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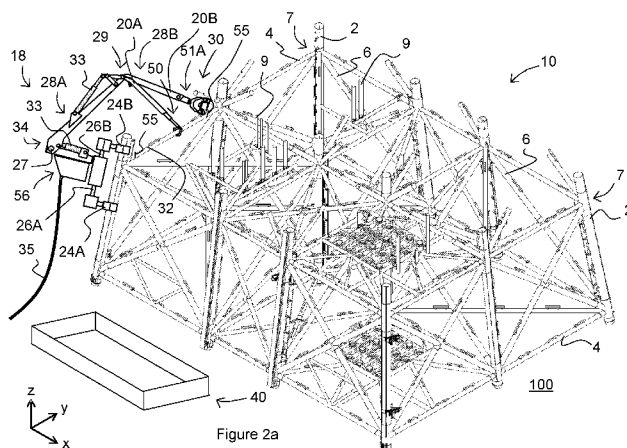
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(54) Title: METHOD AND DEVICE FOR ASSEMBLING OR DISASSEMBLING A STRUCTURE UNDER WATER



(57) Abstract: The invention relates to a method of performing an under water operation on a structure (10) or in the vicinity of the structure, the method comprising: -providing a device (18) comprising a movable arm (20), the device being constructed to perform an under water operation on the structure or in the vicinity of a structure, the device comprising: oat least a first support (22) constructed to be connected to the structure, the support being configured to transfer substantial forces in three dimensions and substantial moments about the X-axis, Y-axis and Z-axis from the movable arm to the structure, including a vertical force required for lifting operations of the device, oat least a first articulated movable arm (20) directly or indirectly connected at a proximal end (34) to said support, the first movable arm comprising a first tool (30) connected to a distal end (36) of said first movable arm, wherein the first tool (30) is movable in a three dimensional working range (98) around the at least first support, oat least one actuator (33) configured to controllably move the first tool (30) in the three dimensional working range in order to position the first tool at a target location, a control device (56) configured to control the at least one actuator and the tool during operation, -attaching the device to the structure via the at least one support, -moving the tool in three dimensions and performing an operation under water.

Title: Method and device for assembling or disassembling a structure under water

Reference

This patent application claims priority from NL2006153, filed on 7/2/2011 having title "Method and device for assembling or disassembling a structure under water" and from US provisional application 61/440,127, filed on 7/2/2011, having a same title, which applications
5 are incorporated by reference herein.

Field of the invention

The present invention relates a method and a device for assembling or
disassembling a structure which is at least in part submerged, in particular for disassembling
10 a jacket structure.

Background of the invention and prior art

In the offshore industry, jacket structures (or jackets in short) are widely used to support and fix platforms above the sea surface. A jacket structure is generally positioned
15 directly onto the seabed. A jacket comprises many tubulars which are interconnected and form a lattice structure. The beams are generally made from steel. A jacket generally comprises a number of beams which are substantially upstanding and which extend from a base of the jacket to a top of the jacket. The upstanding beams are generally connected to one another via horizontal and diagonal cross-beams.

20 Once a jacket reaches the end of its economic or technical lifespan, it may need to be removed. The required removal is dependent on local administrative requirements and can be in part or in full.

In a known method of removing a jacket, a heavy lift vessel is used to support a top part of the jacket. Subsequently, the jacket is cut at a certain distance above the seabed.
25 The section above the cut is lifted and removed with the heavy lift vessel, and the section below the cut remains on location. A further cutting and lifting operation may be required to remove a next part.

The cutting of the jacket generally is a time consuming and expensive operation. Generally, a large vessel with a crew is required in order to perform the cutting. Divers or
30 one or more ROV's and special cutting and lifting equipment are required for the actual cutting itself. For the lifting operation, heavy lift capability is required, which is expensive.

The known removal operation has a further disadvantage in that bad weather can cause significant delays, which further increase the costs.

There is a need in the field of the art for more efficient and cost-effective way of removing jacket structures.

Object of the invention

- 5 It is an object of the invention to provide a method and device for removing in a reliable and efficient manner a large jacket structure which is at least partially submerged.

Summary of the invention

- 10 The invention provides a method of performing an under water operation on a structure (10) or in the vicinity of the structure, the method comprising:
- providing a device (18) comprising a movable arm (20), the device being constructed to perform an under water operation on the structure or in the vicinity of a structure, the device comprising:
 - 15 ○ at least a first support (22) constructed to be connected to the structure, the support being configured to transfer substantial forces in three dimensions and substantial moments about the X-axis, Y-axis and Z-axis from the movable arm to the structure, including a vertical force required for lifting operations of the device,
 - 20 ○ at least a first articulated movable arm (20) directly or indirectly connected at a proximal end (34) to said support, the first movable arm comprising a first tool (30) connected to a distal end (36) of said first movable arm, wherein the first tool (30) is movable in a three dimensional working range (98) around the at least first support,
 - 25 ○ at least one actuator (33) configured to controllably move the first tool (30) in the three dimensional working range in order to position the first tool at a target location,
 - 30 ○ a control device (56) configured to control the at least one actuator and the tool during operation,
 - attaching the device to the structure via the at least one support,
 - moving the tool in three dimensions and performing an operation under water, wherein forces and moments that occur during the operation are transferred to the structure.

With the method according to the invention, under water operations on a structure or in the vicinity of a structure are possible.

- 35 In an embodiment, all forces required for the operation are transferred to the structure.

In an embodiment, the invention provides a method of assembling or disassembling a structure which is located at least partially under water, the method comprising:

- providing a device comprising at least one movable arm, wherein:
 - the movable arm comprises at least a first segment and a second segment connected to one another via at least a first hinge,
 - the support is connected to a proximal end of the first segment via at least one support hinge, the support being constructed to be mounted to the structure,
 - the tool is mounted to a distal end of the second segment,
 - the least one actuator is configured to:
 - controllably move the first segment relative to the support, and to
 - controllably move the second segment relative to the first segment in order to position the tool at a target location in a working range of the arm,
 - the control device is configured to control the at least one actuator and the tool during operation,
- performing a processing operation on the structure for assembling or disassembling the structure

With the present invention, a large jacket structure can be disassembled. It is possible to disassemble a jacket structure of for instance 100 meter. The disassembling operation can be performed substantially independently by the movable arm. The movable arm can be connected to one or several umbilicals providing electrical and/or hydraulic power, communication cables, fibre optics and the like. The umbilical can extend to a vessel at the water surface or straight to shore.

It is also possible to disassemble the bottom part of a jacket after the top part has been removed with a heavy lift operation. The invention may also be used for disassembling large objects which rest on the seabed as a result of a calamity, for instance a sunken ship. The movable arm has a substantial lifting capability, i.e. 10 tons or more. This is required to handle large tools and jacket segments. The movable arm thus does not need an extra under-water balloon to provide extra lifting capacity.

Under water cranes are known for other purposes. US4109480 discloses a submarine cherry picker constructed to be positioned on the seabed and suitable for repairing a pipeline under water. This cherry picker is not suitable for disassembling a jacket structure, at least because the working range above the seabed is too limited. The cherry picker further lacks sufficient lifting capacity to handle parts without an extra balloon. Furthermore, the cherry picker according to US4109480 is limited to lifting parts, and cannot perform any other functionality than lifting, because only a hook is provided at the end of the crane.

US6267037B1 describes a cutting tool for cutting an underwater pipeline. The tool comprises a cutting wire which is rotated to cut the pipeline. The tool has limited capabilities and is not very versatile. A part which is cut from the structure is uncontrolled and drops to the seabed. The apparatus of US6267037B1 therefore is not suitable to disassemble a

5 jacket independently or substantially independently.

In an embodiment, the tool comprises a gripping tool.

In another embodiment, the tool comprises a processing tool selected from a group comprising:

- a cutting tool for cutting in the structure,
- 10 - an excavating device for excavating the seabed or for collecting material which rests on the seabed,
- a drilling device for drilling a hole in the structure, and/or
- a sampling device for taking a sample, in particular from the structure, from the seabed or from the water.

15 In an embodiment, the method comprises:

- gripping a part of the structure with the gripping tool,
- cutting in the structure with the cutting tool such that said part becomes separated from the structure,
- moving the separated part away from the structure with the gripping tool.

20 In this way, the part can be removed in a simple and efficient manner.

In an embodiment, the method comprises simultaneously gripping the part with the gripping tool and cutting in the structure with the cutting tool, thereby preventing the part from falling when the part becomes separated from the structure. The capability of simultaneous gripping in one location and cutting in another location allows safe removal of

25 the parts, without dropping of the parts onto the seabed below.

In an embodiment, the cutting tool is movable relative to the gripping tool, allowing a part of the structure to be held by the gripping tool while the cutting tool cuts the structure in different positions which are required to separate the part from the structure, the method comprising:

- 30 - gripping a part of the structure which is envisaged to be separated from the structure with the gripping tool,
- moving the cutting tool to different locations and cutting in the structure at the different locations for separating the part from the structure while maintaining the grip on the part with the gripping tool.

35 Generally, a part such as a beam is connected to the rest of the structure at multiple locations. Generally, multiple cuts will have to be performed to separate the part completely from the structure. Because the cutting tool is movable relative to the gripping tool, a part of

a substantial size can be separated from the structure. In an embodiment, the working range of the cutting tool extends up to 5 meter from the gripping tool. In this way, parts of up to 10 meter can be removed from the structure.

In an embodiment, the method comprises:

- 5 - providing a container at the seabed within a working range of the movable arm,
 - each time separating a part from the structure,
 - placing the separated parts in the container by the arm,
 - lifting the filled container to the water surface,
 - transporting the container to a remote location with a vessel.
- 10 The parts can be conveniently collected in the container. Littering of parts on the seabed can be avoided, which results in a clean removal operation. The container can be hoisted with a cable by a vessel. A new, empty container may be put in place prior to the removal of the full container in order to enable a non-stop operation.

In an embodiment, the support comprises at least one clamp, the method comprising:

- 15 - clamping the structure at a first position,
- removing at least one first part from the structure, and in particular as many parts as are within the working range of the movable arm at the first position,
- releasing the at least one clamp,
- moving the support to a second position on the structure and clamping the
- 20 structure at the second position,
- removing at least one second part from the structure, and in particular as many parts as are within the working range of the movable arm at the second position,
- repeating these steps until the structure is substantially disassembled.

- By starting at the top of the structure and moving downward, an efficient operation is
- 25 possible. In case of a jacket which is wider than the working range of the movable arm, it is possible that the movable arm is positioned at several locations in one horizontal level before being moved downward to a next, lower horizontal level.

In an embodiment, the movable arm is moved in a downwards spiral along the outer side of the structure for disassembling the structure.

- 30 In an embodiment, the method comprises clamping the at least one clamp to a vertical beam or substantially vertical beam of the structure and moving downwards along said beam from said first position to said second position and further downward until the structure is substantially disassembled.

- The substantially vertical beam is a suitable location to support the movable arm and
- 35 can function as a rail along which the support can move downward.

In an embodiment, an auxiliary rail is mounted to the support structure for supporting the arm, wherein the support of the movable arm is constructed to engage said rail and slide

or roll along said rail. The rail has a vertical or substantially vertical orientation. The rail can be mounted to the vertical or substantially vertical beam and extends substantially parallel to the vertical or substantially vertical beam.

In an embodiment, the control device comprises cameras.

5 In an embodiment, the control device comprises:

- a data processing device comprising a memory configured for storing:
 - geometrical data relating to the initial form of the structure, and
 - disassembly data relating to the progress of disassembling the structure and the current form of the structure,
- 10 - one or more sensors constructed for determining a current position of the arm and of the tool relative to the structure,
and wherein the method comprises:
 - loading the geometrical data into the memory,
 - determining a part to be removed from the structure and determining a target
 - 15 position of the tool on the basis of the geometrical data and the disassembly data,
 - moving the tool to the target position,
 - removing a part from the structure by gripping the part, cutting in the structure until the part is separated and moving the part away from the structure,
 - 20 - updating the disassembly data with data on the removed part,
 - repeating the steps until the structure is disassembled.

With this embodiment, feed forward control and feedback control can be combined for an efficient removal process. With the geometrical data and the disassembly data, a next part which is to be removed can be determined. It can also be determined how the movable

25 arm can reach said part. If the support needs of the movable arm to be repositioned at another support location, this can be performed prior to the cutting operation. The support may need to be replaced vertically or horizontally. Next, the part is gripped and cuts are made in the structure. Next, the part is removed and the disassembly data are updated with the removed part.

30 The sensors provide data for accurate positioning. Although in theory the complete form of the structure is known from the geometrical data, in practice unknown obstacles may be present, due to an incomplete or inaccurate drawing. With the sensors, the actual data can be used for accurate positioning.

In an embodiment, the method comprises:

- 35
- cutting the structure at a cutting point, wherein a top part of the structure is separated from a bottom part of the structure,

- 7 -

- lifting the top part of the structure with a lifting device on a vessel and removing the top part from the location with the vessel,
- disassembling the bottom part of the structure according to the method of claim 1.

5 In some situations, it is more efficient to remove a top part of the jacket with a lift operation. Only the bottom part may then be disassembled with the movable arm. This will speed up the total disassembly time and will allow the movable arm to work at a depth below the water surface where there is no influence from waves.

In an embodiment, the method comprises:

- 10
- providing a first of said movable arm,
 - providing a second of said movable arm,
 - gripping a part of the structure with the gripping tool of the first movable arm,
 - cutting in the structure with the cutting tool of the second movable arm such that said part becomes separated from the structure,
- 15
- moving the separated part away from the structure with the first movable arm.

With a pair of arms, it is possible to speed up the operation. Moreover, some parts may need to be supported in more than one location. This can be performed with two or more arms.

In an embodiment, the method comprises:

- 20
- gripping the first movable arm with the gripping tool of the second movable arm,
 - releasing the support of the first movable arm from the structure,
 - moving the first movable arm with the second movable arm, such that the support of the first movable arm is moved from a first support position to a second support position, thereby changing the working range of the first movable arm.

25 One arm can be used to efficiently replace another arm. This allows easy repositioning of the arms.

In an embodiment, the method comprises:

- providing a device comprising a movable arm, the device further comprising:
 - o a body, the first articulated movable arm being connected to the at least
- 30
- o one support via said body, the first movable arm comprising a gripping tool,
 - o a second articulated movable arm directly or indirectly connected at a proximal end to said support, the second movable arm comprising a processing tool connected to a distal end of said second movable arm,
- 35
- wherein the processing tool is movable in a three dimensional working range around the at least first support,

- performing a processing operation on the structure with the gripping tool and the processing tool.

In an embodiment, the method comprises:

- 5 - providing a device, wherein both at the proximal end and at the distal end of the articulated movable arm there is provided:
 - a support, and
 - a processing tool,wherein the proximal end and the distal end are configured to exchange functions,
- 10 - in a first operating mode, mounting the support at the proximal end to the structure and performing a processing operation with the processing tool at the distal end, and
- 15 - in a second operating mode, mounting the support at the distal end to the structure and performing a processing operation with the processing tool at the proximal end.

In an embodiment, the method comprises: providing a vessel above the structure and assisting the operation by connecting a line from the vessel to the articulated movable arm or to a part of the structure and exerting an upward force on the articulated movable arm or on the part of the structure via the line.

- 20 In an embodiment, the method comprises providing at least one submerged buoyancy tank and assisting the operation by connecting a line from the buoyancy tank to the articulated movable arm or to a part of the structure and exerting an upward force on the articulated movable arm or on the part of the structure via the line.

- 25 In an embodiment, the method comprises connecting an excavating device to the distal end of the at least one articulated movable arm and carrying out at least one excavating operation in the vicinity of the structure.

