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(54) **SEABED SCOUR PROTECTION DEVICE FOR OFFSHORE SUCTION PILE**

MEERESBODEN-SCOUR-SCHUTZVORRICHTUNG FÜR OFFSHORE-SAUGPFAHL

DISPOSITIF DE PROTECTION CONTRE L'AFFOUILLEMENT DE FOND MARIN POUR PILE D'ASPIRATION EN MER

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Description

[0001] The present disclosure relates to a seabed scour protection device for protecting an area of a seabed around at least one offshore suction pile, the at least one offshore suction pile comprised of a tubular element having an open bottom portion and a closed top portion and configured to penetrate the seabed by suction. The disclosure also relates to an assembly comprising at least one suction pile and such seabed scour protection device, a method for protecting an area of a seabed around at least one offshore suction pile with such seabed scour protection device and to a method for of assembling such seabed scour protection device.

[0002] An offshore foundation can be made from one or more offshore piles and provide a base for an offshore upper structure, e.g. a wind turbine projection to a position above the sea water level. An offshore pile is designed for embedment into the underwater bottom (i.e. a seabed), e.g. by removing water (by suction) from the interior of the offshore pile (hence the term "offshore suction pile") and/or by ramming or hammering action. An offshore pile could also be named "seabed embedded pile".

[0003] An offshore pile typically has a diameter of at least 5 m, a height of at least 5 m, and/or a wall thickness of at least 1 cm. In general, the longitudinal axis of such offshore pile and longitudinal axis of the associated supporting leg of the offshore upper structure placed on top of the offshore pile are substantially parallel (i.e. in line or eccentric).

[0004] Offshore piles may suffer from scouring of the seabed around them. To avoid scouring or at least reduce the extent of scouring it is known to cover the seabed by a layer of loose rocks or by a mat of artificial frond. For offshore piles installed by ramming or hammering, several proposals for extendable or unfoldable seabed covering devices mounted to the offshore pile prior to ramming or hammering the offshore pile into the seabed are known. Examples are described in documents GB 2 024 901 A, EP 2 767 637 A1 and GB 1 537 238 A.

[0005] Document EP 3 228 754 A1 is background art which is regarded as useful to understand the invention.

[0006] Offshore piles that are to be rammed or hammered into the seabed typically have a large length to diameter ration (aspect ratio). Offshore suction piles typically have a larger diameter, for instance twice as large, and a smaller length. The aspect ratio therefore is considerably smaller. The diameter of offshore piles and/or the manner in which they are caused to penetrate the seabed (by ramming, hammering, or applying suction) has a considerable influence on the type and/or extent of scouring so that the technical field (including the technical problems encountered) of offshore suction piles differ largely from pile-driven offshore piles.

[0007] Existing anti-scouring systems have a number of disadvantages. For instance, in some systems, the deployment of a system is to be accomplished from the seawater level, for instance by ropes or chains leading from the underwater offshore pile to a vessel at the water surface. This not only restricts the maximum depth at which the offshore foundation can be made, but also has a negative effect on the reliability of the system. In other systems a submersible vessel such as a remotely operated underwater vehicle (ROV), is to be used to deploy the scouring protection. Using ROV's is costly and time consuming.

[0008] A further disadvantage of prior art anti-scouring systems may be that some of these systems are bulky and/or comprises relatively stiff (i.e. insufficiently flexible) portions so that (portions of) the system may be the cause of water currents, especially near the edges of the system, that result in (more) scouring. In other examples an interspace remains between portions of the anti-scouring system and the seabed which interspace may also give rise to water currents that cause scouring around these portions.

[0009] Consequently, there is a need for improvement of the known anti-scouring systems.

[0010] According to the invention, as defined by claim 1, a seabed scour protection device for protecting an area of a seabed around at least one offshore suction pile is provided, the at least one offshore suction pile comprised of a tubular element having an open bottom portion and a closed top portion and configured to penetrate the seabed by suction, is provided, wherein the seabed scour protection device comprises:

- a carrier configured to be attached to the closed top portion of the offshore suction pile, the carrier being shaped as to extend circumferentially with a clearance around the offshore suction pile when attached to the top portion of the offshore suction pile;
- a sheet-like flexible screen extending between an inner circumferential edge attached to the carrier and a free outer circumferential edge, wherein along the free outer circumferential edge one or more flexible ballast elements are provided, wherein the flexible screen is configured to be movable between a retracted state wherein the screen is in a rolled-up position and an expanded state wherein the screen is in an unrolled position so as to cover the area of the seabed;
- the sheet-like flexible screen further including a plurality of flexible radial tubular arms;
- a duct in fluid connection with the flexible radial tubular arms, the duct comprising a pump connection arranged for connecting a pump,

wherein the pump may be connected to the pump connection so as to pump a pressure medium under pressure via the duct into one or more of the flexible radial tubular arms in order to cause the sheet-like flexible screen including the flexible radial tubular arms to move between a retracted state wherein the flexible screen is in a rolled-up position and an expanded state wherein the flexible

screen is in an unrolled position so as to cover the area of the seabed thereby substantially avoiding scouring.

[0011] The pressure of the pressure medium provided by the pump should be larger than the local water pressure at or close to the depth of the seabed so that the pressure medium may inflate as it were the one or more tubular arms. This may cause the arms to unroll from their retracted, rolled-up position to an extended position wherein the arms extend radially outward, like the spokes of a wheel, from the carrier. Since the carrier (herein also referred to as the cradle or the cradle like carrier) is arranged around the side wall of the offshore suction pile, the inflated arms extend radially outward relative to the offshore suction pile as well. Since the arms form part of the sheet-like flexible screen (herein also referred to as the skirt, flexible skirt means, screen, (scour) mat, cover-like device, foil, cover material, etc.), the unrolling of the or more arms cause the flexible screen to be expanded as well.

[0012] Once the flexible arms have served their purpose of the extending the sheet-like flexible screen to the expanded state, the supply of pressure medium may be stopped and the pressure within the flexible arms may return to the local water pressure. The flexible radial tubular arms are now fully flexible again so that they can adapted themselves to the local height variations in the seabed. The screen portion (i.e. the screen segments) is flexible as well. In other words, the local height variations in the seabed can be followed in a more accurate way. This may in itself may already reduce the likelihood of scouring the seabed. This effect may be even stronger in embodiments wherein also the free outer circumferential edge provided with the one or more flexible ballast elements is flexible to the extent that it allows the ballast elements and circumferential outer edge of the screen in the expanded state to track local height variations in the seabed.

[0013] The seabed scour protection device may improve the reliability of the offshore foundation and/or may make the installation of the offshore foundation faster and/or cheaper. The offshore suction pile may be provided, preferably near its top (eg. the top bulkhead of the suction pile) and at a level spaced below the level of this top (viewed in the upright condition of the offshore suction pile) with an extendable seabed scour protection device (SSPD) comprising a flexible screen in order to cover or screen, when extended, the seabed area adjacent the one or more offshore suction piles to avoid scouring or at least reduce the risk and/or extent of scouring. This SSPD is preferably mounted to the offshore pile before the offshore pile is lowered onto the seabed, e.g. while the offshore pile completely or partly projects above the water, is located on a vessel or at an onshore location. The SSPD is mounted at such level that it remains above the seabed once the offshore pile is installed into the seabed, as will be explained later.

[0014] Preferably the flexible ballast element or the flexible ballast elements together extend continuously along essentially the entire outer circumferential edge of the flexible screen. This reduces the risk of existing water currents close to the seabed to lift-up one or more parts of the (circumferential outer edge of the) flexible screen (since the ballast elements extend continuously, in fact essentially uninterrupted, along the entire outer circumference of the scouring protection device) which otherwise would give rise to scouring enabling water flows.

[0015] Such continuous ballast element could be a single chain that extends along the entire outer circumference of the flexible screen. However, in embodiments of the present disclosure, a number of chains are provided, wherein between each pair of neighbouring flexible radial arms a single chain is provided. The single chains together then can be considered to form a continuous, essentially uninterrupted, chain along the entire outer circumference of the flexible screen.

[0016] Preferably the ballast element(s), more specifically the chain(s), are made of material that have a relatively large submerged weight so that they are able to properly hold the outer circumference of the flexible screen firmly on the sea bed. Suitable materials for the ballast elements are iron or steel. In embodiments of the present disclosure the mass per unit of length of the one or more ballast elements should be more than 20 kg/m or more than 30 kg/m, in some situations between 20 kg/m and 50 kg/m. In embodiments of the present disclosure the width of the ballast elements is relatively small, for instance less than 20 cm or even less than 10 cm, so that the ballast element(s) slightly penetrate the (often relatively soft) top layer of the seabed. This may help even further the prevention of the circumferential outer edge of the screen to be lifted upward.

[0017] As mentioned above, in certain embodiments of the present disclosure, the circumferential edge comprises a plurality of separate ballast elements, each of the respective separate ballast elements being arranged between two neighbouring flexible radial tubular arms. Similarly, in embodiments of the disclosure, wherein the flexible screen is subdivided into a plurality of screen segments (i.e. a plurality of separate screen segments), each screen segment may extend in between two neighbouring flexible radial tubular arms. However, in other embodiments, the plurality of screens segments in which the flexible screen has been divided, are connected to each other and the flexible radial tubular arms are attached to respective screen segments, for instance at positions between both side edges (i.e. the radial edges) of each of the screen segments.

[0018] The connection between two neighbouring screen segments and/or between a screen segment and a flexible radial tubular arm can be accomplished by a plurality of loop-shaped connection elements.

[0019] The flexible screen may comprise one screen, generally ring-shaped, so as to cover a ring-shaped area around the suction pile. However, in other embodiments, the flexible screen is subdivided into a plurality of screen

segments. Subdividing the flexible screen in a plurality of screen segments has several advantages.

[0020] The one or more of the screen segments may be configured so that they are foldable to reduce the width of the screen segment. Similarly, the one or more screen segments may be configured to allow the screen segment to be unfoldable in order to increase the width of the screen segment. In the expanded state the flexible screen should cover a large are of the seabed. In certain embodiments the flexible screen (i.e. the combined shape of the screen segments) has - in the expanded state - a shape similar to a disc with a central hole. However, it is difficult to neatly roll-up the flexible screen and provide - in the rolled-up position / retracted state - an essentially torus-shaped package of flexible screen segments when the flexible screen has the above-mentioned disc-shape in the expanded state. Therefore, in accordance with further embodiments of the present disclosure, the screen segments (each of which having in the expanded position typically a shape that tapers outwardly, seen in a radial outward direction, like the spokes of a bicycle wheel) are configured so that they can be folded or pleated to bring the screen segment from the widening shape into a rectangular shape. Rectangular screen segments can be more easily rolled-up than screen segments having a widening shape and the resulting package screen material is more evenly distributed along the circumferential direction of the protection device.

[0021] In order to assist the folding of the flexible screen, one or more of the screen segments may comprise one or more folding lines. The folding line(s) ensure that the screen segments is folded correctly in order to obtain an almost perfect rectangular shape. For instance, the screen segment may have in the expanded state the shape of a truncated triangle. Folding the screen segment once or twice makes it possible the achieve a rectangular shape. This allows a reliable and even rolling-up of the screens segments into the rolled-up/retracted position.

[0022] In embodiments of the present disclosure neighbouring screen segments are mutually connected through a wire connection. Such a wire connection may comprise a wire connected to both screen segments. The wire and the (openings in the radial edge of the respective) screen segment are arranged to allow the screen segments to lace both screen segments together using the wire (for instance, lacing them together as a shoe, as it were). In case such wire connection is used, it may be configured in such a manner that the screen segments can be kept connected irrespective of a varying interspace between the screen segments. For instance, the wire connection can be configured (for instance, by providing a wire that is long enough) to allow the interspace between neighbouring screen segments to be increased by loosening or slackening the wire and allowing the interspace to be reduced by pulling the wire (the wire being fixedly attached to the duct and/or the carrier of the protection device). In other words, the wire connection makes it possible to fold screen segments while that have been connected to each other using this wire connection: by loosening the wire the interspace between the radial edges may be increased while still keeping the radial edges connected. The increased interspace in turn allows for the screen segment to be folded into a suitable shape.

[0023] Furthermore, in embodiments of the present disclosure, each screen segment is connected to an associated flexible tubular arm by a plurality of loop-shaped connection elements. This allows movement of the screen segment in radial direction, relative to the flexible tubular arm, while the connection fixes the screen segment in other directions.

[0024] As will be understood from the above, in particular advantageous embodiments of the present disclosure, the seabed scour protection device is configured so that in the retracted state the flexible screen is in a folded *and* rolled-up position and in the expanded state the screen is in an unrolled *and* unfolded position.

[0025] In embodiments of the present application the seabed scour protection device comprises a hold- and release system connected to the carrier. The hold- and release system is configured to hold the flexible screen in the retracted state and to release the flexible screen allowing the flexible screen to move to the expanded state once the at least one suction pile has penetrated the seabed over a predefined minimum length. In a specific embodiment the hold- and release system comprises a portion configured to trigger the release of the flexible screen as the portion when in contact with the seabed is caused to move relative to the suction pile by the downward movement of the suction pile into the seabed. In other words, the release is made possible automatically, without a need for submersible or vessel-based actuation systems. The hold- and release system is reliable and simple, it only needs the suction pile to be driven far enough into the seabed.

[0026] The hold- and release system may be connected to the carrier and may comprise a plurality of hold- and release units distributed over the circumference of the carrier. In preferred embodiments of the present disclosure one or more of the hold- and release units comprise:

- a plurality of holding elements, for instance holding straps, to be arranged around the flexible screen in the retracted state;
- a frame part fixedly attached to the carrier;
- a guiding element configured to be guided along the frame part in downward direction substantially parallel to the direction of gravity until a lower position relative to the frame part and in opposite, upward direction until an upper position relative to the frame part;
- a foot portion connected to or integrally formed with a bottom portion of the guiding element and configured

to contact the seabed;

- a hook portion connected to or integrally formed with a top portion of the guiding element and configured to releasably hold at least one of the holding elements;

wherein the hook portion is configured to release the at least one of the holding elements when the guiding element is moved from the lower position into the upper position by the downward movement of the at least one suction pile into the seabed.

[0027] As will be made further clear in the description of the exemplifying embodiments the flexible radial tubular arms may be formed by inflatable hoses, the inflatable hoses taking a flattened shape in the retracted state and an inflated shape in the expanded state/

[0028] As mentioned earlier, the carrier of the seabed scour protection device may be attached to the top portion of the suction pile by a plurality of attachment elements, the attachment elements being configured to allow the protection device to be suspended from at least one of the circumferential outer surface of the offshore suction pile and the top bulkhead closing off the top portion of the tubular element. In this manner the suction pile does not have to be adapted or at least less so. In an optional embodiment the attachment element comprises a clamp unit configured to allow attachment by clamping the clamping unit to suction pile, preferably to a top bulkhead thereof. In this case no special measures need to be taken to attach the seabed scour protection device and standard suction piles can be used.

[0029] According to claim 11 an assembly is provided comprising at least one suction pile and a seabed scour protection device as described herein, wherein the seabed scour protection device is attached to the top portion of the suction pile. In further embodiments the assembly comprises two, three or more suction piles, each suction pile being provided with a seabed scour protection device as described herein. In these embodiments the suction piles may be provided with one common seabed scour protection device, but in other embodiments each suction pile is provided with its own seabed scour protection device. When each of the flexible screens in their expanded state have a generally polygonal shape, for instance an octagon, the area around the suction pile has a polygonal shape as well, except when the screens of two or more seabed scour protection devices partially overlap.

[0030] According to claim 12 a method for protecting an area of a seabed around at least one offshore suction pile with a seabed scour protection device as defined herein is provided, wherein the method comprises:

- connecting a pump to the pump connection;
- releasing the sheet-like flexible screen;
- pumping a pressure medium under pressure via de pump connection and the duct into one or more of the flexible radial tubular arms, thereby causing the released sheet-like flexible screen including the flexible radial tubular arms to move between a retracted state wherein the flexible screen is in a rolled-up position and an expanded state wherein the flexible screen is in an unrolled position, thereby covering the area of the seabed.

[0031] The method may further comprise:

- removing water from the at least one suction pile so as to move the at least one suction pile downward into the seabed;
- releasing the flexible screen by causing a portion of a hold- and release system, upon contact of the portion with the seabed, to move relative to the suction pile by the downward movement of the suction pile into the seabed.

[0032] Once the scour protection device has been fully deployed, the overpressure inside the tubular arms may be removed, for instance by reversing the pump action or opening a valve. In this manner the tubular arms become fully flexible again so that they can even better follow the height variations in the seabed. In certain cases, for instance if after a period of time the position of the flexible screen on the seabed should be updated, the pressure medium may be reintroduced into the one or more of the radial tubular arms.

[0033] According to claim 15 a method of assembling a seabed scour protection device is provided wherein the method comprises:

- attaching screen segments of the flexible screen to the carrier;
- connecting one or more screen elements to respective flexible radial tubular arms using wire connections;
- folding at least one of the screen segments over one or more folding lines, thereby allowing the wire connection to be loosened;
- rolling up the at least one screen segment and the respective flexible radial tubular arms into the retracted state;
- tension the wire connection of the least one screen segment.

[0034] Further embodiments and aspects of the present disclosure are described hereafter.

[0035] In embodiments the seabed scour protection device (SSPD) is designed to be unfolded by a translating movement of one of its edges, preferably a free edge (e.g. the edge that is wound onto the roll last, which edge could also be called leading edge), e.g. a movement similar to unwinding a rolled web by pulling at its free end. Such unfolding preferably is provided by and/or powered by an inflating means, e.g. a hose filled with pressurised fluid, e.g. air or water or grout. The SSPD, when retracted, optionally also folded or collapsed, is preferably rolled, optionally also creased or pleated, to be stored to small

dimensions. In embodiments of the present disclosure the dimensions in the retracted stare are less than 10% or 20% of the dimensions in the extended state. Furthermore, the SSPD may be configured to unfold, extend or stretch similar to the screen web of a roller blind, a pleated curtain, an umbrella or a parasol.

[0036] If unfolded the SSPD may cover at least 2 or 5 metres seabed radially from the outer side wall of the offshore pile, may cover a substantially rectangular or circular seabed area, preferably completely around the offshore pile, e.g. without gaps or continuously, adjacent the offshore pile, and the SSPD may slope towards the seabed. Preferably a plurality of SSPD's are provided circumferentially, possibly such that they partly overlap or connect side to side if unfolded.

[0037] As an example the SSPD is constructed similar to an inflatable sail, e.g. comprising a roll of sheet like cover material and one, two or more inflatable arms that, by unfolding, move the free edge of the cover material away from the roll thus unrolling the cover material into an unfolded or stretched condition, wherein the roll and the one end of the inflatable arm are fixed to the offshore pile such that the roll can unwind and the inflatable arm can expand to extend or unfold. Preferably the inflatable arm carries out its extending movement by unrolling itself.

[0038] The flexible screen (web) may comprise a woven or non-woven fabric, may contain heavy elements, e.g. rocks, as a ballast element or ballast means, e.g. in or along the web. The flexible screen may have a rough surface, e.g. an artificial frond, to collect and retain sand from the seabed. The flexible screen is furthermore at least one of pliable, flexible, wrinkable, reliable, foldable (for instance, foldable and unfoldable like a cloth), a textile or textile like product, a fibre-like or fibre product, comprised of pin or strip shaped elements, e.g. providing an artificial frond. The pin or strip shaped elements may be made of rubber or rubber-like material and/or may have varying stiffness over its length.

[0039] The sheet-like screen can be rolled or folded, the latter for instance like, in the retracted condition. A preferred mat can be obtained with Seabed Scour Control Systems Ltd, Norfolk, (UK), sold as SSCS Frond Mat.

[0040] An SSPD may have one or more of: a straight or curved storage means, e.g. a carrier or cradle, to store and/or carry the retracted flexible screen. At the leading edge of the flexible screen a ballast element or ballast means means, e.g. a straight profile of e.g. metal or an iron chain, an inflatable or inflation powered actuator means, e.g. inflatable arm, to move the leading edge, e.g. away from the storage means, to unfold the SSPD.

[0041] The length or height of the offshore pile is the direction parallel to the direction of movement of the offshore pile while it progressively penetrates the seabed, thus the direction of the body axis or the direction from the top to the bottom. Vertical or upward herein means the direction parallel to the length or height of the offshore pile.

[0042] To unfold, the SSPD can have a pump to supply pressurised pressure medium, i.e. pressurized fluid, for providing inflation power and/or to inflate an actuator means to unfold the SSPD.

[0043] Separate from or in combination with one or more of the features disclosed above and/or below, the present disclosure may also relate to an SSPD with one or more of the following features. Designed for release and/or extension by an object separate from the SSPD, e.g. seabed contact, or by progressively penetration of the seabed by the offshore pile. The feature of having elongated elements such as radial tubular arms (herein also referred to as outrigger arms) which are configured to expand by inflation to provide and/or actuate the expansion or unfolding of the SSPD. The feature of inflatable web (flexible screen) carrying arms, which in the extended state may extend radially from the offshore pile or perpendicular to the length or height direction of the offshore pile and preferably substantially horizontal or lying. In the retracted state they may be wound or rolled up, Furthermore, when moving from the retracted state to the extended state the spacing between the end portions of the tubular radial arms (i.e. the distal portion relative the offshore pile) may increase such that the flexible screen mounted to these tubular arms may become unfolded and/or stretched. The flexible screen may be mounted to arms at locations spaced along these arms; the sliding movement may be caused by the seabed, e.g. since the distance between the top of the offshore pile and the seabed decreases due to progressive penetration of the offshore pile during its installation; the orientation of the outrigger arms may change from rolled or wound to straight, e.g. substantially horizontal or lying, to extend radially from the offshore pile. The flexible screen or feel fixedly mounted to the tubular radial arms, unfolds in a way similar to the cloth of an unfolding or unrolling roller blind and/or may become stretched by the outrigger arms as soon as the SSPD arrives at its completely unfolded state. Furthermore, the force of gravity force and/or one or more of tubular arms and hooking element/parts of the SSPD and/or the offshore pile may keep the SSPD biased towards the rolled-up position or retracted state. Finally, the seabed scour protection device in principle is separate from the offshore pile and there is not fixed connection between the seabed scour protection device and the offshore pile.

[0044] The seabed scour protection device, i.e. the hold- and release system thereof, may have a connection or guiding element allowing a mutual stroke, lengthwise, of at least 0.5 or 1.0 metre. The seabed scour protection device circumferentially encircles the offshore pile, preferably completely. The seabed scour protection device also provides a partially, substantially or completely closed loop around the offshore pile. The seabed scour protection device may be shaped to allow a form fit with the offshore pile. The seabed scour protection device is attached to the offshore pile in a manner allowing a lengthwise translation of the seabed scour protection device offshore pile (thus vertically if the offshore pile

in operation is oriented vertically), 'preferably for at least 0.5 or 1.0 metre; relative to the offshore pile, but retaining the same in one or more translation directions. The seabed scour protection device is kept in the retracted state by the hold- and release system. The hold- and release system may comprise holding elements, for instance holding straps, that preferably are releasable, e.g. by hooking elements or parts, e.g elements provided at the SSPD (e.g. hooks or eyes) and/or at the offshore pile (e.g. hooks or eyes). The hook elements may become disengaged as soon as the SSPD is moved downward, e.g. due to further penetration of the offshore pile into the seabed.

[0045] Hooking parts may be provided at a part of the SSPD, e.g. cradle means, preferably close to the offshore pile, preferably engaging hooking parts at the offshore pile, preferably close to the top. A hooking part, e.g. a hook, may be disengaged, e.g. may be lifted from a counter hooking part, e.g. an eye, which preferably initiates unfolding or extending the SSPD. The extension may be accomplished since the initially rolled-up or wound flexible arms, e.g. outrigger arms, expand, causing them to extend in a horizontal or lying orientation while at the same time extending radially from the offshore pile. The flexible arms may have a fixed length.

[0046] Preferably, the unfolded SSPD, surrounding the offshore pile at a level between the lower and upper end (open bottom and closed top, respectively, in case of a suction pile), may be suspended from hook members fixed to the offshore pile in such a manner that with the offshore pile in the upright attitude (longitudinal axis vertical, open bottom below closed top) the movement of the SSPD downward and/or outward (of at least the top edge of the SSPD) is retained by the hook members and upward is not retained by the hook members and sufficient upward movement causes that the SSPD becomes outside the retaining influence of the hook members such that the SSPD is released from the hook members to be no longer retained in downward and/or outward movement by the hook members, to move towards the unfolded position. Preferably the hook members have a design to present a retaining edge having an outward radial extension from the offshore pile (to retain downward movement of the SSPD) and/or an upward extension at a distance from the offshore pile (to retain outward movement of the SSPD). Preferably the outward radial extension projects from the offshore pile and the upward extension connects to the end of the outward radial extension remote from the offshore pile. The SSPD is preferably provided with corresponding hook features to properly co-operate with the hook members. During unhooking the complete SSPD, or only part of it, may move upward along the offshore pile, counter to the gravity action.

[0047] Preferably, the folded SSPD has a shape similar to a cylinder and the unfolded SSPD a shape similar to a disc with central hole. IN both the retracted and expanded state the offshore pile fits within the (central hole of the) SSPD, preferably with a more or less tight fit.

[0048] Preferably, the retracted SSPD has a first and a second edge close to the offshore pile, while the extended SSPD has the first edge close to the suction pile and the second edge remote from the offshore pile, preferably at least 1 or 2 m further away compared to the retracted state.

[0049] Preferably the SSPD is designed such that in the unfolded state the outer circumferential edge of the flexible screen suitable contacts the seafloor or at least extends close to the seafloor to avoid or reduce the risk of scouring below the flexible screen. In some cases, it is allowed that the flexible screen has a gap with the seafloor.

[0050] A tight fit between the SSPD and the offshore pile is preferred for optimum scour protection and jamming free vertical movement of the SSPD relative to the offshore pile. Preferably the SSPD is provided with a collar that at least partially seals the gap or play (typically at least 10 mm and/or less than 50 or 100 mm). Such collar may have a height of at least 250 mm.

[0051] Preferably one or more of the following applies: the web is present below the outrigger arms such that in the unfolded state the web is between these arms and the seafloor; in the unfolded state the web at the SSPD outer edge is closer to the seafloor, e.g. at least 10% or 20%, compared to its distance remote from this outer edge, e.g. the inner edge, or connects to the seafloor while remote from this outer edge the web is spaced from the seafloor, e.g. at the outer edge the web seafloor distance 30 is between zero and 20 mm while remote from the outer edge the web seafloor distance is at least 100 or 200 mm, at least at the location of the outrigger arms; the web is ballasted or made heavier at the outer edge, e.g. by an elongate ballast means, e.g. of at least 20 kg/metre weight, e.g. a chain of metal or by ballast, e.g. of granular type, e.g. stones, e.g. within a hollow elongated envelope, e.g. a tube, fixed to the web, to bias the web towards the seafloor.

[0052] The function of the screen (also: skirt) may be considered to offer protection against washing away of the seabed at the edge of the completed pile foundation, and this may be very effectively achieved and almost all washing away may be prevented if the flexible screen comprises ducting fillable with a pressure medium to extend the screen laterally of the piles when the screen is submerged. To assist manufacture and assembly, the screen or each screen segment may comprise a plurality of interconnected screen segments and may reliably lie against the pile when the ducting is unpressurised. By these measures, the screen may remain unpressurised during the lowering of the foundation means and have only a small resistance so as not to be unnecessarily loaded. The screen may be extended laterally of the pile only when required during the founding. Once the screen lies on the seabed, it surrounds the foundation to such an extent that it may prevent an underwater current disturbance at the edge of the foundation. So that the central

duct can be filled by the pressure medium with minimum effort, the ring-shaped duct expediently comprises a plurality of spaced-apart duct members extending outwardly from the ring-shaped duct, preferably substantially radially of the ring-shaped duct. By trials, it has been shown to be particularly advantageous to use pressurised liquid (but compressed air could be an alternative) as the pressure medium for the ducting. The lateral extension of the or each screen can be held in flotation underwater so that its attitude can be accurately monitored, for example by underwater cameras. Expediently, the screen in the unfilled state of the ducting is heavier and in the filled state lighter than water, by proper selection of the pressure medium filling the ducting. By this means the or each screen may float with a complete or partial filling of the ducting, and may yet lies on the ground at a later time, e.g. when the ducting is finally unpressurised. The screens automatically adapt themselves to the contour of the seabed.

[0053] The common, ring-shaped duct is supplied at one or more points with pressurised fluid, so that the hoses have a tendency to stretch and thus impart to the screen the shape of a fan. During flotation and submerging of the offshore structure, the screen is rolled up against the offshore piles and fastened in this positioned by means of releasable ropes. Because of its large size, the screen is subdivided into more easily manageable segments, which overlap and/or contact at their edges and are interconnected. These segments also facilitate the assumption of the fan shape when the hoses are stressed. When the offshore structure has been lowered, the rolled-up screen is released and the hoses are filled with pressurised fluid. By this means the screen is expanded. The hoses and the fluid could be so dimensioned that they cause the screen to float when subjected to the pressurised fluid. In this condition, they endeavour to straighten themselves. Thus, the screen, like a fan, is spared freely and substantially horizontally for a few metres above the seabed. Subsequently, the fluid pressure in the hoses is released and the screen drops and rests on the seabed. The width of the fan formed by the screen is chosen according to the known conditions of the location of the offshore structure. In any event it is designed to extend on the seabed sufficiently far beyond the foundation to adequately cover most of the region of the underwater current caused by the foundation. For this purpose, it is as a rule sufficient for the width of the screen to correspond to at least a third of the diameter of the base of the associated offshore pile. If required, the screen may be even wider, or weights may be attached to its free edge so that the current cannot lift this edge.

[0054] The segments of the screen may be comprised of strong and seawater-resistant sheets of synthetic material, which are reinforced by wire mesh or by inserts of stainless steel. The screen or screen segments may advantageously be formed from a sheet of synthetic material provided with metal reinforcing means (wherein examples of synthetic material are: polymeric material, plastic, or mineral material (e.g. fibres spun from molten rock or stone such as basalt)). The ducting may comprise one or more hoses resiliently mounted to the or each screen. To further improve the screening effect against erosion, the screen can be provided at an edge thereof remote from the pile with weighting means, herein also referred to as ballast elements.

[0055] Holding elements, for instance holding straps, may be applied to keep the protection device in the retracted state. These holding elements are preferably automatically released to allow the protection device to move to the expanded state, for instance by unrolling the flexible screen as soon as a certain portion (i.e. a foot portion) of the hold- and release system of the protection device engages the seabed during the penetration process of the offshore pile into the seabed. The automatic release further involves a hook portion and a guiding element.

[0056] The cradle (i.e. carrier) preferably comprises a space frame comprising at least two endless pipes each encompassing the offshore pile and spaced in longitudinal direction of the offshore pipe and rigidly fastened to each other by vertical bridging elements, such that these parts provide a shape retaining frame providing a closed loop tightly around the offshore pile.

[0057] The foot portion of the automatic hold- and release system is designed to engage the seabed, e.g. at a distance below the cradle. The foot portion may be rigidly connected through a movable guiding element (i.e. a guiding element movable with respect to a frame part fixedly attached to or integrally formed with the carrier or cradle) to a hook portion. The assembly of foot portion, guiding element and hook portion can move freely relative to the carrier.

