embodiment of to the invention is shown. The alignment device 800 comprises a base frame 88 having an inner side 81 and an outer side 80. As the alignment device 800 is configured to receive a silo panel, the inner and outer side 81,80 are positioned on the two sides of that silo panel. The inner and outer side 81, 80 with respect to a silo panel 100 are better shown in Fig.9.

**[0085]** In this embodiment, the inner side provides a platform 89 where a worker can be positioned to monitor the process and to provide alterations to e.g., the welding process. Accordingly, the alignment device is arranged to weld silo panels on an inner side thereof. The alignment device 800 further comprises a welding arrangement, provided on the inner side 81.

**[0086]** The alignment device 800 may further comprise a plurality of clamping units 82, 85, arranged to clamp the flanges of two panels together. The clamping units 82, 85 are provided on the outer side 80, the clamping units 82, 85 being arranged to clamp two flanges of a lower arced silo panel and newly positioned upper arced silo panel together. The clamping units 82, 85 each comprise a plurality of opposing clamping wheels, here four, provided on substantially parallel and substantially horizontal axes, said axes being vertically spaced from one another. The clamping wheels are arranged to clamp two flanges of two arced silo panels together.

**[0087]** The wheels of the clamping unit are also arranged to suspend from the flange. In embodiment the centre of gravity of the alignment device is close to or in the plane of the flange of the silo panel.

**[0088]** The wheels of the clamping unit allow movement of the alignment device over a flange of an arced silo panel. The clamping wheels are driven by one or more drives 83, which are arranged to provide a driving force to move the alignment device 800 along the periphery of the silo under construction.

**[0089]** The alignment device 800 further comprises a plurality of outer panel aligners, which form part of the pressing unit. The inner panel aligners are not shown for clarity. The outer panel aligners comprise at least one outer pressing unit comprising at least one outer pressing wheel 86 provided on a substantially vertical axis, the outer pressing wheels 86 being arranged to engage with two arced silo panels and to provide an inwardly directed pressing force on the two arced silo panels. In the shown embodiment, the outer pressing wheel 86 provides a force directed inwardly.

**[0090]** In the specific embodiment of Fig.6, one wheel 86 can engage the lower flange of the two clamped flanges and press that flange inwardly until wheel 86 engages on the two flanges, including the upper flange of the already part-of-the-constructed silo panel. To the end the wheel 86 is positioned at a height / horizontal plane that correspond to the height of the space between the upper and lower clamping wheel of clamping units 82,85. In an

alternative or additional embodiment, outer pressing wheels may be provided in a vertically spaced manner such that they engage with the top and bottom arced silo panels separately.

**[0091]** The alignment device 800 further comprises a pre-alignment unit 84 comprising a further clamping unit and/or a further pressing unit 87. The pre-alignment unit 84 is arranged at a lateral distance such that the pre-alignment unit is arranged to engage with an arced silo panel to pre-align the arced silo panel. This allows the pre-alignment unit 84 to limit misalignment of arced silo panels being moved between the inner and outer side of the alignment device 800.

**[0092]** Now referring to FIG. 7, a detailed cross-sectional side view of the alignment device according to an embodiment of to the invention is shown, where the left side shows the inner side of the alignment device, and the right side shows the outer side of the alignment device.

**[0093]** The inner panel aligner 120 provides a pressing force in direction 127, such that the top panel 100 and the bottom panel 104 are radially aligned. The pressing force is provided in direction 127 by the pressing unit 123, which is connected to the frame 121.

**[0094]** The top panel 100 has a vertical flange 101 and a horizontal flange 102. The bottom panel 104 has a horizontal flange 105. The outer panel aligner 132 presses in a direction opposite to direction 127 such that a reaction force may be applied between the inner and outer panel aligners to radially align the panels 100, 104. This alignment will be shown in more in detail with reference to FIGs 8-10.

**[0095]** The clamping unit comprises two wheels 110, 111, which are provided on substantially horizontal axes 112, 113, respectively. The bottom horizontal shaft 112 can pivot in direction 115, along guide 116 to move wheel 110 away from wheel 111, allowing the entry of to flanges 102, 105 between the wheels 110, 111, even if the flanges 102, 105 are slightly spaced apart. For clamping, the wheels 110 and 111 are moved towards each other. Suitable hydraulic means can be used.

**[0096]** Now referring to FIG. 8, a top view of the alignment device according to an embodiment of to the invention is shown. Here, the inner panel aligner 113 is shown, providing an opposite force to the outer panel aligner, having outer pressing wheels 132 to radially align the panels. The pre-alignment device 130 is arranged to provide the panels entering from side 131 into the system such that the panels are accepted in the further clamping units without large misalignment.

**[0097]** Referring now to FIG. 9, a side view of the alignment device according to an embodiment of to the invention is shown. The inner alignment unit 120 is shown to have two inner pressing wheels 122 which provide an alignment force opposite to the outer pressing wheel provided on a vertical axis on the outer side 80 of the alignment device. FIG. 9 further shows that the panels 100, 104 are clamped together using clamping wheels 110, 111, which are provided on horizontal axes. Once clamped, the welding unit 140 joins the two panels together.

**[0098]** Now referring to FIG. 10, a top view of the alignment device 316 according to an embodiment of to the invention is shown, during the construction of the silo. The pre-alignment unit 318 positions the new panel 312 such that it is received by the pressing unit, comprising the inner panel aligner 320 and the outer panel aligner, having outer pressing wheels 321, 323. As illustrated in Fig. 10, wheels 321,323 engage on an outer side of the clamped flanges, while clamping wheel 322 engage on a top side of the clamped flange. Further, the alignment device 316 comprises a clamping unit 325, arranged to vertically align the panels such that the welding unit 340 can join the panels together. A still further arced silo panel 313 is attached to the new arced silo panel 312, before it is brough into pre-alignment by the pre-alignment unit 318 and provided to the pressing unit and the clamping unit.