The present invention relates to a method of assembling or disassembling a structure which is located at least partially under water, the method comprising:

- 30 - providing a device comprising at least one movable arm, the device comprising:
 - at least one movable arm comprising at least a first segment and a second segment connected to one another via at least a first hinge,
 - a support connected to a proximal end of the first segment via at least one support hinge, the support being constructed to be mounted to the structure or placed on the seabed,
 - 35 ○ a processing tool mounted to a distal end of the second segment,
 - at least one actuator configured to:

- controllably move the first segment relative to the support, and to
 - controllably move the second segment relative to the first segment,
- 5 in order to position the processing tool at a target location in a working range of the arm,
- control device configured to control the at least one actuator and the processing tool during operation,
- 10 - performing a processing operation on the structure for assembling or disassembling the structure.

The present invention further relates to a device comprising a movable arm, the device being constructed to perform an under water operation on an at least partially submerged structure or in the vicinity of the at least partially submerged structure, the device comprising:

- 15 - at least a first support constructed to be connected to the structure, the support being configured to transfer substantial forces in three dimensions and substantial moments about the X-axis, Y-axis and Z-axis from the movable arm to the structure, including a vertical force required for lifting operations of the device,
- 20 - at least a first articulated movable arm directly or indirectly connected at a proximal end to said support, the first movable arm comprising a first tool connected to a distal end of said first movable arm, wherein the first tool is movable in a three dimensional working range around the at least first support,
- 25 - at least one actuator configured to controllably move the first tool in the three dimensional working range in order to position the tool at a target location,
- a control device configured to control the at least one actuator and the tool during operation.

- The present invention further relates to a device comprising a movable arm for
- 30 disassembling or assembling a structure extending at least partially under water, wherein:
- the movable arm comprises at least a first segment and a second segment connected to one another via at least a first hinge,
 - the support is connected to a proximal end of the first segment via at least one support hinge, the support being constructed to be mounted to the structure or to
- 35 be placed on the seabed,
- the tool is mounted to a distal end of the second segment,
 - at least one actuator configured to:

- 10 -

- controllably move the first segment relative to the support, and to
- controllably move the second segment relative to the first segment in order to position the processing tool at a target location in a working range of the arm,

- 5 - the control device is configured to control the at least one actuator and the tool during operation.

The movable arm provides substantially the same advantages as described in relation to the method above.

In an embodiment, the tool comprises:

- 10 - a gripping tool for gripping a part of the structure, and/or
- a processing tool for performing a processing operation on the structure or in the vicinity of the structure.

In an embodiment, the gripping tool and/or the processing tool is rotatable about the distal end of the articulated movable arm about three independent axes, providing the

15 gripping tool and/or processing tool with six degrees of freedom relative to the support.

In an embodiment, the processing tool is selected from a group comprising:

- a cutting tool for cutting in the structure,
 - a sampling device for taking a sample, in particular from the structure, from the seabed or from the water,
- 20 - a drilling device for drilling a hole in the structure, and/or
- an excavating device for excavating the seabed or for collecting material which rests on the seabed.

In an embodiment, the cutting tool is movable relative to the gripping tool, allowing a part of the structure to be held by the gripping tool while the cutting tool cuts the structure in

25 different positions which are required to separate the part from the structure.

In an embodiment, the cutting tool is connected to the gripping tool or to the movable arm via a movable cutting arm which provides the cutting tool with a working range which extends around the gripping tool.

In an embodiment, the support comprises a clamping device which comprises

30 clamping members constructed to clamp to a vertical or substantially vertical beam of the structure. The clamp comprises clamping members which have substantially vertically extending gripping surfaces.

In an embodiment, the support comprises:

- a first clamp,
- 35 - a second clamp spaced apart from the first clamp, and

- at least one support beam connecting the first and second clamp to one another, wherein the first segment is connected to said support beam via the support hinge.

In an embodiment, the control device comprises:

- 5 - a data processing device comprising a memory configured for storing:
 - geometrical data relating to the form of the structure,
 - assembly data or disassembly data relating to the individual steps of assembling or disassembling the structure,
- 10 - one or more sensors constructed for determining a current position of the arm and of the tool relative to the structure.

In an embodiment, the device comprises:

- a body, the first articulated movable arm being connected to the at least one support via said body, wherein a gripping tool is provided at the distal end,
- a second articulated movable arm directly or indirectly connected at a proximal end to said support, the second movable arm comprising a processing tool connected to a distal end of said second movable arm, wherein the processing tool is movable in a three dimensional working range around the at least first support.

In an embodiment, the device comprises a movable arm comprising:

- 20 - a first support connected to the body and comprising at a distal end thereof a clamp for clamping to the structure or an insertion device constructed to be inserted into the structure for providing a secure connection with the structure, and
- 25 - a second support connected to the body and comprising at a distal end thereof a clamp for clamping to the structure or an insertion device constructed to be inserted into the structure for providing a secure connection with the structure.

In an embodiment, the device comprises a movable arm, wherein the first support comprises a first articulated leg being connected at a proximal end to the body and comprising at a distal end thereof the clamp or insertion device, and wherein the second support comprises a second articulated leg being connected at a proximal end to the body and comprising at a distal end thereof the clamp or insertion device, the first and second legs comprising actuators for moving the first and second clamp in a three dimensional working range around the body.

In an embodiment, the device comprises an articulated movable arm, wherein both at 35 the proximal end and at the distal end of the articulated movable arm there is provided:

- a support and
- a processing tool,

wherein the proximal end and the distal end are configured to exchange functions, wherein:

- in a first operating mode the support at the proximal end is connected to the structure and the processing tool at the distal end is operable to perform a processing operation on the structure, and
- in a second operating mode the support at the distal end is connected to the structure and the processing tool at the proximal end is operable to perform a processing operation.

In an embodiment, the device comprises a movable arm, wherein the at least one articulated arm comprises a first, a second and a third segment connected to one another via a first and a second hinge.

In an embodiment, the device comprises a movable arm, further comprising at least one buoyancy device connected to the at least one articulated arm for increasing the lift capacity of the movable arm.

The present invention further relates to a combination of a first device comprising a movable arm according to any of claims 25-40 and a second device comprising a movable arm according to any of claims 25-40.

In an embodiment of the combination, the first device comprises a first coupling part and the second device comprises a second coupling part, the first and second coupling part being configured to be coupled to one another to form a joint movable arm assembly comprising at least two movable arms.

In an embodiment of the combination, the coupling parts are provided substantially in a central area of the first movable arm and the second movable arm.

The present invention further relates to an assembly for disassembling a structure extending at least partially under water, the assembly comprising:

- at least one movable arm according to the invention, and
- at least one container for accommodating removed parts from the structure.

The present invention relates to a movable arm for disassembling or assembling a structure extending at least partially under water, the movable arm comprising:

- at least a first segment and a second segment connected to one another via at least a first hinge,
- a support connected to a proximal end of the first segment via at least one support hinge, the support being constructed to be mounted to the structure or to be placed on the seabed,
- a processing tool mounted to a distal end of the second segment,
- at least one actuator configured to:
 - controllably move the first segment relative to the support, and to

- controllably move the second segment relative to the first segment in order to position the processing tool at a target location in a working range of the arm,
- a control device configured to control the at least one actuator and the processing tool during operation.

Brief description of the drawings

The previous and other features and advantages of the present invention will be more fully understood from the following detailed description of exemplary embodiments with reference to the attached drawings.

Figure 1A shows a schematic side view of the movable arm according to the invention comprising a cutting tool.

Figure 1B shows a schematic side view of the movable arm according to the invention comprising a gripping tool.

Figure 2A shows an orthogonal view of an embodiment of the movable arm in a first operational step.

Figure 2B shows an orthogonal view an embodiment of the movable arm in a next operational step.

Figures 3-8 show schematic side views of respective steps of the method according to the invention.

Figure 9 shows a schematic top view of another embodiment of the invention.

Figure 10 shows a schematic side view of another embodiment of the invention.

Figure 11 shows a detailed view of a processing tool.

Figures 12A and 12B show a schematic side view of a jacket with an embodiment of the invention connected to it.

Figure 13 shows a schematic side view of another embodiment of the invention.

Figures 14A and 14 B show a schematic side view of another embodiment of the invention.

Figure 15 shows a schematic side view of another embodiment according to the invention.

Figure 16 shows a schematic side view of yet another embodiment according to the invention.

Figure 17 shows a schematic side view of another embodiment according to the invention.

Figure 18 shows a schematic side view of yet another embodiment according to the invention.

Figure 19 shows a schematic side view of another embodiment according to the invention.

Figure 20 shows a schematic view of another embodiment according to the invention.

Figure 21 shows a schematic view of another embodiment according to the invention.

5

Detailed description of the figures

Turning to Figure 1A, a device 18 comprising an articulated movable arm 20 according to the invention is shown. The movable arm 20 comprises a support 22 having
10 two clamps 24A, 24B. The two clamps 24A, 24B are connected to the support 22 and to one another via two intermediate beams 26A, 26B, which are preferably adjustable in length.

The clamps are constructed to transfer substantial forces in three dimensions and substantial moments about the X-axis, Y-axis and Z-axis from the device 18 to the structure
10. In particular when a lifting operation is performed, a downward vertical force is exerted
15 by the device 18 via the support 22 onto the structure 10. If a current exists in the water, horizontal forces will also be transferred via the support 22 to the structure 10.

In an embodiment, the device does not comprise a support 22 configured to rest on the seabed 100. In this embodiment, all forces and moments are transferred to the structure
10.

20 In an embodiment, the support 22 is constructed to be connected to the structure 10 under water.

The movable arm 20 is mounted on a turret 63. The turret 63 comprises a pivot 61 via which the arm 20 is rotatable relative to the support 22 about rotation axis 62.

A proximal end 34 of a first segment 28A is connected to the turret 63 via a hinge
25 27.

The arm comprises a first segment 28A and a second segment 28B. The first and second segments are connected to one another via a hinge 29. The movable arm may comprise additional segments, i.e. three or four segments.

The movable arm 20 comprises a number of actuators 33 with which the movable
30 arm can be moved. The actuators 33 can be electric or hydraulic. A power cable 35 is provided which extends between the movable arm 20 and an auxiliary vessel for providing power to a motor 31 of the movable arm 20.

A tool 30 is provided at a distal end 36 of the second segment 28B. In an embodiment, the tool 30 comprises a gripping tool 50. In an embodiment, the tool 30
35 comprises a processing tool 51, for instance a cutting tool 51A. The processing tool may also be another type of equipment such as a tool for drilling 51B, grinding and the like. The cutting tool 51A may be a saw, a flame cutting tool, a welding tool, a laser device or a

different kind of cutting tool. In an embodiment, the cutting tool comprises a wrench for connecting or disconnecting bolts.

The rotation axis 62, the hinge 27 and the hinge 29 provide the segment 28b with three degrees of freedom relative to the support 22.

5 The tool 30 is rotatable relative to segment 28B about three independent axes of rotation 80, 81, 82 via a hinge 84. This provides the tool 30 with six degrees of freedom. The six degrees of freedom allow the tool 30 to be positioned in any position within the 3D working range and have any orientation in that position.

10 The cutting tool 51A is provided with a rotating cutting wire 109. In use, the rotating cutting wire 109 cuts through steel tubulars in a practical manner.

Turning to figures 2A and 2B, a jacket 10 or different kind of structure which is to be removed comprises a plurality of substantially vertical (or upstanding) beams 2. The beams may be oriented at an angle of 0-8 degrees to the vertical. The jacket 10 comprises a grid of 4 by 2 upstanding beams 2. The jacket further comprises horizontal cross-beams 4 which
15 extend between the upstanding beams 2 and diagonal beams 6, which also extend between the diagonal beams. The beams 2, 4, 6 are connected to one another at joints 7 and form a lattice structure.

The jacket 10 may also comprise ducts 9 and other equipment which is mounted to the lattice structure.

20 The jacket 10 which is shown in figures 2A, 2B is only a part of the original jacket. It is the bottom part, and the top part of the jacket is already removed, for instance via a heavy lift operation.

Returning to figure 1A, the clamps 24A, 24B are constructed to be connected to the vertical beams 2. To this end, the clamps comprise clamp members 23 which have
25 substantially vertically extending gripping surfaces. The gripping surface 23 are pivotable relative to the intermediate beams 26A, 26B such that their gripping surfaces can be aligned with the intermediate beams. This allows the intermediate beams 26A, 26B to be oriented substantially parallel to an upstanding beam 2 of the jacket. See also figure 4.

Turning to Figure 1B, a gripping tool 50 is connected to the distal end of the second
30 segment 28B. The gripping tool comprises fingers 101 which are movable relative to one another for gripping a part of the structure.

The arm 20 may comprise both a gripping tool 50 and a processing tool 51.

Alternatively, the arm may comprise only a gripping tool 50, or only a processing tool 51.

Returning to figure 2A, the device 18 is a different embodiment than the device 18
35 shown in figures 1a and 1b, in the sense that the arm 20 comprises both a gripping tool 50 and a cutting tool 51A, and the device 18 comprises a joint where the arm 20 splits in a gripping arm 20A and a processing arm 20B. The processing arm 20B provides the cutting

tool 51A with a working range about the gripping tool 50. The movable processing arm 20B is equipped with an actuator, so that the cutting tool 51A can be controllably positioned around the gripping tool 50.

5 The movable arm comprises at least one actuator and the actuator is coupled to a control unit 60.

In an embodiment, the control unit 60 comprises a data processing device. The data processing device comprises a memory configured for storing geometrical data relating to the initial form of the structure, and disassembly data relating to the progress of disassembling the structure and the current form of the structure.

10 The geometrical data may be obtained from measurements or a computer file which was used to design the jacket, an AutoCAD file or similar file from another design program.

The disassembly data may comprise a sequence of removal operations according to which the structure is to be disassembled. In the sequence, the structure may be divided into separate parts which are to be removed in sequence.

15 In an embodiment, the device 18 comprising the movable arm 20 comprises several sensors 102 which are used for determining a current position of the movable arm and of the processing tool relative to the structure. These sensors may be ultrasonic sensors, video cameras and/or touch sensors which register an engagement of the movable arm with the structure.

20 Other sensors are also provided, such as a current sensor 104 for measuring the current, a weight sensor 103 for measuring the weight of the part 32 which is lifted.

Operation

25 With reference to figure 3, the device 18 comprising the movable arm according to figures 1a, 1b operates as follows. When a jacket 10 needs to be removed, an auxiliary vessel 110 is positioned at the water surface 111 nearby. An ROV 112 which is connected to the auxiliary vessel via an umbilical 114 is used to make a cut in the jacket 10, dividing the jacket in a bottom part 10A and a top part 10B.

30 Turning to figure 4, two devices 18A, 18B comprising movable arms 20A, 20B are subsequently positioned on the jacket 10. The movable arms 20 are positioned on the jacket 10 from the vessel 110, for instance by lowering the movable arms 20A, 20B with a hoisting system from the vessel. The clamps 24A, 24B are clamped onto one of the upstanding beams 2, see figure 1. The movable arms 20A, 20B may also start the operation at a position which is above the water level, however this is less preferred.

35 One movable arm 20A comprises at least a gripping tool 50, and one movable arm 20B comprises at least a cutting tool 51A. In one embodiment, both arms 20A, 20B comprise both a gripping tool 50 and a cutting tool 51A.

Two containers 40 are positioned at the seabed 100, within working range of the movable arms 20. The containers comprise one or more connectors 41 for connecting a cable to the container 40. The containers comprise a bottom and side walls and are open at the top, so that a part can be placed in the container with relative ease.

5 Turning to figure 5, a heavy lift vessel 120 is positioned at the jacket 10. The heavy lift vessel 120 comprises a crane 122 and lifts the top part 10B of the jacket 10. The bottom part 10B remains on the seabed 100.

With reference to figure 6, the movable arms 20A, 20B then start with the operation of cutting a part 32 from the jacket 10. The part will generally be a beam 2, 4, 6 or a part of a
10 beam, but may also be a joint 7 or a beam in combination with a joint 7.