[0058] Preferably, the screen segments are assembled with the carrier (e.g. cradle) as follows: The web segments are added to the carrier. The (e.g. truncated) triangle shape is transformed into a right angled shape e.g. by folding one or both radial web edges (i.e. the one carrying the hose and the one opposite the hose carrying edge) . This folding may be performed along two straight folding lines, the folding lines extending under a sharp angle of not more than e.g. 20 degrees relative to the radial direction, such that web area adjacent this radial edge may be folded in a zigzag manner and the radial edge may be folded onto the radial outer edge of the relevant right angled shaped web segment. The rectangular web segments are wound into roll shape. Preferably while in rolled shape, the radial edges of adjacent roll shaped web segments are permanently fastened to each other, e.g. by interconnecting the wire(s) provided regularly spaced along each radial edge.

BRIEF DESCRIPTION OF THE DRAWINGS

[0059] The above and/or other aspects of the present disclosure will become apparent and more readily appreciated from the following detailed description of exemp-

lary embodiments, taken in conjunction with the accompanying drawings of which:

Figures 1A and 1B are side views in perspective of an example embodiment of an offshore foundation for carrying an offshore construction (not shown), the offshore foundation comprising three suction piles provided with a seabed scour protection device in a retracted state (figure 1A) and in an expanded state (figure 1B).

Figure 2 is a side view in perspective of another example embodiment of an offshore foundation;

Figure 3 is a side view of a detail of figure 1B;

Figures 4A and 4B are top views of examples of different configurations of the offshore scour protection device, with 8 and 16 radial tubular arms, respectively;

Figure 5 is a side view of a suction pile provided with a different exemplifying embodiment of an offshore scour protection device, with an alternative pump;

Figure 6 is a partially taken away side view of a suction pile provide with the exemplifying embodiment of an offshore scour protection device according to figures 1A, 1B and 3;

Figures 7A-7C are partially taken away side views of a suction pile provided with three respective embodiments of an offshore scour protection device;

Figure 8 is a partially taken away side view of the embodiment of figure 5, showing the alternative pump, pump connection, duct, one flexible tubular radial arm (in rolled-up position, without the screen segments connected thereto), and one attachment element in more detail;

Figures 9 and 10 are partially taken away side views of the embodiment of figure 8, further showing a portion of an embodiment of a hold- and release system for holding the flexible screen in place (in the retracted state) and releasing the flexible screen so that it can be moved to the expanded state when the suction pile has been sufficiently penetrated the seabed;

Figure 11A is a side view of the embodiment of figure 7C, without the flexible screen, i.e. without the flexible screen segments and the flexible tubular arms;

Figure 11B is the side view of 11A, including the flexible screen, i.e. including the flexible screen segments and the flexible tubular arms;

Figure 12 is a side view of the embodiment of the suction pile and protection device, especially the hold- and release system thereof;

Figures 13A and 13B are respectively a top view of a further embodiment of different type of suction pile provided with an embodiment of an offshore scour protection device;

Figures 14, 15 and 16 are an elevational view, top view and side view of an embodiment of a carrier with a ring-shaped duct and a number of hold- and release systems;

Figure 17 is a top view of an embodiment of a screen segment provided with an elongated ballast element;

Figures 18A-18K depict a first sequence of assembly steps performed to form a flexible screen from various screen segments, connect the screen segments with various wire connections, fold the sheets into a rectangular shape, and roll-up individual folded screen segments into the retracted state;

Figures 19A-19Kdepict a second, different sequence of assembly steps performed to form a flexible screen from various screen segments, connect the screen segments with various wire connections, fold the sheets into a rectangular shape, and roll-up individual folded screen segments into the retracted state;

Figure 20 an partially taken away elevational view of an embodiment of the offshore scour protection device, especially shown the hold- and release system;

Figures 21A, 21B and 21C are cross-sectional views of a suction pile that is moving into the seabed (by removing water from the interior of the suction pile), thereby activating (i.e. triggering the release of the holding elements) of the hold- and seal system of the protection device, the views also showing a frame part, guiding element, foot portion and hook portion of the hold and release system in more detail, wherein the figures respectively relate to lower position, intermediate position and upper position;

Figure 22 shows a screen segment provided with a collar segment configured to seal the gap with the suction pile (not shown);

Figure 23A an elevational view of a clamp unit for clampingly attaching an offshore scour protection device to a reinforcement beam that form part of the top wall 11 of a suction pile, figure 23B a cross-section of the clamp unit of figure 23A and figure 23C a detail side view of the clamp unit of figures 23A and 23B.

[0060] The present disclosure will be elucidated further by describing particular exemplifying embodiments and with reference to certain drawings. The drawings described are only schematic and are non-limiting. In the drawings, the size of some of the elements may be exaggerated and not drawn on scale for illustrative purposes. The dimensions and the relative dimensions do not necessarily correspond to actual reductions to practice of the disclosure.

[0061] Furthermore, it is noted that, as used herein and in the appended claims, the singular forms "a", "an", and "the" include plural referents unless the context clearly dictates otherwise. It is further noted that the claims may be drafted to exclude any optional element. As such, this statement is intended to serve as antecedent basis for use of such exclusive terminology as "solely," "only" and the like in connection with the recitation of claim elements, or use of a "negative" limitation.

[0062] As will be apparent to those of skill in the art upon reading this disclosure, each of the individual embodiments described and illustrated herein has discrete components and features which may be readily separated from or combined with the features of any of the other several embodiments without departing from the scope of the present invention. Any recited method can be carried out in the order of events recited or in any other order which is logically possible.

[0063] Figures 1A and 1B show an embodiment of an offshore foundation 1 comprising of three offshore suction piles 6, at a connection 12 of the upper wall or top wall 11 (herein also referred to as the (top) bulkhead) of which respective legs 2 have been mounted. The legs 2 are interconnected via diagonal braces 5 and a top piece 9. Each of the offshore suction piles 6-8 is comprised of a tubular element 3 (for instance a cylindrical element) having an open bottom portion 7 and a closed top portion 8 and configured to penetrate the seabed by suction, i.e. by pumping water from the interior of the suction pile 6 so that the pile is caused to move downward into the seabed under the influence of the local water pressure.

[0064] Each of the offshore duction piles 6 is provided with an embodiment of a seabed scour protection device 10, as shown in figures 1A and 1B. To this end the seabed scour protection devices 10 each comprise a ring-shaped carrier 23 configured to be attached to the offshore suction pile 6, the carrier being shaped as to extend circumferentially with a gap 33 or clearance around the side wall of the suction pile. The carrier 23 is provided at its inner circumference with a number of nylon blocks 70 (cf. figure 14) to protect the carrier 23 when it is suspended from a suction pile. In the figures the carrier 23 is a ring-shaped carrier configured to be attached to the closed top portion of the offshore suction pile. The gap 33 between the inner circumferential edge of the carrier 23 and the outer surface of the wall 3 of the offshore suction pile 6 may be at least partially sealed by a flexible collar 80 resting against the outer surface of the offshore suction pile (cf. figure 22).

[0065] The carriers of each of the seabed scour protection devices 10 are attached to the respective top portions 8 of the suction piles 6. The top portion 8 of an offshore suction pile may be defined as the portion of the suction pile within 5 m, preferably within 1 m, of its upper bulkhead 11. The top portion 8 includes the side wall 3 of the suction pile (in case the offshore suction pile has a cylindrical shape, the cylinder wall of the pile) and the top wall 11.

[0066] In the embodiments of figures 1A, 1B, 2, 4A, 4B, 6, 11A, 11B, 13A, 13B a pump 15 and in the embodiments of figures 5, 7A-7C, 8-10, 12 a different pump 15' is shown. In all embodiments shown the pump 15, 15' is attached to the top wall 11 of each of the suction piles 6-8, for instance to one or more of the reinforcement beams 13 or to a support 31 (cf. figure 3) forming part of the top wall 11. In other embodiments only one pump is provided for the combination of the three suction piles, while in still other embodiments the pump is provided in a vessel at sea level (and connected to the protection device via a riser pipe). Furthermore, the pump 15, 15' may be a pump that is used exclusively by the associated seabed scour protection device 10 or may be a pump that is also used to remove water from the interior of the suction pile(s), as is discussed above. The suction pile 6 and the seabed scour protection device 10 may have one single, common pump 15. Referring to figure 6, the pump 15 comprises a switch valve 35 that may be switched between two positions. In a first position the valve 35 is switched so as to allow the pump 15 to remove water from the interior of the suction pile, through a pipe part 37 (direction 36). In a second position of the valve 35 the pipe part 37 is closed and water is sucked in and transported through the pipe connection 17 towards a duct 18 (to be described hereafter) and then via connectors 44 to the flexible radial tubular arms 19 (cf. direction 34, figure 6).

[0067] Preferably the pump 15, 15' is attached in a removable manner to the suction pile 6 and also in a removable manner to a pump connection (to be described later) so that after the suction pile has been embedded into the seabed and the scour protection device 10 has been deployed, the pump 15, 15' may be removed, if needed.

[0068] Attached to the carrier 23 is a ring-shaped duct 18. The duct 18 is in fluid connection with a number of radially extending tubular flexible arms 19 via respective connectors 44. In the shown embodiment, for example in figures 14-16, the duct 18 is comprised of a ring-shaped pipeline (ring pipeline), more specifically a ring pipeline formed of at least two interconnected steel pipe segments. The duct 18 is arranged around the circumference of the at least one suction pile as well, similar to the carrier 23, but is attached to the carrier 23 rather than to the suction pile 6 itself. The duct 18 further comprises one or more pump connection 17 allowing one or more pumps (for instance pump 15 or pump 15') to be brought in fluid connection (see double arrow 34 in figure 6) with the duct 18 and the above-mentioned radially extending tubular flexible arms 19.

[0069] The flexible tubular arms 19 are flexible to such extent that they may be rolled-up and unrolled causing the screen segments (herein also referred to as scour mats) of the sheet-like flexible screen 29 to be rolled-up and unrolled as well. The unrolling of the flexible tubular arms 19 can be accomplished by pumping into the arms 19 a sufficiently pressurized pressure medium, like a pressurized liquid, such as water, a pressurized mixture of liquid and solids, such as grout, and/or compressed air. The number of flexible radial tubular arms 19 may vary, depending for instance on the size of the suction piles 6. In preferred embodiments the number of flexible radial tubular arms 19 is at least four, for instance eight arms (cf. figure 4A) or sixteen arms (cf. figure 4B). Furthermore, the flexible radial tubular arms 19 extend in radial directions at positions that are evenly distributed along the circumference of the carrier 23.

[0070] Figure 1A shows the seabed scour protection device 10 in the retracted state. This is the initial state before the suction pile 6 is arranged inside the seabed. As the suction pile 6 is caused to move downward into the seabed, the distance between the seabed scour protection device 10 and the seabed is reduced until almost the entire suction pile had moved into the seabed and only the top portion 8 of the suction pile extends above the seabed. When the suction pile 6 is moved further downward, the downward movement of the suction pile 6 automatically triggers the release of the flexible screen 29 so that the pump 15 may be operated to move the flexible screen 10 radially outward, from the retracted state of figure 1A to the expanded state of figure 1B.

[0071] Further details of the seabed scour protection device 10 are shown, for instance, in figures 2, 3, 4A and 4B. The flexible screen 29 extends between an inner circumferential edge (that may be attached to the duct 18 and/or the carrier 23 or may be free from the duct 18 / carrier 23 except for the connection points between the flexible arms 19 of the flexible screen 29 and the duct 18) and a free outer circumferential edge 32 (figure 4A, 4B). Along the free outer circumferential edge one or more flexible ballast elements 20 are provided. In the shown embodiment the flexible ballast elements 20 are comprised of a number of chains, wherein each chain is attached between the free ends of two neighbouring flexible arms 19 (the number of chains being equal to the number of arms 19).

[0072] More generally, the free outer circumferential edge that is provided with the one or more flexible ballast elements 20 should be flexible to the extent that it allows the ballast elements and circumferential outer edge of the screen in the expanded state to track or follow the local height variations in the seabed. If the circumferential edge is able to follow local height variations of the seabed, the risk of water currents to be received between the flexible screen 29 and the seabed (which currents would otherwise be able to cause scouring of the seabed) is reduced.

[0073] Referring to figures 4A and 4B it is shown that the radial width (W) of the flexible segment (wherein the width equals the total diameter (A) of the protection device in its expanded state minus the (maximum) diameter (D) of the suction pile) satisfies and the (maximum) diameter (D) of the suction pile is selected to fall in the following range: $0{,}75D < W < 1.5D$. Typically the diameter (D) of suction piles ranges between 5 m and 10 m (although larger diameters are also feasible). Furthermore, the length (L) -diameter (D) ratio (aspect ratio) for offshore suction piles generally is smaller than for offshore piles that are embedded in the seabed by ramming or hammering. For offshore suction piles such ratio may typically be slightly less than one ($L/D < 1$) or about one ($L/D \approx 1$). Hammering or ramming type of offshore piles may typically have an aspect ratio >> 1.

[0074] In embodiments of the present disclosure the radial width (W) of the flexible segment is at least 2 m (i.e. $W \geq 2$ m). Preferably the radial width is at least 5 m (i.e. $W \geq 5$ m). In practical situations the radial width (W) may range between 4 and 15 m (i.e. $4 \leq W < 15$ m), although larger or smaller widths may sometimes also be useful.

[0075] Figure 17 shows an embodiment of a screen segment 99 forming part of the flexible screen 29. The screen segment 99 (herein also referred to as the scour mat) may be made of synthetic material, possibly reinforced by wire mesh or by inserts of stainless steel. In the shown embodiment the screen segment 99 comprises a number of radial reinforcement elements 98 and a number of lateral reinforcement elements 101. The screen segment 99 has a generally widening shape, seen from its inner circumferential edge. At one side of the screen segment 99 a number of attachment elements 55 (including attachment loops) are provided for connection of the screen segment 99 to one of the radial arms 19. At the opposite side of the screen segment attachment elements 56 (for instance, slings with end loops) are provided. At the outer circumferential edge 32 loops have been provided that allow a ballast element 20, in this case a steel chain, to be attached to the screen segment 99. Whereas in the embodiment of figure 17 a radial tubular arm 19 (not shown in this figure) is attached at a side edge of the screen segment 99, in other embodiments, for instance in the embodiment shown in figure 18A, the radial tubular arm 19 is attached at a position between (for instance, halfway) both side edges of the screen segment 99.

[0076] Figures 18A-18K show a first embodiment of a sequence of steps of a method of assembling a seabed scour protection device, i.e. before this device is attached to a suction pile 6. Figure 18A shows a screen segment 99 having a radial tubular arm 19 connected (using loops 55) at a position between the left and right side of the screen segment 99. Figure 18B shows that the carrier 23 (more specifically, a half of the carrier; two halves are to be connected in a later stage of the assembly method) is placed on (wooden) blocks 72. Temporary slings 71 are attached to the carrier 23 for assisting the rolling-up operation of the screen 29 in a later stage. The radial tubular arm 19 is connected to the connector 44 of the duct 18 carried by the carrier 23, preferably using a plurality of clamps. Two or more screen segments 99 are mutually connected using a wire connection (including a wire 73). The wire 83 is fixed at the side of the suction pile 6. A spare length of the wire 73 is needed for the folding procedure to be described hereafter. Figure 18C shows the step of connecting a ballast element 20, for instance a ballast chain made of steel, to the outer circumferential edge of the screen segments 99. A forklift 76 or similar vehicle may be used to lift the ballast element 20. Figure 18D shows the folding of the consecutive screen segments 99 along folding lines 75 and at the same time the folding of the ballast element 20 so as to adapt the shape of the screen segments 99 from the widening shape of figure 18A to a rectangular shape. In this case the screen 29 is folded starting from the left side

(i.e. the side of the tubular flexible arm 19). Using the folding lines 75 makes it easier to obtain the right shape. However, in other embodiments the folding lines 75 are dispensed with. Again a vehicle 76 like a forklift may be used to handle the weight of the ballast element 29. The screen segments 99 are mutually coupled / connected using the earlier mentioned wire 73 of the wire connection. Figures 18E and 18F show how the temporary slings 71 arranged underneath the screen segments 99 are connected to the vehicle 76 (i.e. to the fork of the forklift). The slings then are lifted, causing the screen segments 99 of the flexible screen 29 to start to roll. Next the holding elements 60 are connected to the respective hold- and release units 40 to prevent unfolding and unrolling of the screen segments 99. Figure 18I shows the steps of tensioning the slack wires 73 of the respective wire connections between neighbouring screen segment 99 to make a tightened connection between the screen segments (so that the side edges of the screen segments 99 will essentially touch each other or at least run parallel close to each other when the flexible screen 29 is brought from the retracted state to the expanded state). Figures 18J and 18K show the final assembly, right before the (half) carrier 23 with flexible screen 29 in retracted position are transported and lifted to be attached at the top portion of the suction pile 6.

[0077] Figures 19A-19K show a second embodiment of a sequence of steps of a method of assembling a seabed scour protection device, i.e. before this device is attached to a suction pile 6. The steps of the second sequence correspond for a large part with the steps according to the first sequence and therefore a detailed description is dispensed with. Rather than connecting the flexible radial tubular arm 19 at a position between the left- and right-handed side of the screen segment 99, the flexible radial tubular arm 19 is connected (using loops 55) the left side of the screen segment 99. The remaining sequence of steps as depicted in figures 19B-19K are basically the same as the steps shown in figures 18B-18K.

[0078] Next, a hold- and release system for holding the flexible screen 29 in place before deployment of the protection device 10 is described. Reference is made to figures 5-12,13B, 20 wherein embodiments of a hold- and release system are shown. The hold- and release system comprises a plurality of hold- and release units 40 connected to the carrier 23 at positions evenly distributed over the circumference of the same. The hold- and release system is configured to automatically release the holding function of the system once the suction pile has reached its final destination (i.e. penetrated at a sufficient depth in the seabed), in principle without the need for mechanical and/or electric actuators or controllers that should be operated at sea level (from a vessel) or operated locally by divers and/or an ROV. More specifically, in preferred embodiments, the release of the hold- and release unit 40 is triggered by the movement itself of the suction pile into the seabed, i.e. the relative movement of the suction pile 6 and the protection device 10 attached thereto on the one hand and the (stationary) seabed or sea bottom on the other hand.

[0079] In specific embodiments the hold- and release unit 40 comprises one or more holding elements 60, for instance holding straps. These holding elements 60 are connected to the carrier 23, preferably using two or more connections 61 provided at a lower position relative to the carrier 23. The holding element(s) 60 may be arranged around a rolled-up flexible screen 29 and then held at an upper position by a hook portion 46 arranged at a first, lower position (cf. figures 9, 10). The holding element element(s) 60 at least partially surround as it were the rolled-up flexible screen 29 and prevent the flexible screen from inadvertently unrolling.

[0080] The hook portion 46 is connected to or integrally formed with a top portion of a guiding element 41 and is configured to releasably hold at least one of the holding elements 60. The guiding element 41 is configured to be guided along (i.e. inside) a frame part 43 (the frame part 43 being fixedly attached to or integrally formed with the carrier 23) in downward direction substantially parallel to the direction of gravity to a lower position relative to the frame part and in opposite, upward direction to an upper position relative to the frame part 43 (and therefore relative to the suction pile 6). A foot portion 42 is connected to or integrally formed with a bottom portion of the same guiding element 41 and is configured to contact the seabed when the suction pile 6 is about to be sufficiently embedded in the seabed.

[0081] When the suction pile 6 is moving downward, the foot portion 42 will eventually come into contact with the seabed. When the suction pile 6 is moving further downward into the seabed, the foot portion 42 resting on the seabed causes the guiding element 41 and the hook portion 46 to attain an intermediate position. Note that the foot portion 42, guiding element 41 and hook portion 46 remain stationary while the suction pile 6 is moving downward and that there is a relative movement of the hook portion 46 with respect to the suction pile 6. When the suction pile 6 moved further, the upper (relative) position is reached. In this (relative) position the hook portion 46 is located such that it can no longer hold the holding element(s) 60 in place. The holding element(s) 60 come loose from the hook portion 46 and the protection device 20 now is ready to be deployed (in the manner described earlier, i.e. by activating the pump 15, 15').

[0082] The hold- and release unit 40 is therefore configured to automatically release the at least one of the holding elements when the guiding element 41 is moved from the lower (relative) position into the upper (relative) position by the downward movement of the at least one suction pile 6 into the seabed. No further measures need to be taken to make the protection device 10 ready for deployment.

[0083] More specifically, figures 21A, 21B and 21C are side views showing different stages of a particular embodiment of a hold- and release unit 40 triggering the

release of the seabed scour protection device 10, wherein in figure 21A the foot portion 42 is in the lower position wherein it is not yet touching the seabed, while at the same time moving along with the downward movement of the offshore suction pile 6 that is penetrating (i.e. is moving downward into) the seabed. In figure 21B the foot portion 42 is in the intermediate position. This figure shows the situation that the foot portion 42 has come into contact with the seabed due to the continuous downward movement of the suction pile. The foot portion 42 now remains stationary as the offshore suction pile 6 continues to move downward, but the position of the foot portion 42 relative to the suction pile 6 of course changes (from the lower position to an intermediate position). This also results in a change of the (relative) position of the hook portion 46 that is fixedly connected or integrally formed with the foot portion 42 via the guiding element 41. The guiding element 41 is movable (i.e. can be guided) in the frame part 43 that in turn is fixedly attached to or integrally formed with the carrier 23 (or the steel duct 18). In figure 21C the suction pile has moved further downward so that the upper position relative to the suction pile 6 is eventually reached. The carrier may be touching the seabed or might extend at a small height relative to the seabed. In this position the hook portion 46 no longer holds the holding elements 60 (for instance, holding straps) so that the holding elements 60 are therefore released and the flexible screen is no longer held in position by the hold- and release system 40. Now the pump 15 may be activated to force the flexible radial tubular arms 19 to unroll to the stretched-out (more or less straight) arrangement bringing the protection device in the expanded state.

[0084] In figure 9 is shown how the carrier 23 is attached to the suction pile, i.e. by a plurality of attachment elements 50 located at evenly distributed positions along the side wall 3 of the suction pile 6. In the shown embodiment the attachment element 50 comprises a support 51 formed at the side wall 3 of the suction pile 6 having an opening (eye) for attaching one end of a suspension element 52, such as a steel chain, wherein the opposite end of the suspension element 52 is attached to a similar support 54 provided on the carrier 23. Using the attachments elements 50 the scour protection device 10 can suspended from the suction pile 6 is an easy and reliable manner, proving the scour protection device 10 with a certain freedom of movement relative to the suction pile and only requiring a minimum adaption of a standard suction pile (since only the support 51 is to be formed at the side wall of the pile 6).

[0085] However, in some situations it is not possible or not allowed by the owner of the suction pile to provide any support at the (side wall of the) suction pile 6. For these situations use can be made of a specially designed clamp unit allowing attachment of the protection device 10 by clamping this clamping unit 90 to suction pile, preferably to a top bulkhead thereof, as is shown in figure 11A. Furthermore, in figures 23A-23C an example of such clamping unit 90 is shown in more detail.

[0086] Figure 23A is an elevational view of a clamp unit 90 for clampingly attaching an offshore scour protection device 10 to a reinforcement beam 13 that forms part of the top wall 11 of a suction pile 6, figure 23B a cross-section of the clamp unit 90 and figure 23C a more detailed side view of the clamp unit 90. The clamp unit 90 comprises a central body 91, at opposing sides of which two hook-shaped flanges 92 are formed. The hook-shaped flanges 92 are shaped in such a manner that they can be placed around a ridge typically present at the head end of the reinforcement beam 13. Once the clamp unit 90 is placed with its hook-shaped flanges around the reinforcement beam, the central body is tightened to the reinforcement beam, for instance by two bolts that are bolted into threaded openings 95. The central body 90 further comprises a support 94 having an opening (eye) allowing for attachment of the earlier-mentioned attachment element 50.

[0087] It is to be understood that this invention is not limited to particular aspects described, and, as such, may vary. It is also to be understood that the terminology used herein is for the purpose of describing particular aspects only, and is not intended to be limiting, since the scope of the present invention will be limited only by the appended claims.

Claims

1. Seabed scour protection device for protecting an area of a seabed around at least one offshore suction pile, the at least one offshore suction pile (6-8) comprised of a tubular element

having an open bottom portion and a closed top portion and configured to penetrate the seabed by suction, the seabed scour protection device comprising:

- a carrier (23) configured to be attached to the closed top portion of the offshore

suction pile, the carrier being shaped as to extend circumferentially with a clearance around the offshore suction pile when attached to the top portion of the offshore suction pile;

- a sheet-like flexible screen (29) extending between an inner circumferential edge and

a free outer circumferential edge, wherein along the free outer circumferential edge one or more flexible ballast elements (20) are provided, wherein the flexible screen is configured to be movable between a retracted state wherein the screen is in a rolled-up position and an expanded state wherein the screen is in an un-

rolled position so as to cover the area of the seabed;

- the sheet-like flexible screen further including a plurality of flexible radial tubular arms; **characterised by**
- a duct (18) in fluid connection with the flexible radial tubular arms (19), the duct comprising a pump connection arranged for connecting a pump,
wherein the pump (15) may be connected to the pump connection so as to pump a pressure medium under pressure via the duct into one or more of the flexible radial tubular arms in order to cause the sheet-like flexible screen including the flexible radial tubular arms to move between a retracted state wherein the flexible screen is in a rolled-up position and an expanded state wherein the flexible screen is in an unrolled position so as to cover the area of the seabed thereby substantially avoiding scouring.

2. Seabed scour protection device as claimed in claim 1, wherein the free outer circumferential edge provided with the one or more flexible ballast elements is flexible to the extent that it allows the ballast elements and circumferential outer edge of the screen in the expanded state to track local height variations in the seabed and/or wherein the flexible ballast element or the flexible ballast elements together extend continuously along essentially the entire outer circumferential edge of the flexible screen and/or wherein the one or more ballast elements are formed by one or more steel or iron chains and/or wherein the mass per unit of length of the one or more ballast elements is more than 20 kg/m, preferably between 20 kg/m and 50 kg/m and/or wherein circumferential edge comprises a plurality of separate ballast elements, each of the respective separate ballast elements being arranged between two neighbouring flexible radial tubular arms.

3. Seabed scour protection device as claimed in any of the preceding claims, wherein the flexible screen is subdivided into a plurality of screen segments (99), wherein preferably one or more of the screen segments is foldable to reduce the width of the screen segment and/or wherein one or more of the screen segments are unfoldable to increase the width of the screen segment, wherein one or more of the screen segments preferably comprise one or more folding lines arranged for assisting folding of the screen segment and/or wherein in the expanded state a screen segment preferably has the shape of a truncated triangle, and, preferably, is arranged to be foldable into a rectangular shape.

4. Seabed scour protection device as claimed in claim 3, wherein neighbouring screen segments are mutually connected through a wire connection, wherein the wire connection preferably comprises a wire connected to both screen segments, wherein preferably the wire connection is configured to lace both screen segments together using the wire and/or wherein the wire connection preferably is configured to keep the screen segments connected irrespective of a varying interspace between the screen segments and/or wherein each screen segment preferably is connected to an associated flexible tubular arm by a plurality of loop-shaped connection elements and/or wherein the wire connection is configured to allow it to loosen when the screen segment is folded into the rectangular shape.

5. Seabed scour protection device as claimed in any of the preceding claims, wherein in the retracted state the flexible screen is in a folded and rolled-up position and in the expanded state the screen is in an unrolled and unfolded position and/or wherein the flexible screen in the retracted state has a shape similar to a torus and/or in the expanded state a shape similar to a disc with a central hole and/or wherein the radial width (W) of the flexible segment satisfies $0{,}75D < W < 1.5D$, wherein D is the maximum diameter of the at least one suction pile and/or wherein the radial width (W) of the flexible segment satisfies $W > 2$ m or, preferably, $W > 5$ m.

6. Seabed scour protection device as claimed in any of the preceding claims, further comprising a hold- and release system connected to the carrier and configured to hold the flexible screen in the retracted state and to release the flexible screen allowing the flexible screen to move to the expanded state once the at least one suction pile has penetrated the seabed over a predefined minimum length, wherein the hold- and release system preferably comprises a portion configured to trigger the release of the flexible screen as the portion when in contact with the seabed is caused to move relative to the suction pile by the downward movement of the suction pile into the seabed.

7. Seabed scour protection device as claimed in any of the preceding claims, further comprising a hold- and release system connected to the carrier, the hold- and release system comprising a plurality of hold- and release units distributed over the circumference of the carrier, each hold- and release unit preferably comprising:

- a plurality of holding elements, for instance holding straps, to be arranged around the flexible screen in the retracted state;
- a frame part fixedly attached to or integrally

formed with the carrier;
- a guiding element configured to be guided along the frame part in downward direction substantially parallel to the direction of gravity until a lower position relative to the frame part and in opposite, upward direction until an upper position relative to the frame part;
- a foot portion connected to or integrally formed with a bottom portion of the guiding element and configured to contact the seabed;
- a hook portion connected to or integrally formed with a top portion of the guiding element and configured to releasably hold at least one of the holding elements;
wherein the hook portion is configured to release the at least one of the holding elements when the guiding element is moved from the lower position into the upper position by the downward movement of the at least one suction pile into the seabed.

8. Seabed scour protection device as claimed in any of the preceding claims, wherein the flexible radial tubular arms are formed by inflatable hoses, the inflatable hoses taking a flattened shape in the retracted state and an inflated shape in the expanded state and/or the seabed scour protection device further comprising a pump configured for connection with the pump connection, wherein preferably the pump is removably attached an upper bulkhead in the top portion of the at least one suction pile and/or wherein the pump preferably is configured for inflating the plurality of flexible radial tubular arms in a first mode of operation and for sucking water from the at least one suction pile in a second mode of operation and/or wherein the pump preferably is configured to pump a pressure medium into the flexible radial tubular arms with pressurized fluid with a pressure larger than the local water pressure at the level of the seabed, the pressure medium preferably being a pressurized fluid, for instance, a pressurized liquid, such as water, a pressurized mixture of liquid and solids, such as grout, and/or compressed air.

9. Seabed scour protection device as claimed in any of the preceding claims, wherein the carrier is attached to the top portion of the suction pile by a plurality of attachment elements, the attachment elements being configured to allow the protection device to be suspended from at least one of the circumferential outer surfaces of the offshore suction pile and the top bulkhead closing off the top portion of the tubular element, wherein the attachment element preferably comprises a clamp unit configured to allow attachment by clamping the clamping unit to suction pile, preferably to a top bulkhead thereof.

10. Seabed scour protection device as claimed in any of the preceding claims, wherein the flexible radial tubular arms extend in radial directions at positions that are evenly distributed along the circumference of the carrier and/or wherein the number of arms is at least four, preferably at least eight, more preferably at least sixteen arms and/or wherein the duct comprises a ring pipeline, preferably formed of at least two interconnected steel pipe segments, arranged around the circumference of the at least one suction pile and/or wherein a gap between the inner circumferential edge of the carrier and the outer surface of the offshore suction pile is at least partially sealed by a flexible collar resting against the outer surface of the offshore suction pile.

11. An assembly comprising at least one suction pile and a seabed scour protection device as claimed in any of the preceding claims, wherein the seabed scour protection device is attached to the top portion of the suction pile, the assembly preferably comprising two or more suction piles, each suction pile being provided with a seabed scour protection device and/or two or more suction piles, provided with one common seabed scour protection device, wherein the flexible screen in the expanded state preferably has a generally polygonal shape, for instance an octagon.