**[0099]** Thus, the invention has been described by reference to certain embodiments discussed above. It will be recognized that these embodiments are susceptible to various modifications and alternative forms well known to those of skill in the art. In particular, while different reference signs have been used in different figures to denote similar or the same components, these may be combined to form further embodiments.

**[0100]** Further modifications in addition to those described above may be made to the structures and techniques described herein without departing from the spirit and scope of the invention. Accordingly, although specific embodiments have been described, these are examples only and are not limiting upon the scope of the invention.

## Claims

1. An alignment device for aligning arced silo panels to form a silo wall during construction of a silo, the alignment device comprising:

   - a base frame supporting an outer side and an inner side, forming a U-shape having a space for receiving an arced silo panel in between the outer and inner side;
   - a drive arranged to move along a stationary silo wall during construction of the silo ;
   - at least one clamping unit provided on the outer side; and
   - at least one pressing unit, comprising an inner panel aligner provided on the inner side and an outer panel aligner provided on the outer side, the pressing unit being arranged to engage the lower arced silo panel and the upper arced silo panel;

   wherein the clamping unit being arranged to clamp

two flanges of a lower arced silo panel and upper arced silo panel together,

wherein the pressing unit is arranged to provide opposing alignment forces on inner and an outer sides of lower and upper arced silo panels, and wherein the pressing unit and the clamping unit are arranged to align the lower arced silo panel and the upper arced silo panel radially and vertically.

**2.** The alignment device of claim 1, wherein the clamping unit comprises two opposing clamping wheels provided on two substantially parallel and substantially horizontal axes, said axes being vertically spaced from one another, the clamping wheels being arranged to clamp two flanges of two arced silo panels together and wherein the clamping unit is preferably arranged to suspend the alignment device from a flange of an arced silo panel
wherein preferably the drive is arranged to drive the clamping wheels to move the alignment along the periphery of the stationary silo.

**3.** The alignment device of claims 1 or 2, wherein the alignment device further comprises a welding unit, the welding unit comprising a welding torch mounted on the inner side, preferably being mounted adjacent to the inner panel aligner, the welding torch being arranged to provide an elongated weld along two arced silo panels as the alignment device travels along the arced silo panels.

**4.** The alignment device of any preceding claim, wherein the inner panel aligner comprises at least one inner pressing unit comprising at least one inner pressing wheel provided on a substantially vertical axis, the inner pressing wheel being arranged to engage with two arced silo panels and to provide an outwardly directed pressing force on the two arced silo panels.

**5.** The alignment device of any preceding claim, wherein the outer panel aligner comprises at least one outer pressing unit comprising at least one outer pressing wheel provided on a substantially vertical axis, the outer pressing wheel being arranged to engage with two arced silo panels and to provide an inwardly directed pressing force on the two arced silo panels.

**6.** The alignment device of any preceding claim, further comprising a pre-alignment unit comprising a further clamping unit and/or a further pressing unit, said pre-alignment unit being arranged at a lateral distance such that the pre-alignment unit is arranged to engage with an arced silo panel to pre-align the arced silo panel.

**7.** The alignment device of any preceding claim, comprising at least two laterally positioned clamping units, preferably at least four laterally positioned clamping units, more preferably at least eight laterally positioned clamping units, and/or comprising at least two laterally positioned pressing units, preferably comprising at least three laterally positioned pressing units, more preferably comprising at least four laterally positioned pressing units.

**8.** The alignment device of any preceding claim, wherein the alignment device further comprises one or more wheels provided on the base frame, the wheel being arranged to support the alignment device on ground, and to move the alignment device along the periphery of a silo under construction and/or wherein the alignment device further comprises a rail wheel provided on the base frame, the rail wheel being arranged to support the alignment device on a track.

**9.** An arced silo panel for the construction of a silo, the arced silo panel comprising:

- an arced wall defining a section of a cylindrical shape to form a silo panel body being arced in a first angular direction, and substantially straight in a second direction defining a height, perpendicular to the first angular direction so that a multiplicity of laterally positioned panel bodies defines a cylinder and such that the arced panel body defines a convex outer surface;
- a circumferential flange provided around the periphery of the arced panel body, said flange extending outwardly, in the direction of the convex outer surface;

wherein said flange defines arced top and bottom sections, and straight opposing side sections, and wherein said flange is interrupted at the ends of the opposing side sections, to allow a wheel to pass over the arced top and bottom sections, between adjacent arced silo panels.

**10.** The arced silo panel according to claim 9, further comprising a lifting clamp extending outwardly from the outer surface, preferably provided at a distance of about a quarter along the first angular direction of the arced silo panel, said lifting clamp comprising an engagement element to communicate with a lifting device.

**11.** The arced silo panel according to any of claims 10, wherein the lifting clamp is a central lifting clamp, provided substantially parallel to the straight opposing side sections, and provided substantially in the middle of the first angular direction.

**12.** The arced silo panel according to claim 11, wherein the central lifting clamp extends upwards over be-

tween about 5% and 80% of the height, preferably to between about 5% and 60% of the height, more preferably to between about 5% and 50% of the height.

**13.** A lifting device for lifting arced silo panels during the construction of a silo, the lifting apparatus comprising:

- a base;
- a vertical frame, connected to the base; and
- a lifting jack, arranged to travel along the vertical frame,

wherein the lifting jack comprises an engagement unit, preferably a hook, said engagement unit being moveable in a direction substantially perpendicular to the vertical frame, so that the engagement unit can move outwardly and inwardly to engage and disengage with an engagement element on an arced silo panel.

**14.** The lifting device according to claim 13, wherein the lifting jack is arranged to engage with the engagement element of the arced silo panel according to claim 10.

**15.** Method for constructing a silo, the method comprising the steps of:

- providing a plurality of arced silo panels according to any of claims 9 to 12;
- providing an alignment device according to any of claims 1 to 7;
- laterally joining arced silo panels to construct a first cylindrical ring;
- providing a lifting device according to any of claims 13 to 14;
- raising the cylindrical ring with the lifting device to provide space for a next cylindrical ring;
- aligning and joining arced silo panels with the alignment device to form the next cylindrical ring;
- repeating the steps of raising and aligning to form the silo.