Each part 32 is gripped with a gripping tool 50. The movement of the gripping tool to the part 32 and the subsequent gripping of the part 32 by the gripping tool may be performed manually or automatically. In the case of a manual movement, an operator may be present above the water surface in the auxiliary vessel 110, and control the movement of
15 the movable arm 2 via a connection such as a cable 35.

The part 32 is firmly held by the gripping tool 50. While the part 32 is held by the gripping tool 50, the cutting tool 51A makes cuts 55 in the jacket 2 with the cutting wire 109, so that part 32 becomes separated.

If the operation is carried out with a single arm 20, the processing tool 30 comprises
20 a cutting tool 51A which is movable independently from the gripping tool 50 and which has a three-dimensional working range 52 around the gripping tool 50, as is disclosed in figures 2a,2b. Thus, while the gripping tool 50 holds the part 32, the cutting tool 51A moves to the locations where the cuts 55 need to be made and makes the cuts.

If the operation is carried out with two arms 20A, 20B as is shown in figures 5 and
25 6, the arms 20A, 20B may cooperate. One arm 20A may hold the part 32 with the gripping tool while the other arm 20B cuts the part 32

When the part 32 is disconnected from the jacket 2, the movable arm moves the part 32 away from the jacket. The movable arm moves the part 32 toward the seabed and places the part 32 in the container 40. The gripping tool 50 then releases the part 32. The
30 movable arm 20 then continues with another part 32.

When all removable parts 32 within the working range of the movable arm 20 have been removed and put in the container, the movable arm 20 may need to be repositioned to another position. It is possible that the movable arm 20 is positioned at another location at a same horizontal level. For instance, the movable arm 20 may be repositioned on a different
35 upstanding beam 2 at the same level.

In one embodiment, this repositioning operation is carried out with a crane positioned on board the working vessel 110. A cable is connected to the movable arm 20.

The clamps 24A, 24B are released from the structure 10 and the movable arm may be repositioned at a new location.

In another embodiment, the movable arm 20 has a capability of relocating itself. The movable arm comprises multiple clamps. Two clamps are shown, 24A, 24B, but more than two is also possible. These clamps are mounted on movable clamp arms 26. Each clamp is mounted at an end of a movable clamp arm.

In another embodiment, two movable arms 20A, 20B are provided. Both movable arms 20 comprise clamps 24A, 24B via which the structure is gripped. A first movable arm can move the second movable arm by gripping the second movable arm with its gripping tool 50. The second movable arm then releases its clamps 24A, 24B from the structure. The first movable arm moves the second movable arm to another location, where the clamps of the second movable arm clamp the structure again. The operation may also be performed the other way around, i.e. the second movable arm may move the first movable arm. Thus, when the movable arms are operated in tandem, the disassembly is performed relatively fast, and the repositioning of the movable arms is relatively simple.

When all removable parts 32 within the working range of the movable arm have been removed, the movable arm 20 is lowered, to a new lower position. For instance, the movable arm 20 can be repositioned on the same upstanding beam 2, but at a lower position. When the movable arm is repositioned to a lower location, the working range is also lowered and the jacket structure can be further disassembled.

Turning to figures 7 and 8, when a container 40 is full, the container is lifted to the surface by a vessel 120 and transported to shore. This can be a crane vessel or any other vessel with sufficient hoisting capacity to lift the loaded containers 40. A crane vessel can also lift the containers from the seabed and load them on a transportation barge. An empty container may replace the full container. When the disassembly operation is completed, all the containers 40 are lifted to the surface.

In an embodiment, the processing tool 51 or the gripping tool 50 comprises a hoisting device with a winch. If the jacket is very large, the movable arm may not be able to position a part of the structure on the seabed, because the arm is too short and the working range too limited. The removed part may then be lowered to the seabed with the hoisting device.

In an embodiment, the movable arm is equipped with tracks to allow movement around and positioning on the seabed 100.

The skilled person will understand that the present invention may also be used for assembling a structure under water. The opposite procedure will then be followed. The parts will be provided in a container at the seabed. The device 18 comprising the movable arm will be positioned at a first position near the seabed. Each time a part will be picked from the

container by the movable arm and the part will be connected to the parts which are already in place. In this way, a complete jacket can be erected. When the jacket 10 becomes so tall that the movable arm 20 cannot reach the upper end, the support 22 of the movable arm is repositioned at a higher position.

5 Turning to figures 9, 10 and 11, another embodiment of the device 18 comprising a movable arm 20 is shown. The device comprises a support 22 which comprises an insertion device 150 which is constructed to be inserted into a pipe end. The insertion device is expandable in order to be securely fitted in a pipe end. To this end, the insertion device comprises expanding members 152 which are movable from a retracted position to an
10 outward position in order to engage the inner wall of the pipe end. The expanding members are also retractable back to the retracted position to loosen the device 18 from the pipe end.

The device comprises a turret or slewing ring 63 which is rotatable about the support 22. The first segment 28a is connected to the slewing ring via hinge 27.

At a distal end of segment 28B, thrusters 154 are provided for moving the arm.

15 A further actuator 33 is provided at a distal end 36 of the second segment. The actuator 33 is constructed to move the processing tool relative to the second segment 28B.

In figures 9 and 10, the shown processing tool is a cutting tool 51. The cutting tool comprises a gate 156 which can be opened to let a part of the construction in and can subsequently be closed to confine the part in a closed space. The gate 154 is connected to
20 a body 159 of the cutting tool 51 via a hinge 158 and is driven by a drive. The cutting tool 51 comprises a shear tool 160 which performs the cut.

The body 159 of the cutting tool is rotatable relative to the second segment via a rotary connection 162. The hinge 84 provides two degrees of freedom. Together, the hinge 84 and the rotary connection 162 provide three degrees of freedom for the cutting tool 51A
25 relative to the second segment 28B. A quick coupling 164 is provided in order to quickly exchange the cutting tool 51 for another tool.

Figure 11 shows a grabbing tool 50 having curved projections 166.

Turning to figures 12A and 12B, the device 18 according to the invention may comprise a support having clamps 23 which can clamp a part of a structure, shown with A1
30 in figure 12A. Alternatively, the device 18 may comprise an insertion device 150 which in use is inserted into a cut-off leg 2 of a structure 10. This is shown with A2 in figure 12A. The insertion device 150 is indicated by a dotted line. In figure 12B, with A3, it is shown that the device 18 comprising an insertion device 150 may also be inserted into one of the piles 168 which extend from the seabed upward and to which the structure 10 is anchored.

35 Turning to figure 13, in an embodiment, the device 18 further comprises a buoyancy device 170 which is connected to the arm 20 via a line 172. Buoyancy elements can also be connected directly to the arm, for instance via a buoyant block 177. The buoyancy device

increases the lifting capacity of the movable arm. The position 174 at which the buoyancy device is connected to the arm may be variable in direction 175, i.e. along the arm, with a drive 176.

In an embodiment, the buoyancy of the buoyancy device is variable in a controlled manner. To this end, the buoyancy device comprises a control unit 178 for varying the buoyancy, for instance by inflating the buoyancy device with a gas stored in a cylinder.

In an embodiment, as an alternative or in addition to the buoyancy device 170, a buoyancy device 180 is connected to a part 32 of the structure which is to be removed. The buoyancy device 180 is to the part directly or alternatively is connected via a line 172 to said part 32.

The working range 98 is a sphere around the support 22.

Turning to figures 14A and 14B, in an embodiment, an auxiliary vessel 110 is provided. The vessel 110 comprises a crane 181 or other lifting device. A cable 180 extends from the crane to the device 18 comprising the movable arm 20. The cable is attached to the movable arm 20, near a joint 29. An anti-heave device 184 is provided on board the vessel to compensate for heave motions of the vessel. Anti-heave devices 184 are known in the prior art.

In figure 14B, the cable is connected to a part of the structure which is to be removed.

Turning to figure 15, another embodiment of a device 18 according to the invention is shown. The device 18 comprises a central body 190 and two articulated arms 20A, 20B which are connected at a proximal end 34 to the central body 190. One arm 20A comprises a gripping tool 50 at the distal end 36 and one arm 20B comprises a cutting tool 51 at the distal end 36. The device 18 further comprises two supports 22A, 22B. The supports 22A, 22B are connected to the body via articulated legs 200A, 200B. The articulated legs are connected to the body 190 via hinges 202 and each comprise a first segment 205 and a second segment 206 connected to the first segment via a hinge 208. The articulated legs comprise actuators to move the legs. The supports 22A, 22B comprise clamps for gripping a part of the structure 10.

The arm 20A comprising the gripping tool 50 may provide assistance when the device 18 is to be moved to another position on the structure 10. The gripping tool 50 may grip the structure and provide further stability. Next, one of the legs 200A, 200B may release the structure 10 and be moved to another position on the structure and clamp the structure in that position. Next, the other leg 200 may release the structure and be moved to another position and subsequently grip the structure in that position. It is noted that the gripping tool 50 in this operation functions as a support 22.

It is also possible that a third leg 200 is provided in order to create more stability and allow the device 18 to be connected to the structure at three positions when a lifting operation is carried out by the gripper tool 50, i.e. when a separated part 32 is lifted by the gripping tool 50. The third leg is similar to the first and second leg 200a, 200B. It is also possible that arm 20B comprises a gripping tool 50 in addition to the cutting tool 51, so that the device 18 has two arms 20A, 20B and two legs 200A, 200B with which it can move, i.e. climb, over the structure, more or less like a Orangutan.

Turning to figure 16, another embodiment of the device 18 is shown. The body 190 is splittable in two body parts 190A, 190B. The body parts 190A, 190B comprise couplings 220A, 220B with which the parts 190A, 190B can be coupled to one another and uncoupled from one another.

In the uncoupled operating mode, there are two devices 18A, 18B which may each operate independently, for instance for removing relatively light parts. In the coupled operating mode, there is a single device 18. The device 18 may be more stable and perform operations which require more stability, such as the removal of heavy parts.

Turning to figure 17, two devices 18A, 18B are shown which have a both a gripping tool 50 at a proximal end 34 and a gripping tool 50 at a distal end 36. The gripping tools 50 also function as support 22. The devices 18A, 18B also each comprise a processing tool 51 at the proximal end and a processing tool 51 at the distal end. The processing tool may be a cutting tool (51A).

Turning to figure 18, a device 18 is provided which has a support 22 which is mounted to the structure 10 above the water line 240. The tool 30 is constructed to be provided below the water line. A rail 242 may be provided along which the device 18 can move. The rail may extend horizontally. The rail 242 may also extend over a vertical distance, allowing the device 18 to move along said rail 242.

Turning to figure 19, a device 18 comprising an excavating tool 51B is shown. The excavating tool 51B can be used to remove drill cuttings 250 in the vicinity of a drilling platform. The drill cuttings typically form a pile around the structure 10. A container 40 as shown in figure 2A can be provided in which the drill cuttings 250 can be deposited with the excavating device 51B. It is also possible to just replace the drill cuttings, thereby allowing access to a bottom part 252 of the structure 10 which would otherwise be impossible to reach. In a subsequent step, the bottom part 252 may be disassembled with the device 18 equipped with a cutting tool 51.

The support 22 can be of the insertion type and be inserted into a pile or a leg of the structure 10.

Turning to figure 20, a processing tool 51 in the form of a drill 51C is provided at the distal end of a movable arm. Another movable arm 20 is provided with a gripping tool 50.

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Turning to figure 21, a processing tool 51 in the form of a sampling tool 51D is provided at the end of the arm 20. The sampling tool 51D is constructed to take a sample from the structure 10, from the seabed 100, from the water, from the drill cuttings 250, or another sample. The excavating device 51B, drill 51C and sampling tool 51D are connected
5 to the arm 20 via a quick coupling, allowing easy exchange of the processing tool 51 for another processing tool 51.

It will be obvious to a person skilled in the art that the details and the arrangement of the parts may be varied over considerable range without departing from the spirit of the invention and the scope of the claims.

CLAIMS

1. Method of performing an under water operation on a structure (10) or in the vicinity of the structure, the method comprising:
- providing a device (18) comprising a movable arm (20), the device being constructed to perform an under water operation on the structure or in the vicinity of a structure, the device comprising:
 - at least a first support (22) constructed to be connected to the structure, the support being configured to transfer substantial forces in three dimensions and substantial moments about the X-axis, Y-axis and Z-axis from the movable arm to the structure, including a vertical force required for lifting operations of the device,
 - at least a first articulated movable arm (20) directly or indirectly connected at a proximal end (34) to said support, the first movable arm comprising a first tool (30) connected to a distal end (36) of said first movable arm, wherein the first tool (30) is movable in a three dimensional working range (98) around the at least first support,
 - at least one actuator (33) configured to controllably move the first tool (30) in the three dimensional working range in order to position the first tool at a target location,
 - a control device (56) configured to control the at least one actuator and the tool during operation,
 - attaching the device to the structure via the at least one support,
 - moving the tool in three dimensions and performing an operation under water, wherein forces and moments that occur during the operation are transferred to the structure.
2. Method of claim 1, comprising assembling or disassembling a structure (10) which is located at least partially under water, the method comprising:
- providing a device comprising at least one movable arm (20), wherein:
 - the at least one movable arm comprises at least a first segment (28A) and a second segment (28B) connected to one another via at least a first hinge (29),
 - the support (22) is connected to a proximal end (34) of the first segment via at least one support hinge (27, 61), the support being constructed to be mounted to the structure,
 - the tool (30) is mounted to a distal end (36) of the second segment,
 - the at least one actuator (33) is configured to:

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- controllably move the first segment relative to the support, and to
 - controllably move the second segment relative to the first segment, in order to position the processing tool at a target location in a working range of the arm,
- 5 ▪ the control device (56) configured to control the at least one actuator and the processing tool during operation,
- performing a processing operation on the structure for assembling or disassembling the structure.
- 10 3. Method of claim 1 or 2, wherein the tool comprises a processing tool selected from a group comprising:
 - a cutting tool (51A) for cutting in the structure,
 - an excavating device (51B) for excavating the seabed or for collecting material which rests on the seabed,
 - 15 - a drilling device (51C) for drilling a hole in the structure, and/or
 - a welding device for performing a welding operation,
 - a sampling device (51D) for taking a sample, in particular from the structure, from the seabed or from the water.
- 20 4. Method of claim 3, wherein the processing operation comprises:
 - gripping a part (32) of the structure with the gripping tool,
 - cutting in the structure with the cutting tool (51) such that said part becomes separated from the structure,
 - moving the separated part away from the structure with the gripping tool.
- 25 5. Method according to any of claims 3 or 4, comprising simultaneously gripping the part with the gripping tool (50) and cutting in the structure with the cutting tool (51), thereby preventing the part from falling when the part becomes separated from the structure.
- 30 6. Method according to any of claims 1 - 5, wherein the cutting tool is movable relative to the gripping tool, allowing a part of the structure to be held by the gripping tool while the cutting tool cuts the structure in different positions which are required to separate the part from the structure, the method comprising:
 - 35 - gripping a part of the structure which is envisaged to be separated from the structure with the gripping tool,

- 25 -

- moving the cutting tool to different locations and cutting in the structure at the different locations for separating the part from the structure while maintaining the grip on the part with the gripping tool.
- 5 7. Method according to any of claims 1 - 6, comprising:
- providing a container (40) at the seabed within a working range of the movable arm,
 - each time separating a part from the structure,
 - placing the separated parts in the container by the at least one arm,
 - 10 - lifting the filled container to the water surface (111),
 - transporting the container to a remote location with a vessel (120;130).
8. Method according to any of claims 1 - 7, wherein the support comprises at least one clamp (24A, 24B), the method comprising:
- 15 - clamping the support (22) to the structure at a first position,
- removing at least one first part from the structure, and in particular as many parts as are within the working range of the movable arm at the first position,
 - releasing the at least one clamp,
 - moving the support (22) to a second position on the structure and clamping the
 - 20 structure at the second position,
 - removing at least one second part from the structure, and in particular as many parts as are within the working range of the movable arm at the second position,
 - repeating these steps until the structure is substantially disassembled.
- 25 9. Method according to claim 8, comprising clamping the at least one clamp to a vertical beam (2) or substantially vertical beam (2) of the structure and moving downwards along said beam from said first position to said second position and further downward until the structure is substantially disassembled.
- 30 10. Method according to any of claims 1-9, wherein the control device comprises:
- a data processing device comprising a memory configured for storing:
 - geometrical data relating to the initial form of the structure,
 - disassembly data relating to the progress of disassembling the structure and the current form of the structure,
 - 35 - one or more sensors constructed for determining a current position of the arm and of the processing tool relative to the structure,
- and wherein the method comprises:

- loading the geometrical data into the memory,
 - determining a part to be removed from the structure and determining a target position of the processing tool on the basis of the geometrical data and the disassembly data,
 - 5 - moving the processing tool to the target position,
 - removing a part from the structure by gripping the part, cutting in the structure until the part is separated and moving the part away from the structure,
 - updating the disassembly data with data on the removed part,
 - repeating the steps until the structure is disassembled.
- 10
11. Method of any of claims 1 – 10, comprising:
- cutting the structure at a cutting level, wherein a top part of the structure is separated from a bottom part of the structure,
 - lifting the top part of the structure with a lifting device on a vessel
 - 15 - removing the top part from the location,
 - disassembling the bottom part of the structure according to the method of claim 1.
- 20
12. Method of claim 11, wherein the top part is removed by the vessel.
13. Method of claim 11 or 12, wherein the top part is removed on a transportation barge.
14. Method of any of claims 11 - 13, wherein the top part is suspended from the lifting device during the removal step.
- 25
15. Method of any of claims 11 - 14, wherein the disassembled sections of the bottom part are collected in at least one container on the seabed.
16. Method of claim 15, wherein the filled containers are removed from the seabed by a
- 30 lifting device on a vessel.
17. Method according to any of claims 1 - 15, comprising:
- providing a first of said movable arm,
 - providing a second of said movable arm,
 - 35 - gripping a part of the structure with the gripping tool of the first movable arm,
 - cutting in the structure with the cutting tool of the second movable arm device such that said part becomes separated from the structure,

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- moving the separated part away from the structure with the first movable arm.