12. Method for protecting an area of a seabed around at least one offshore suction pile with a seabed scour protection device as claimed in any of claims 1-10 and/or an assembly as claimed in claim 11, the method comprising:

- connecting a pump to the pump connection;
- releasing the sheet-like flexible screen;
- pumping a pressure medium under pressure via de pump connection and the duct into one or more of the flexible radial tubular arms, thereby causing the released sheet-like flexible screen including the flexible radial tubular arms to move between a retracted state wherein the flexible screen is in a rolled-up position and an expanded state wherein the flexible screen is in an unrolled position, thereby covering the area of the seabed.

13. Method as claimed in claim 12, comprising:

- removing water from the at least one suction pile so as to move the at least one suction pile downward into the seabed;
- releasing the flexible screen by causing a portion of a hold- and release system, upon contact of the portion with the seabed, to move relative to the suction pile by the downward movement of the suction pile into the seabed.

14. Method as claimed in claim 12 or 13, comprising:

- removing at least a portion of the pressure medium from the one or more radial tubular arms after the flexible screen has attained the expanded state;

and/or comprising reintroducing the pressure medium into one or more of the radial tubular arms under sufficient pressure after the pressure medium has been removed from the one or more radial tubular arms.

15. Method of assembling a seabed scour protection device as claimed in any of claims 1-10, the method comprising:

- attaching screen segments of the flexible screen to the carrier;
- connecting one or more screen elements to respective flexible radial tubular arms using wire connections;
- folding at least one of the screen segments over one or more folding lines, thereby allowing the wire connection to be loosened;
- rolling up the at least one screen segment and the respective flexible radial tubular arms into the retracted state;
- tension the wire connection of the least one screen segment.

Patentansprüche

1. Meeresbodenkolkschutzvorrichtung zum Schutz eines Bereichs eines Meeresbodens um mindestens einen Offshore-Saugpfahl herum, wobei der mindestens eine Offshore-Saugpfahl (6-8) ein rohrförmiges Element umfasst, das einen offenen unteren Abschnitt und einen geschlossenen oberen Abschnitt aufweist und so konfiguriert ist, dass es durch Saugen in den Meeresboden eindringt, die Meeresbodenkolkschutzvorrichtung umfassend:

- einen Träger (23), der konfiguriert ist, um an dem geschlossenen oberen Abschnitt des Offshore-Saugpfahls befestigt zu werden, wobei der Träger so geformt ist, dass er sich in Umfangsrichtung mit einem Abstand um den Offshore-Saugpfahl erstreckt, wenn er an dem oberen Abschnitt des Offshore-Saugpfahls befestigt ist;
- einen blattartigen flexiblen Bildschirm (29), der sich zwischen einem inneren umlaufenden Rand und einem freien äußeren umlaufenden Rand erstreckt, wobei entlang des freien äußeren umlaufenden Randes ein oder mehrere flexible Ballastelemente (20) vorgesehen sind, wobei der flexible Bildschirm so konfiguriert ist, dass er zwischen einem eingezogenen Zustand, in dem sich der Bildschirm in einer aufgerollten Position befindet, und einem aufgeweiteten Zustand, in dem sich der Bildschirm in einer ausgerollten Position befindet, beweglich ist, um den Bereich des Meeresbodens abzudecken;
- der blattartige flexible Bildschirm ferner eine Vielzahl flexibler radialer rohrförmiger Arme einschließt; **gekennzeichnet durch**
- einen Kanal (18), der in Fluidverbindung mit den flexiblen radialen rohrförmigen Armen (19) steht, wobei der Kanal eine Pumpenverbindung umfasst, die zum Verbinden einer Pumpe angeordnet ist,
wobei die Pumpe (15) mit der Pumpenverbindung verbunden sein kann, um ein Druckmedium unter Druck über den Kanal in einen oder mehrere der flexiblen radialen Rohrarme zu pumpen, um zu bewirken, dass sich der blattartige flexible Bildschirm, der die flexiblen radialen rohrförmigen Arme einschließt, zwischen einem eingezogenen Zustand, in dem sich der flexible Bildschirm in einer aufgerollten Position befindet, und einem ausgedehnten Zustand, in dem sich der flexible Bildschirm in einer ausgerollten Position befindet, bewegt, um den Bereich des Meeresbodens abzudecken und dadurch im Wesentlichen eine Kolkbildung zu vermeiden.

2. Meeresbodenkolkschutzvorrichtung nach Anspruch 1, wobei der mit dem einen oder den mehreren flexiblen Ballastelementen bereitgestellte freie äußere umlaufende Rand so flexibel ist, dass er es den Ballastelementen und dem umlaufenden äußeren Rand des Bildschirms im expandierten Zustand ermöglicht, lokalen Höhenschwankungen des Meeresbodens zu folgen und/oder wobei sich das flexible Ballastelement oder die flexiblen Ballastelemente zusammen kontinuierlich entlang im Wesentlichen des gesamten äußeren Umfangsrandes des flexiblen Bildschirms erstrecken und/oder wobei das eine oder die mehreren Ballastelemente durch eine oder mehrere Stahl- oder Eisenketten gebildet werden und/oder wobei die Masse pro Längeneinheit des einen oder der mehreren Ballastelemente mehr als 20 kg/m, vorzugsweise zwischen 20 kg/m und 50 kg/m beträgt und/oder wobei der Umfangsrand eine Vielzahl von separaten Ballastelementen umfasst, wobei jedes der jeweiligen separaten Ballastelemente zwischen zwei benachbarten flexiblen radialen rohrförmigen Armen angeordnet ist.

3. Meeresbodenkolkschutzvorrichtung nach einem der vorstehenden Ansprüche, wobei der flexible Bildschirm in eine Vielzahl von Bildschirmsegmenten (99) unterteilt ist,
wobei vorzugsweise eines oder mehrere der Bildschirmsegmente gefaltet werden können, um die

Breite des Bildschirmsegments zu verringern, und/oder wobei eines oder mehrere der Bildschirmsegmente aufgefaltet werden können, um die Breite des Bildschirmsegments zu erhöhen, wobei eines oder mehrere der Bildschirmsegmente vorzugsweise eine oder mehrere Faltleitungen aufweisen, die so angeordnet sind, dass sie das Falten des Bildschirmsegments unterstützen, und/oder wobei ein Bildschirmsegment im aufgefalteten Zustand vorzugsweise die Form eines Dreiecksstumpfs aufweist und vorzugsweise so angeordnet ist, dass es in eine rechteckige Form gefaltet werden kann.

4. Meeresbodenkolkschutzvorrichtung nach Anspruch 3, wobei benachbarte Bildschirmsegmente durch eine Drahtverbindung miteinander verbunden sind, wobei die Drahtverbindung vorzugsweise einen Draht umfasst, der mit beiden Bildschirmsegmenten verbunden ist, wobei vorzugsweise die Drahtverbindung so konfiguriert ist, dass sie beide Bildschirmsegmente unter Verwendung des Drahtes zusammenschnürt und/oder wobei die Drahtverbindung vorzugsweise konfiguriert ist, um die Bildschirmsegmente unabhängig von einem variierenden Zwischenraum zwischen den Bildschirmsegmenten verbunden zu halten und/oder wobei jedes Bildschirmsegment vorzugsweise mit einem zugeordneten flexiblen röhrenförmigen Arm durch eine Vielzahl von schleifenförmigen Verbindungselementen verbunden ist und/oder wobei die Drahtverbindung konfiguriert ist, um zu ermöglichen, dass sie sich löst, wenn das Bildschirmsegment in die rechteckige Form gefaltet wird.

5. Meeresbodenkolkschutzvorrichtung nach einem der vorstehenden Ansprüche, wobei sich der flexible Bildschirm im eingefahrenen Zustand in einer gefalteten und aufgerollten Position und im ausgefahrenen Zustand in einer ausgerollten und ausgeklappten Position befindet und/oder wobei der flexible Bildschirm im eingefahrenen Zustand eine torusähnliche Form und/oder im ausgefahrenen Zustand eine scheibenähnliche Form mit einem zentralen Loch aufweist und/oder wobei die radiale Breite (W) des flexiblen Segments $0{,}75D < W < 1{,}5D$ genügt, wobei D der maximale Durchmesser des mindestens einen Saugpfahls ist und/oder wobei die radiale Breite (W) des flexiblen Segments $W > 2$ m oder vorzugsweise $W > 5$ m genügt.

6. Meeresbodenkolkschutzvorrichtung nach einem der vorstehenden Ansprüche, die ferner ein Halte- und Freigabesystem umfasst, das mit dem Träger verbunden und konfiguriert ist, um den flexiblen Bildschirm in dem eingezogenen Zustand zu halten und den flexiblen Bildschirm freizugeben, sodass sich der flexible Bildschirm in den expandierten Zustand bewegen kann, sobald der mindestens eine Saugpfahl den Meeresboden über eine vordefinierte Mindestlänge durchdrungen hat, wobei das Halte- und Freigabesystem vorzugsweise einen Abschnitt umfasst, der konfiguriert ist, um die Freigabe des flexiblen Bildschirms auszulösen, wenn der Abschnitt, wenn er in Kontakt mit dem Meeresboden ist, durch die Abwärtsbewegung des Saugpfahls in den Meeresboden zu einer Bewegung relativ zum Saugpfahl veranlasst wird.

7. Meeresbodenkolkschutzvorrichtung nach einem der vorstehenden Ansprüche, ferner umfassend ein mit dem Träger verbundenes Halte- und Freigabesystem, wobei das Halte- und Freigabesystem eine Vielzahl von über den Umfang des Trägers verteilten Halte- und Freigabeeinheiten umfasst, jede Halte- und Freigabeeinheit vorzugsweise umfassend:

- eine Vielzahl von Halteelementen, zum Beispiel Haltebänder, die im eingefahrenen Zustand um den flexiblen Bildschirm herum angeordnet werden;
- einen Rahmenteill, der fest mit dem Träger verbunden oder einstückig mit diesem geformt ist;
- ein Führungselement, das konfiguriert ist, um entlang des Rahmenteils in Abwärtsrichtung im Wesentlichen parallel zur Richtung der Schwerkraft bis zu einer unteren Position relativ zum Rahmenteil und in entgegengesetzter, aufwärts gerichteter Richtung bis zu einer oberen Position relativ zum Rahmenteil geführt zu werden;
- einen Fußabschnitt, der mit einem unteren Abschnitt des Führungselements verbunden oder einstückig damit ausgebildet ist und konfiguriert ist, den Meeresboden zu berühren;
- einen Hakenabschnitt, der mit einem oberen Abschnitt des Führungselements verbunden oder einstückig damit ausgebildet ist und konfiguriert ist, um mindestens eines der Halteelemente lösbar zu halten;

wobei der Hakenabschnitt konfiguriert ist, um das mindestens eine der Halteelemente freizugeben, wenn das Führungselement durch die Abwärtsbewegung des mindestens einen Saugpfahls in den Meeresboden von der unteren Position in die obere Position bewegt wird.

8. Meeresbodenkolkschutzvorrichtung nach einem der vorstehenden Ansprüche, wobei die flexiblen radialen rohrförmigen Arme durch aufblasbare Schläuche gebildet werden, wobei die aufblasbaren Schläuche im eingefahrenen Zustand eine abgeflachte Form und im ausgefahrenen Zustand eine aufgeblasene Form annehmen und/oder die Meeresbodenkolkschutzvorrichtung ferner eine Pumpe umfasst, die für die Verbindung mit der Pumpenverbindung konfiguriert ist, wobei die Pumpe vorzugsweise an ei-

nem oberen Schott im oberen Abschnitt des mindestens einen Saugpfahls entfernbar angebracht ist und/oder wobei die Pumpe vorzugsweise konfiguriert ist, um die Vielzahl von flexiblen radialen rohrförmigen Armen in einem ersten Betriebsmodus aufzublasen und um in einem zweiten Betriebsmodus Wasser aus dem mindestens einen Saugpfahl anzusaugen und/oder wobei die Pumpe vorzugsweise konfiguriert ist, um ein Druckmedium in die flexiblen radialen rohrförmigen Arme mit unter Druck stehendem Fluid zu pumpen, dessen Druck größer ist als der lokale Wasserdruck auf der Ebene des Meeresbodens, wobei das Druckmedium vorzugsweise ein unter Druck stehendes Fluid ist, beispielsweise eine unter Druck stehende Flüssigkeit, wie Wasser, eine unter Druck stehende Mischung aus Flüssigkeit und Feststoffen, wie Mörtel, und/oder Druckluft.

9. Meeresbodenkolkschutzvorrichtung nach einem der vorstehenden Ansprüche, wobei der Träger am oberen Abschnitt des Saugpfahls durch eine Vielzahl von Befestigungselementen befestigt ist, wobei die Befestigungselemente konfiguriert sind, um zu ermöglichen, dass die Schutzvorrichtung an mindestens einer der äußeren Umfangsoberflächen des Offshore-Saugpfahls und des oberen Schotts, das den oberen Abschnitt des rohrförmigen Elements abschließt, aufgehängt werden kann, wobei das Befestigungselement vorzugsweise eine Klemmeinheit umfasst, die konfiguriert ist, um eine Befestigung durch Festklemmen der Klemmeinheit am Saugpfahl, vorzugsweise an einem oberen Schott davon, zu ermöglichen.

10. Meeresbodenkolkschutzvorrichtung nach einem der vorstehenden Ansprüche, wobei sich die flexiblen radialen rohrförmigen Arme in radialen Richtungen an Positionen erstrecken, die gleichmäßig über den Umfang des Trägers verteilt sind, und/oder wobei die Anzahl der Arme mindestens vier, vorzugsweise mindestens acht, besonders bevorzugt mindestens sechzehn Arme beträgt und/oder wobei der Kanal eine Ringleitung umfasst, die vorzugsweise aus mindestens zwei miteinander verbundenen Stahlrohrsegmenten gebildet ist, die um den Umfang des mindestens einen Saugpfahls angeordnet sind und/oder wobei ein Spalt zwischen dem inneren umlaufenden Rand des Trägers und der äußeren Oberfläche des Offshore-Saugpfahls mindestens teilweise durch einen flexiblen Kragen abgedichtet ist, der an der äußeren Oberfläche des Offshore-Saugpfahls anliegt.

11. Baugruppe, umfassend mindestens einen Saugpfahl und eine Meeresbodenkolkschutzvorrichtung nach einem der vorstehenden Ansprüche, wobei die Meeresbodenkolkschutzvorrichtung am oberen Abschnitt des Saugpfahls angebracht ist, wobei die Baugruppe vorzugsweise zwei oder mehr Saugpfähle umfasst, wobei jeder Saugpfahl mit einer Meeresbodenkolkschutzvorrichtung und/oder zwei oder mehr Saugpfähle, die mit einer gemeinsamen Meeresbodenkolkschutzvorrichtung versehen sind, versehen ist, wobei der flexible Bildschirm im expandierten Zustand vorzugsweise eine im Allgemeinen polygonale Form, beispielsweise ein Achteck, aufweist.

12. Verfahren zum Schützen eines Bereichs eines Meeresbodens um mindestens einen Offshore-Saugpfahl mit einer Meeresbodenkolkschutzvorrichtung nach einem der Ansprüche 1 bis 10 und/oder einer Baugruppe nach Anspruch 11, das Verfahren umfassend:

- Verbinden einer Pumpe mit der Pumpenverbindung;
- Freigeben des blattförmigen, flexiblen Bildschirms;
- Pumpen eines Druckmediums unter Druck über die Pumpenverbindung und den Kanal in einen oder mehrere der flexiblen radialen rohrförmigen Arme, wodurch bewirkt wird, dass sich der freigegebene blattartige flexible Bildschirm, der die flexiblen radialen rohrförmigen Arme umfasst, zwischen einem eingezogenen Zustand, wobei sich der flexible Bildschirm in einer aufgerollten Position befindet, und einem ausgedehnten Zustand, wobei sich der flexible Bildschirm in einer ausgerollten Position befindet, bewegt, wodurch der Bereich des Meeresbodens abgedeckt wird.

13. Verfahren nach Anspruch 12, umfassend:

- Entfernen von Wasser aus dem mindestens einen Saugpfahl, um den mindestens einen Saugpfahl nach unten in den Meeresboden zu bewegen;
- Freigeben des flexiblen Bildschirms, indem ein Abschnitt eines Halte- und Freigabesystems bei Kontakt des Abschnitts mit dem Meeresboden durch die Abwärtsbewegung des Saugpfahls in den Meeresboden relativ zum Saugpfahl bewegt wird.

14. Verfahren nach Anspruch 12 oder 13, umfassend:

- Entfernen mindestens eines Abschnitts des Druckmediums von dem einen oder den mehreren radialen rohrförmigen Armen, nachdem der flexible Bildschirm den expandierten Zustand erreicht hat;

und/oder umfassend das Wiedereinführen des Druckmediums in einen oder mehrere der radialen rohrförmigen Arme unter ausreichendem

Druck, nachdem das Druckmedium aus dem einen oder den mehreren radialen rohrförmigen Armen entfernt worden ist.

15. Verfahren zur Montage einer Meeresbodenkolkschutzvorrichtung nach einem der Ansprüche 1 bis 10, das Verfahren umfassend:

- Befestigen von Bildschirmsegmenten des flexiblen Bildschirms auf dem Träger;
- Verbinden eines oder mehrerer Bildschirmelemente mit entsprechenden flexiblen radialen rohrförmigen Armen über Drahtverbindungen;
- Falten mindestens eines der Bildschirmsegmente über eine oder mehrere Faltungslinien, wodurch die Drahtverbindung gelockert werden kann;
- Aufrollen des mindestens einen Bildschirmsegments und der jeweiligen flexiblen radialen rohrförmigen Arme in den eingefahrenen Zustand;
- Spannen der Drahtverbindung des mindestens einen Bildschirmsegments.

Revendications

1. Dispositif de protection contre l'affouillement de fond marin pour protéger une zone d'un fond marin autour d'au moins un pieu d'aspiration en mer, l'au moins un pieu d'aspiration en mer (6-8) étant constituée d'un élément tubulaire ayant une partie inférieure ouverte et une partie supérieure fermée et conçue pour pénétrer dans le fond marin par aspiration, le dispositif de protection contre l'affouillement de fond marin comprenant :

- un support (23) conçu pour être fixé à la partie supérieure fermée du pieu d'aspiration en mer, le support étant façonné de manière à s'étendre circonférentiellement avec un jeu autour du pieu d'aspiration en mer lorsqu'il est fixé à la partie supérieure du pieu d'aspiration en mer ;
- un tamis souple en forme de feuille (29) s'étendant entre un bord circonférentiel intérieur et un bord circonférentiel extérieur libre, dans lequel le long du bord circonférentiel extérieur libre est pourvu d'un ou de plusieurs éléments de lestage souples (20), dans lequel le tamis souple est conçu pour être déplacé entre un état rétracté dans lequel le tamis est en position enroulée et un état déployé dans lequel le tamis est en position déroulée, de manière à couvrir la zone du fond marin ;
- le tamis souple en forme de feuille comportant en outre une pluralité de bras tubulaires radiaux souples ; **caractérisé par**
- un conduit (18) en liaison fluidique avec les bras tubulaires radiaux souples (19), le conduit comprenant un raccord de pompe prévu pour raccorder une pompe,
dans lequel la pompe (15) peut être raccordée au raccord de pompe de manière à pomper un moyen de pression sous pression par l'intermédiaire du conduit dans un ou plusieurs des bras tubulaires radiaux souples afin d'amener le tamis souple en forme de feuille, y compris les bras tubulaires radiaux souples, à se déplacer entre un état rétracté dans lequel le tamis souple est en position enroulée et un état déployé dans lequel le tamis souple est en position déroulée de manière à couvrir la zone du fond marin, évitant essentiellement ainsi l'affouillement.

2. Dispositif de protection contre l'affouillement de fond marin selon la revendication 1, dans lequel le bord circonférentiel extérieur libre pourvu du ou des éléments de lestage souples est souple dans la mesure où il permet aux éléments de lestage et au bord circonférentiel extérieur du tamis à l'état déployé de suivre les variations locales de hauteur du fond marin et/ou dans lequel l'élément de lestage souple ou les éléments de lestage souples se déploient ensemble de manière continue le long de la quasi-totalité du bord circonférentiel extérieur du tamis souple et/ou dans lequel le ou les éléments de lestage sont formés d'une ou de plusieurs chaînes en acier ou en fer et/ou dans lequel la masse par unité de longueur du ou des éléments de lestage est supérieure à 20 kg/m, de préférence entre 20 kg/m et 50 kg/m et/ou dans lequel le bord circonférentiel comprend une pluralité d'éléments de lestage séparés, chacun des éléments de lestage séparés respectifs étant disposé entre deux bras tubulaires radiaux souples voisins.

3. Dispositif de protection contre l'affouillement de fond marin selon l'une quelconque des revendications précédentes, dans lequel le tamis souple est divisé en une pluralité de segments de tamis (99),
dans lequel, de préférence, un ou plusieurs segments de tamis sont pliables pour réduire la largeur du segment de tamis et/ou dans lequel un ou plusieurs segments de tamis sont dépliables pour augmenter la largeur du segment de tamis, dans lequel un ou plusieurs segments de tamis comprennent de préférence une ou plusieurs lignes de pliage disposées de manière à faciliter le pliage du segment de tamis et/ou dans lequel, à l'état déployé, un segment de tamis a de préférence la forme d'un triangle tronqué et, de préférence, est disposé pour pouvoir être plié en une forme rectangulaire.

4. Dispositif de protection contre l'affouillement de fond marin selon la revendication 3, dans lequel les segments de tamis voisins sont mutuellement reliés par

une liaison filaire, dans lequel la liaison filaire comprend de préférence un fil relié aux deux segments de tamis, dans lequel, de préférence, la liaison filaire est conçue pour relier les deux segments de tamis à l'aide du fil et/ou dans lequel la liaison filaire est de préférence conçue pour maintenir les segments de tamis reliés indépendamment d'un espace intermédiaire variable entre les segments de tamis et/ou dans lequel chaque segment de tamis est de préférence relié à un bras tubulaire souple associé par une pluralité d'éléments de liaison en forme de boucle et/ou dans lequel la liaison filaire est conçue pour lui permettre de se desserrer lorsque le segment de tamis est plié dans la forme rectangulaire.

5. Dispositif de protection contre l'affouillement de fond marin selon l'une quelconque des revendications précédentes, dans lequel, à l'état rétracté, le tamis souple est en position pliée et enroulée et, à l'état déployé, le tamis est en position déroulée et dépliée et/ou dans lequel le tamis souple, à l'état rétracté, a une forme similaire à un tore et/ou, à l'état déployé, une forme similaire à un disque avec un trou central et/ou dans lequel la largeur radiale (W) du segment souple satisfait à $0,75D < W < 1,5D$, dans lequel D est le diamètre maximal de l'au moins un pieu d'aspiration et/ou dans lequel la largeur radiale (W) du segment souple est égale à $W > 2$ m ou, de préférence, à $W > 5$ m.

6. Dispositif de protection contre l'affouillement de fond marin selon l'une quelconque des revendications précédentes, comprenant en outre un système de maintien et de libération relié au support et conçu pour maintenir le tamis souple à l'état rétracté et pour libérer le tamis souple afin qu'il passe à l'état déployé une fois que le pieu d'aspiration a au moins pénétré le fond marin sur une longueur minimale prédéfinie, dans lequel le système de maintien et de libération comprend de préférence une partie conçue pour déclencher la libération du tamis souple lorsque la partie en contact avec le fond marin est amenée à se déplacer par rapport au pieu d'aspiration par le mouvement descendant du pieu d'aspiration dans le fond marin.

7. Dispositif de protection contre l'affouillement de fond marin selon l'une quelconque des revendications précédentes, comprenant en outre un système de maintien et de libération relié au support, le système de maintien et de libération comprenant une pluralité d'unités de maintien et de libération réparties sur la circonférence du support, chaque unité de maintien et de libération comprenant de préférence :

- une pluralité d'éléments de maintien, par exemple des sangles de maintien, à disposer autour du tamis souple à l'état rétracté ;
- une partie de cadre fixée de manière fixe ou intégrée au support ;
- un élément de guidage conçu pour être guidé le long de la partie du cadre dans une direction descendante sensiblement parallèle à la direction de gravité jusqu'à une position inférieure par rapport à la partie de cadre et dans une direction opposée, ascendante, jusqu'à une position supérieure par rapport à la partie de cadre ;
- une partie de pied relié à la partie inférieure de l'élément de guidage ou formé intégralement avec elle et conçu pour entrer en contact avec le fond marin ;
- une partie crochet reliée ou formée intégralement avec une partie supérieure de l'élément de guidage et conçue pour retenir de manière amovible au moins un des éléments de maintien ;

dans lequel la partie crochet est conçue pour libérer au moins un des éléments de maintien lorsque l'élément de guidage est déplacé de la position inférieure à la position supérieure par le mouvement vers le bas d'au moins un pieu d'aspiration dans le fond marin.

8. Dispositif de protection contre l'affouillement de fond marin selon l'une quelconque des revendications précédentes, dans lequel les bras tubulaires radiaux souples sont formés par des tuyaux gonflables, les tuyaux gonflables prenant une forme aplatie à l'état rétracté et une forme gonflée à l'état déployé et/ou le dispositif de protection contre l'affouillement de fond marin comprend en outre une pompe conçue pour être reliée à la liaison de pompe, dans lequel la pompe est de préférence fixée de manière amovible à une cloison supérieure dans la partie supérieure de l'au moins un pieu d'aspiration et/ou la pompe est de préférence conçue pour gonfler la pluralité de bras tubulaires radiaux souples dans un premier mode de fonctionnement et pour aspirer l'eau de l'au moins un pieu d'aspiration dans un second mode de fonctionnement et/ou la pompe est de préférence conçue pour pomper un moyen sous pression dans les bras tubulaires radiaux souples avec un fluide sous pression dont la pression est supérieure à la pression locale de l'eau au niveau du fond de la mer, le moyen de pression est de préférence un fluide sous pression, par exemple un liquide sous pression, tel que de l'eau, un mélange sous pression de liquide et de solides, tel qu'un coulis, et/ou de l'air comprimé.

9. Dispositif de protection contre l'affouillement de fond marin selon l'une quelconque des revendications précédentes, dans lequel le support est fixé à la partie supérieure du pieu d'aspiration par une pluralité d'éléments de fixation, les éléments de fixation étant conçus pour permettre au dispositif de protection d'être suspendu à au moins l'une des surfaces

extérieures circonférentielles du pieu d'aspiration en mer et à la cloison supérieure fermant la partie supérieure de l'élément tubulaire, dans lequel l'élément de fixation comprend de préférence une unité de serrage conçue pour permettre la fixation par serrage de l'unité de serrage au pieu d'aspiration, de préférence à une cloison supérieure de cette dernière.

10. Dispositif de protection contre l'affouillement de fond marin selon l'une quelconque des revendications précédentes, dans lequel les bras tubulaires radiaux souples s'étendent dans des directions radiales à des positions qui sont uniformément réparties le long de la circonférence du support et/ou dans lequel le nombre de bras est d'au moins quatre, de préférence d'au moins huit, plus préférablement d'au moins seize bras et/ou dans lequel le conduit comprend une canalisation circulaire, de préférence formée d'au moins deux segments de tuyaux en acier reliés entre eux, disposés autour de la circonférence de l'au moins un pieu d'aspiration et/ou dans lequel un espace entre le bord circonférentiel intérieur du support et la surface extérieure du pieu d'aspiration en mer est au moins partiellement scellé par un collier souple reposant sur la surface extérieure du pieu d'aspiration en mer.

11. Ensemble comprenant au moins un pieu d'aspiration et un dispositif de protection contre l'affouillement de fond marin selon l'une quelconque des revendications précédentes, dans lequel le dispositif de protection contre l'affouillement de fond marin est fixé à la partie supérieure du pieu d'aspiration, l'ensemble comprenant de préférence deux pieux d'aspiration ou plus, chaque pieu d'aspiration étant pourvue d'un dispositif de protection contre l'affouillement de fond marin et/ou deux pieux d'aspiration ou plus, pourvues d'un dispositif commun de protection contre l'affouillement de fond marin, dans lequel le tamis souple à l'état déployé a de préférence une forme généralement polygonale, par exemple un octogone.

12. Procédé de protection d'une zone d'un fond marin autour d'au moins un pieu d'aspiration en mer à l'aide d'un dispositif de protection contre l'affouillement de fond marin selon l'une quelconque des revendications 1 à 10 et/ou d'un ensemble selon la revendication 11, le procédé comprenant :

- le raccordement d'une pompe au raccord de pompe ;
- la libération du tamis souple en forme de feuille ;
- le pompage d'un moyen de pression sous pression par l'intermédiaire du raccord de pompe et du conduit dans un ou plusieurs des bras tubulaires radiaux souples, amenant ainsi le déplacement du tamis souple en forme de feuille libérée, y compris les bras tubulaires radiaux souples, entre un état rétracté dans lequel le tamis souple est en position enroulée et un état déployé dans lequel le tamis souple est en position déroulée, recouvrant ainsi la zone du fond marin.

13. Procédé selon la revendication 12, comprenant :

- l'évacuation de l'eau de l'au moins un pieu d'aspiration de manière à déplacer l'au moins un pieu d'aspiration vers le bas dans le fond marin ;
- la libération du tamis souple en amenant une partie d'un système de maintien et de libération, au contact de la partie avec le fond marin, à se déplacer par rapport au pieu d'aspiration par le mouvement descendant du pieu d'aspiration dans le fond marin.

14. Procédé selon les revendications 12 ou 13, comprenant :

- le retrait d'au moins une partie du moyen de pression du ou des bras tubulaires radiaux une fois que le tamis souple a atteint l'état de déploiement ;

et/ou comprenant la réintroduction du moyen de pression dans un ou plusieurs des bras tubulaires radiaux sous une pression suffisante après que le moyen de pression a été éliminé du ou des bras tubulaires radiaux.

15. Procédé d'assemblage d'un dispositif de protection contre l'affouillement de fond marin selon l'une quelconque des revendications 1 à 10, comprenant :

- la fixation des segments de tamis souple sur le support ;
- la liaison d'un ou plusieurs éléments de tamis aux bras tubulaires radiaux souples respectifs à l'aide de liaisons filaires ;
- le pliage d'au moins un des segments de tamis sur une ou plusieurs lignes de pliage, ce qui permet ainsi de desserrer la liaison de fil ;
- l'enroulement d'au moins un segment de tamis et des bras tubulaires radiaux souples respectifs dans l'état rétracté ;
- le fait de tendre la liaison filaire de l'au moins un segment de tamis.