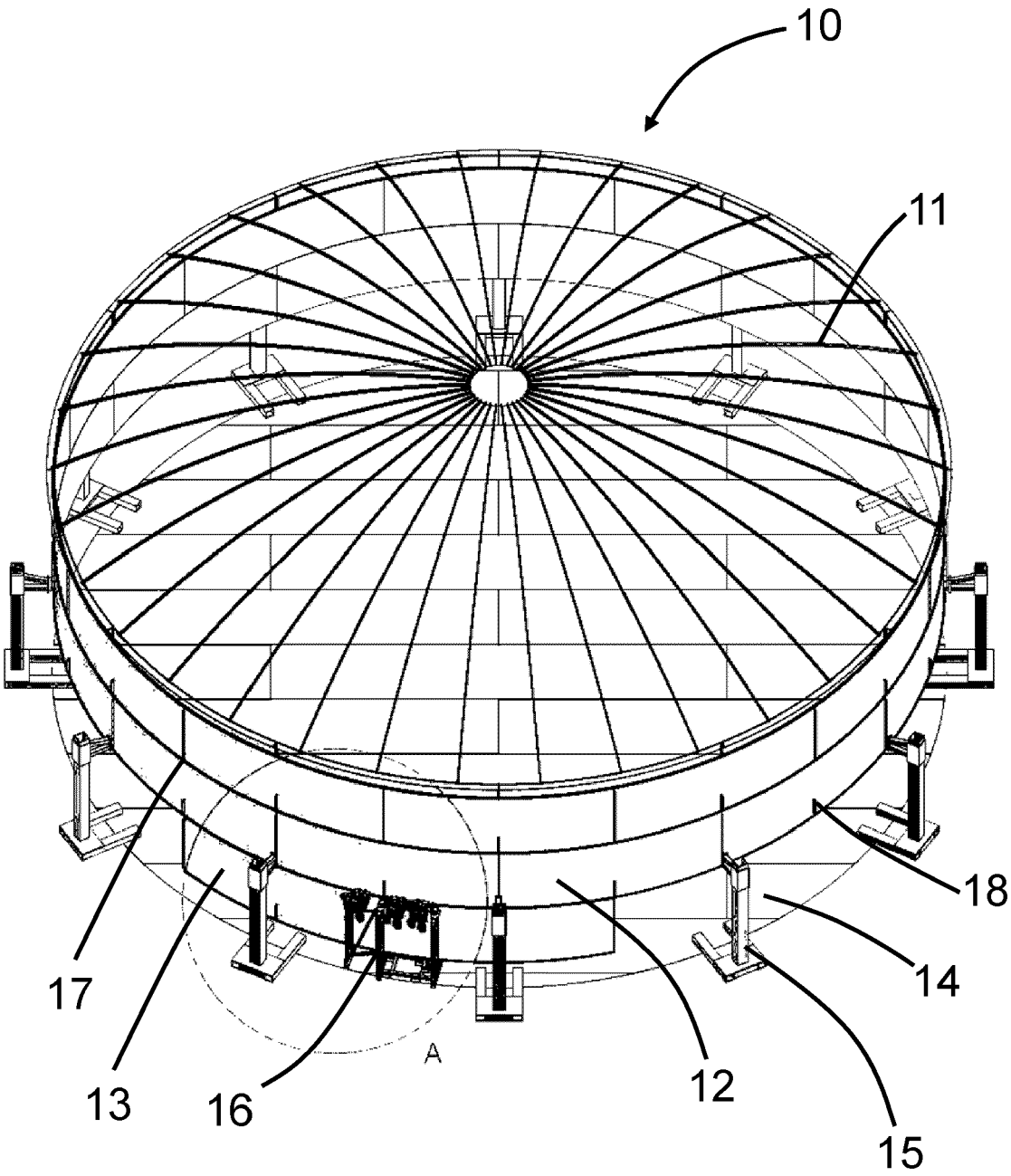



FIG. 1

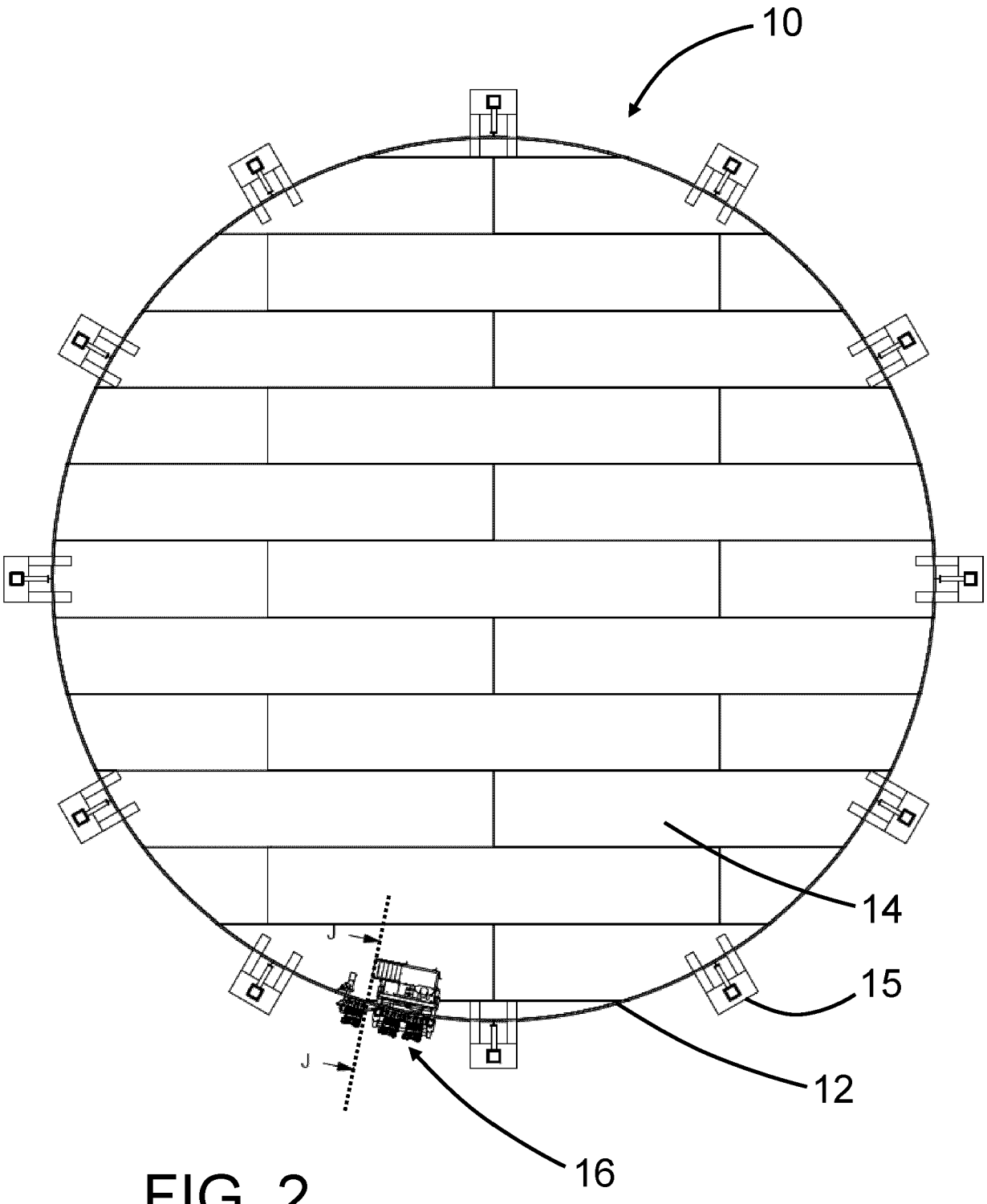