18. Method of claim 16, comprising:

- gripping the first movable arm with the gripping tool of the second movable arm,
- releasing the support of the first movable arm from the structure,
- 5 - moving the first movable arm with the second movable arm, such that the support of the first movable arm is moved from a first support position to a second support position, thereby changing the working range of the first movable arm.

19. Method of any of claims 1-18, comprising :

- 10 - providing a device comprising a movable arm, the device further comprising:
 - o a body (190), the first articulated movable (20A) arm being connected to the at least one support via said body, the first movable arm comprising a gripping tool (50),
 - o a second articulated movable arm (20B) directly or indirectly connected at
 - 15 a proximal end (34) to said support, the second movable arm comprising a processing tool (51) connected to a distal end of said second movable arm, wherein the processing tool is movable in a three dimensional working range around the at least first support,
- performing a processing operation on the structure with the gripping tool and the
- 20 processing tool.

20. Method of any of claims 1-19, comprising :

- providing a device, wherein both at the proximal end (34) and at the distal end (36) of the articulated movable arm there is provided:
 - 25 o a support (22A, 22B) and
 - o a processing tool (30A, 30B),wherein the proximal end and the distal end are configured to exchange functions,
- in a first operating mode, mounting the support (22A) at the proximal end to the
- 30 structure and performing a processing operation with the processing tool (30A) at the distal end, and
- in a second operating mode, mounting the support (22B) at the distal end to the structure and performing a processing operation with the processing tool (30B) at the proximal end.

35

21. Method of any of claims 1-20, comprising providing a vessel (110) above the structure and assisting the operation by connecting a line (180) from the vessel to the

articulated movable arm or to a part of the structure and exerting an upward force on the articulated movable arm or on the part of the structure via the line.

22. Method of any of claims 1-21, comprising providing at least one buoyancy device (170) and assisting the operation by connecting the buoyancy device to the articulated movable arm or to a part of the structure, directly or via a line, and exerting an upward force on the articulated movable arm or on the part of the structure via the buoyancy device.
23. Method of any of claims 1-22, comprising connecting an excavating device (51B) to the distal end of the at least one articulated movable arm and carrying out at least one excavating operation in the vicinity of the structure.
24. Method of assembling or disassembling a structure (10) which is located at least partially under water, the method comprising:
- providing a device comprising at least one movable arm (20), the device comprising:
 - at least one movable arm comprising at least a first segment (28A) and a second segment (28B) connected to one another via at least a first hinge (29),
 - a support (22) connected to a proximal end (34) of the first segment via at least one support hinge (27, 61), the support being constructed to be mounted to the structure or placed on the seabed,
 - a processing tool (30) mounted to a distal end (36) of the second segment,
 - at least one actuator (33) configured to:
 - controllably move the first segment relative to the support, and to
 - controllably move the second segment relative to the first segment, in order to position the processing tool at a target location in a working range of the arm,
 - a control device (56) configured to control the at least one actuator and the processing tool during operation,
 - performing a processing operation on the structure for assembling or disassembling the structure.
25. Device (18) comprising a movable arm (20), the device being constructed to perform an under water operation on an at least partially submerged structure or in the vicinity of the at least partially submerged structure, the device comprising:

- 5 - at least a first support (22) constructed to be connected to the structure, the support being configured to transfer substantial forces in three dimensions and substantial moments about the X-axis, Y-axis and Z-axis from the movable arm to the structure, including a vertical force required for lifting operations of the device,
- 10 - at least a first articulated movable arm (20) directly or indirectly connected at a proximal end (34) to said support, the first movable arm comprising a first tool (30) connected to a distal end (36) of said first movable arm, wherein the first tool is movable in a three dimensional working range around the at least first support,
- 15 - at least one actuator (33) configured to controllably move the first tool in the three dimensional working range in order to position the tool at a target location,
- a control device (56) configured to control the at least one actuator and the tool during operation.

26. Device comprising a movable arm (20) according to claim 25, the device configured for disassembling or assembling a structure extending at least partially under water, wherein:

- 20 - the movable arm comprises at least a first segment (28A) and a second segment (28B) connected to one another via at least a first hinge (29),
- the support (22) is connected to a proximal end (34) of the first segment via at least one support hinge (27, 61), the support being constructed to be mounted to the structure,
- 25 - the tool (30) is mounted to a distal end (36) of the second segment,
- the at least one actuator (33) is configured to:
 - controllably move the first segment relative to the support, and to
 - controllably move the second segment relative to the first segment in order to position the tool at a target location in a working range of the arm,
- 30 - the control device (56) configured to control the at least one actuator and the tool during operation.

27. Device comprising a movable arm of claim 25 or 26, wherein the tool (30) comprises:

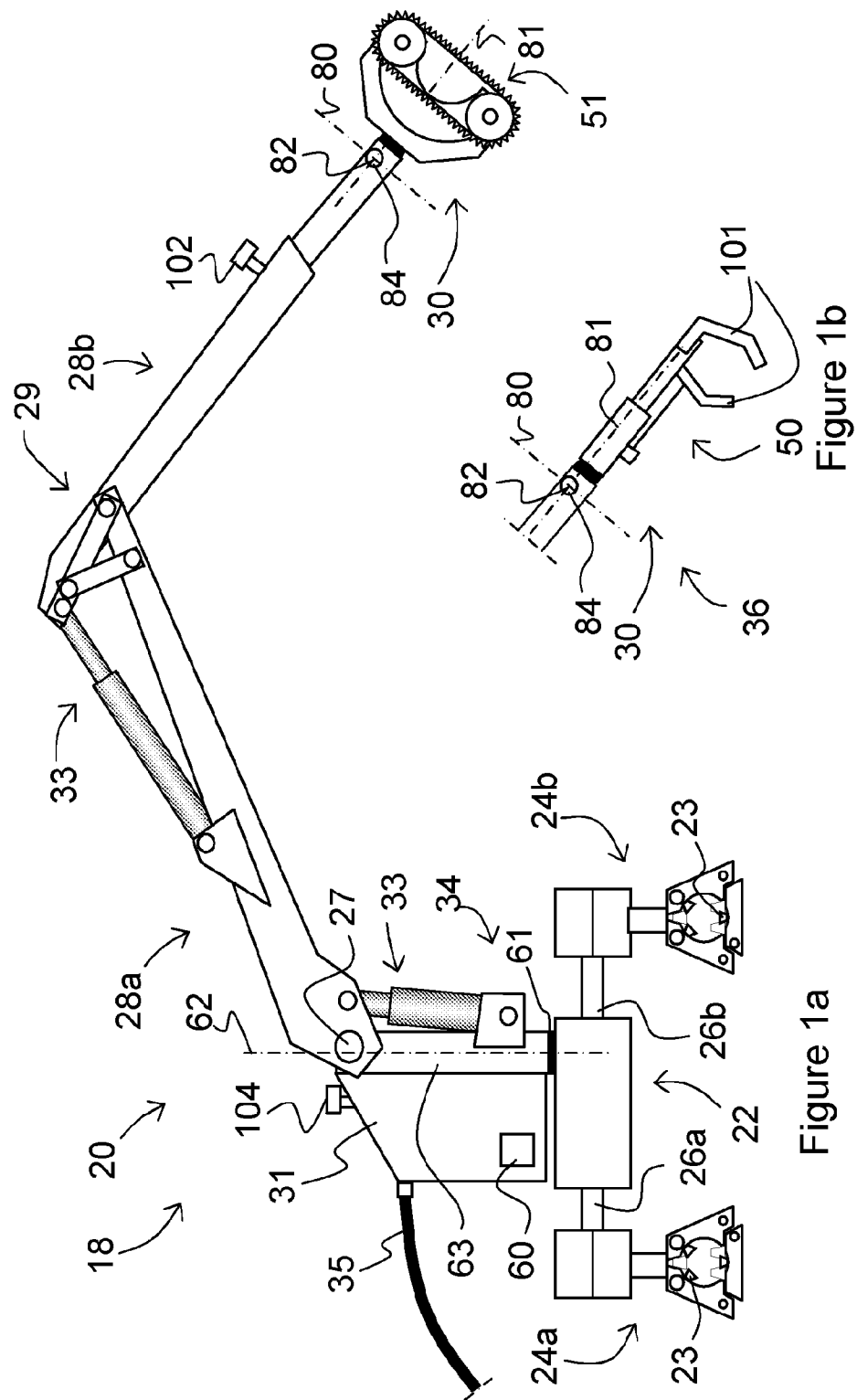
- 35 - a gripping tool (50) for gripping a part of the structure, and/or
- a processing tool (51) for performing a processing operation on the structure or in the vicinity of the structure.

28. Device comprising a movable arm according to claim 27, wherein the processing tool (51) is selected from a group comprising:
- a cutting tool (51A) for cutting in the structure,
 - an excavating device (51B) for excavating the seabed or for collecting material which rests on the seabed,
 - a drilling device (51C) for drilling a hole in the structure,
 - a sampling device (51D) for taking a sample, in particular from the structure, from the seabed or from the water,.
29. Device comprising a movable arm of any of claims 25 - 28, comprising a gripping tool and a cutting tool, wherein the cutting tool is movable relative to the gripping tool, allowing a part of the structure to be held by the gripping tool while the cutting tool cuts the structure in different positions which are required to separate the part from the structure.
30. Device comprising a movable arm of any of claims 25 - 29, wherein a distal end (36) of the movable arm has three degrees of freedom relative to the support (22) of the movable arm such that the distal end (36) can be positioned in any position within the working range of the movable arm, and wherein the tool (30) is pivotable about three independent axes of rotation about the distal end, thereby allowing the tool to be oriented in any direction in said position.
31. Device comprising a movable arm of any of claims 25 - 30, comprising a gripping tool and a cutting tool, wherein the cutting tool is connected to the gripping tool or to the movable arm via a movable cutting arm which provides the cutting tool with a working range which extends around the gripping tool.
32. Device comprising a movable arm of any of claims 25 - 31, wherein the support comprises a clamping device which comprises clamping members constructed to clamp to a vertical or substantially vertical beam of the structure.
33. Device comprising a movable arm of any of claims 25 - 32, comprising:
- a first clamp (24A),
 - a second clamp (24B) spaced apart from the first clamp, and
 - at least one support beam (26A, 26B) connecting the first and second clamp to one another, wherein the first segment is connected to said support beam via at least one support hinge (27, 61).

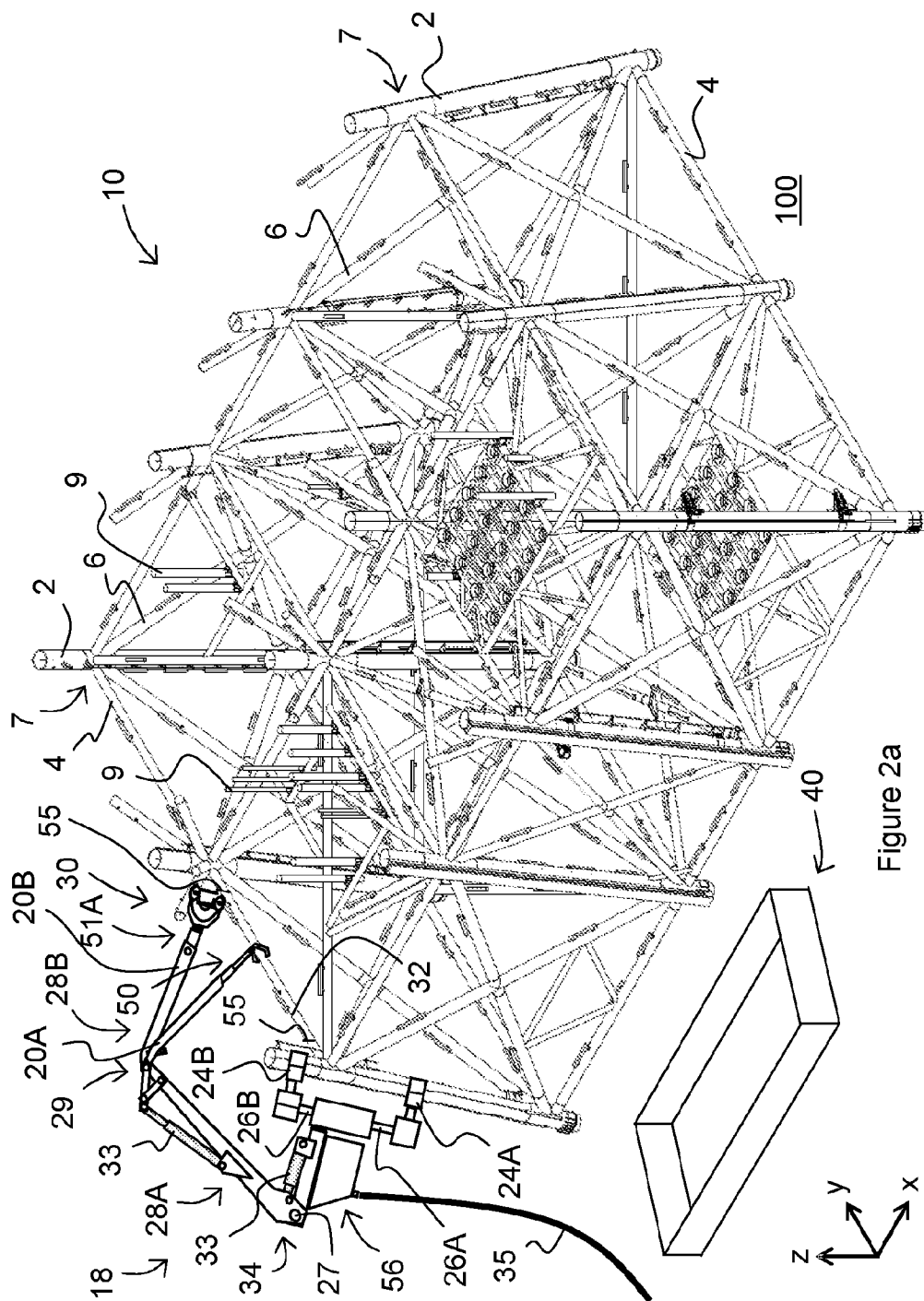
34. Device comprising a movable arm of any of claims 25 - 33, wherein the control device comprises:
- a data processing device comprising a memory configured for storing:
 - geometrical data relating to the form of the structure,
 - assembly data or disassembly data relating to the individual steps of assembling or disassembling the structure,
 - one or more sensors (102, 103, 104) constructed for determining a current position of the arm and of the processing tool relative to the structure.
35. Device comprising a movable arm of any of claims 25 - 34, further comprising:
- a body (190), the first articulated movable arm being connected to the at least one support via said body, wherein a gripping tool is provided at the distal end thereof,
 - a second articulated movable arm (20B) directly or indirectly connected at a proximal end (34) to said support, the second movable arm comprising a processing tool (51) connected to a distal end of said second movable arm, wherein the processing tool is movable in a three dimensional working range around the at least first support.
36. Device comprising a movable arm of claim 35, further comprising:
- a first support connected to the body and comprising at a distal end thereof a clamp for clamping to the structure or an insertion device constructed to be inserted into the structure for providing a secure connection with the structure, and
 - a second support connected to the body and comprising at a distal end thereof a clamp for clamping to the structure or an insertion device constructed to be inserted into the structure for providing a secure connection with the structure.
37. Device comprising a movable arm according to claim 34 or 35, wherein the first support comprises a first articulated leg being connected at a proximal end to the body and comprising at a distal end thereof the clamp or insertion device, and wherein the second support comprises a second articulated leg being connected at a proximal end to the body and comprising at a distal end thereof the clamp or insertion device, the first and second legs comprising actuators for moving the first and second clamp in a three dimensional working range around the body.