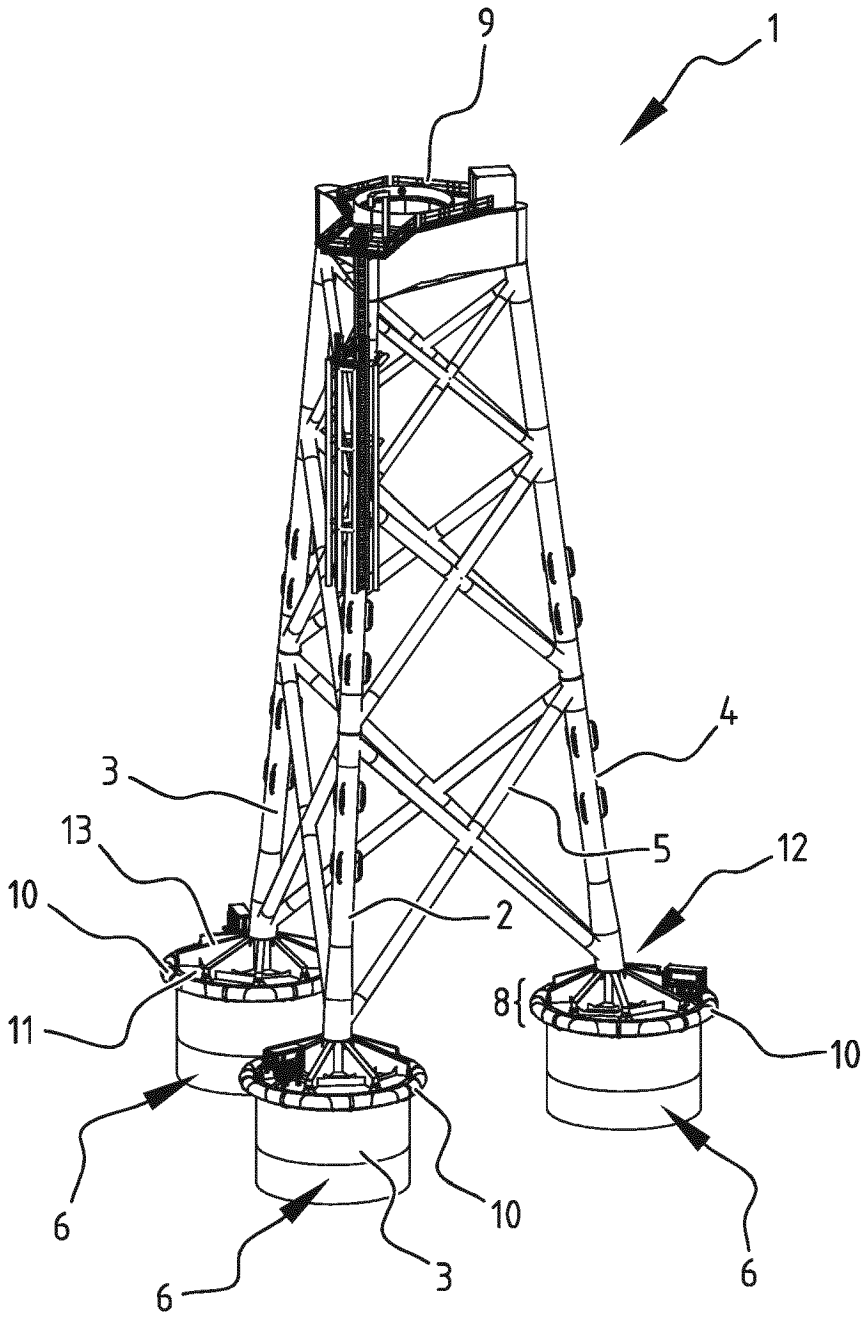

FIG. 1A

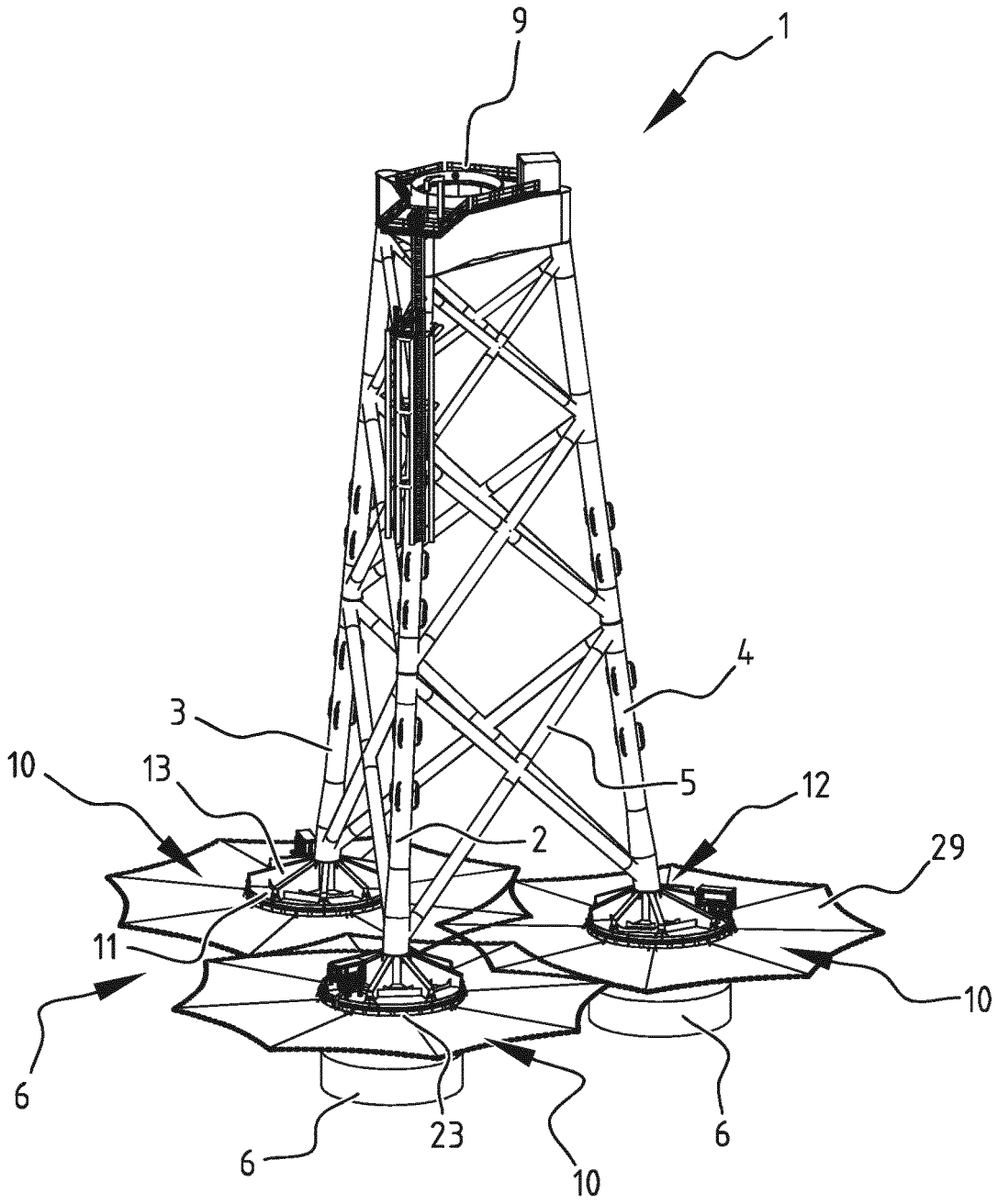

FIG. 1B

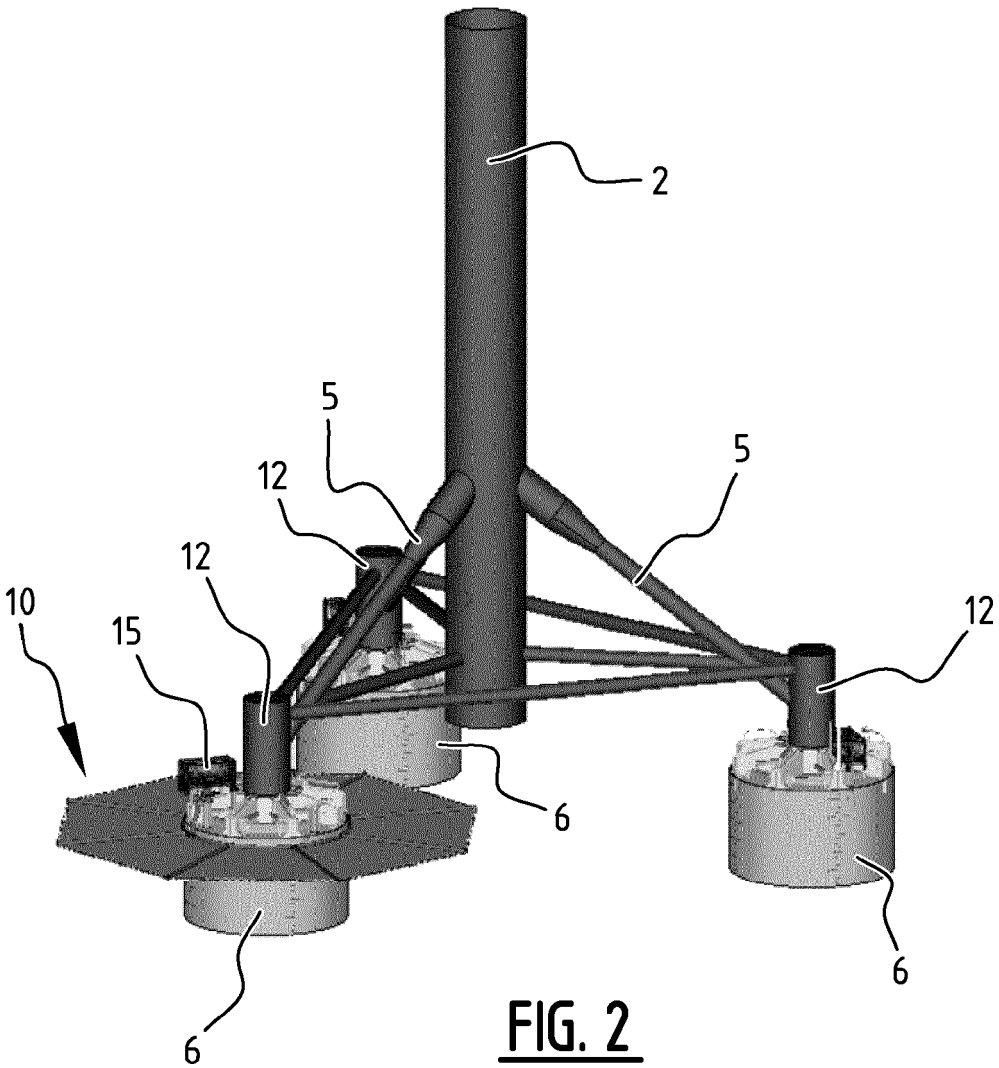

FIG. 2

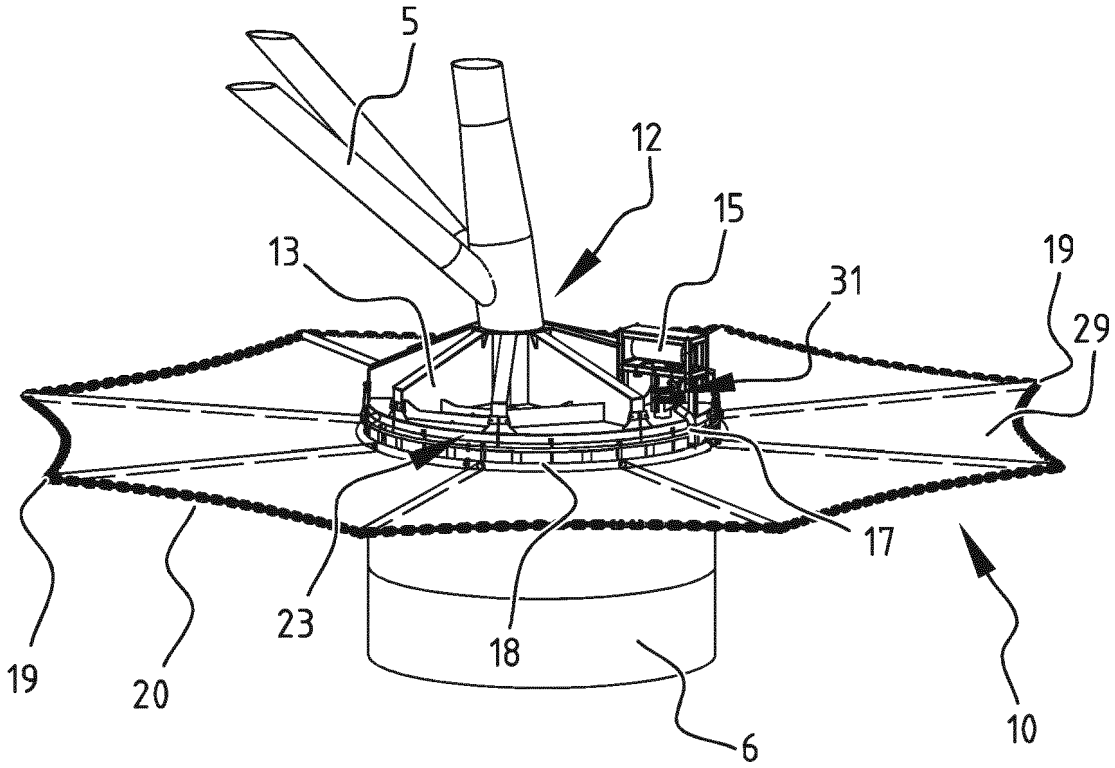

FIG. 3

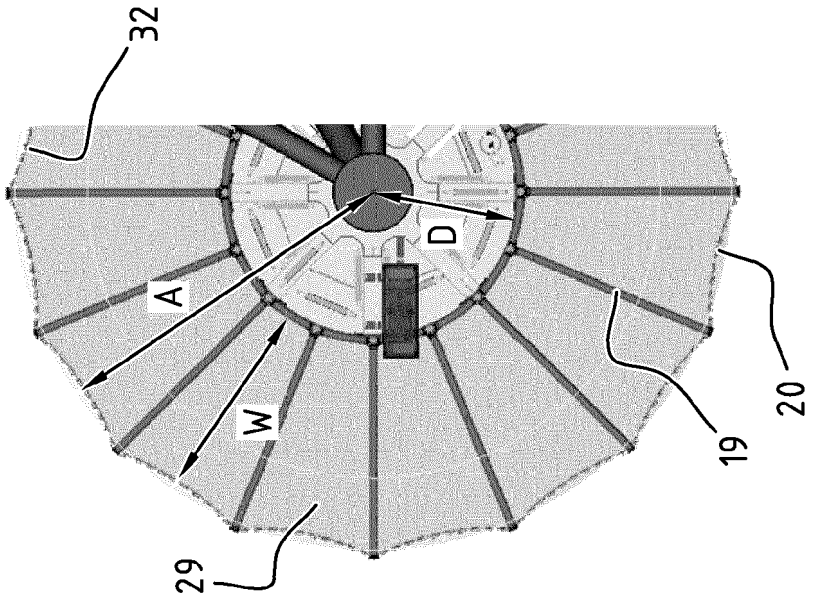

FIG. 4B

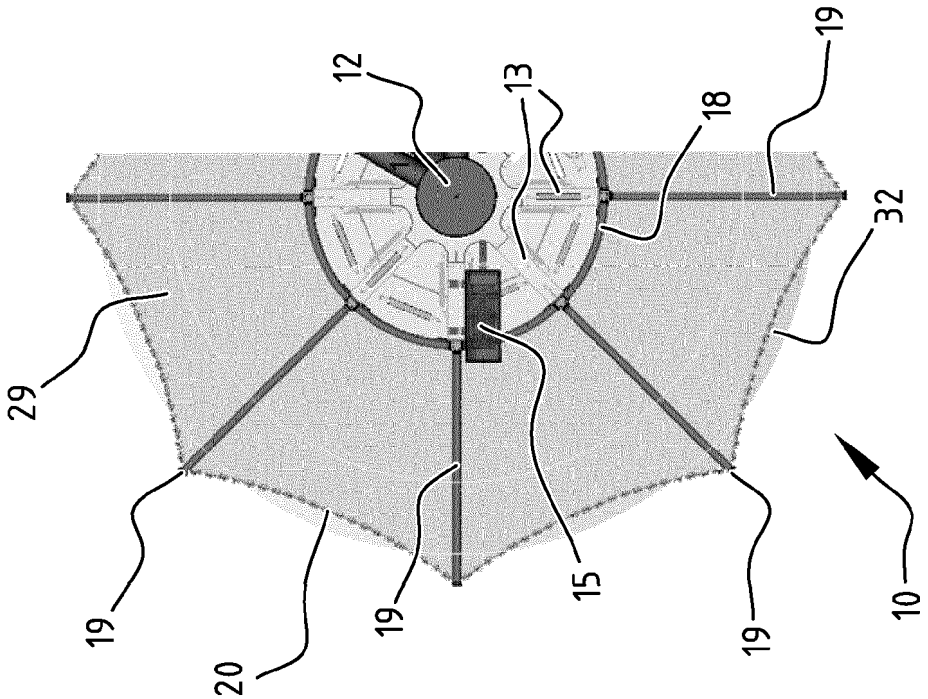

FIG. 4A

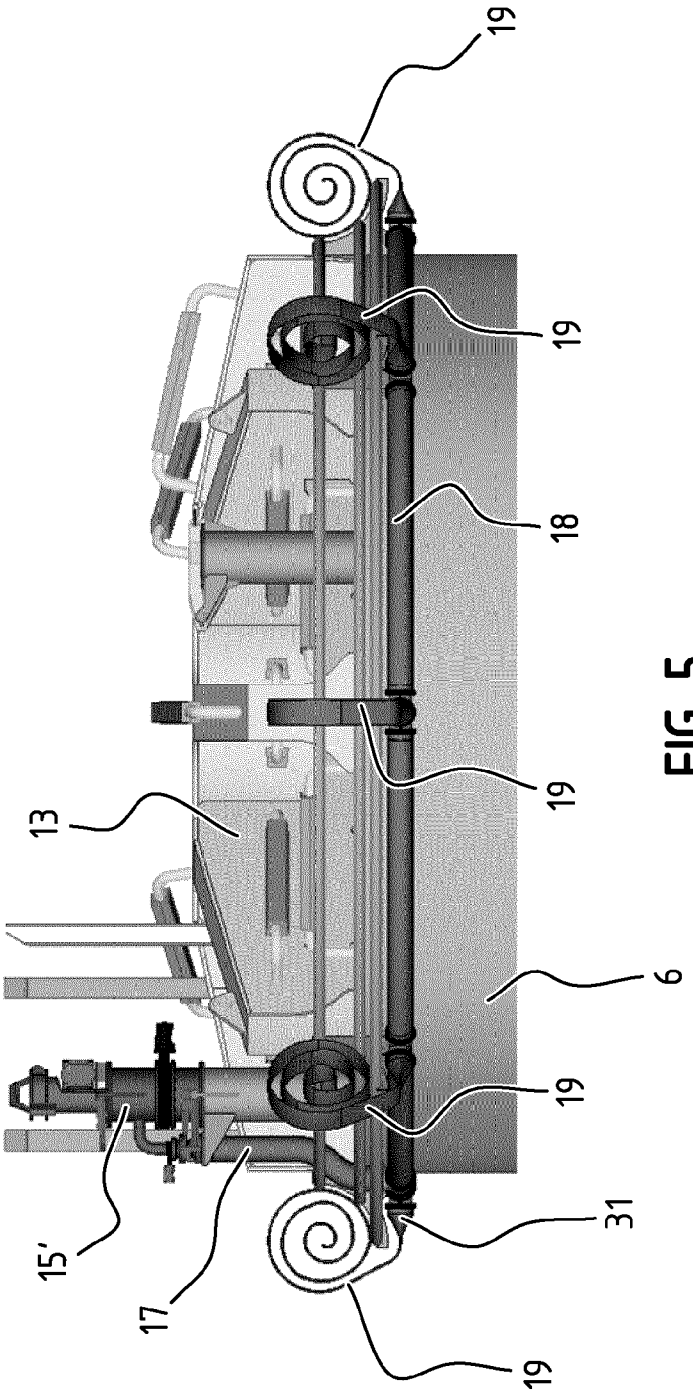

FIG. 5

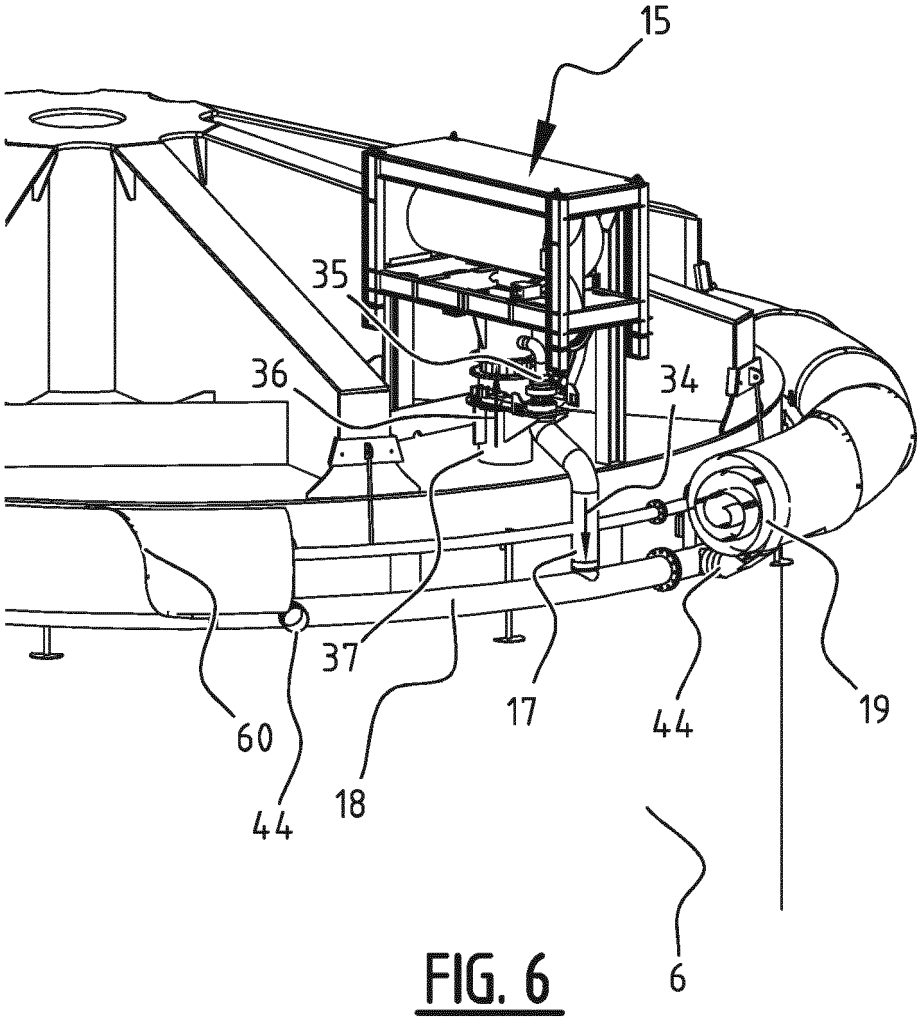

FIG. 6

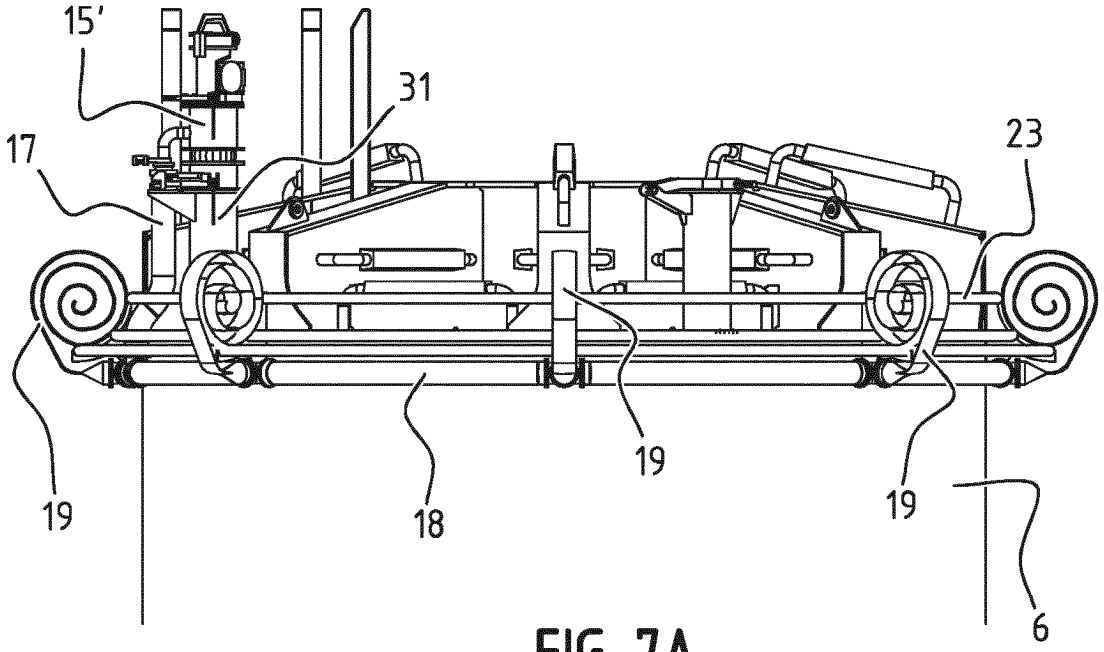

FIG. 7A

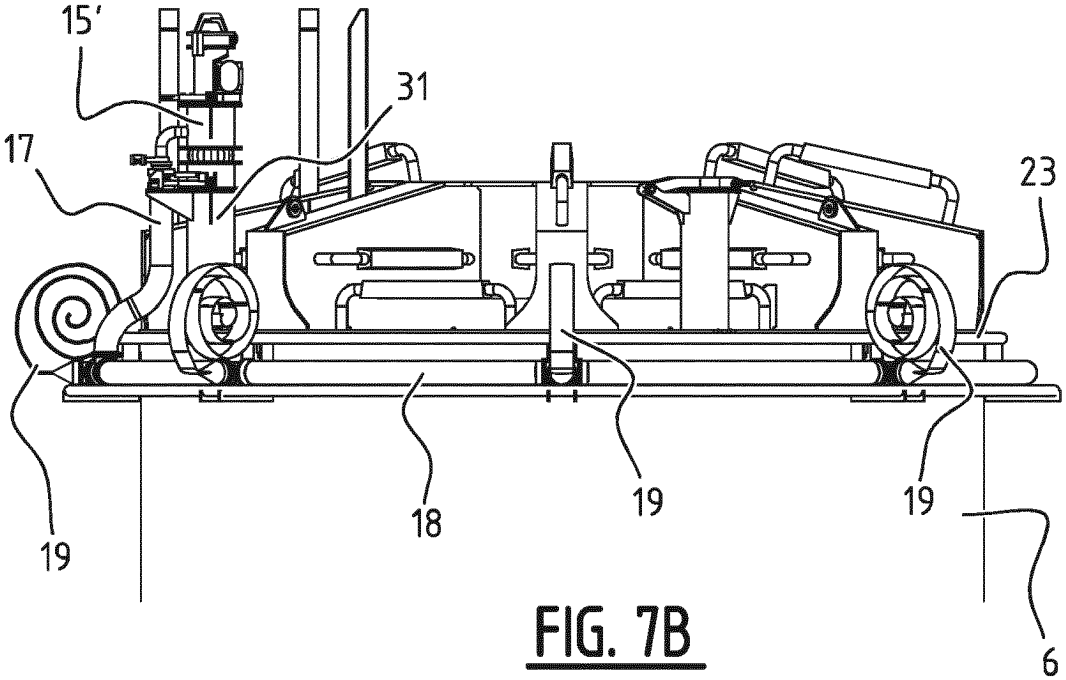

FIG. 7B

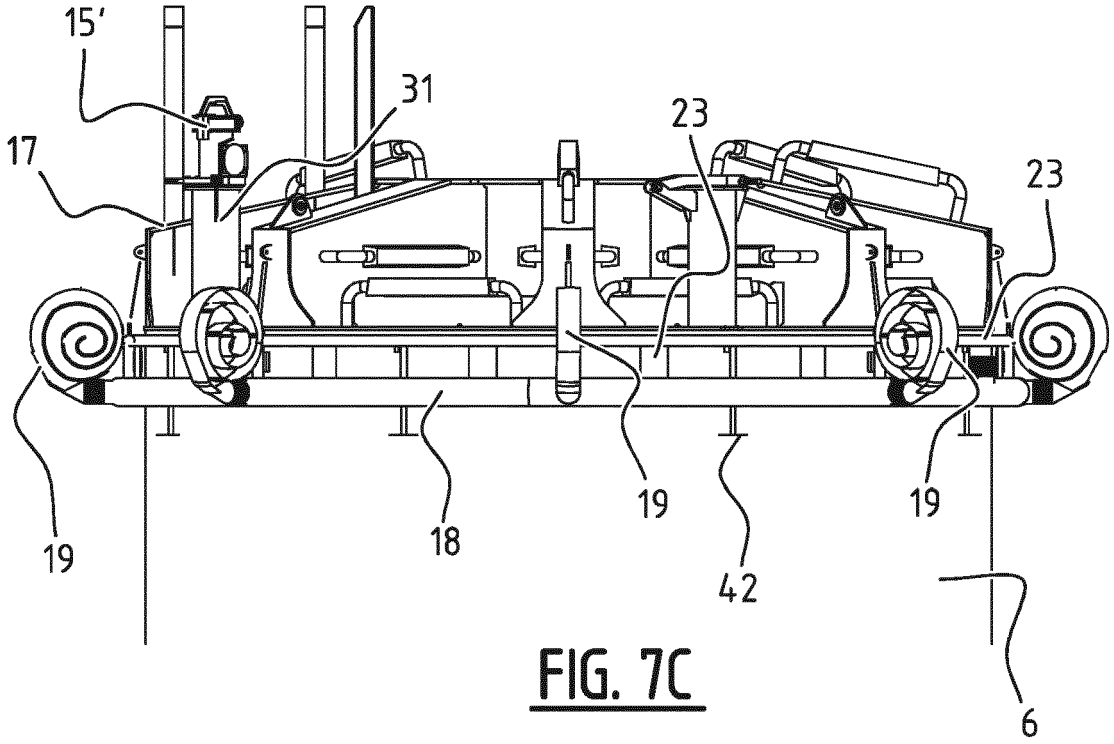

FIG. 7C

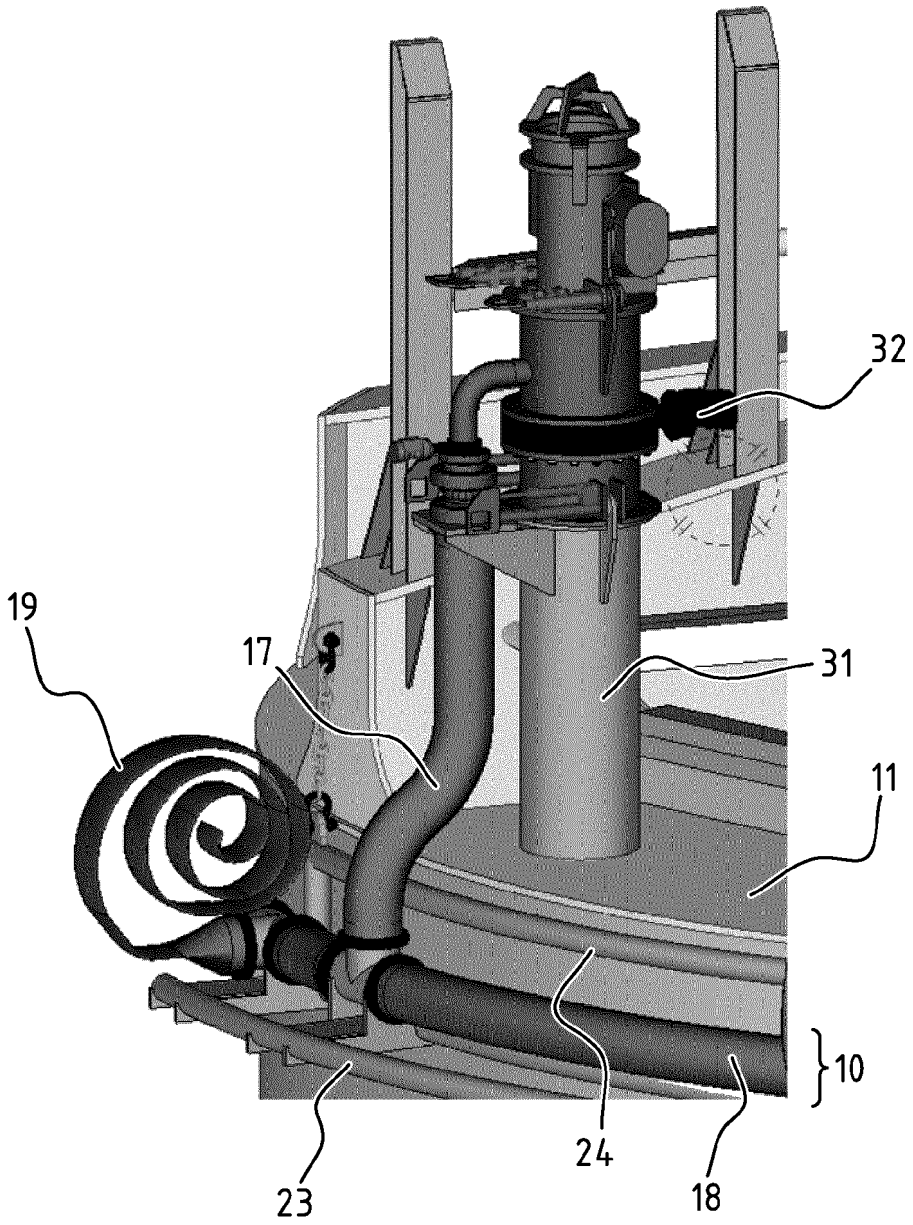

FIG. 8