FIG. 2

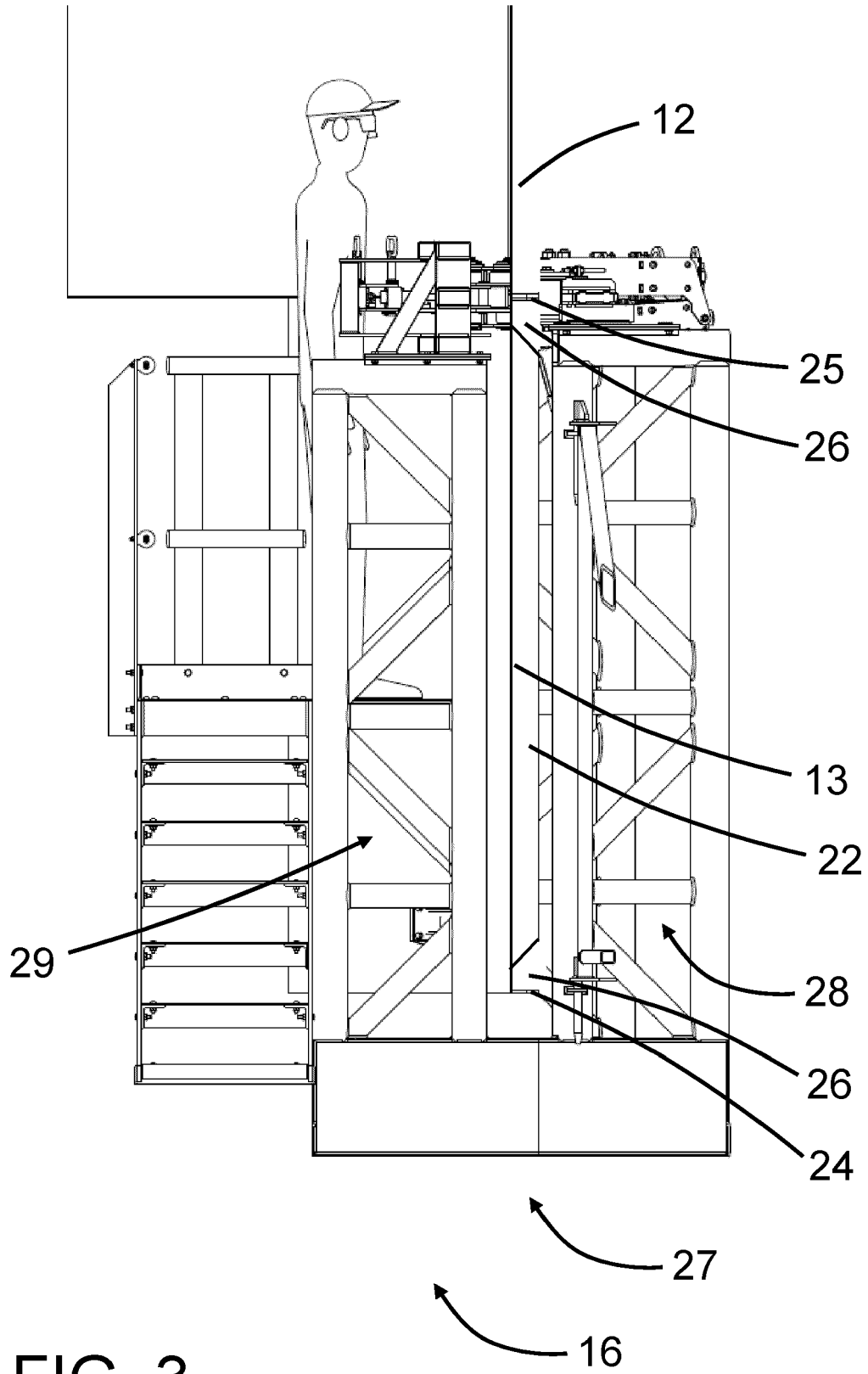



FIG. 3