38. Device comprising a movable arm of any of claims 25 -37, wherein both at the proximal end (34) and at the distal end (36) of the articulated arm there is provided:
- a support (22A, 22B)) and
 - a processing tool (51A, 51B),
- 5 wherein the proximal end and the distal end are configured to exchange functions, wherein:
- in a first operating mode the support (22A) at the proximal end is connected to the structure and the processing tool (51A) at the distal end is operable to perform a processing operation on the structure, and
 - 10 - in a second operating mode the support (22B) at the distal end is connected to the structure and the processing tool (51B) at the proximal end is operable to perform a processing operation.
39. Device comprising a movable arm of any of claims 25-37, wherein the at least one articulated arm comprises a first, a second and a third segment (28A, 28B, 28C) connected to one another via a first and a second hinge (29A, 29B).
- 15
40. Device comprising a movable arm of any of claims 25-39, further comprising at least one buoyancy device connected to the at least one articulated arm for increasing the lift capacity of the movable arm.
- 20
41. Combination of a first device (18A) comprising a movable arm according to any of claims 25-40 and a second device (18B) comprising a movable arm according to any of claims 25-40.
- 25
42. Combination according to claim 41, wherein the first device (18A) comprises a first coupling part (220A) and the second device (18B) comprises a second coupling part (220B), the first and second coupling part being configured to be coupled to one another to form a joint movable arm assembly comprising at least two movable arms.
- 30
43. Combination according to claim 34, wherein the coupling parts are provided substantially in a central area of the first movable arm and the second movable arm.
44. Combination for disassembling a structure extending at least partially under water, the assembly comprising:
- 35
- at least one device comprising a movable arm according to claim 25, and
 - at least one container for accommodating removed parts from the structure.

45. Movable arm (20) for disassembling or assembling a structure extending at least partially under water, the movable arm comprising:
- 5 - at least a first segment (28A) and a second segment (28B) connected to one another via at least a first hinge (29),
 - a support (22) connected to a proximal end (34) of the first segment via at least one support hinge (27, 61), the support being constructed to be mounted to the structure or to be placed on the seabed (100),
 - a processing tool (30) mounted to a distal end (36) of the second segment,
 - 10 - at least one actuator (33) configured to:
 - controllably move the first segment relative to the support, and to
 - controllably move the second segment relative to the first segmentin order to position the processing tool at a target location in a working range of the arm,
 - 15 - a control device (56) configured to control the at least one actuator and the processing tool during operation.



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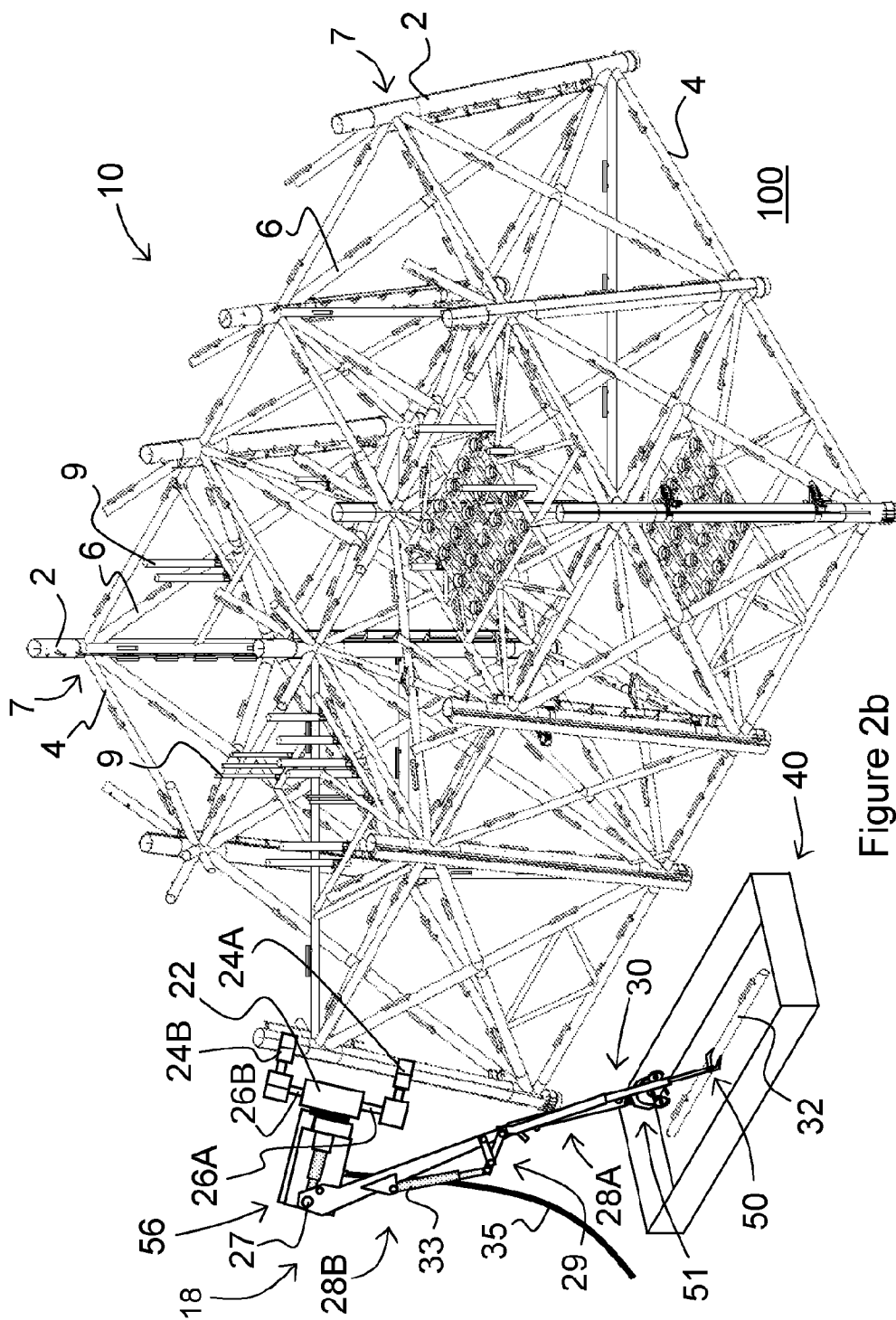