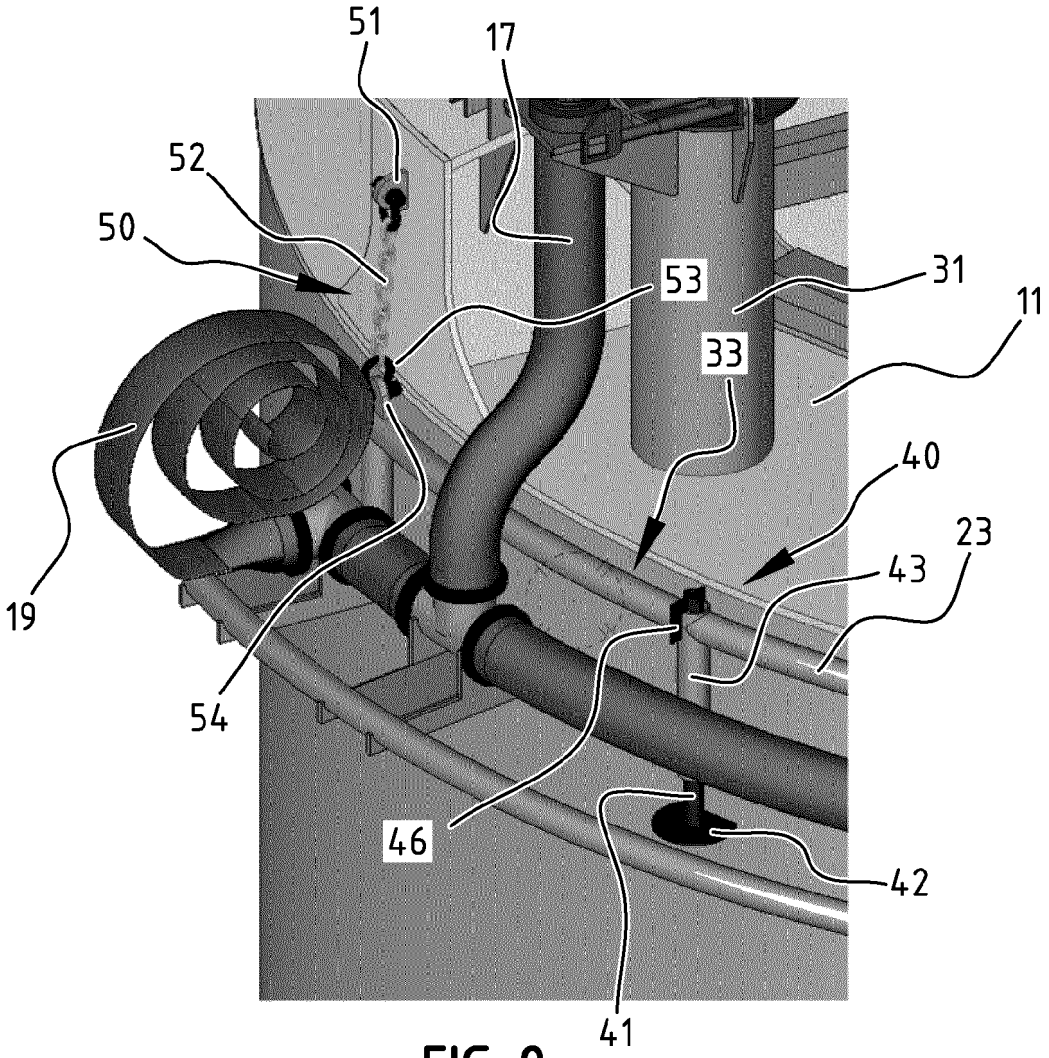

FIG. 9

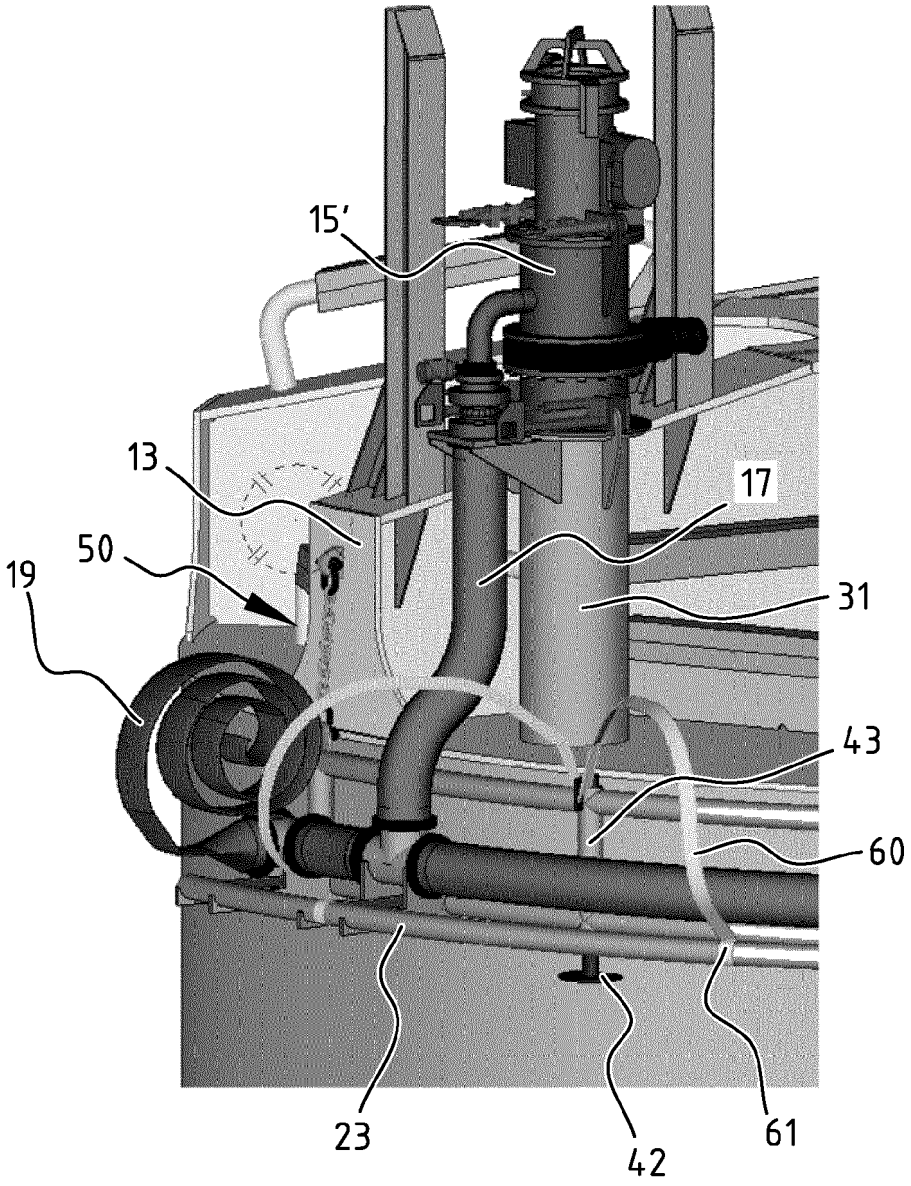

FIG. 10

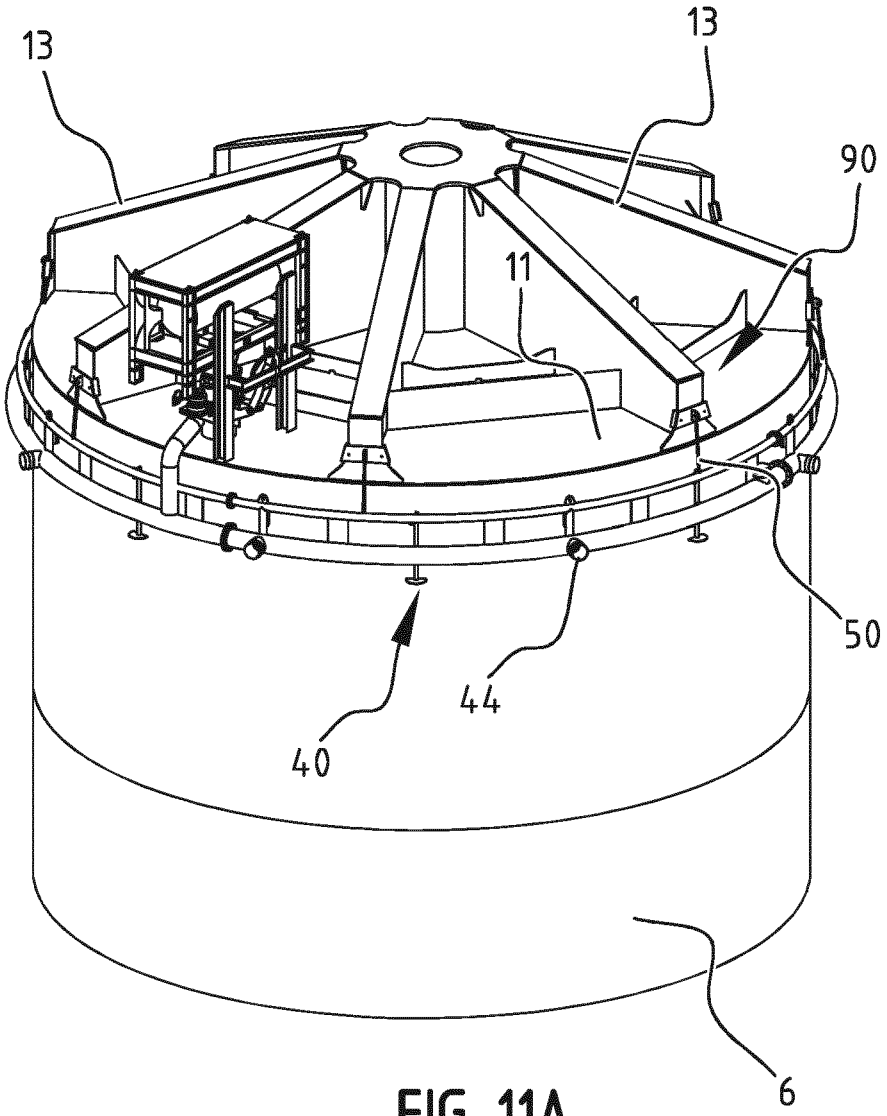

FIG. 11A

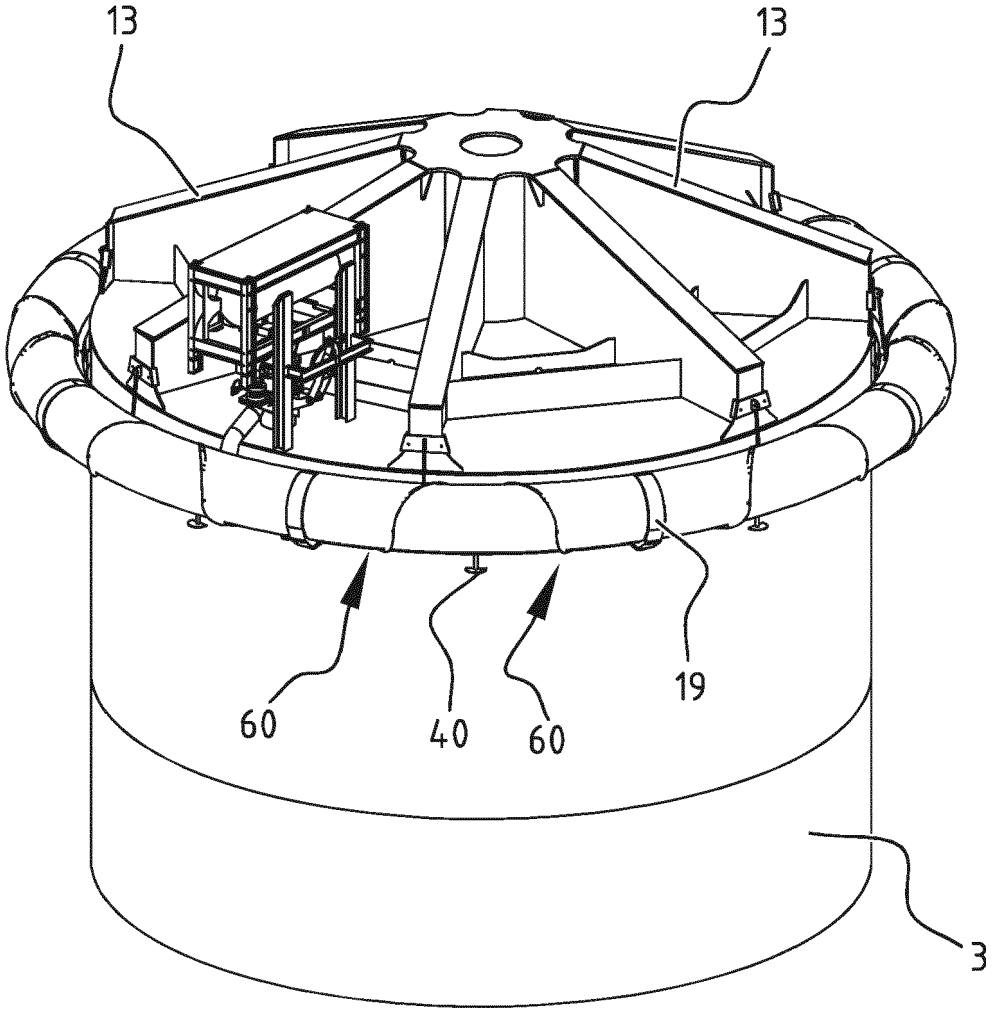

FIG. 11B

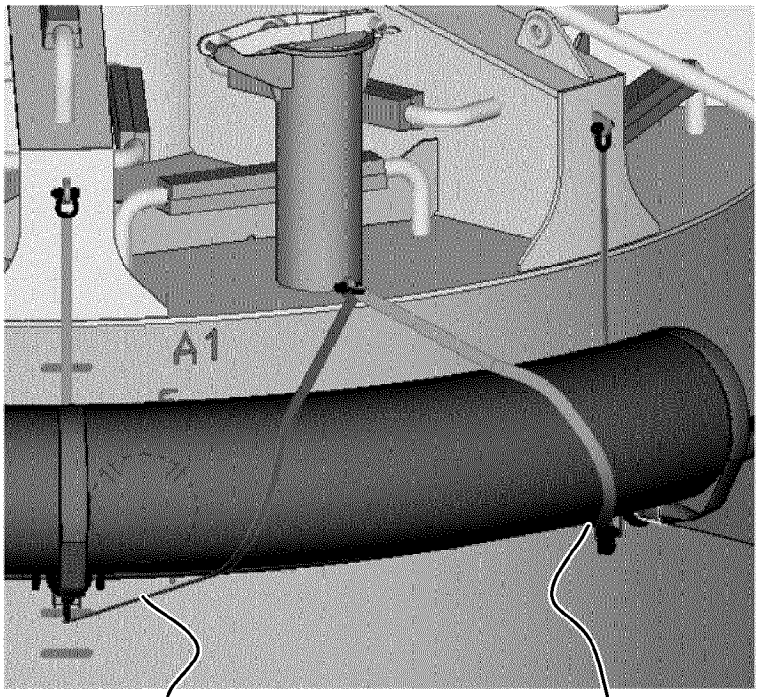

FIG. 12

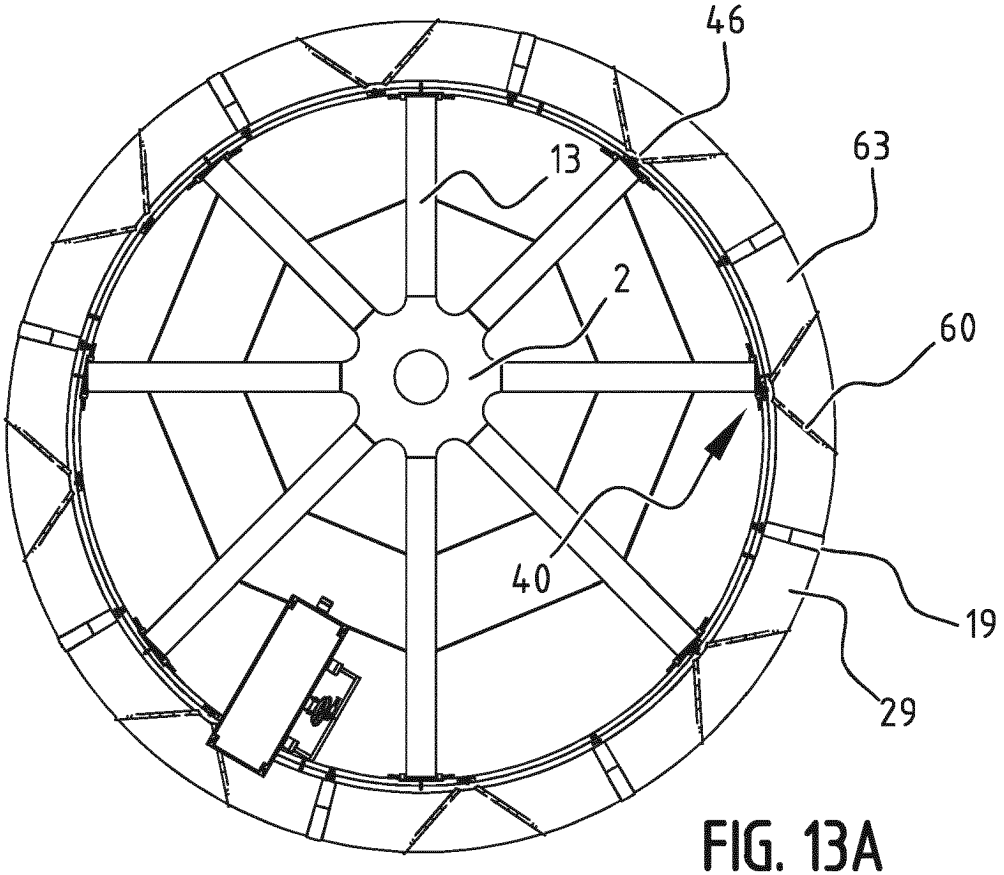

FIG. 13A

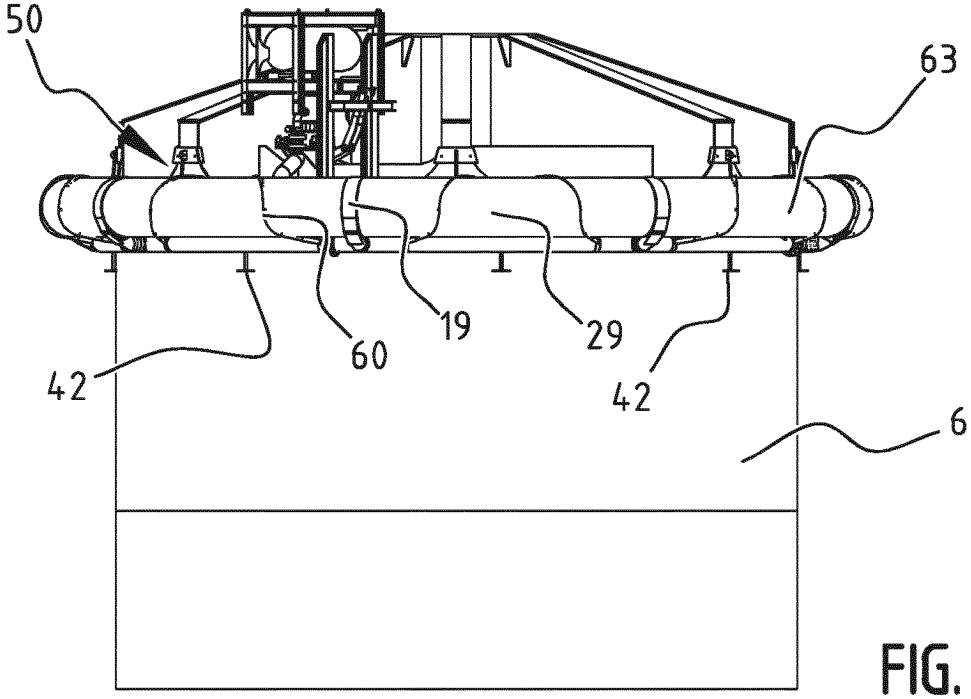

FIG. 13B

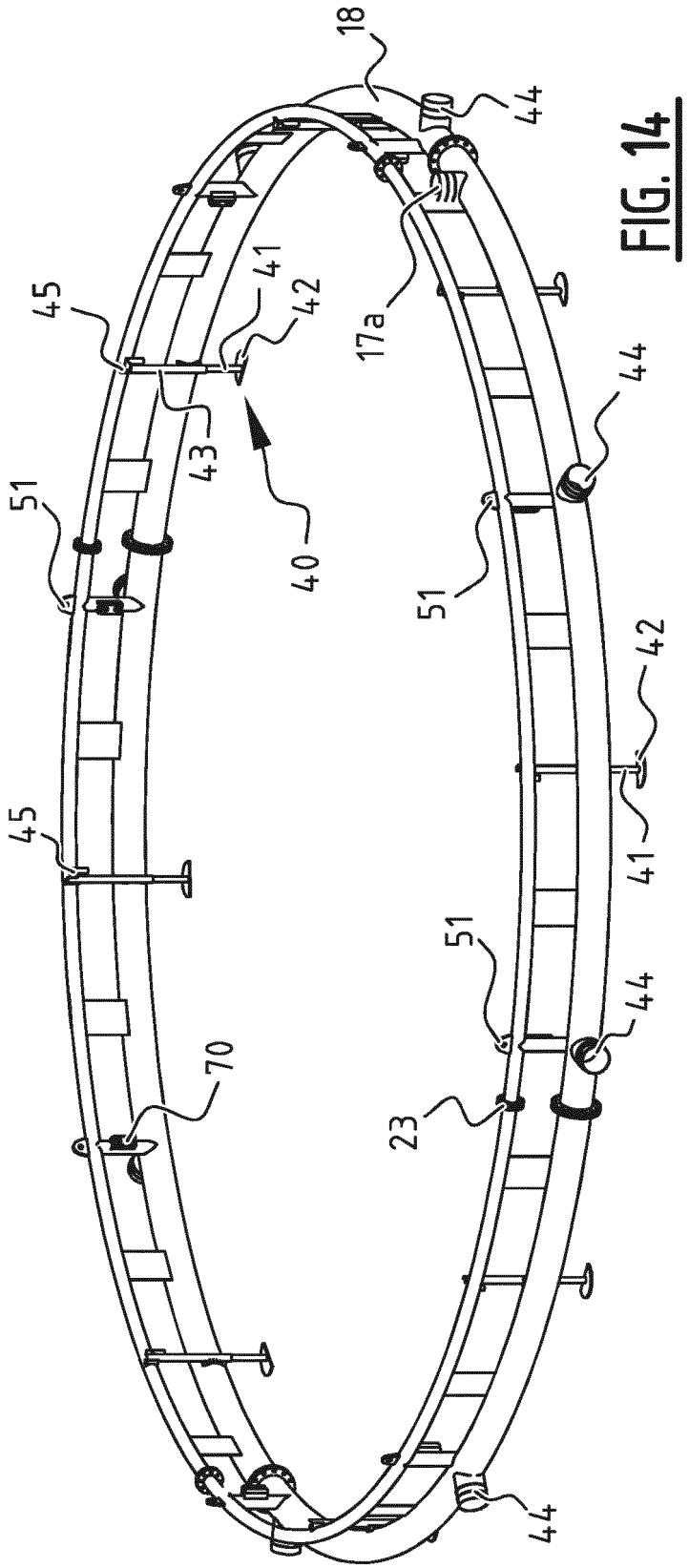
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FIG. 14

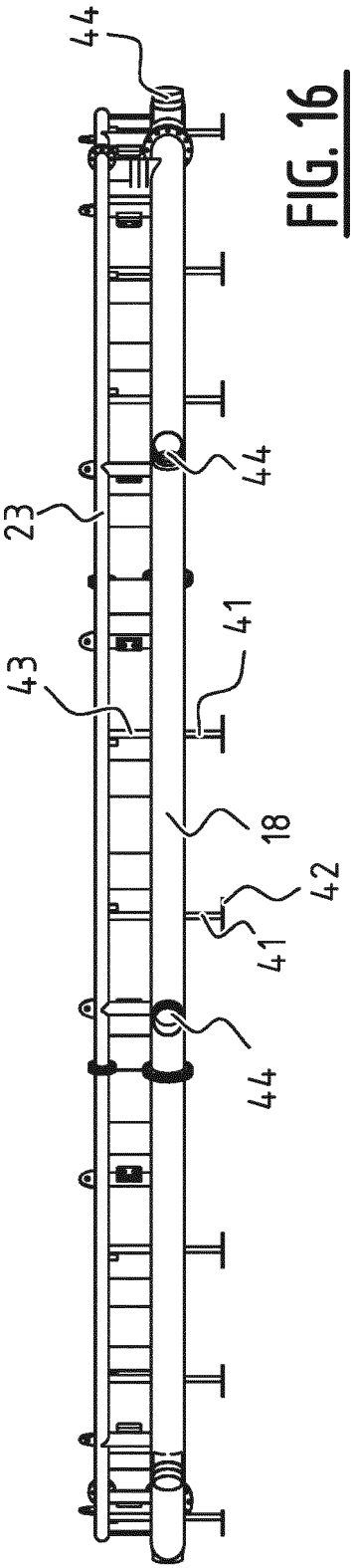
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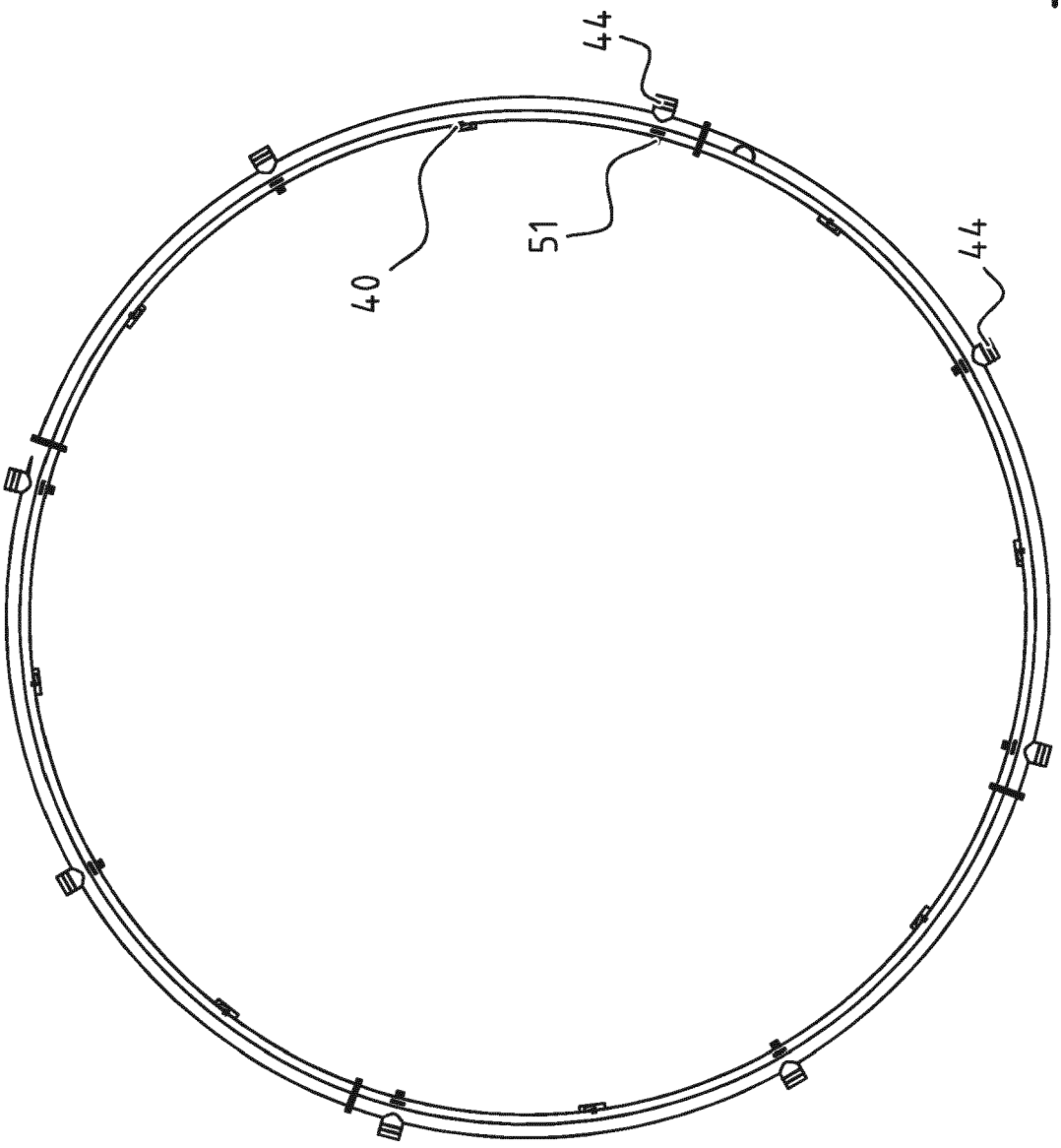
FIG. 16