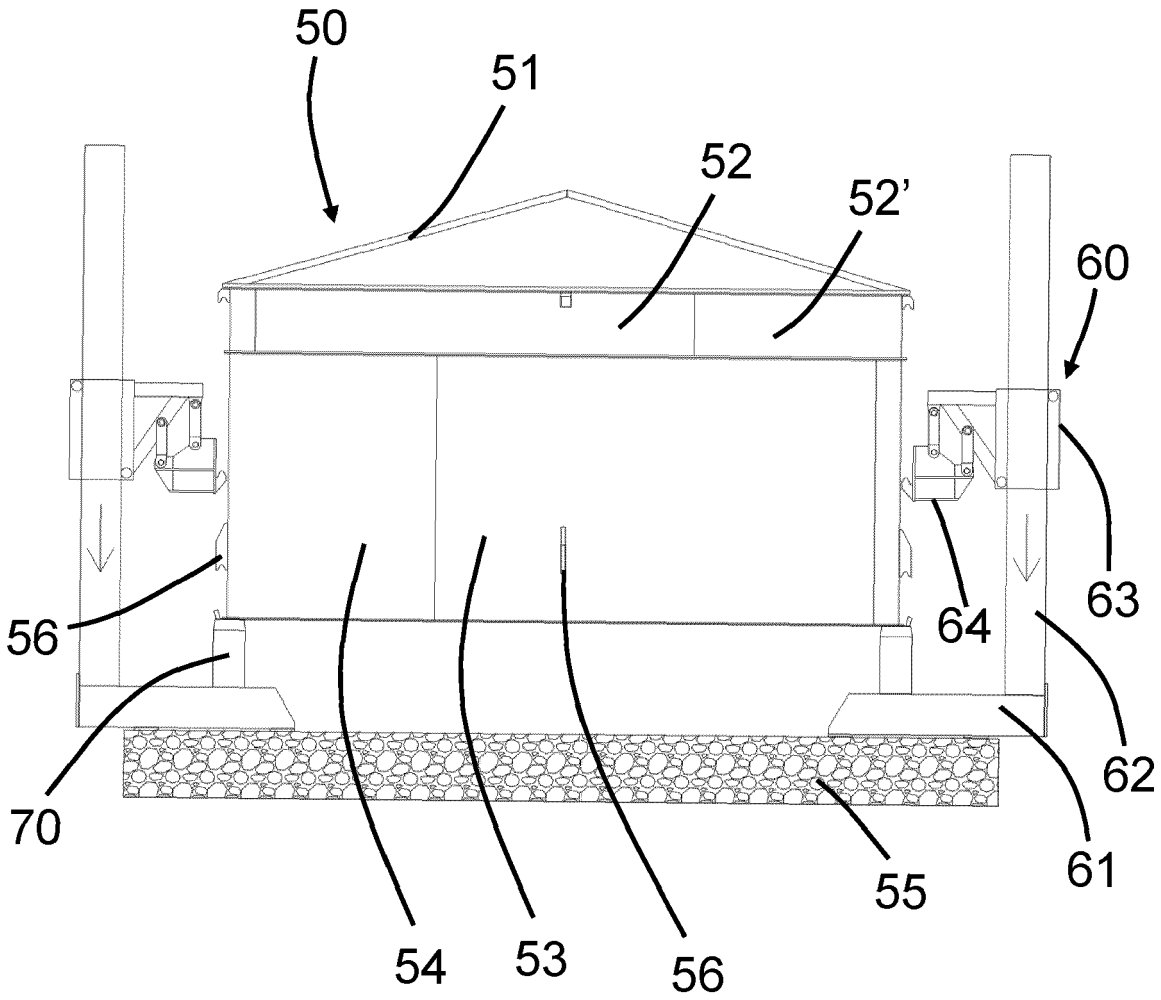



FIG. 4

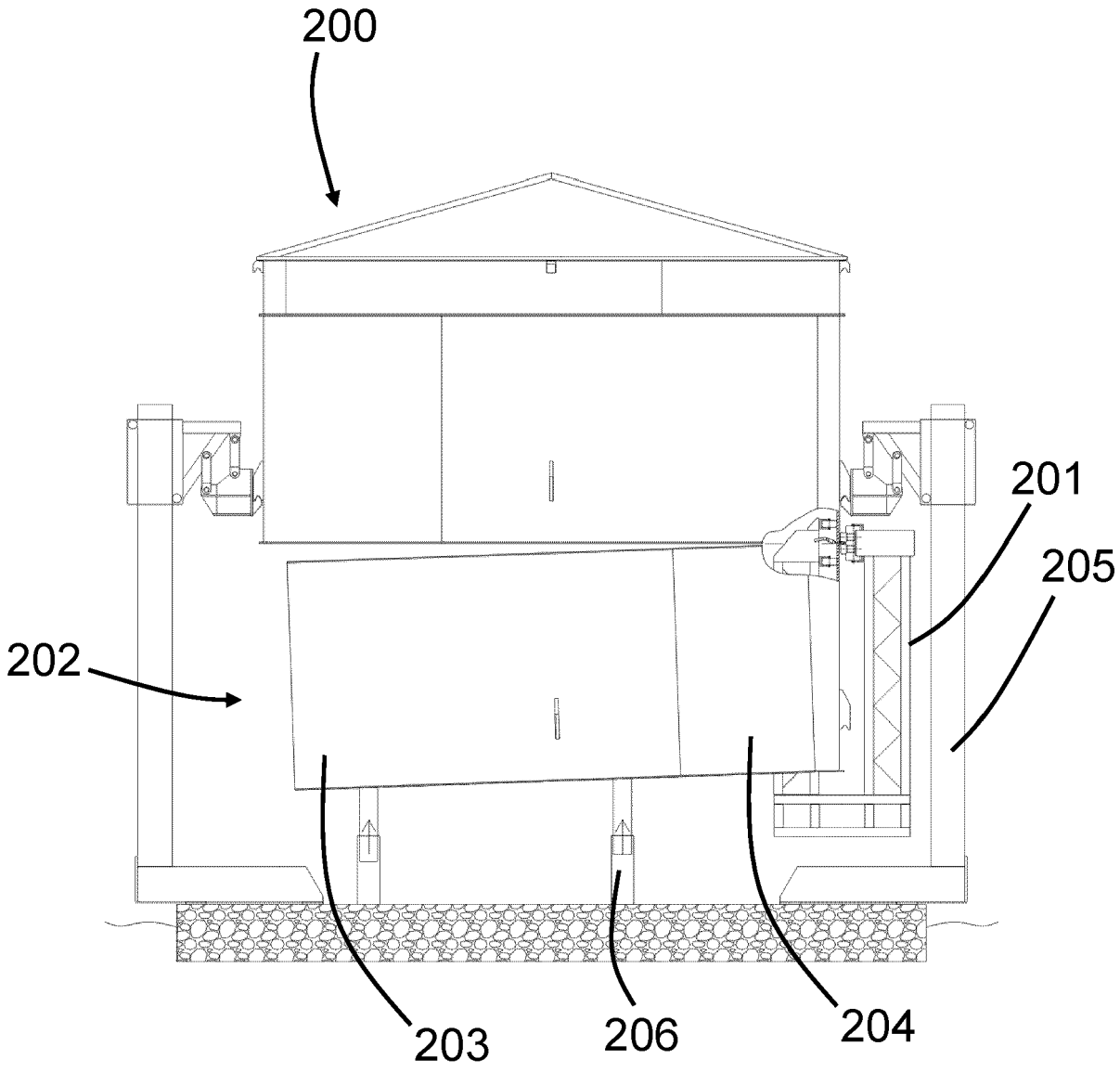



FIG. 5