Figure 2b

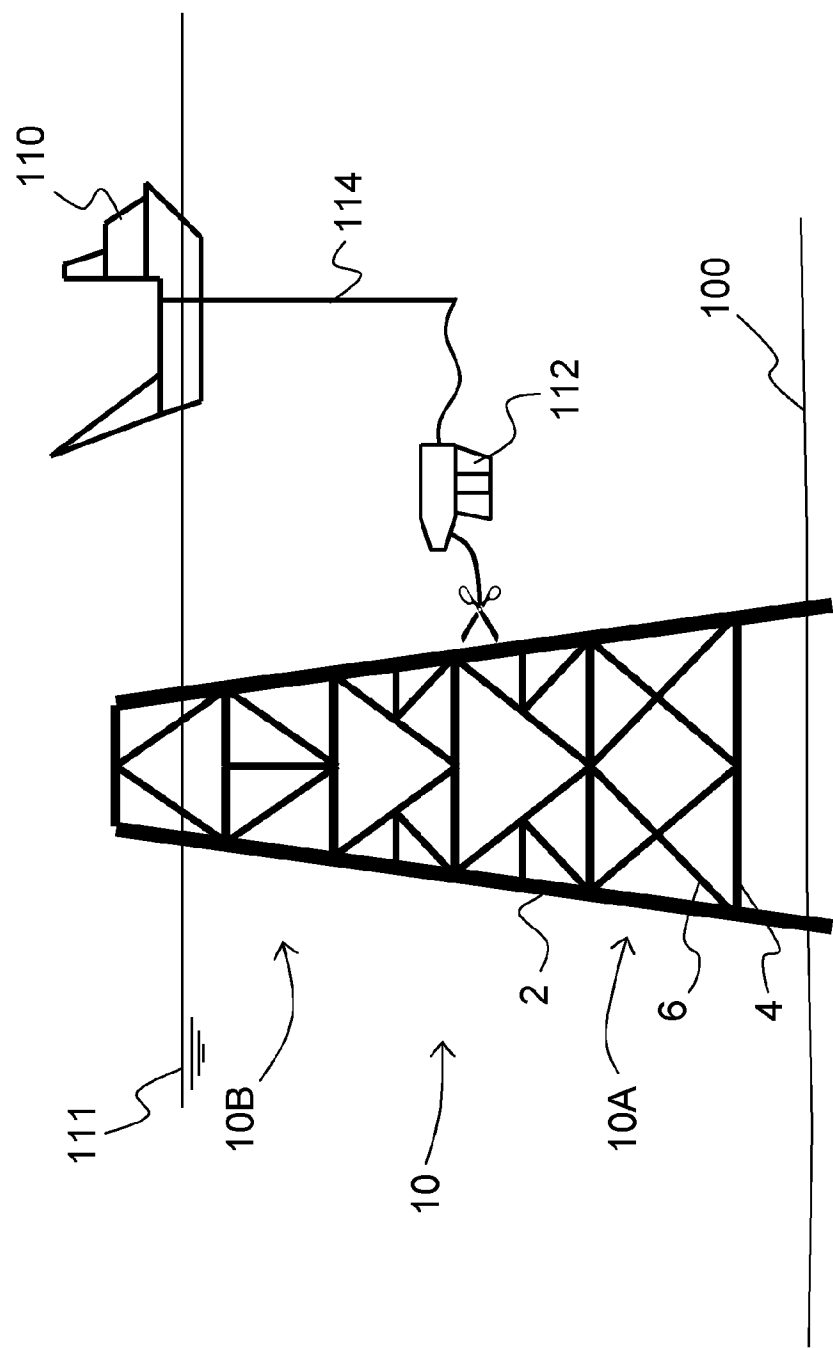


Figure 3

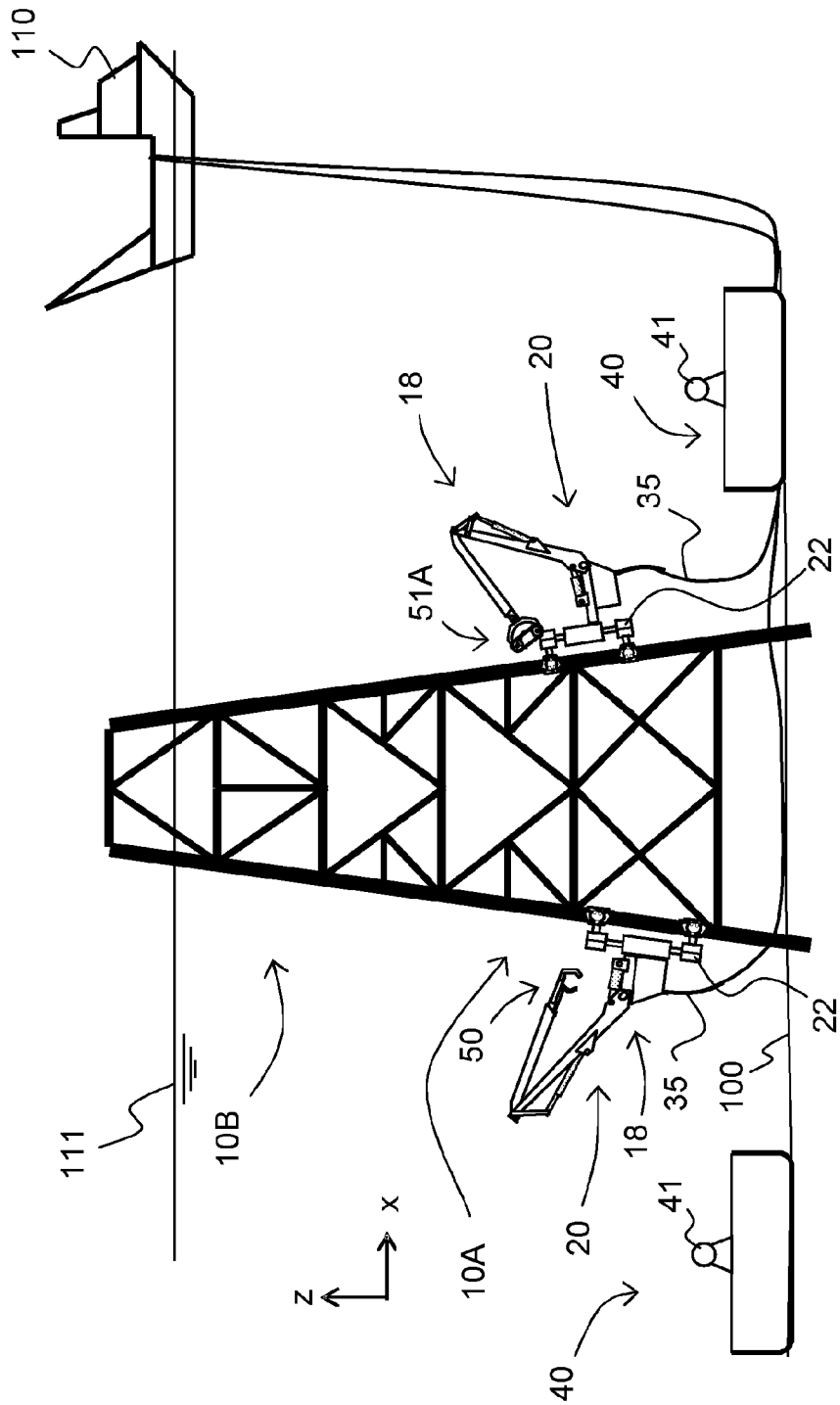


Figure 4

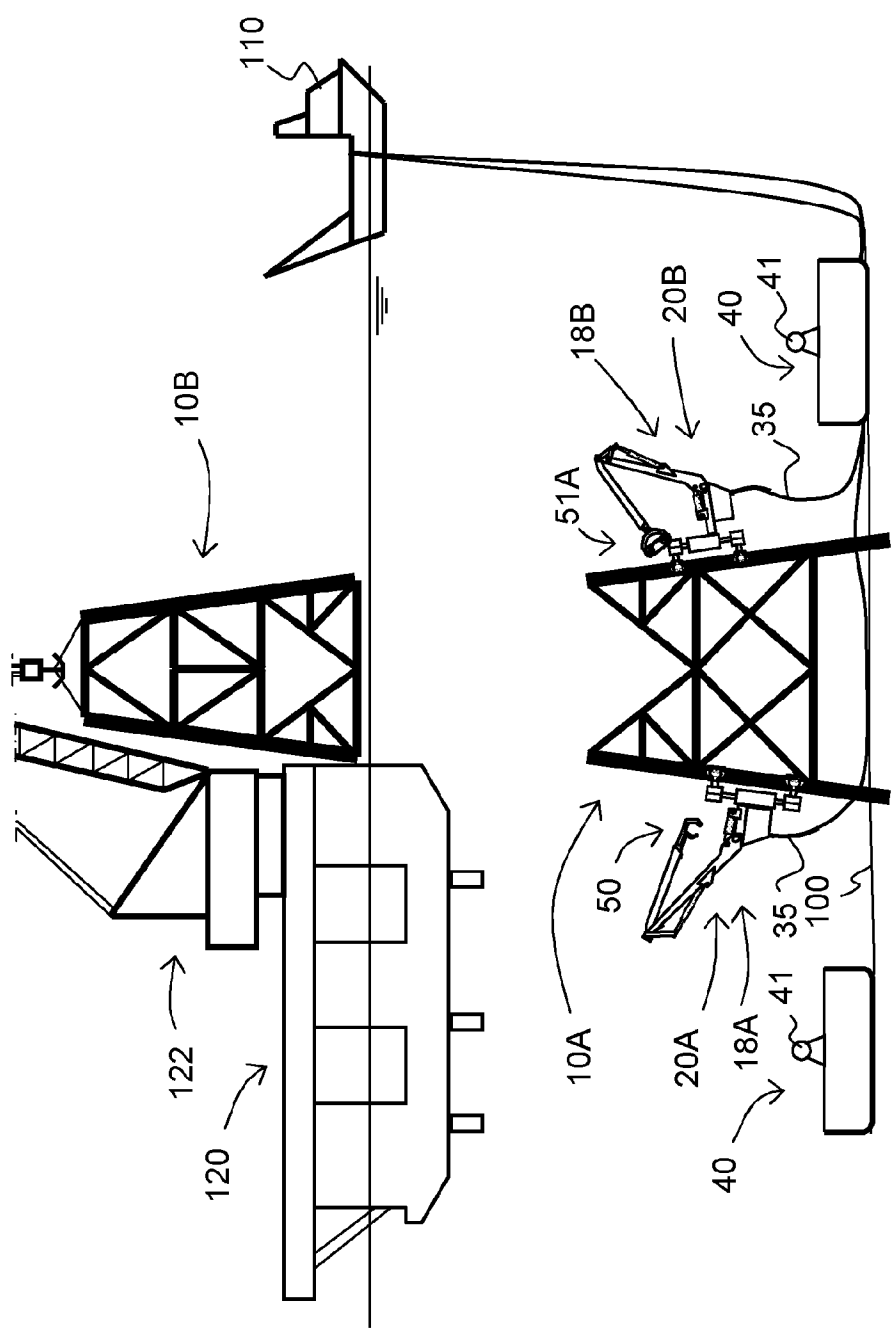


Figure 5

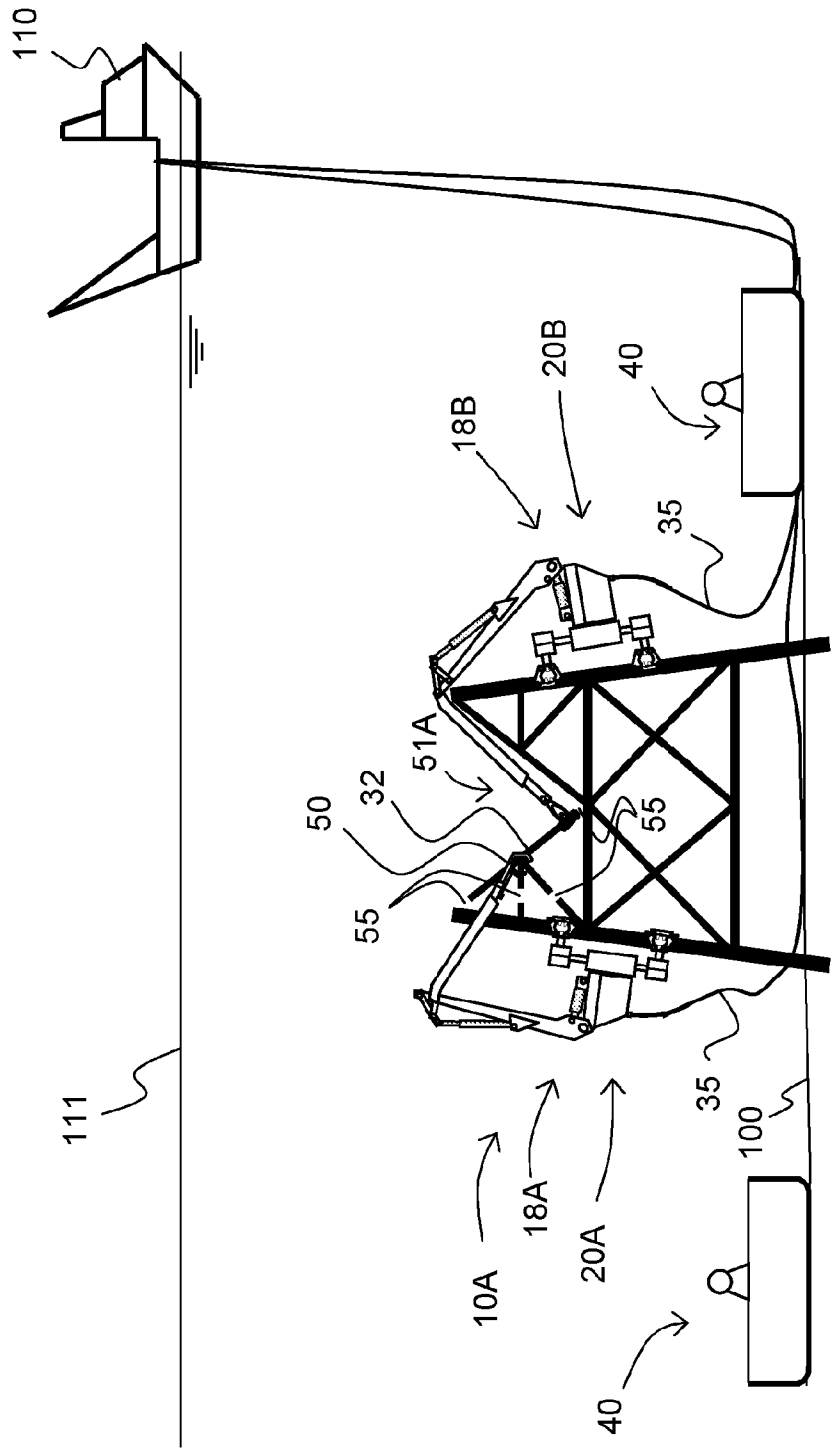


Figure 6

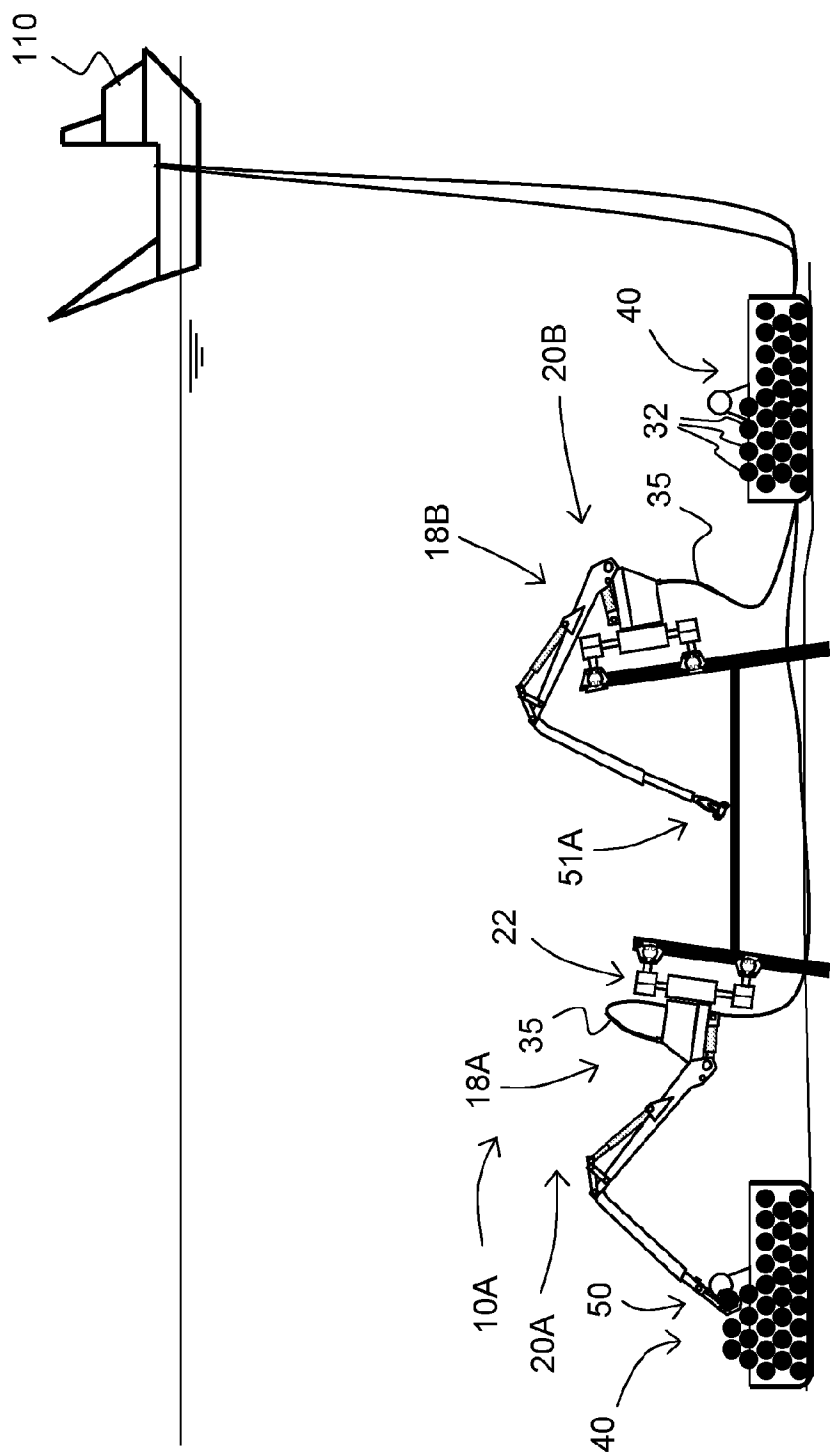


Figure 7

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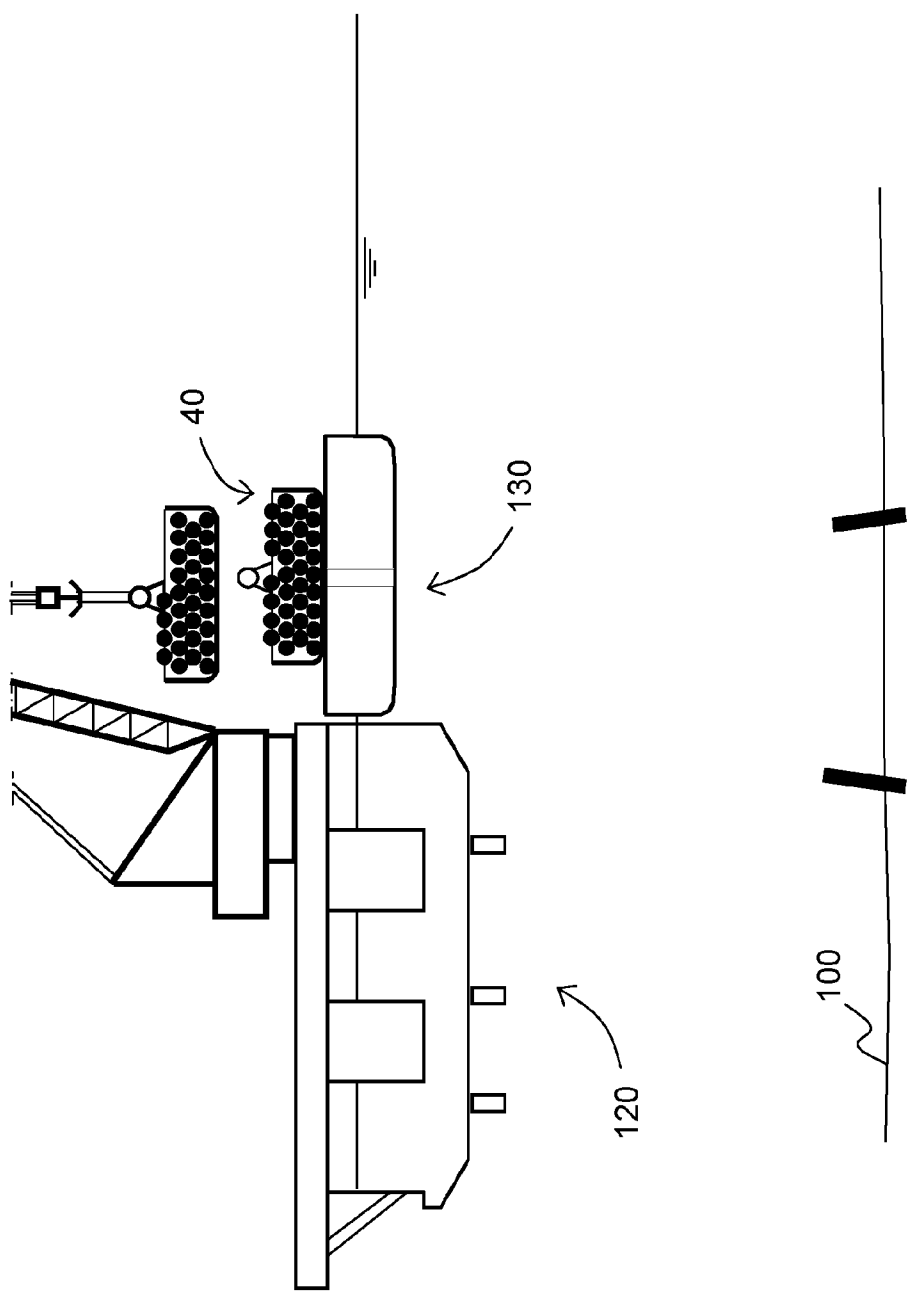
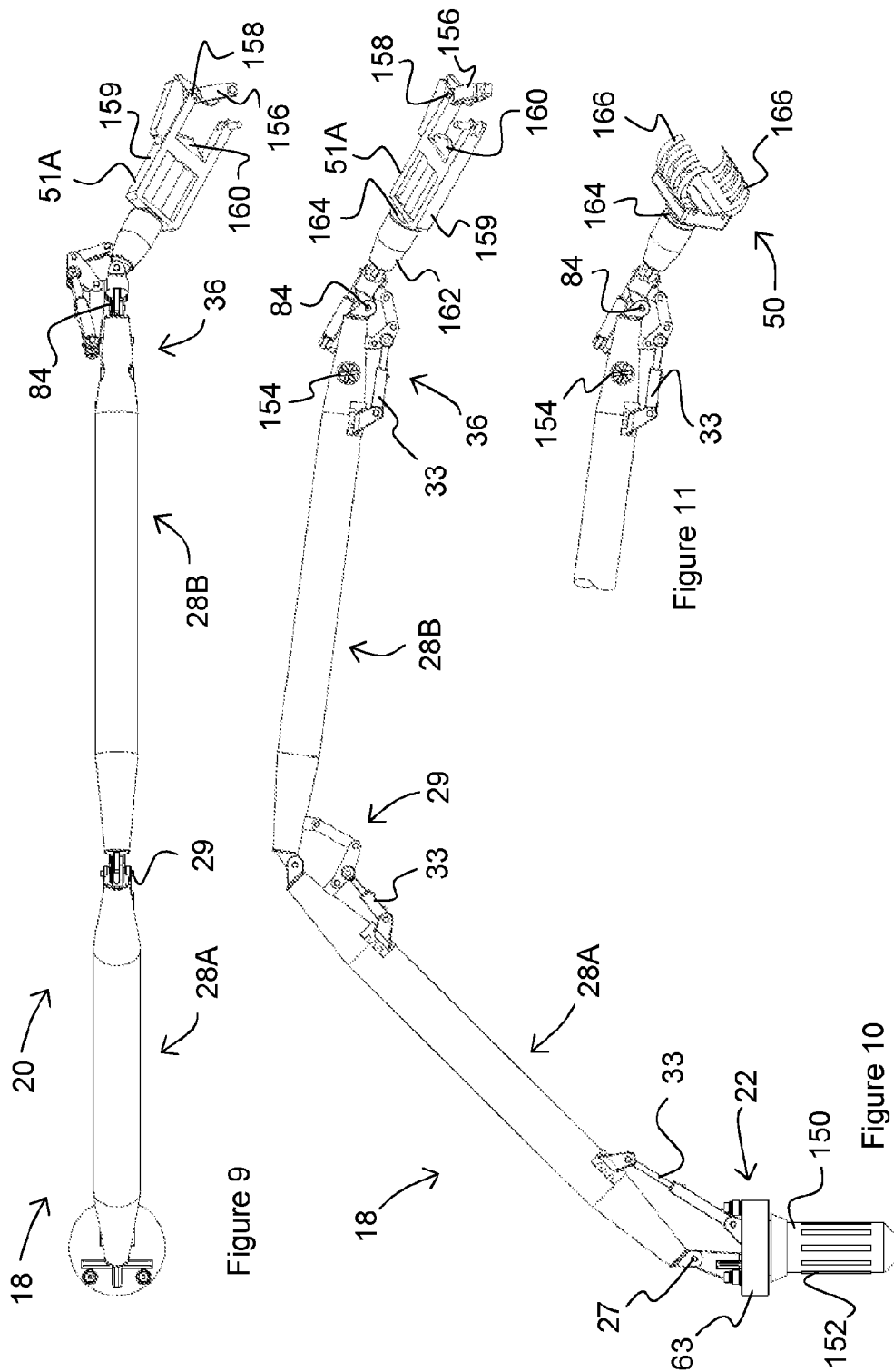