FIG. 15



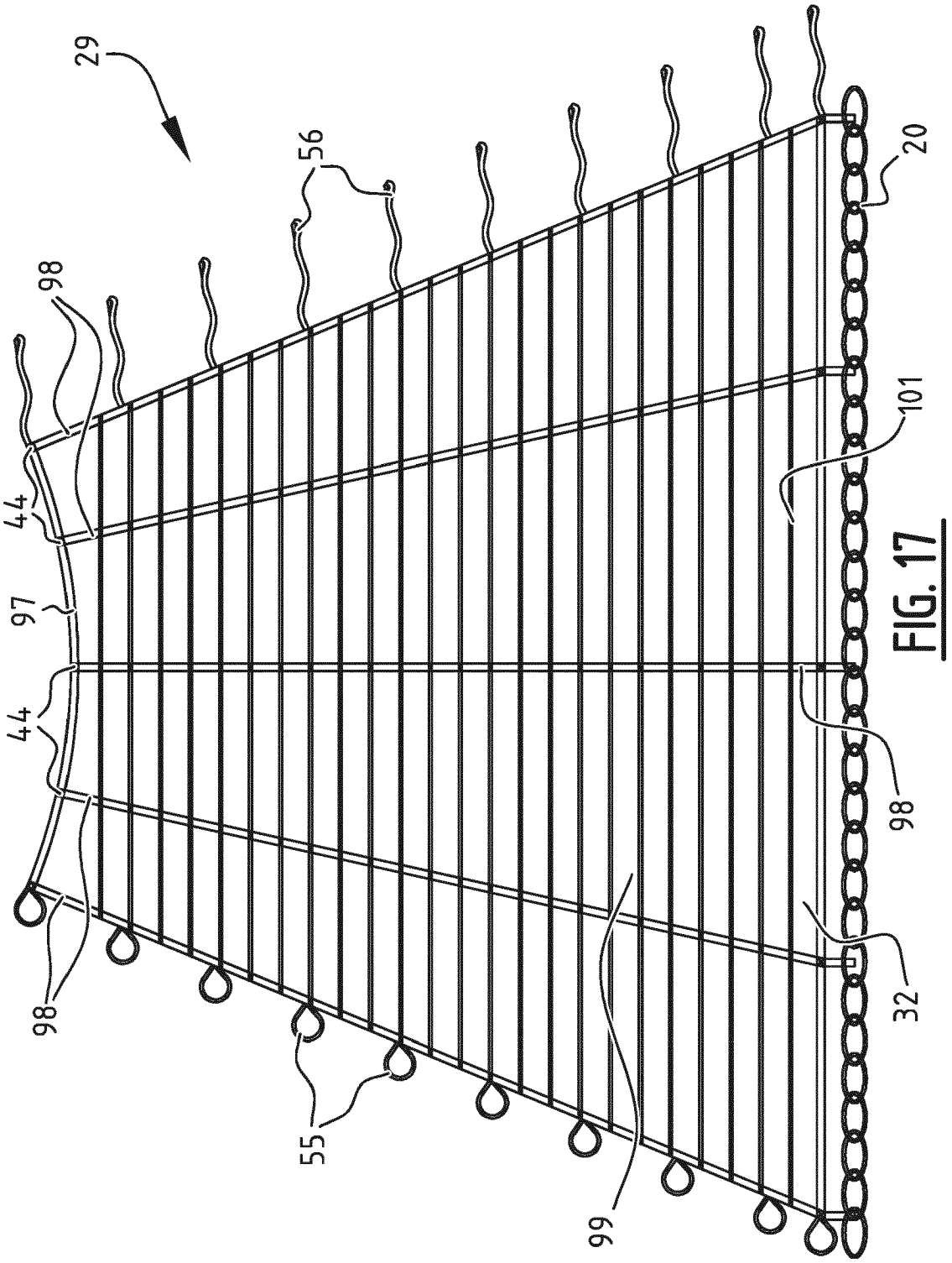


FIG. 17

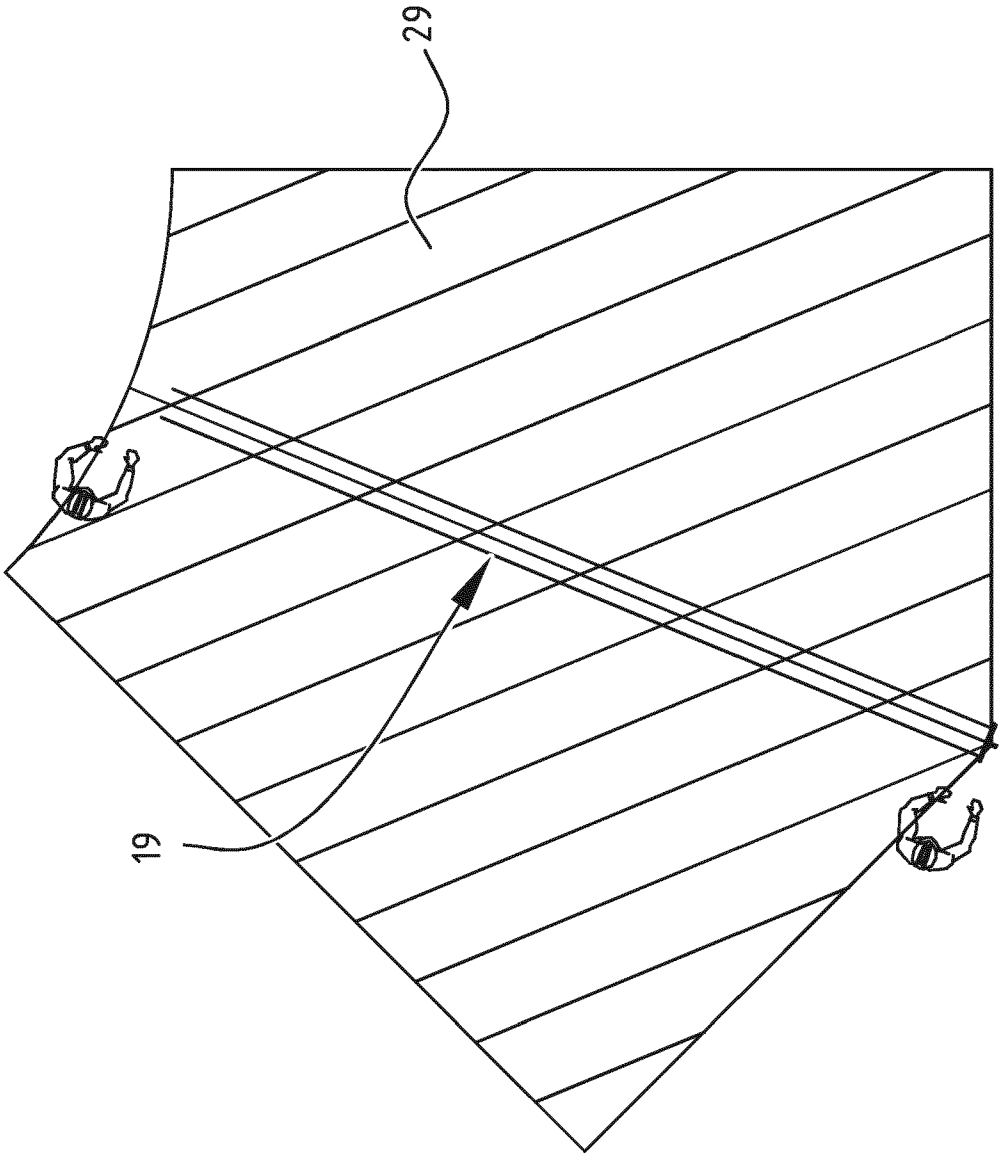


FIG. 18A

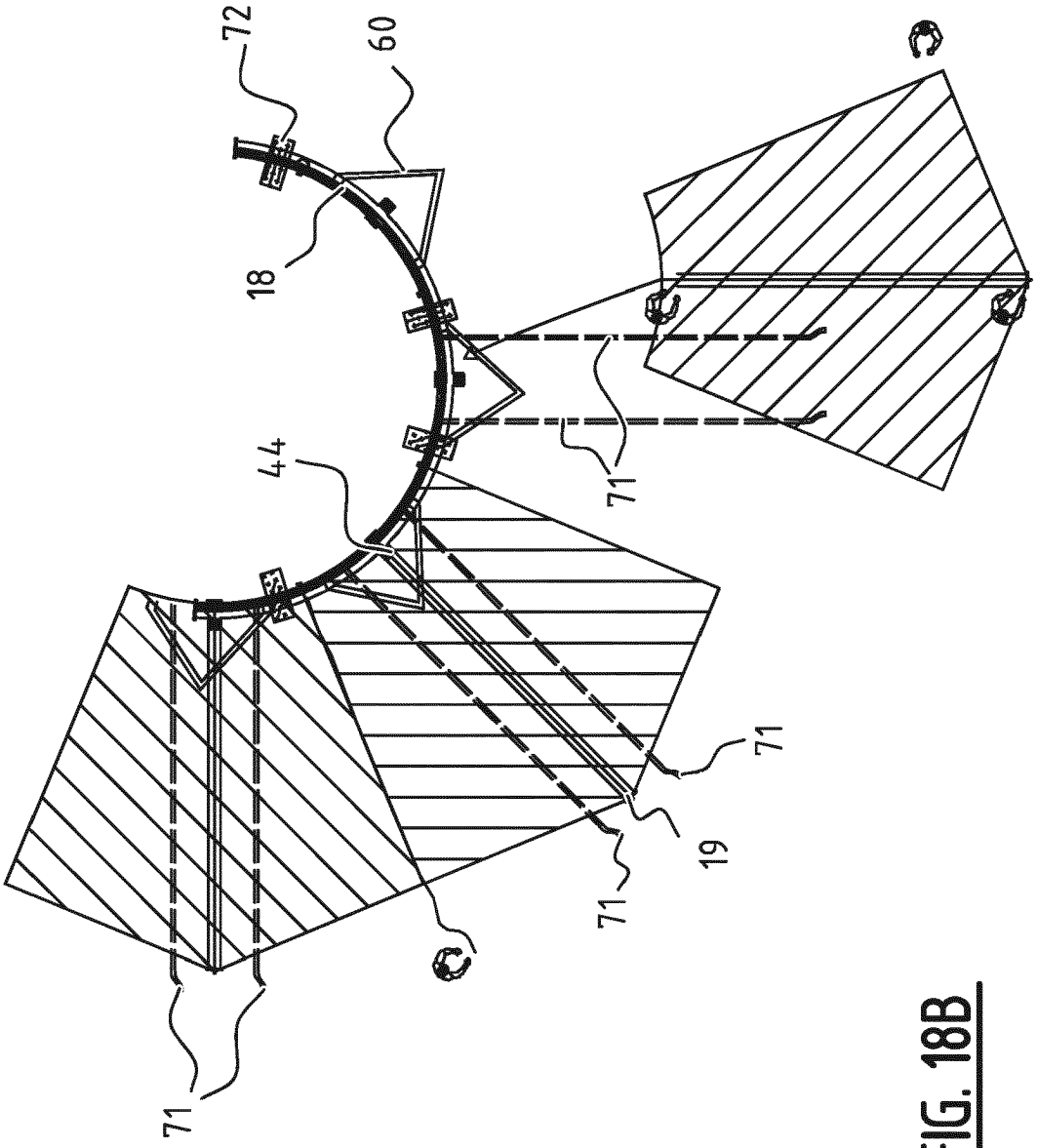


FIG. 18B

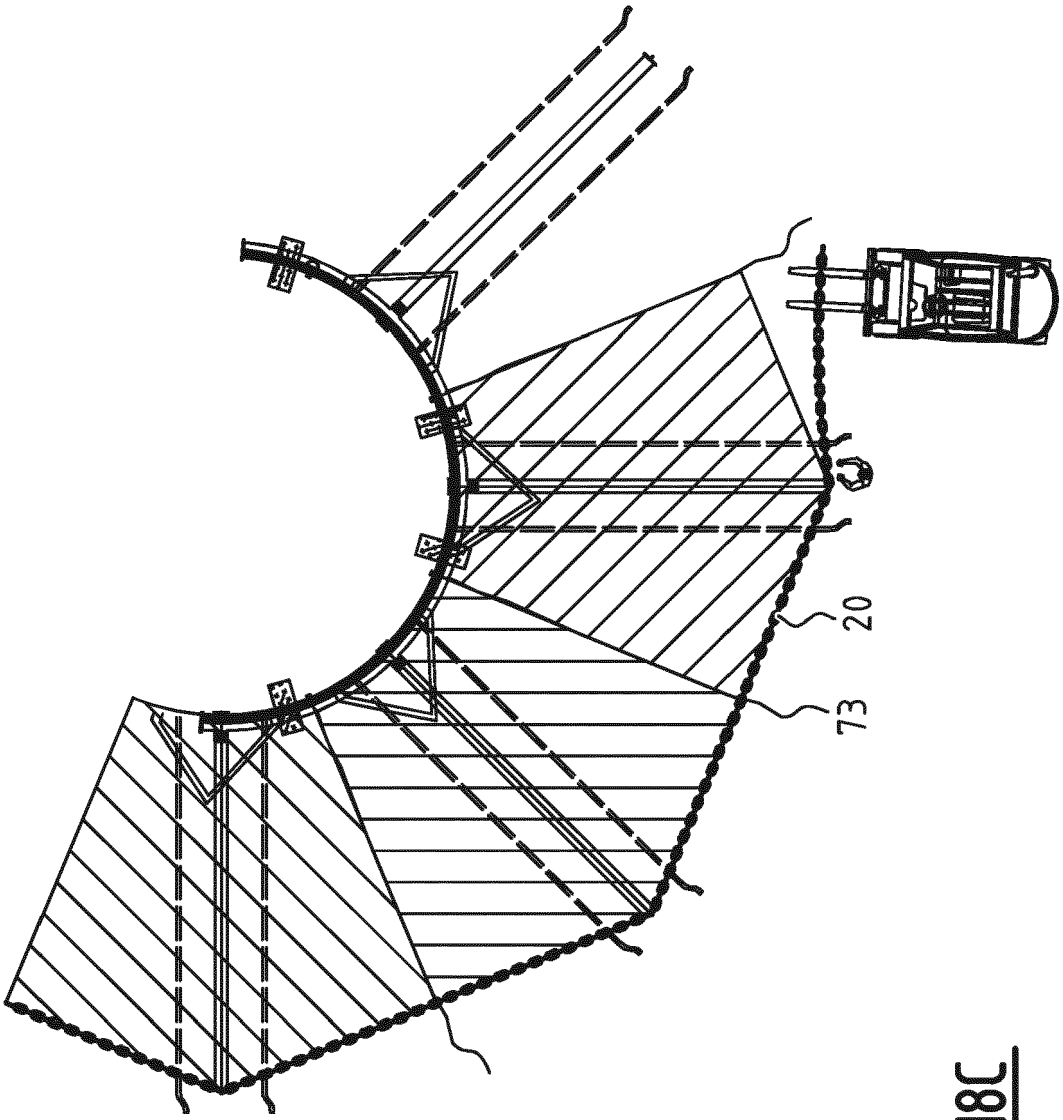


FIG. 18C

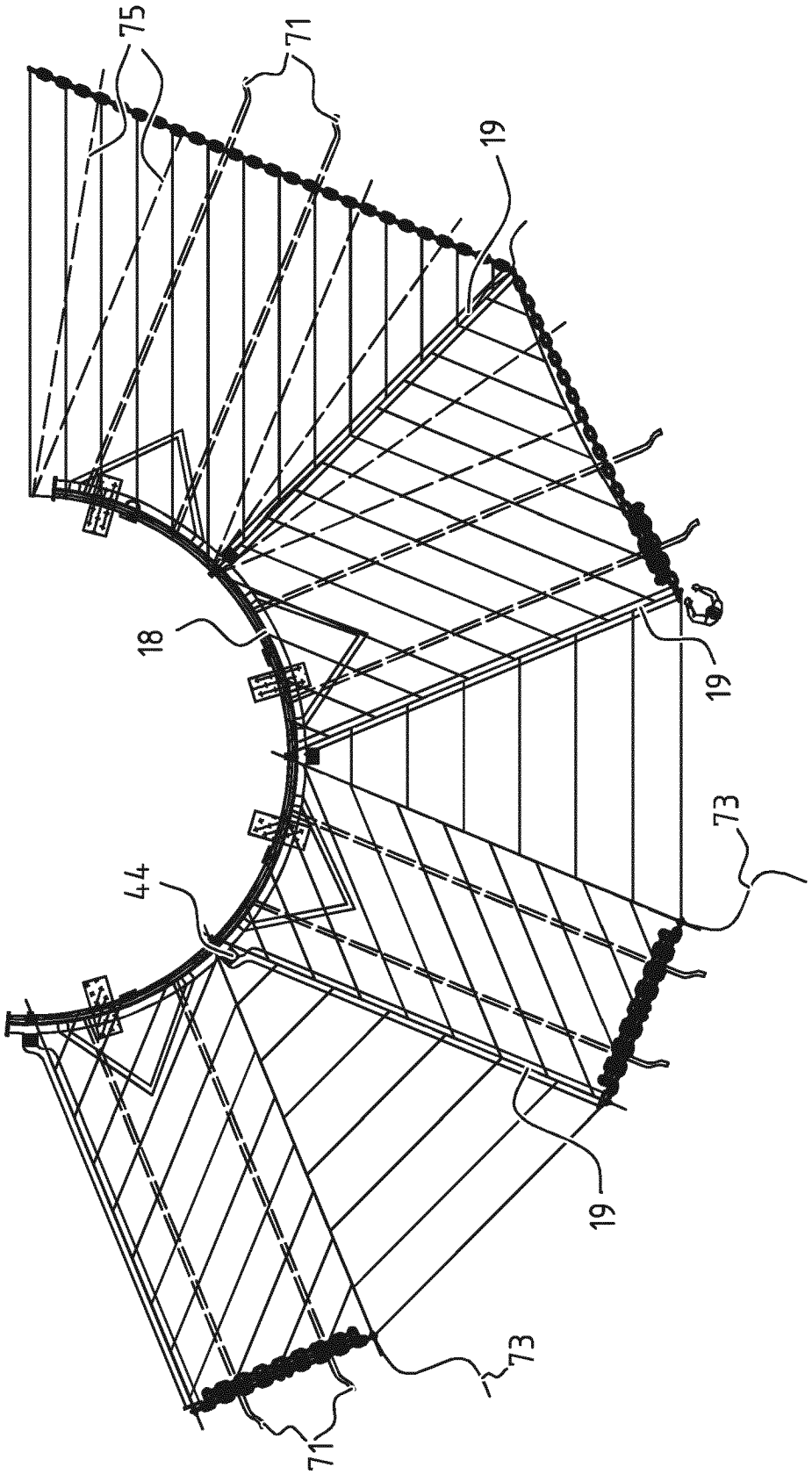


FIG. 18D

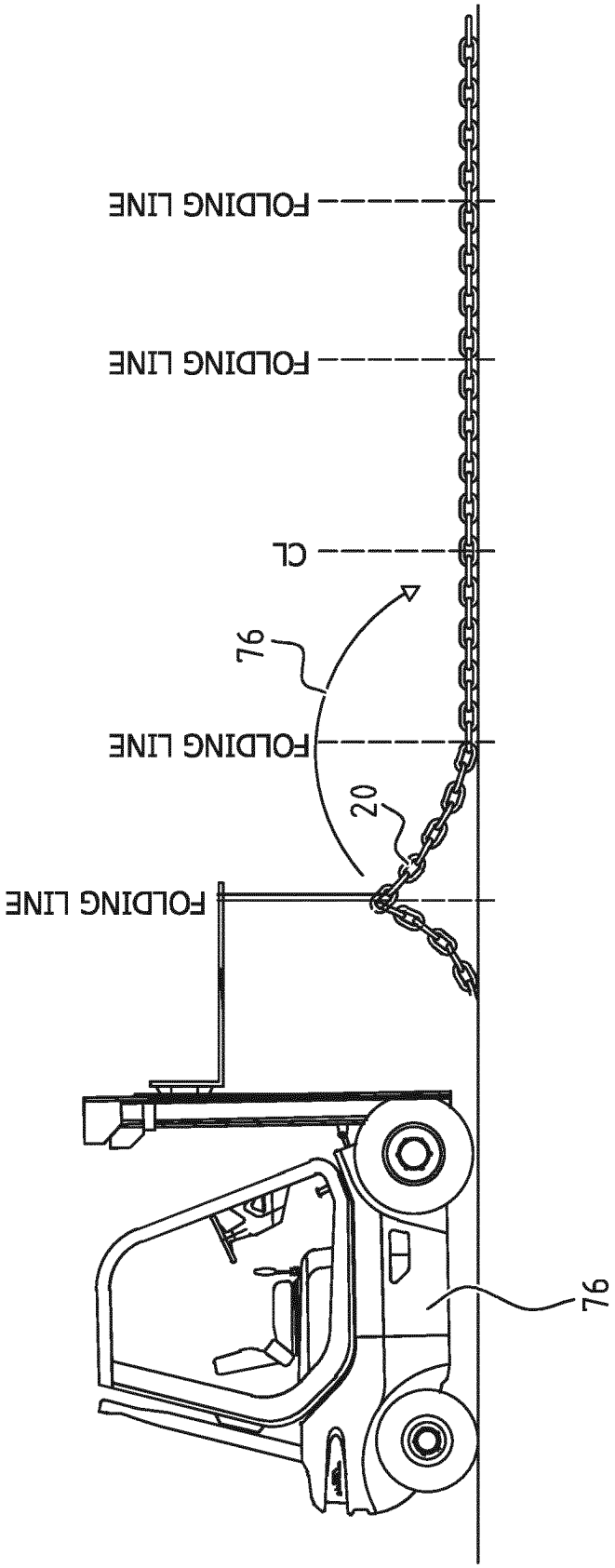

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FIG. 18E

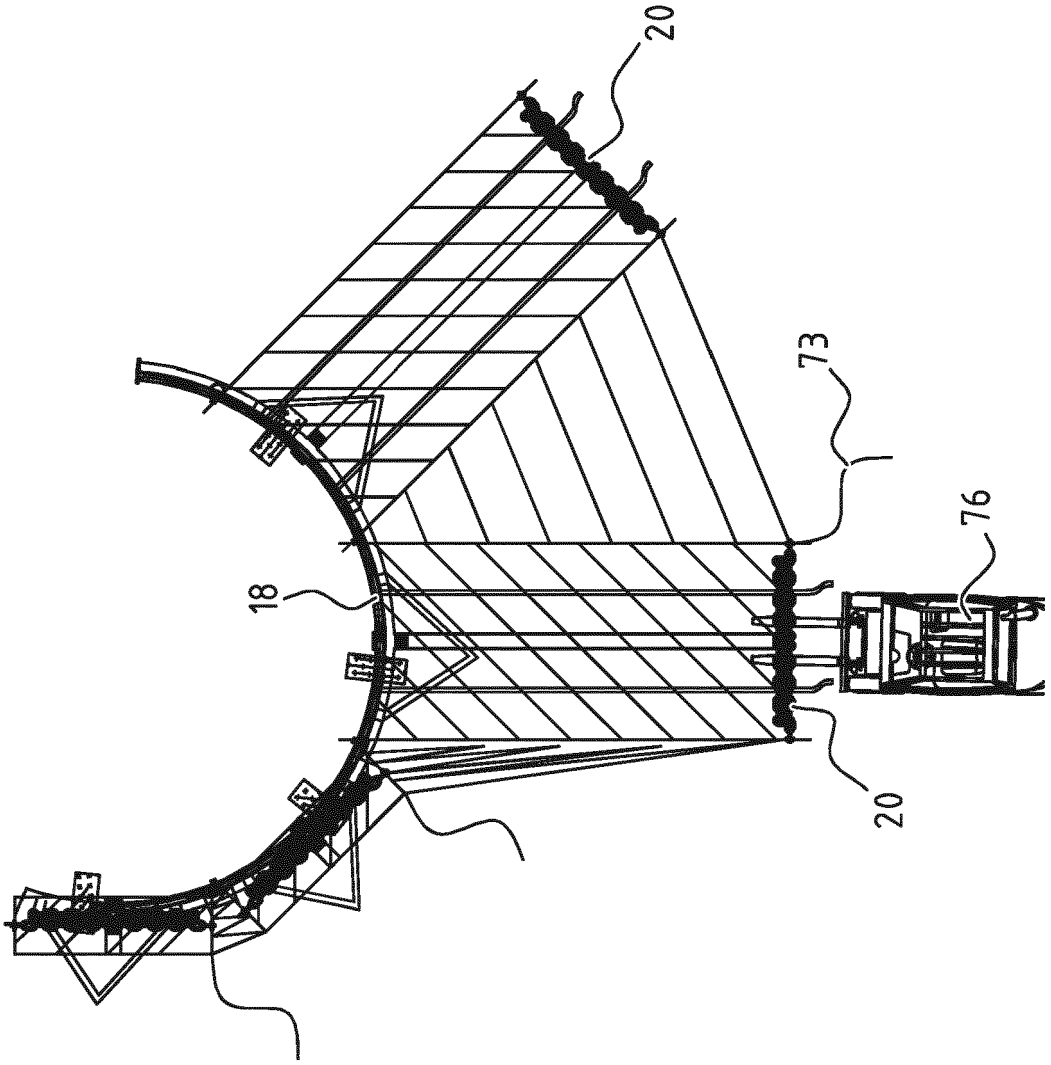


FIG. 18F

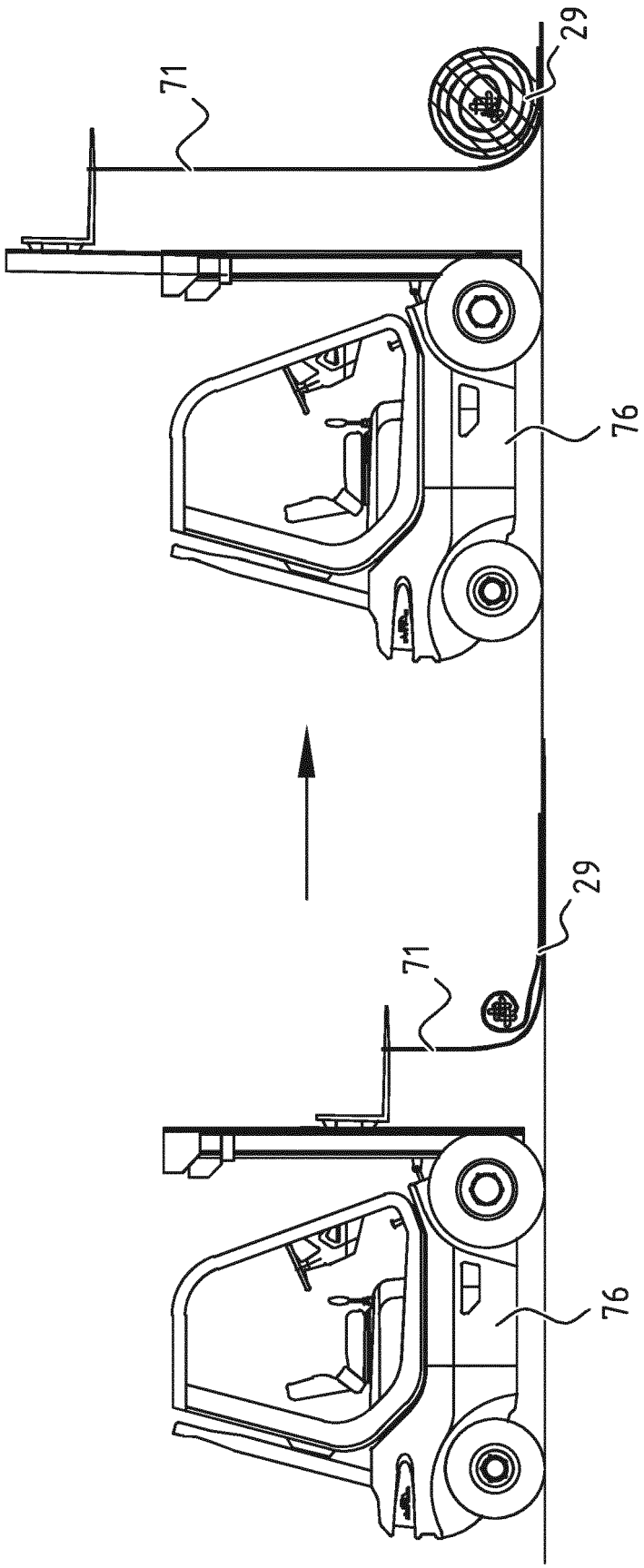


FIG. 18G

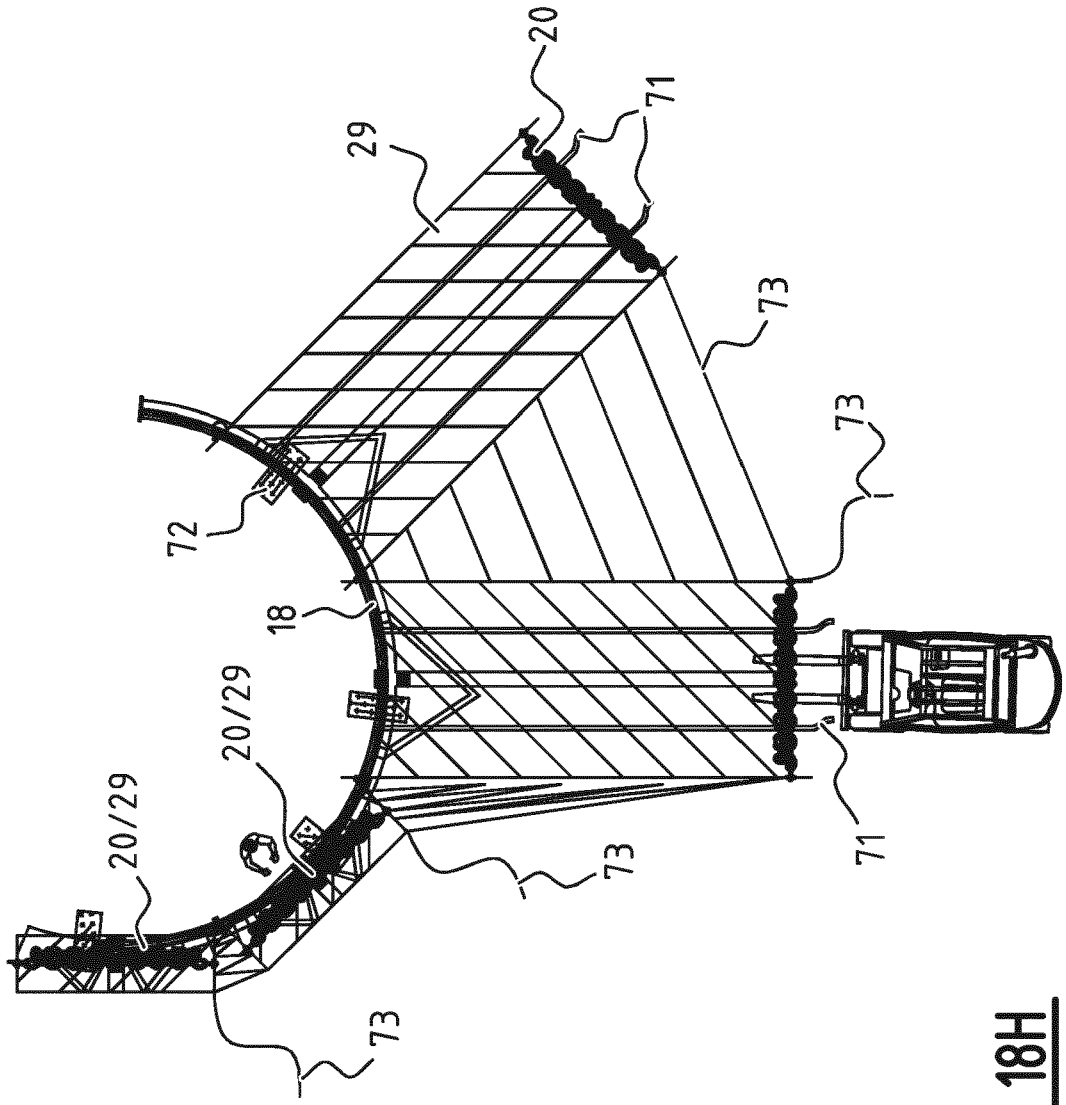


FIG. 18H