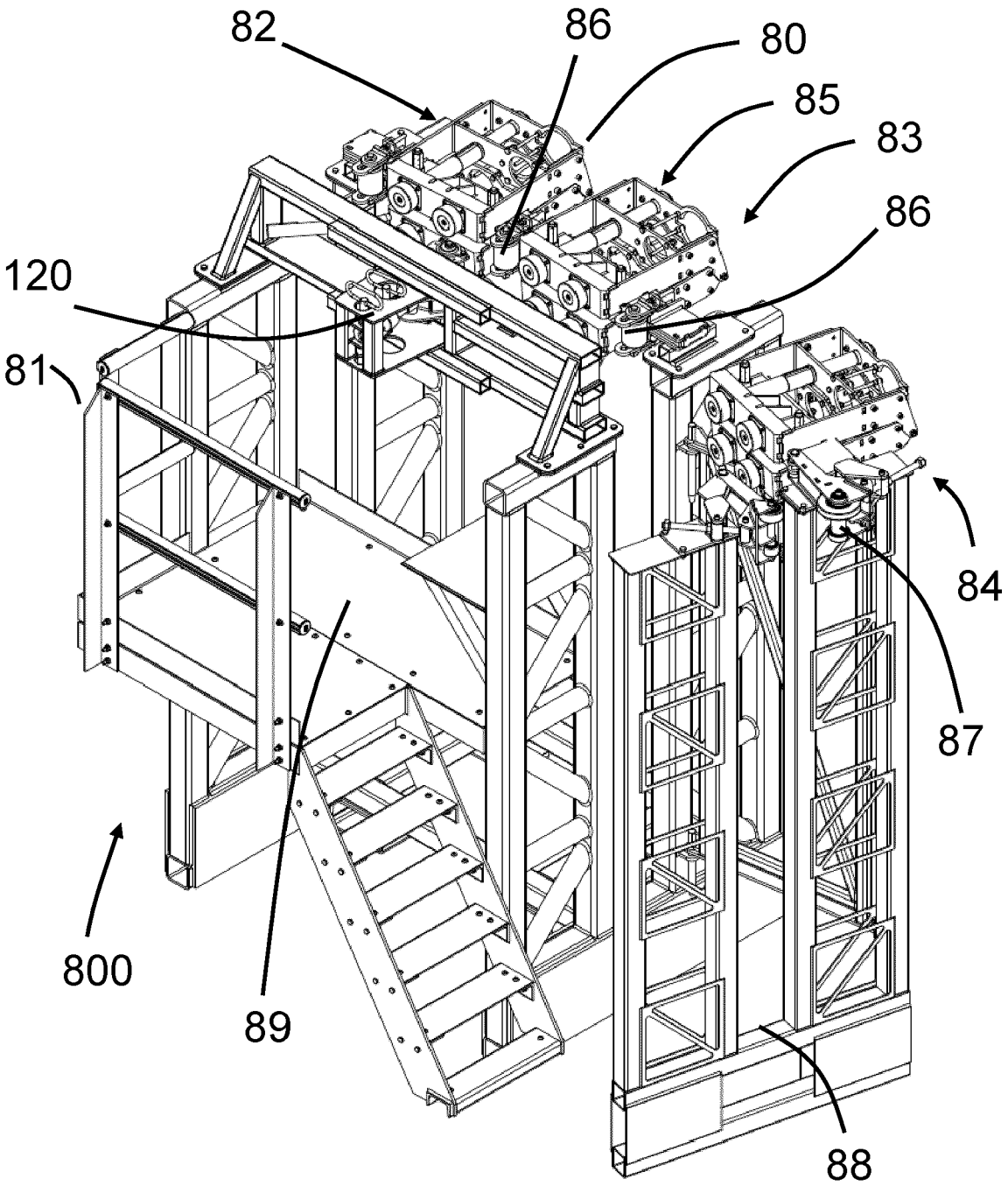
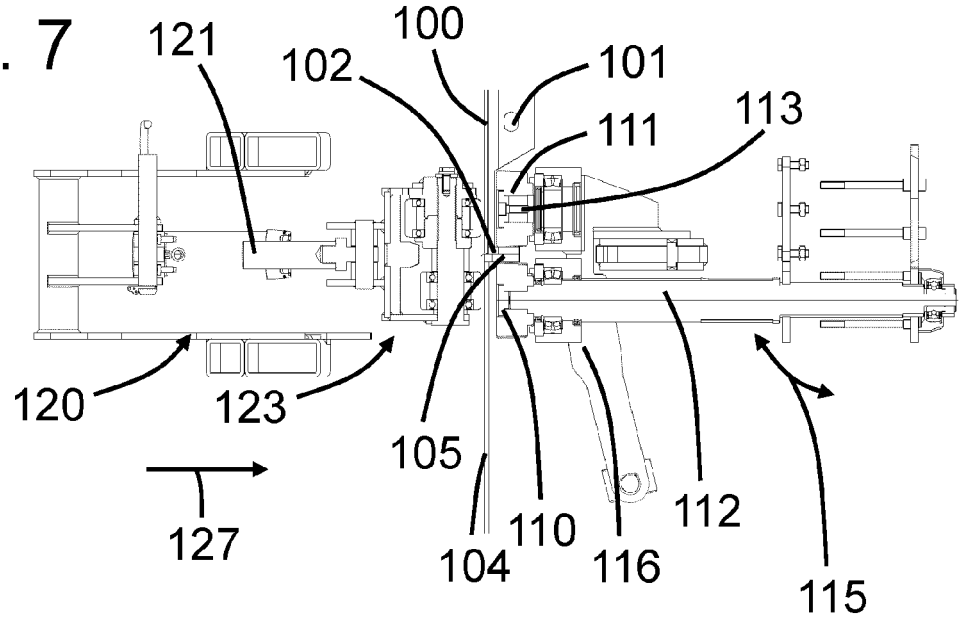