Figure 8

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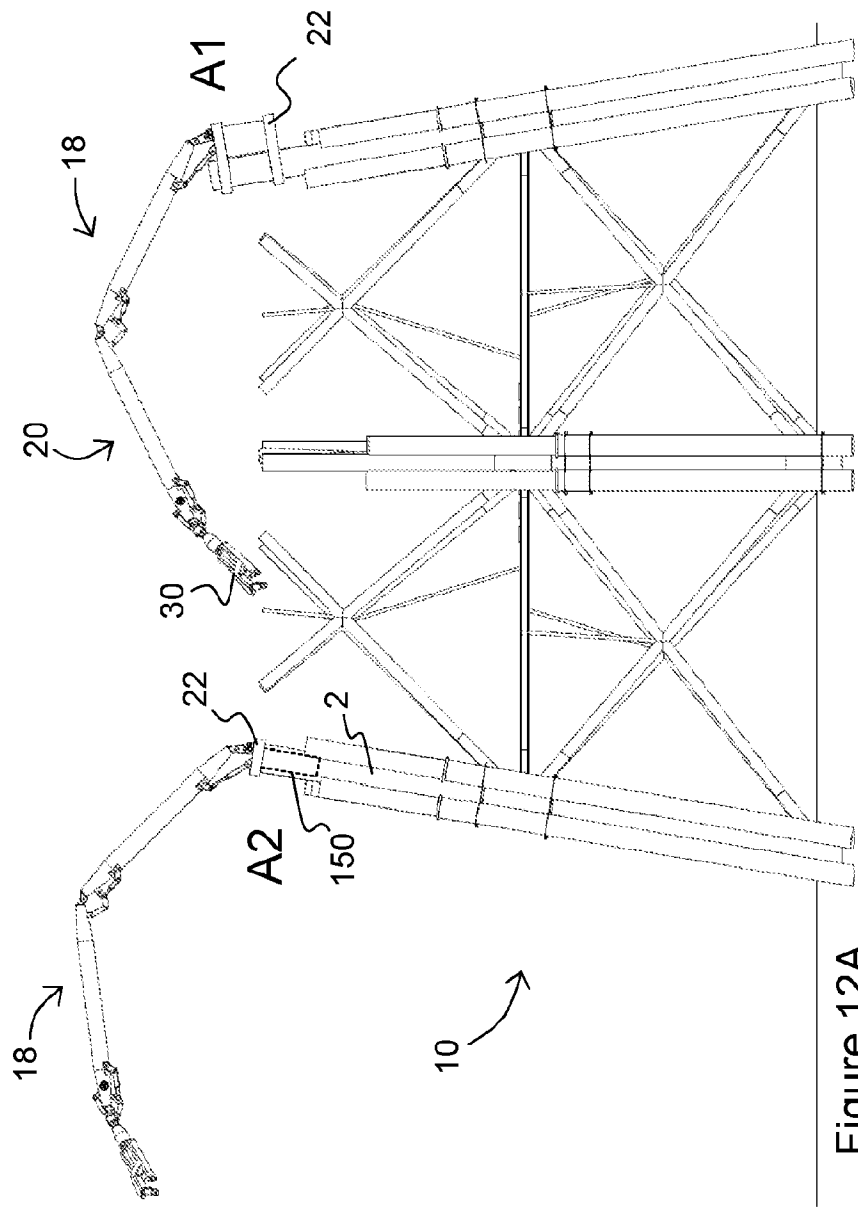