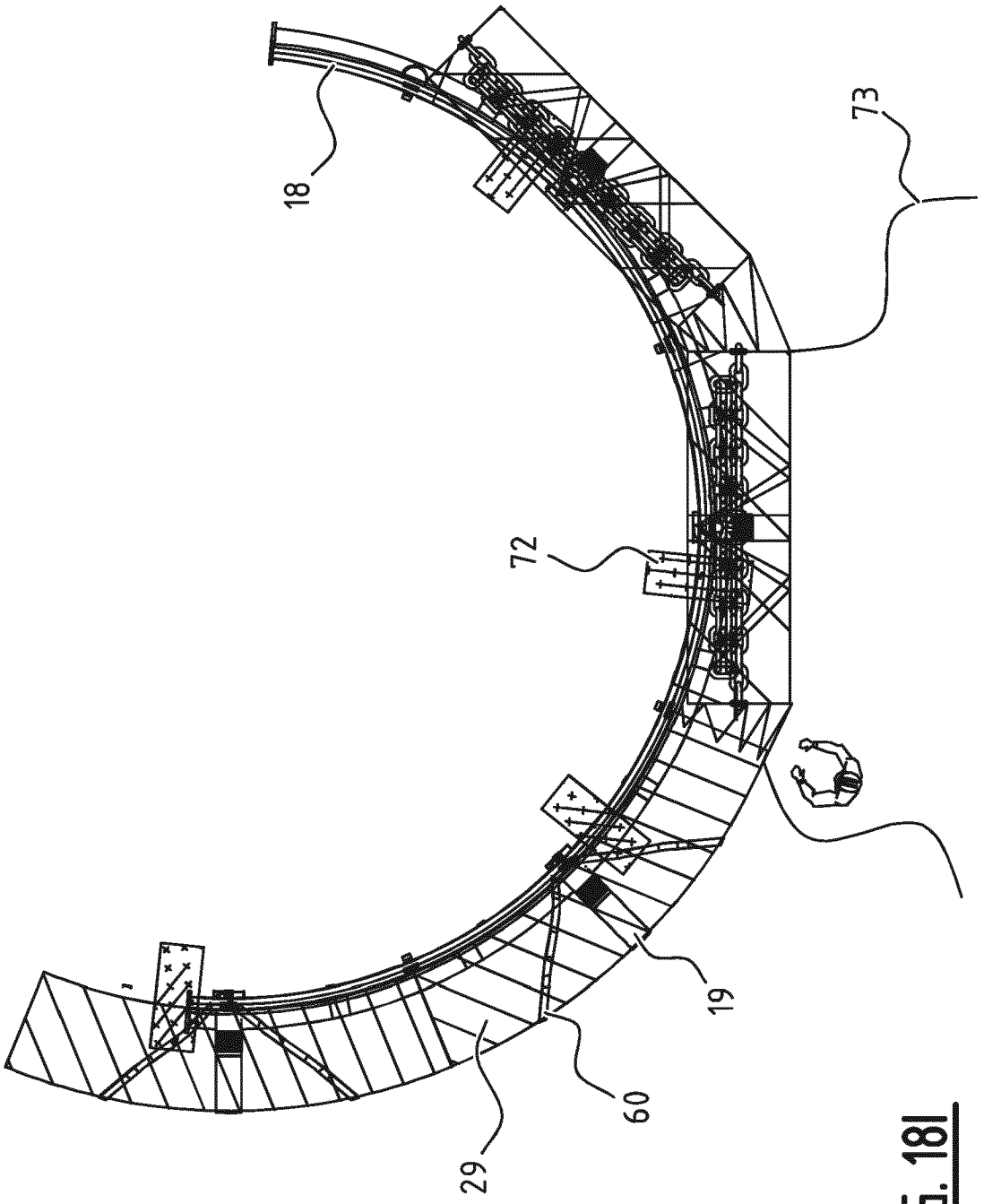


FIG. 18I

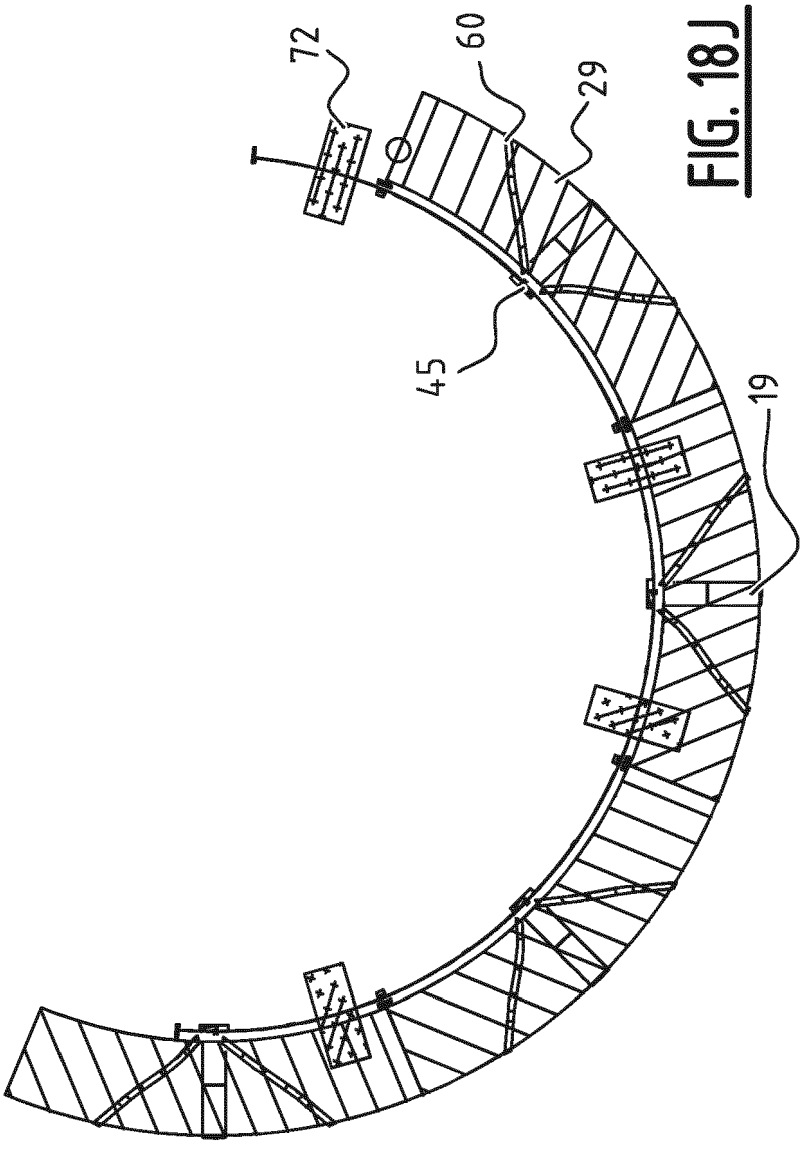


FIG. 18J

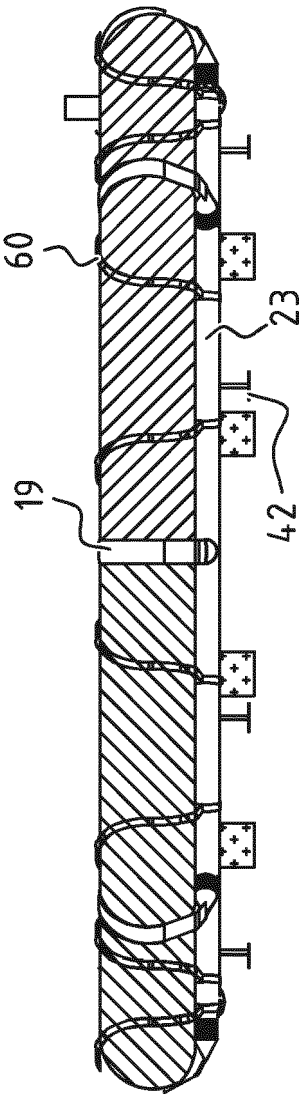


FIG. 18K

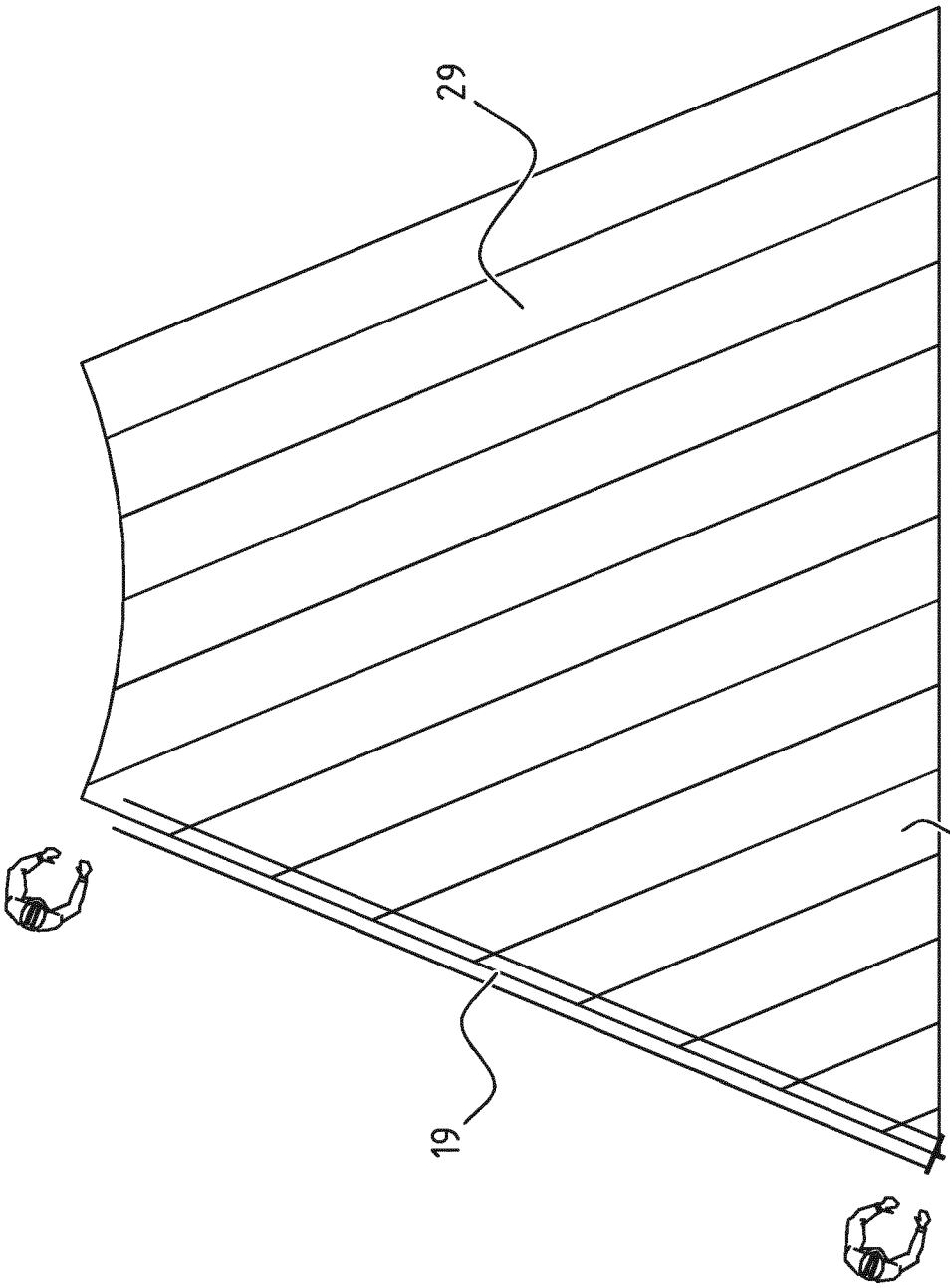


FIG. 19A

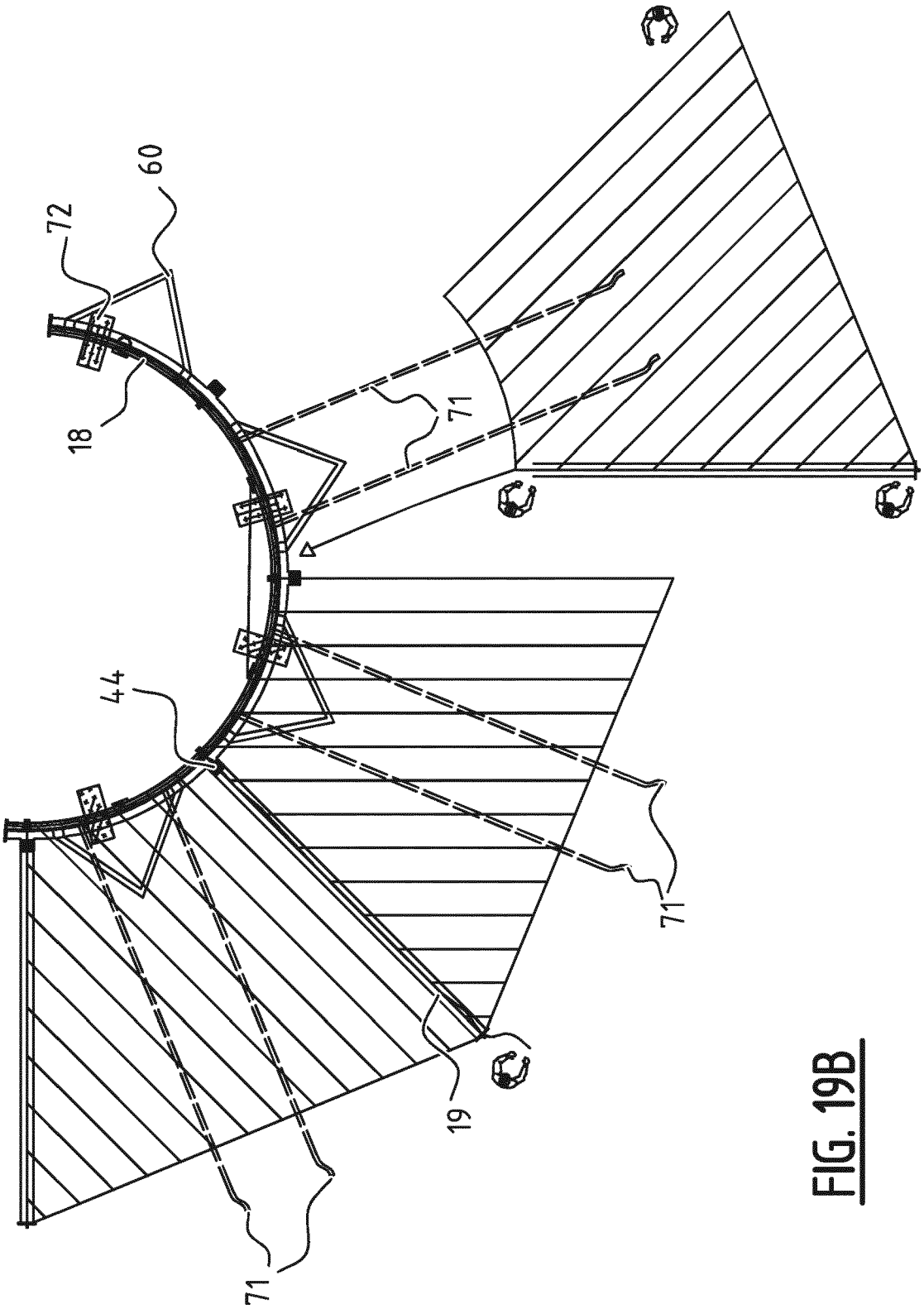


FIG. 19B

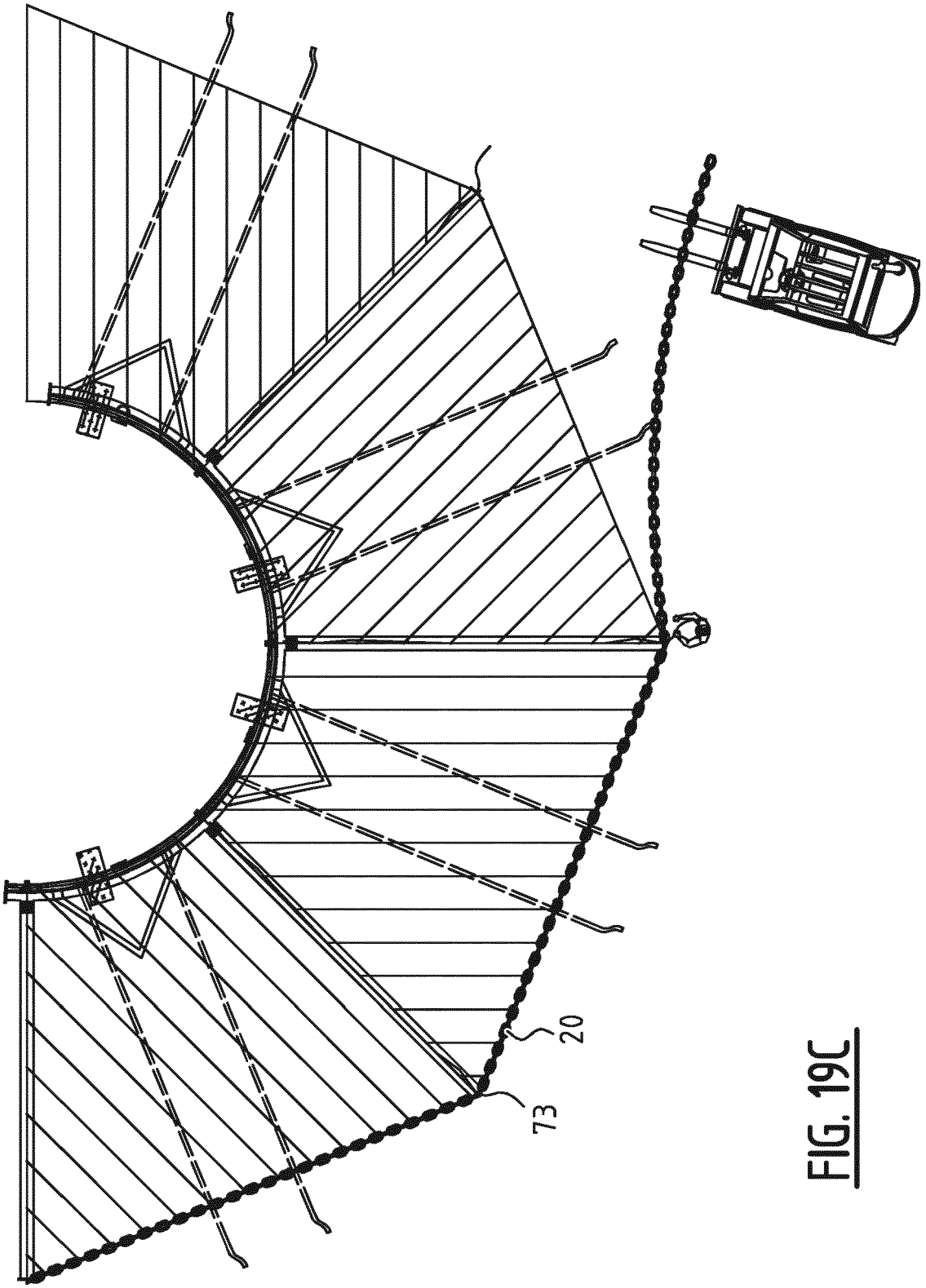


FIG. 19C

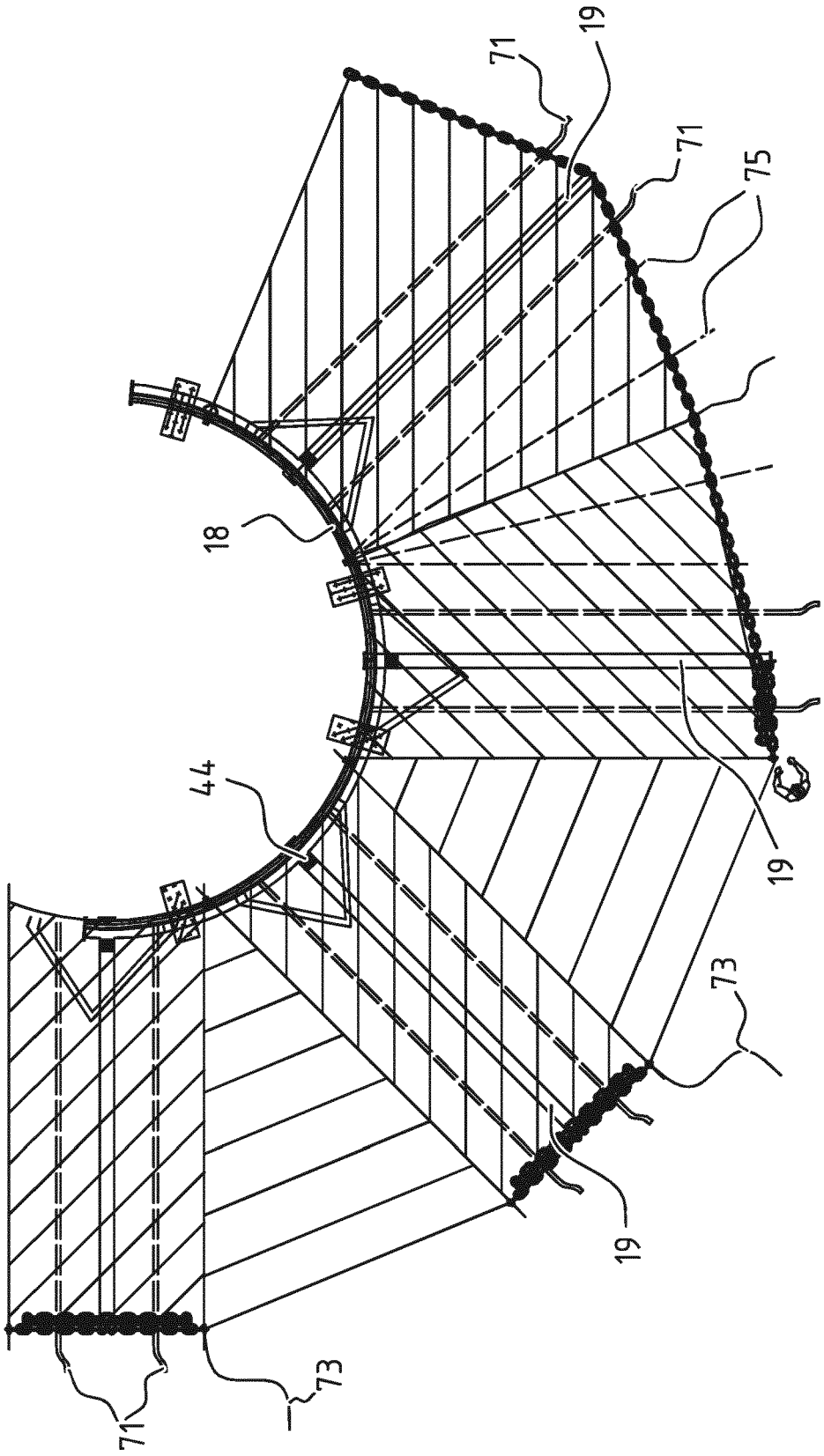
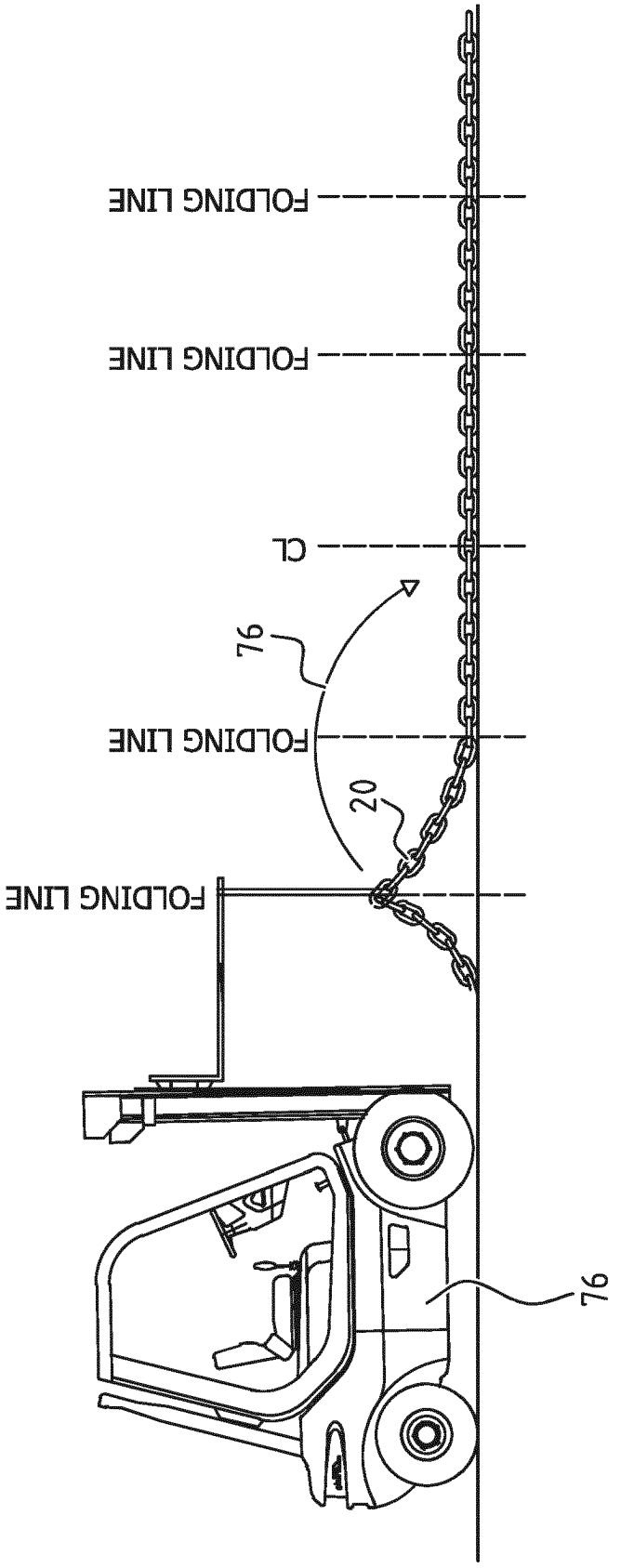


FIG. 19D


FOLDING LINE
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CL
76
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FOLDING LINE
76