FIG. 6

FIG. 7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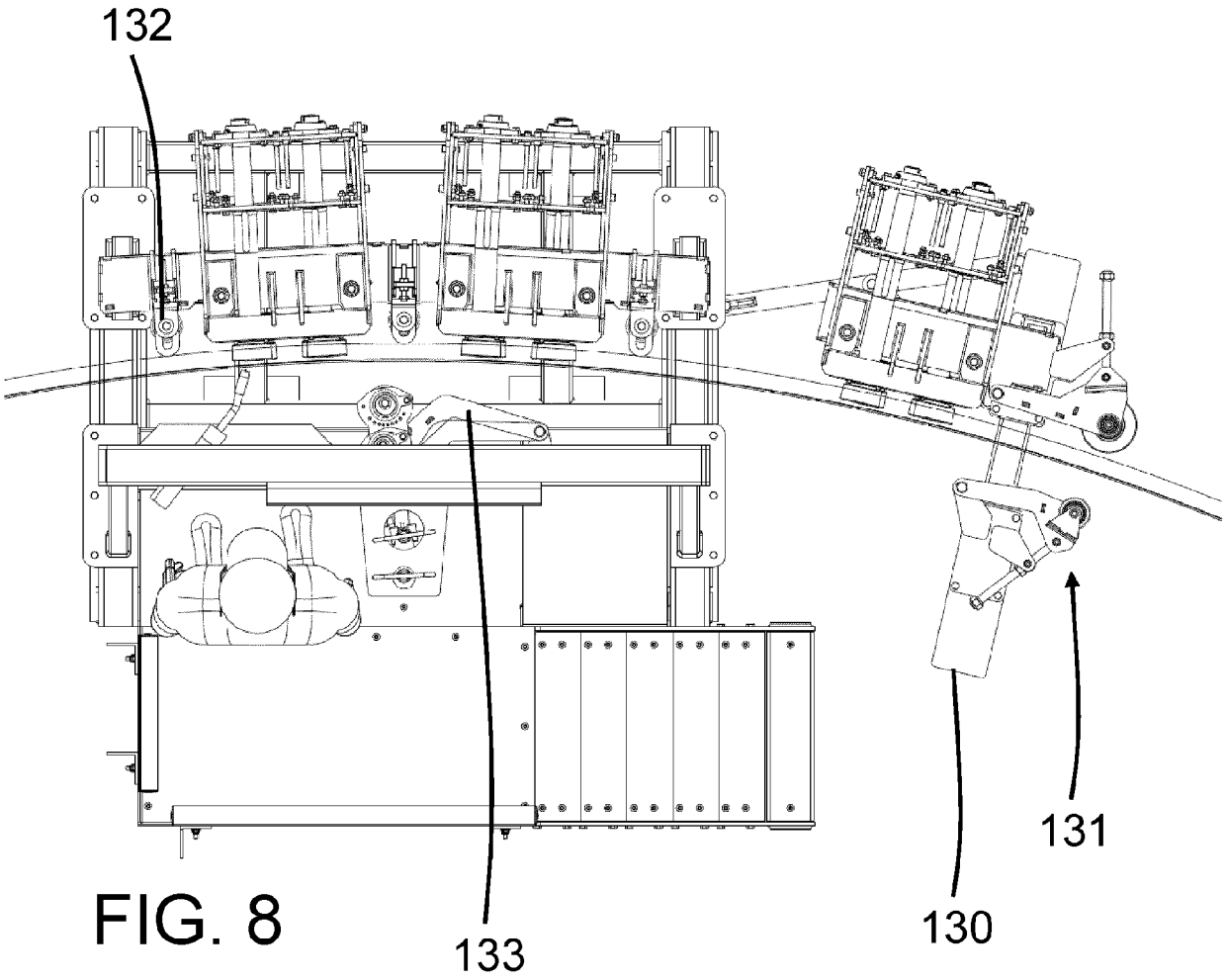
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FIG. 8