FIG. 19E

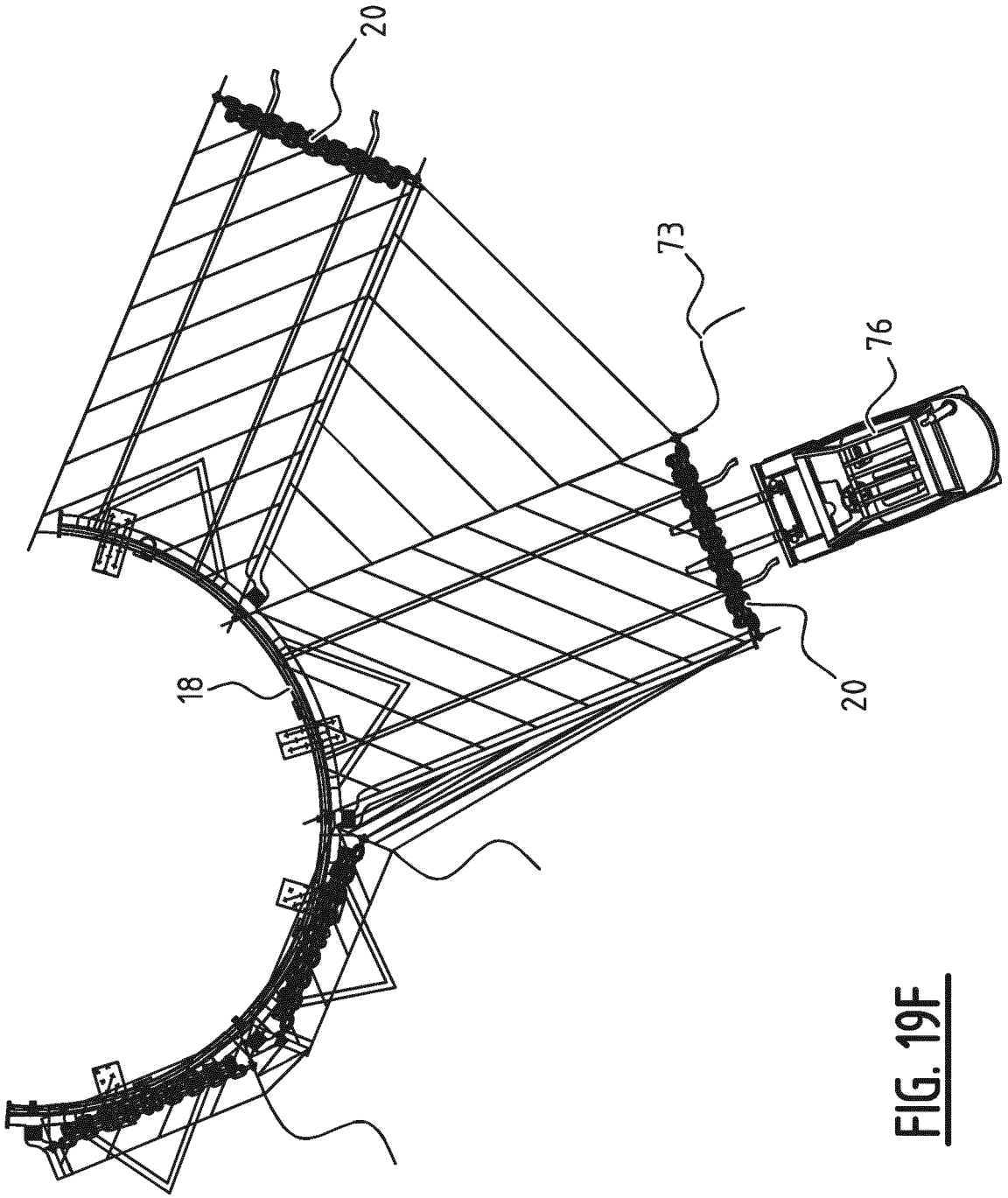

FIG. 19F

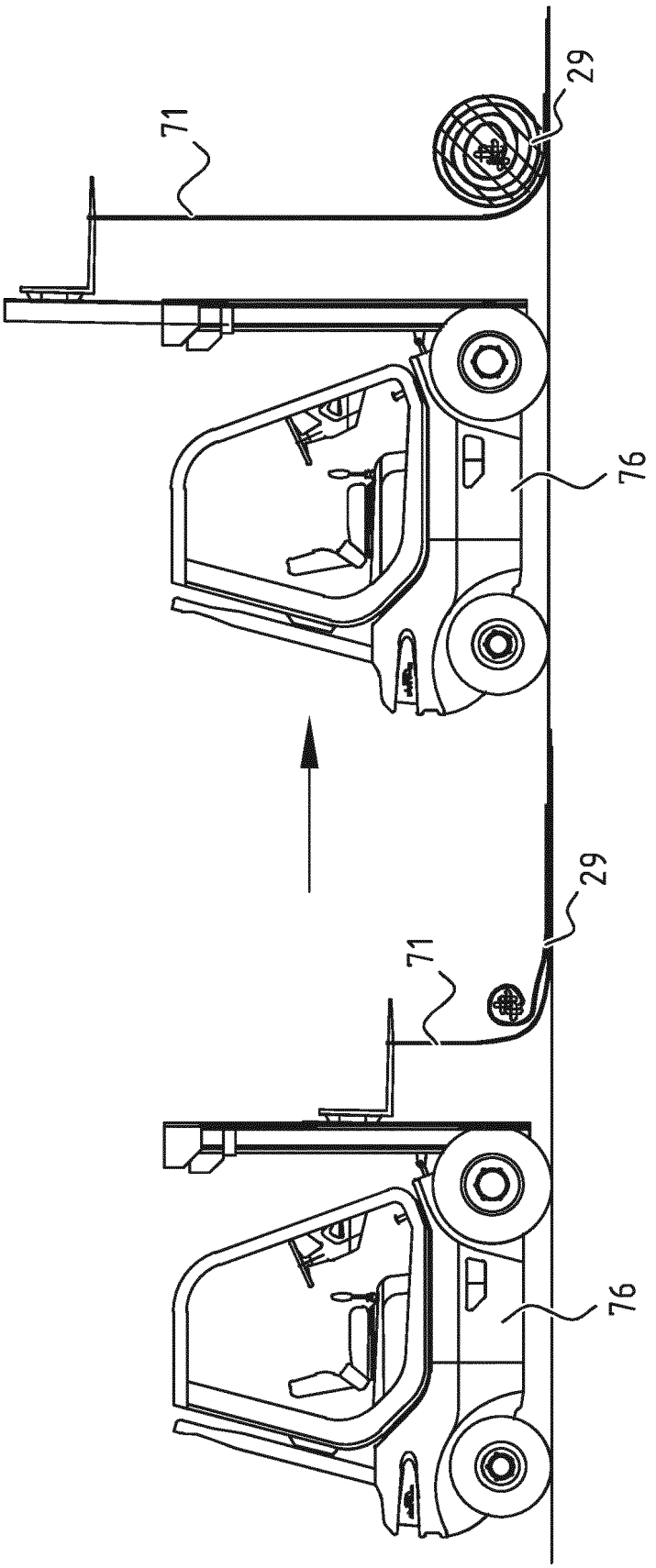

FIG. 19G

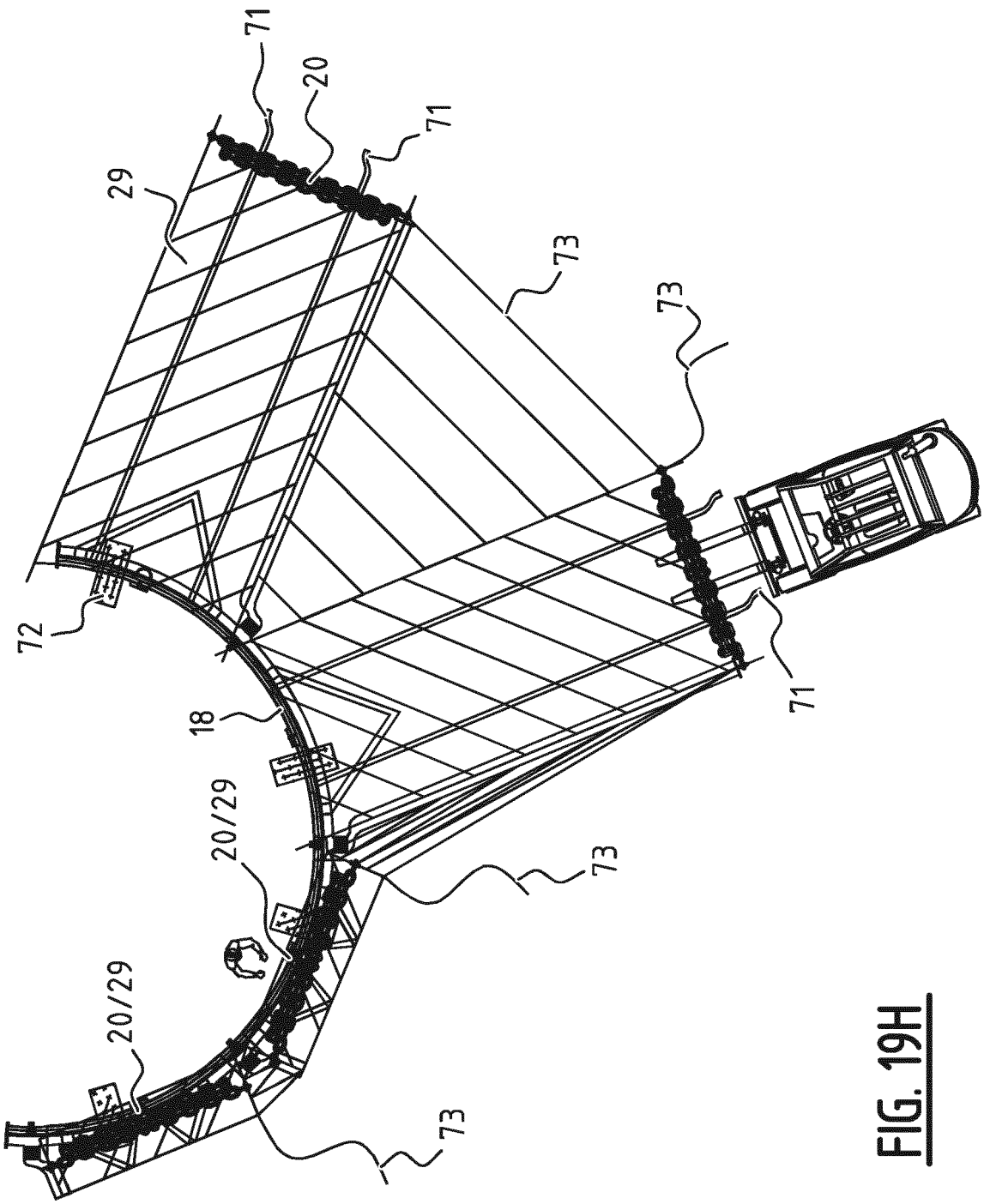

FIG. 19H

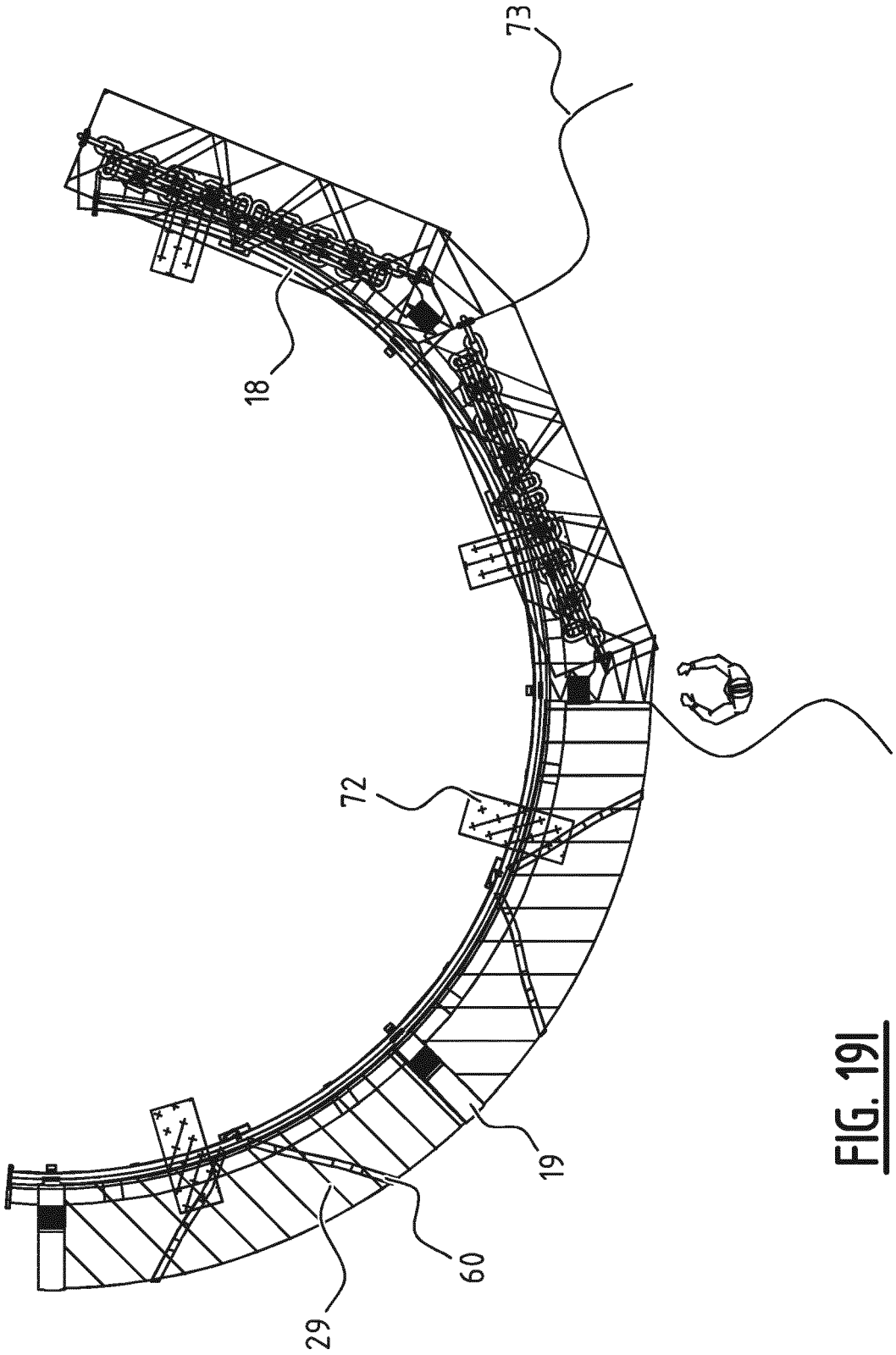

FIG. 19I

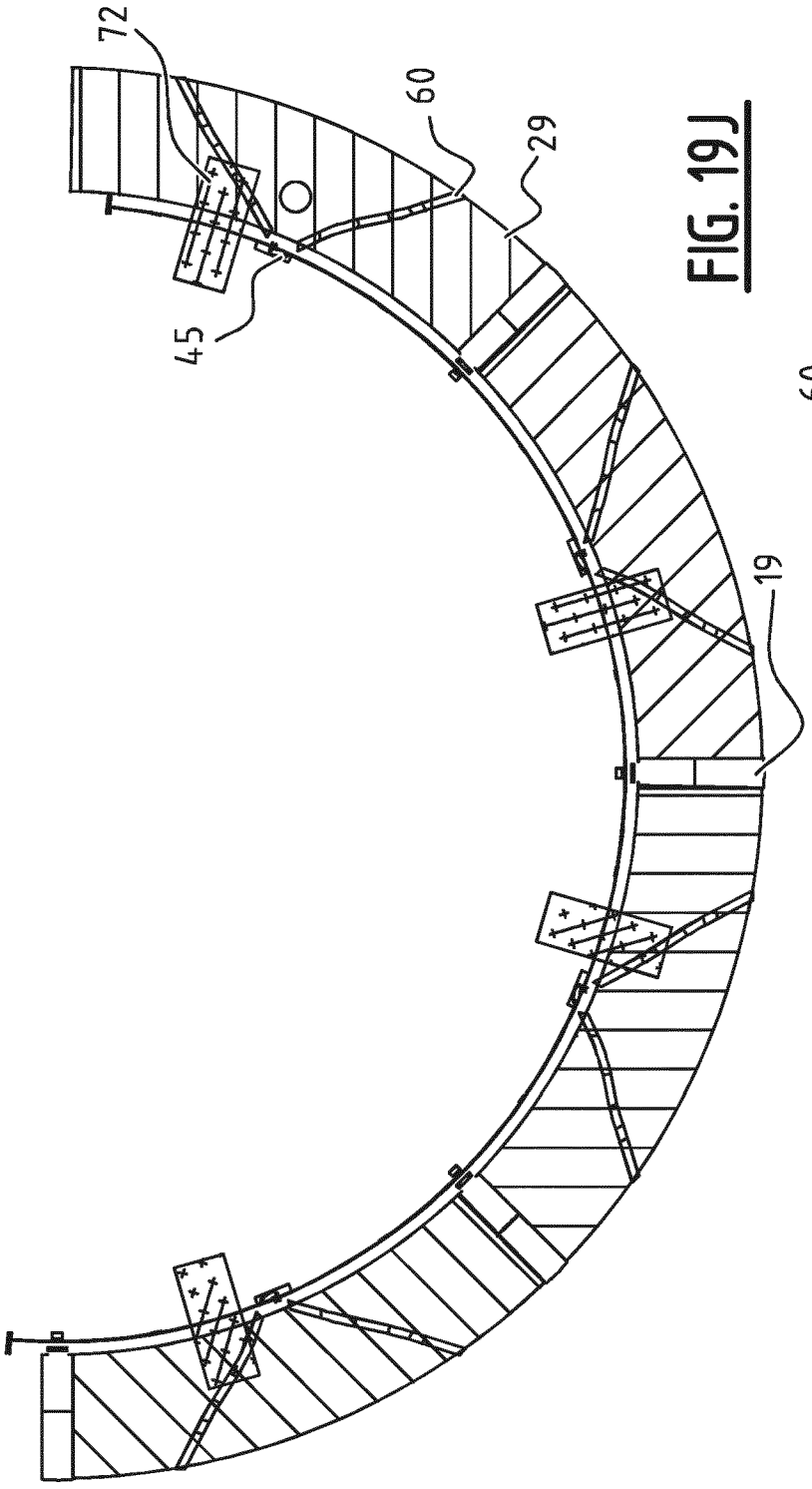

FIG. 19J

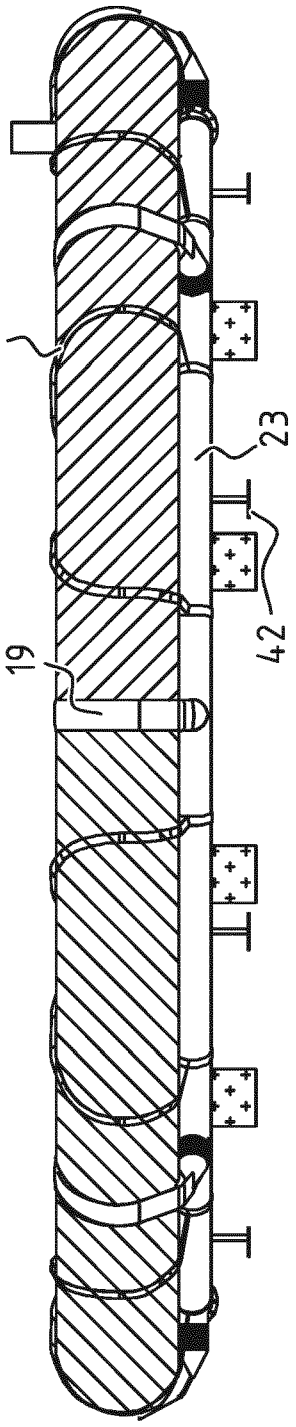

FIG. 19K

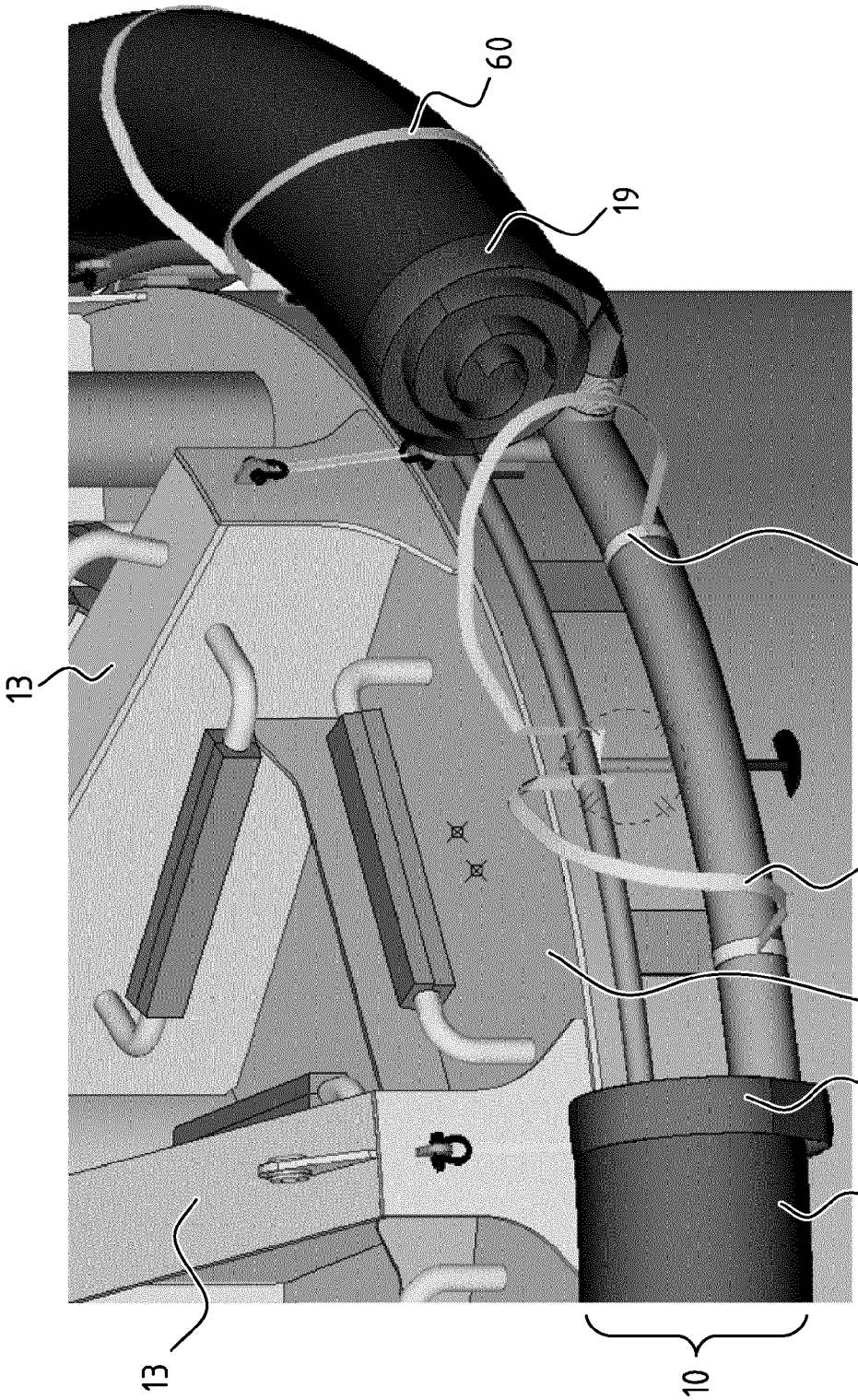

FIG. 20

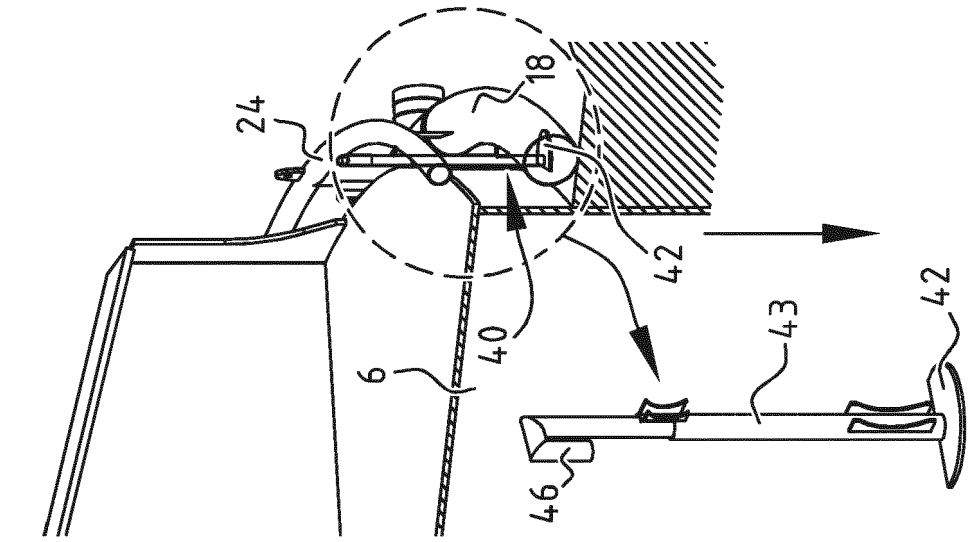

FIG. 21C

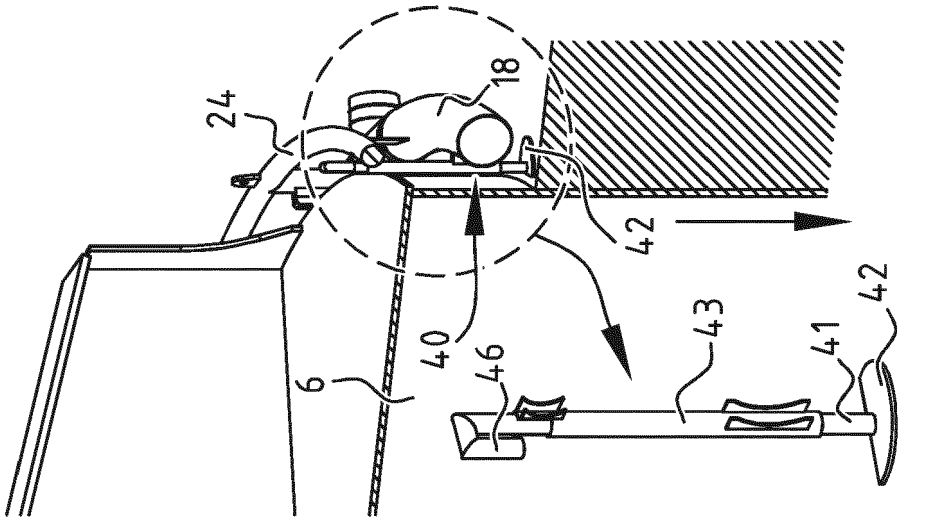

FIG. 21B

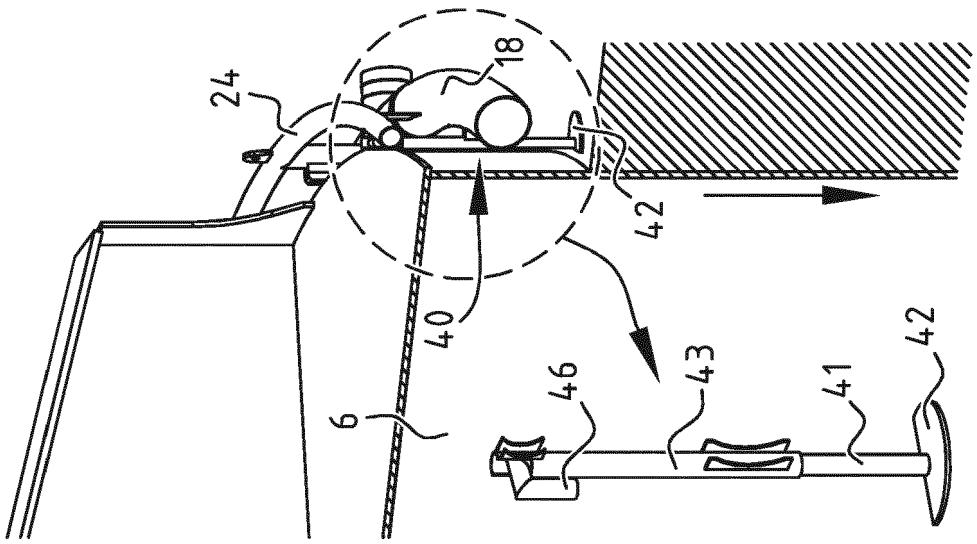

FIG. 21A

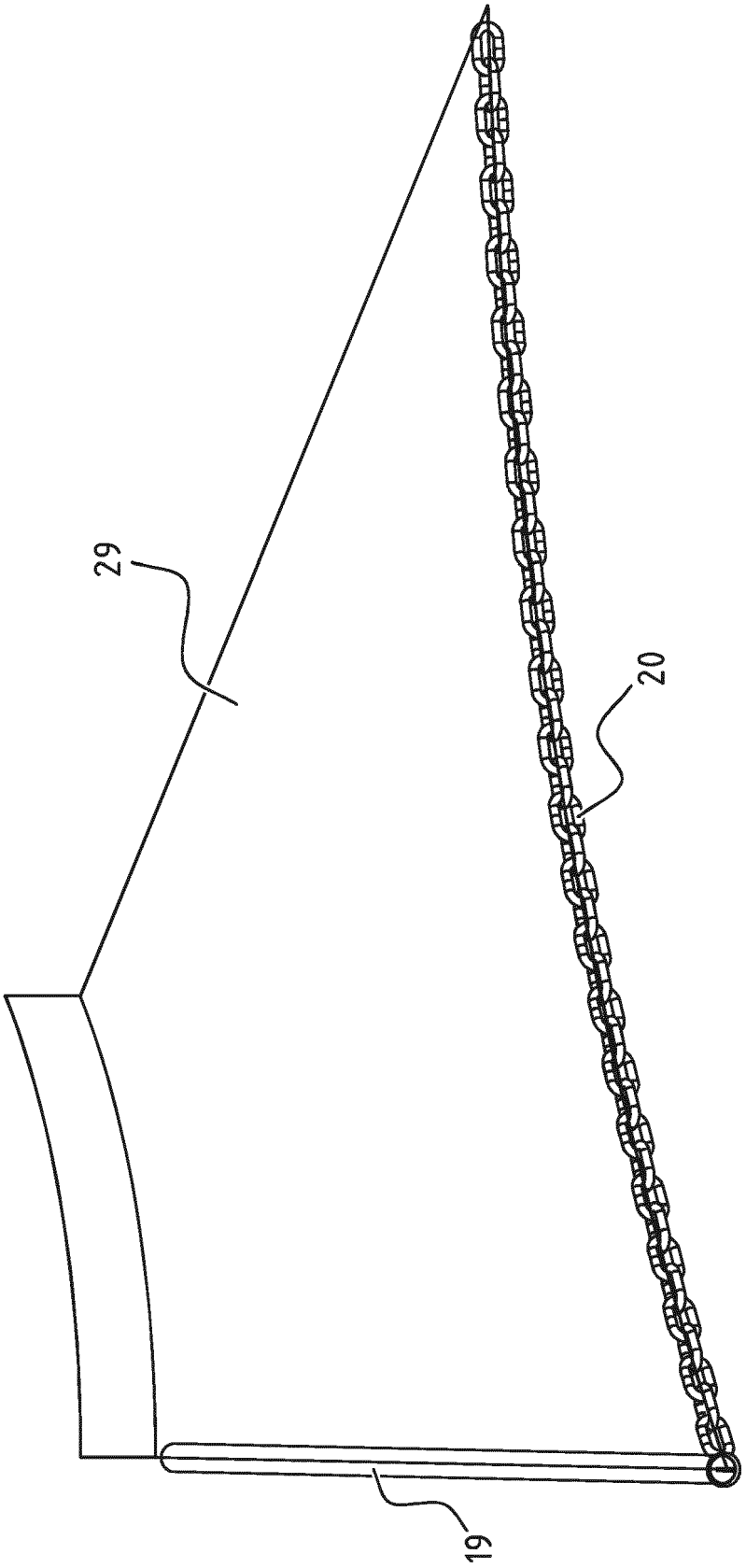

FIG. 22

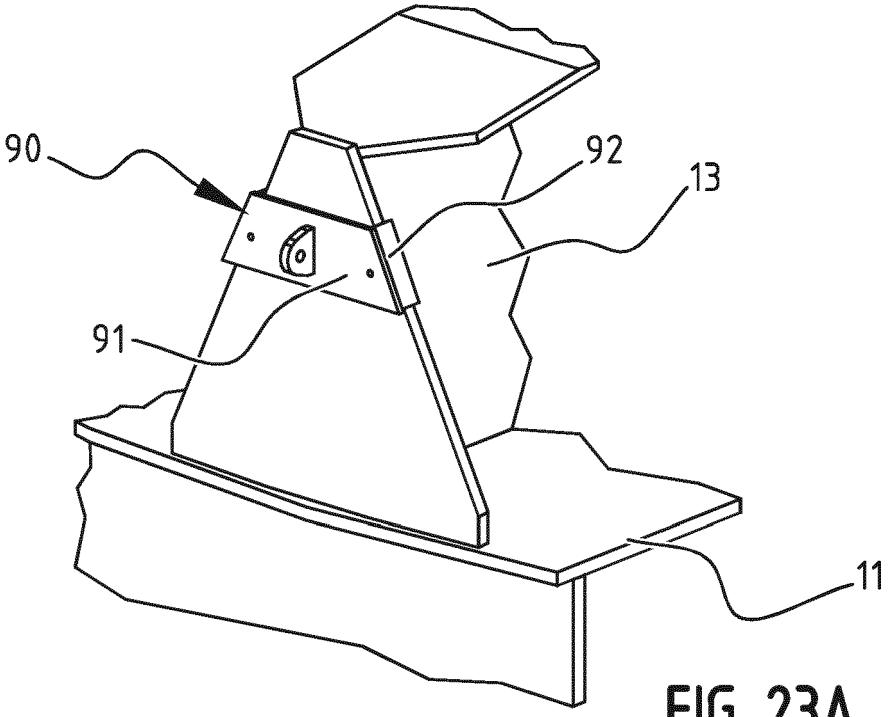

FIG. 23A

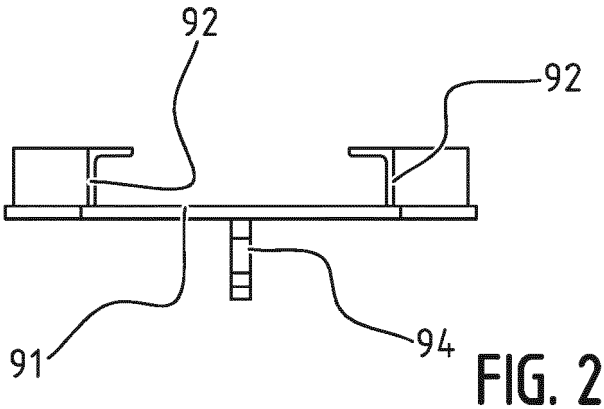

FIG. 23B

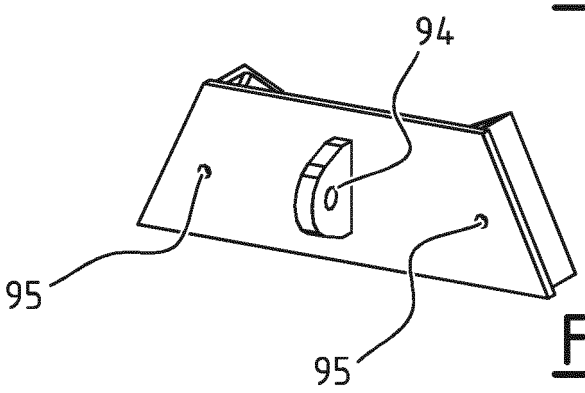

FIG. 23C

REFERENCES CITED IN THE DESCRIPTION

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