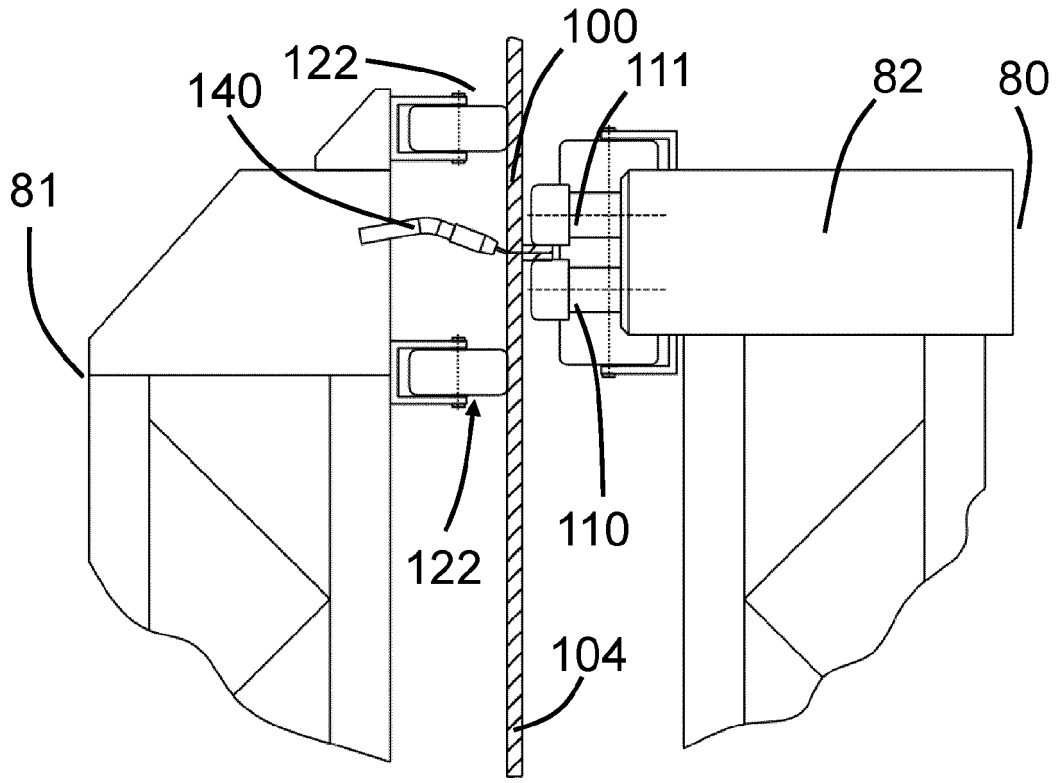
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FIG. 9

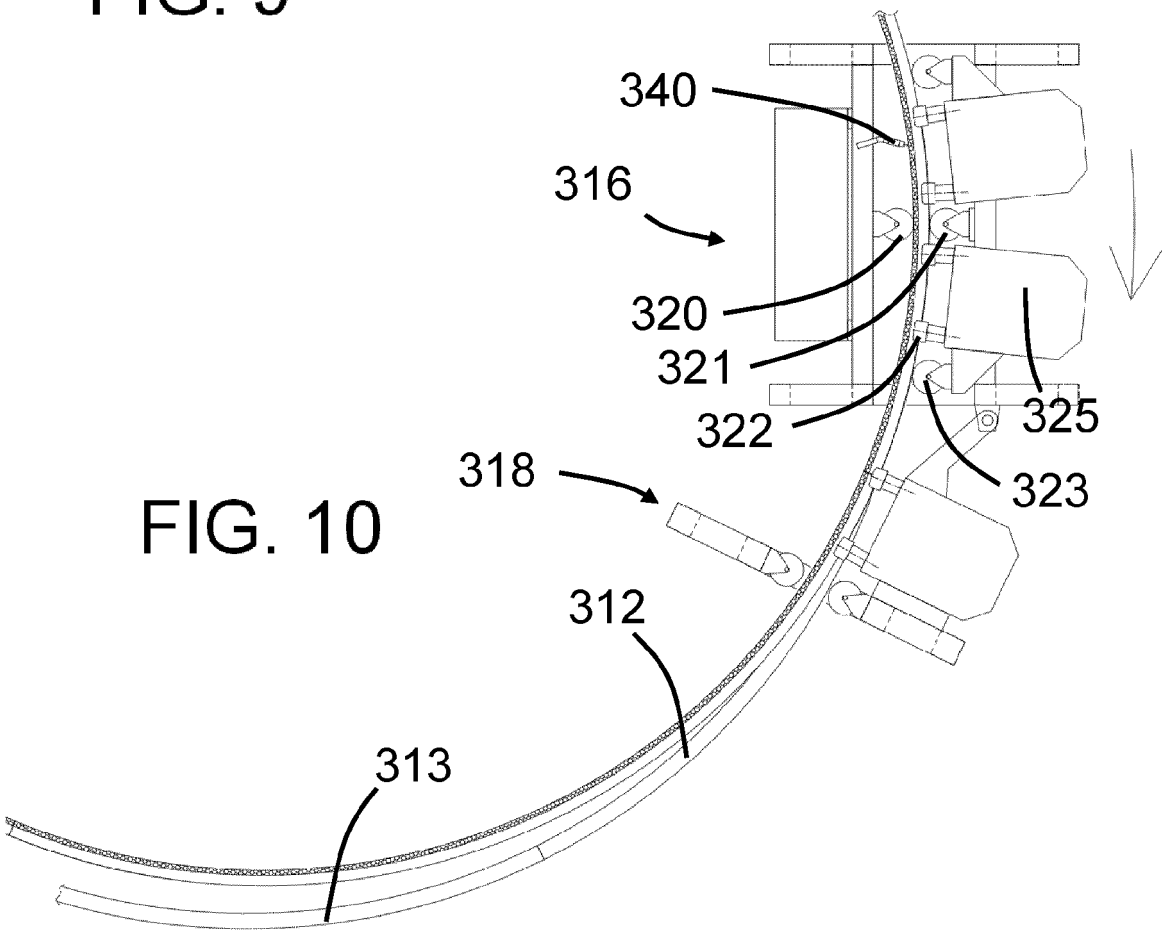
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FIG. 10

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# EUROPEAN SEARCH REPORT

Application Number
EP 22 17 9313

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The present search report has been drawn up for all claims

| Place of search | Date of completion of the search | Examiner |
|---|---|---|
| Munich | 25 November 2022 | Brucksch, Carola |

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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EPO FORM 1503 03.82 (P04C01)

# ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 22 17 9313

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