Figure 12A

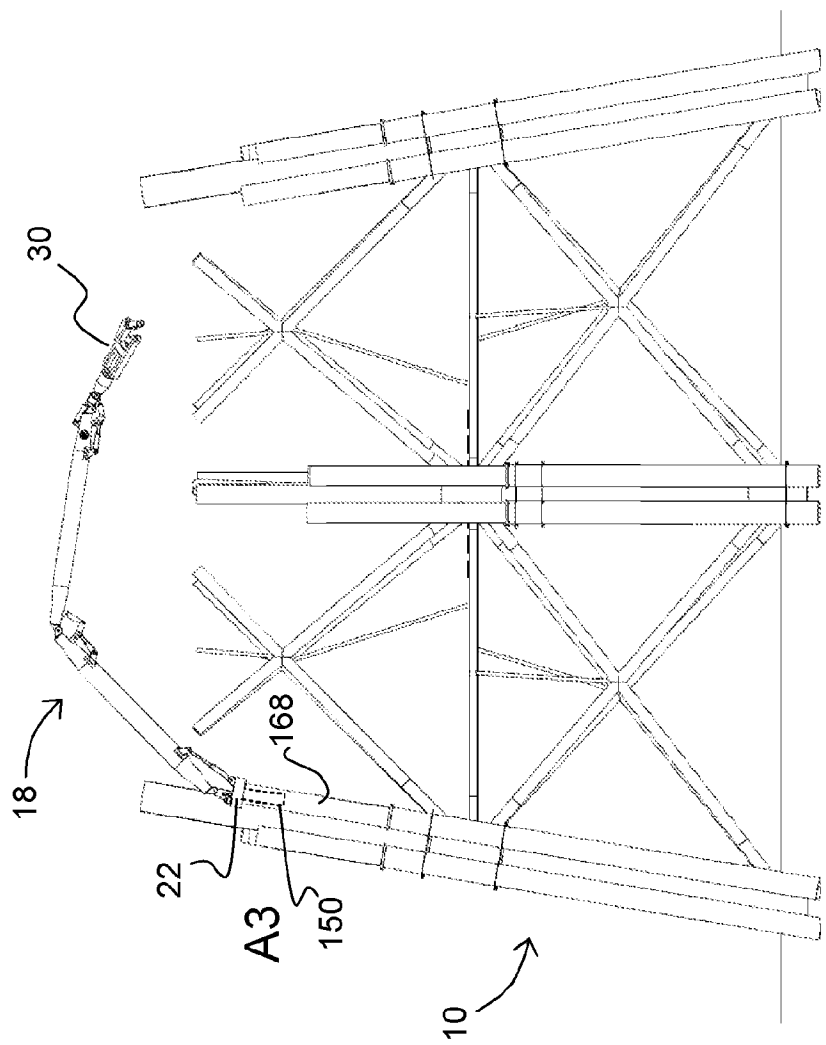


Figure 12B

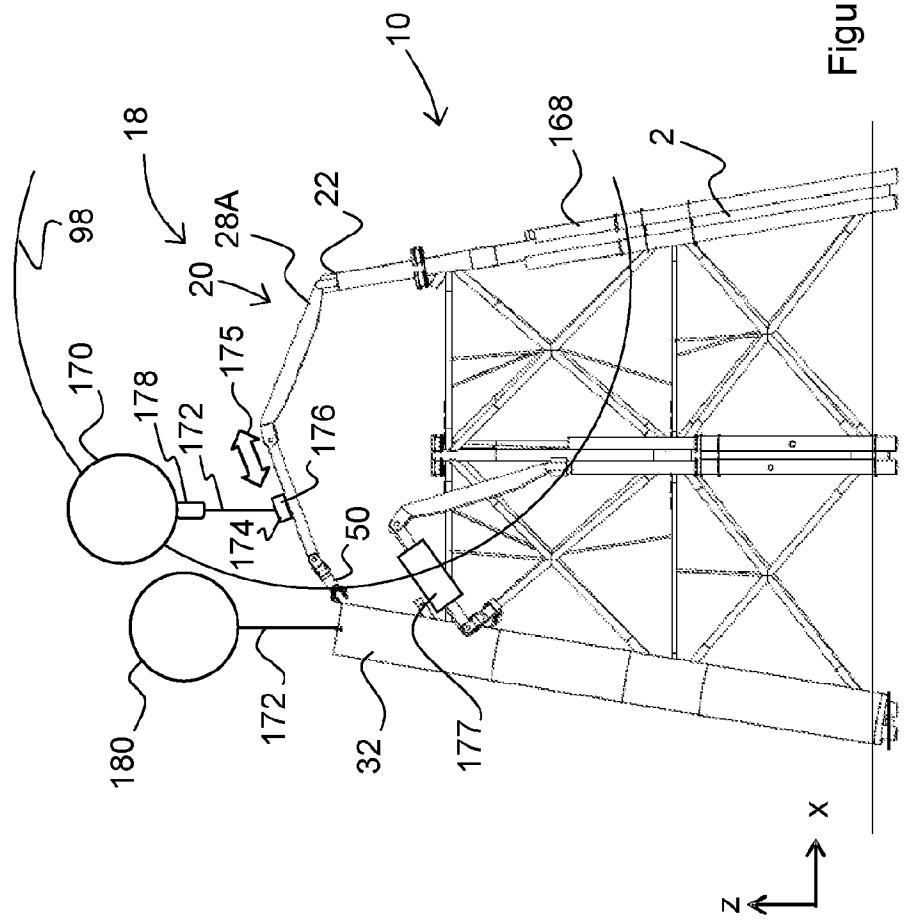


Figure 13

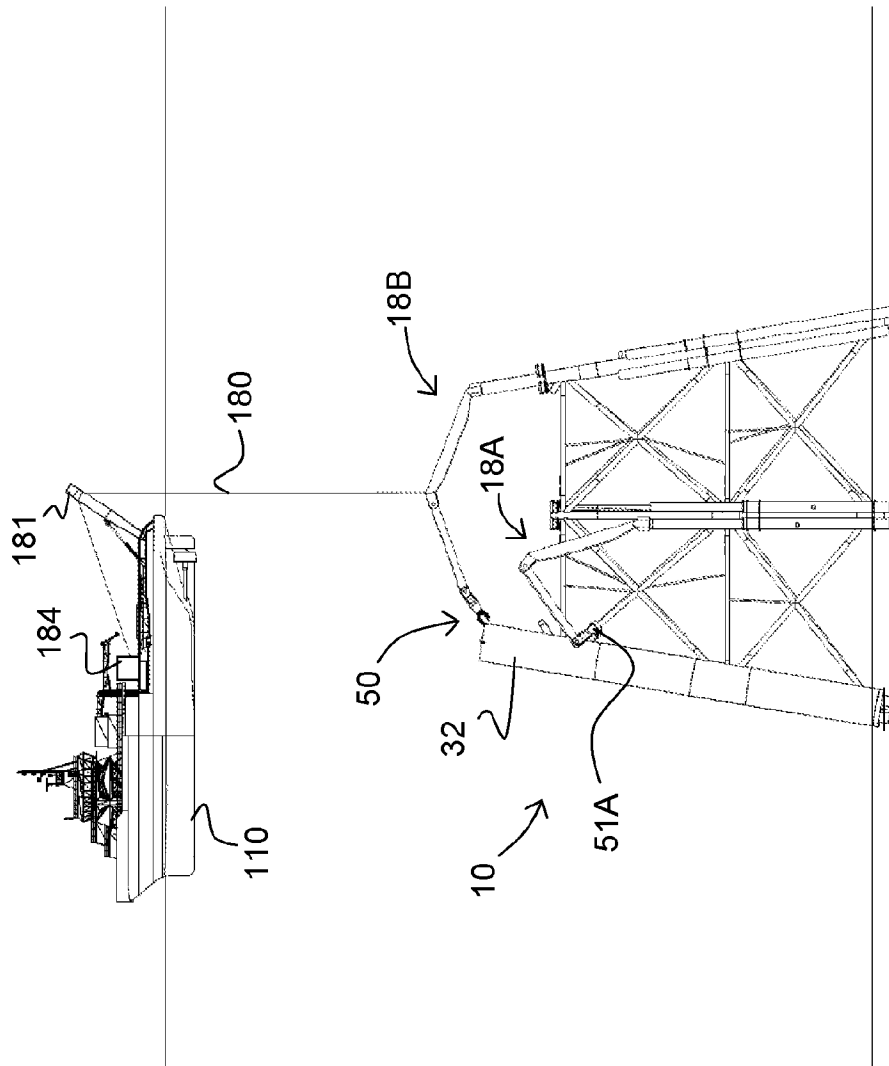


Figure 14A

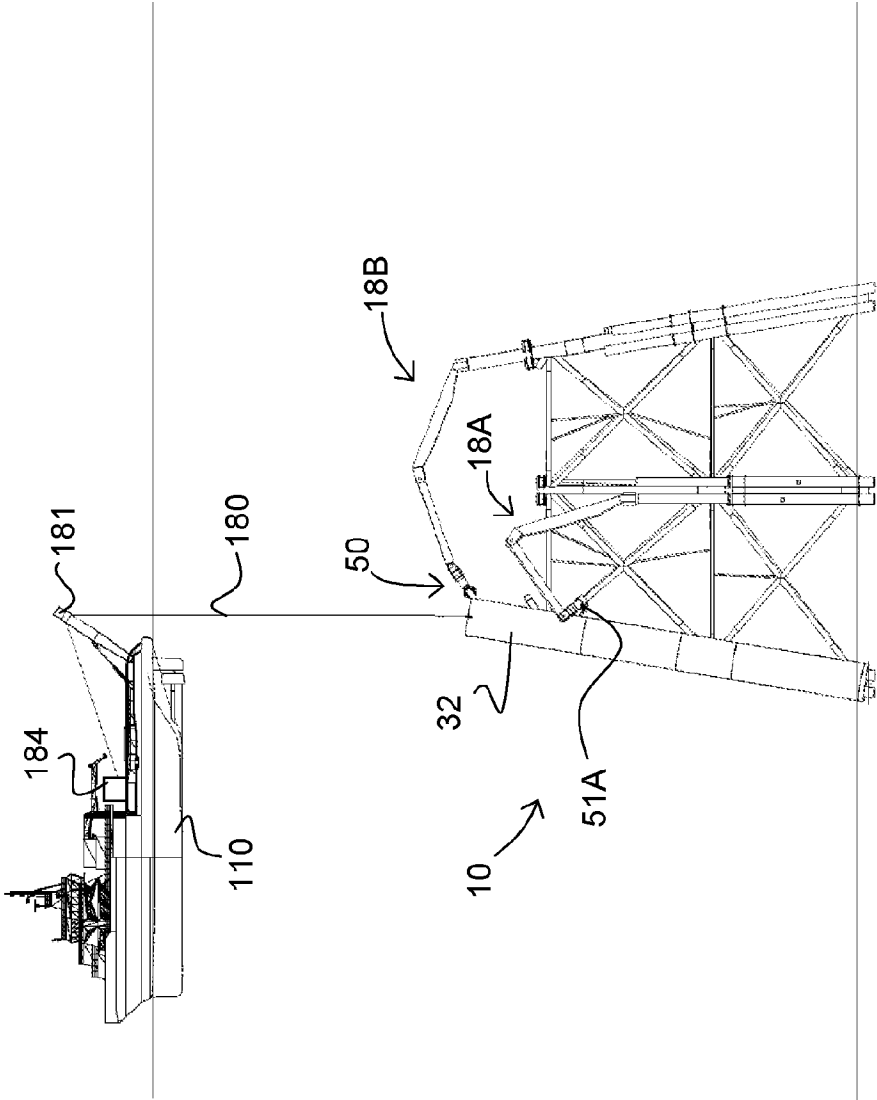


Figure 14B

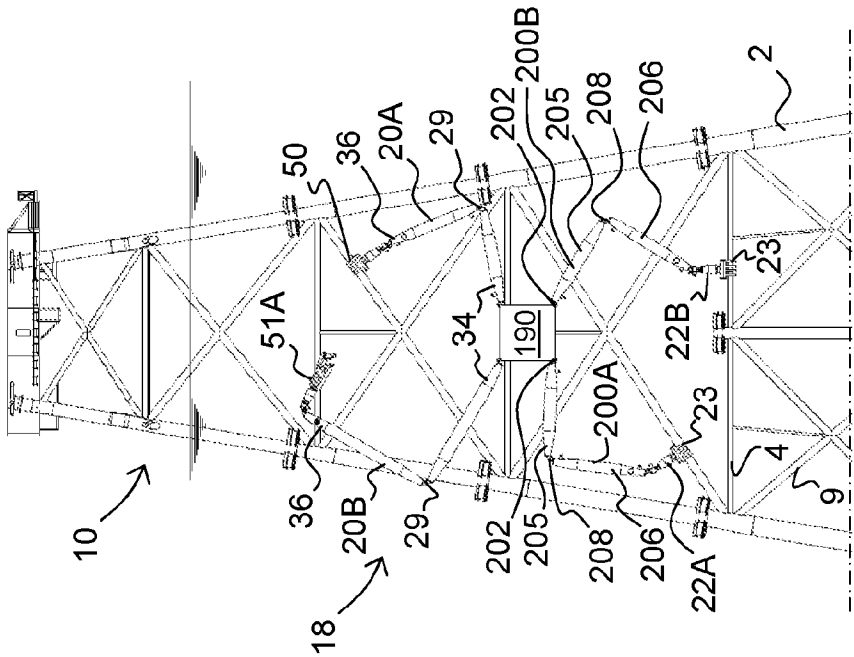


Figure 15

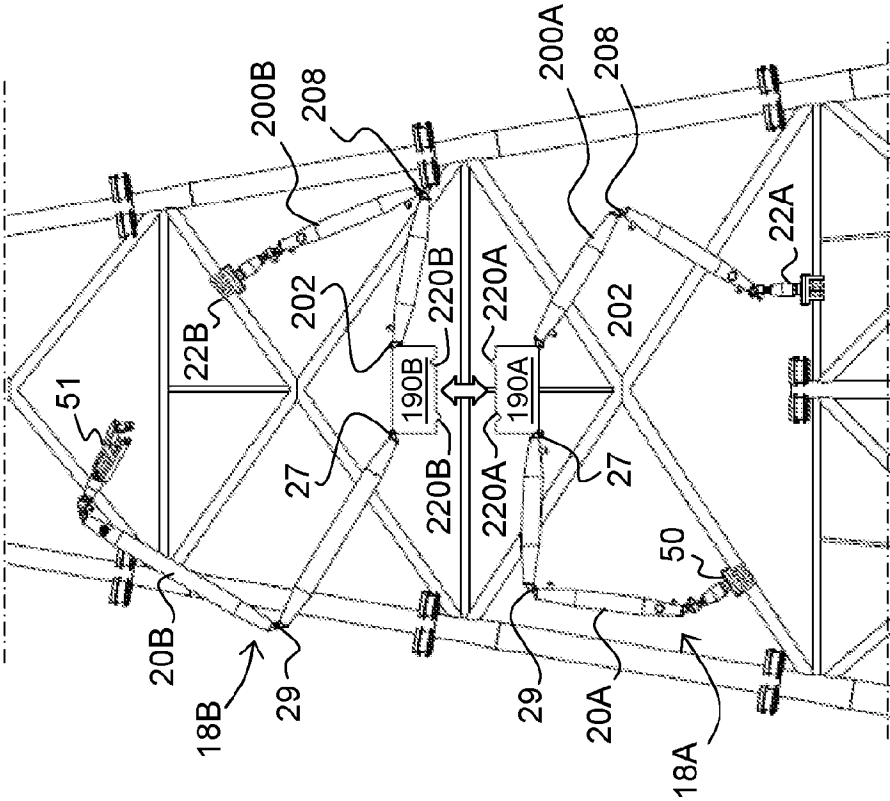
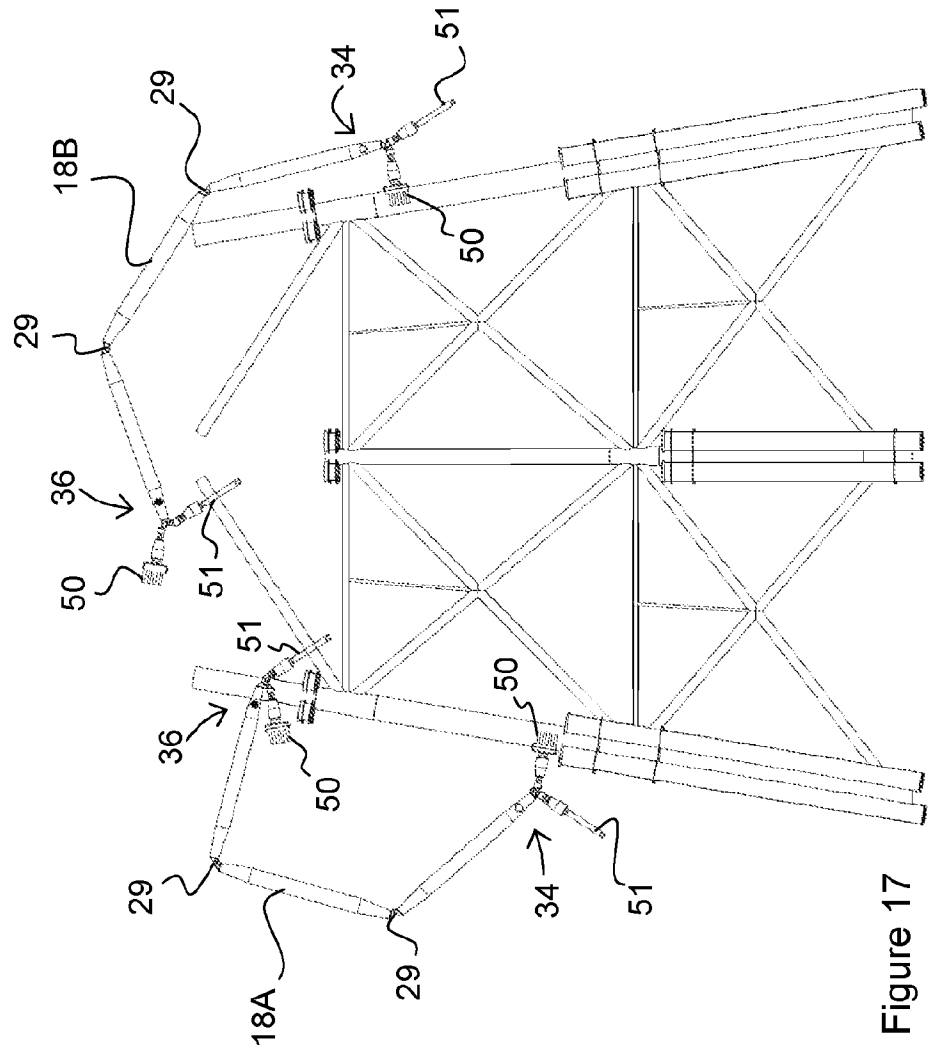


Figure 16



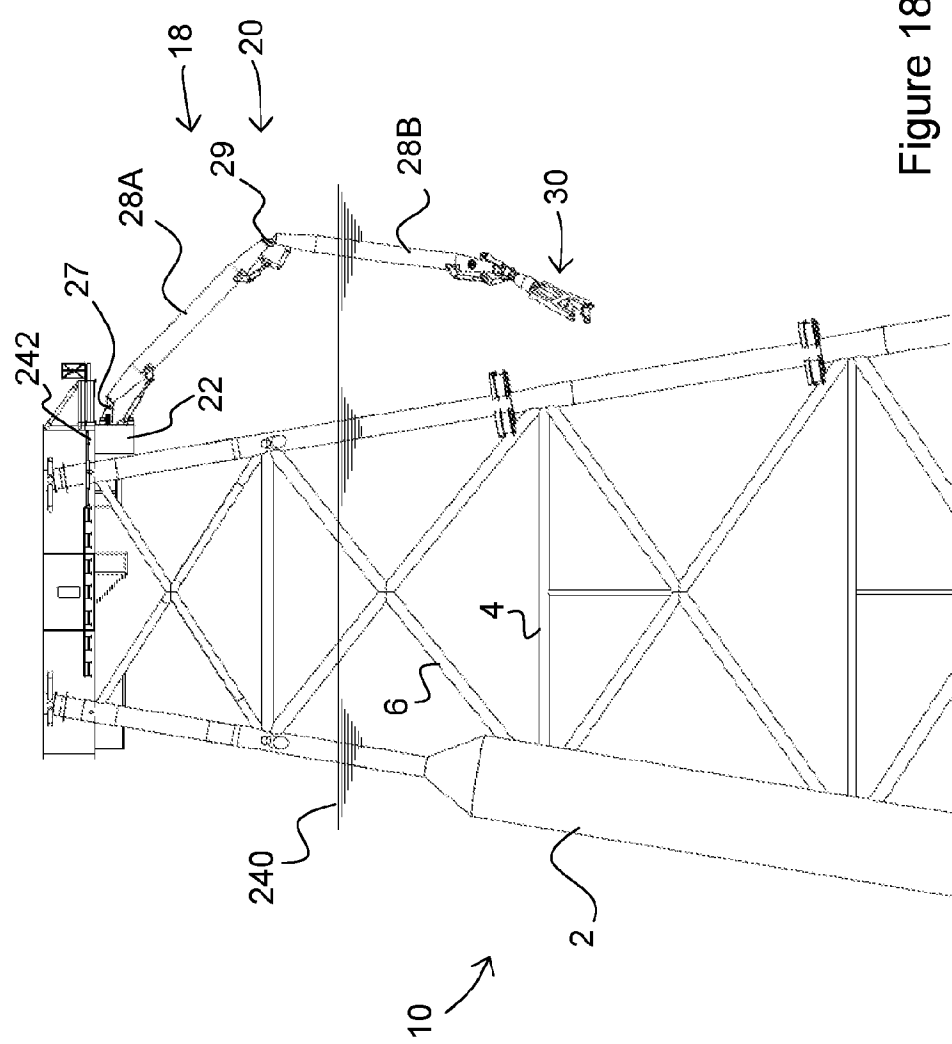


Figure 18

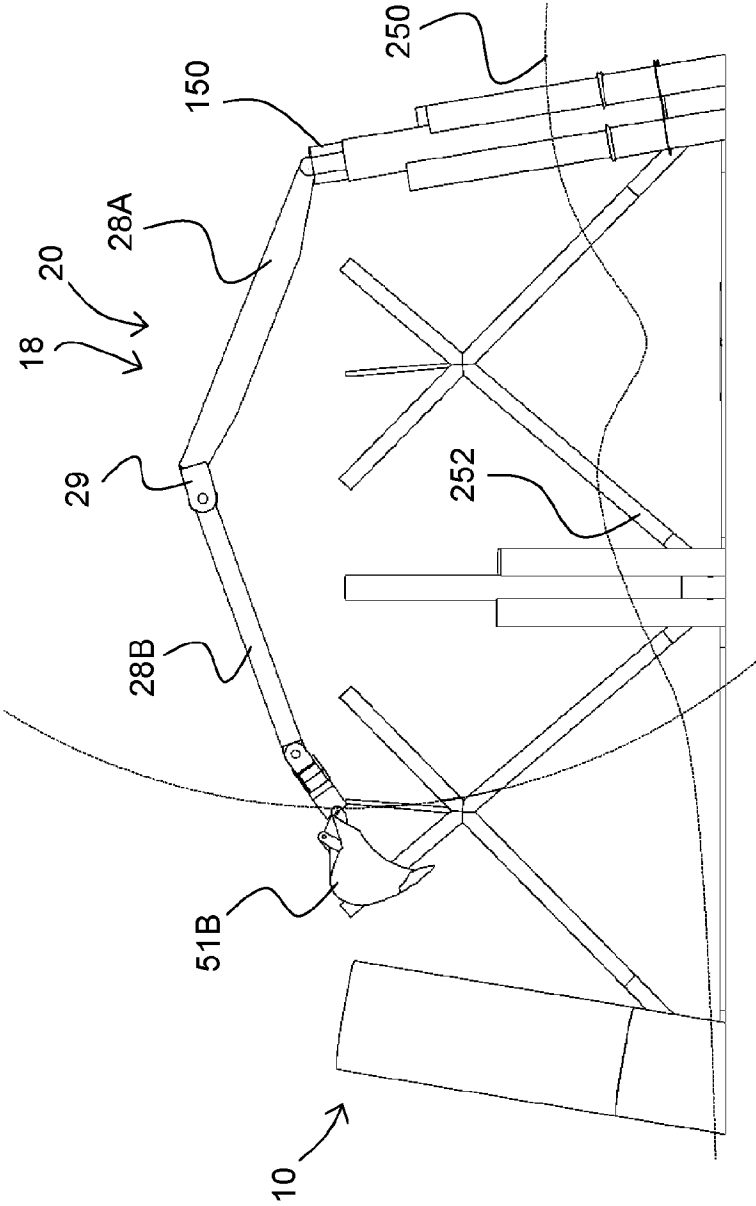


Figure 19

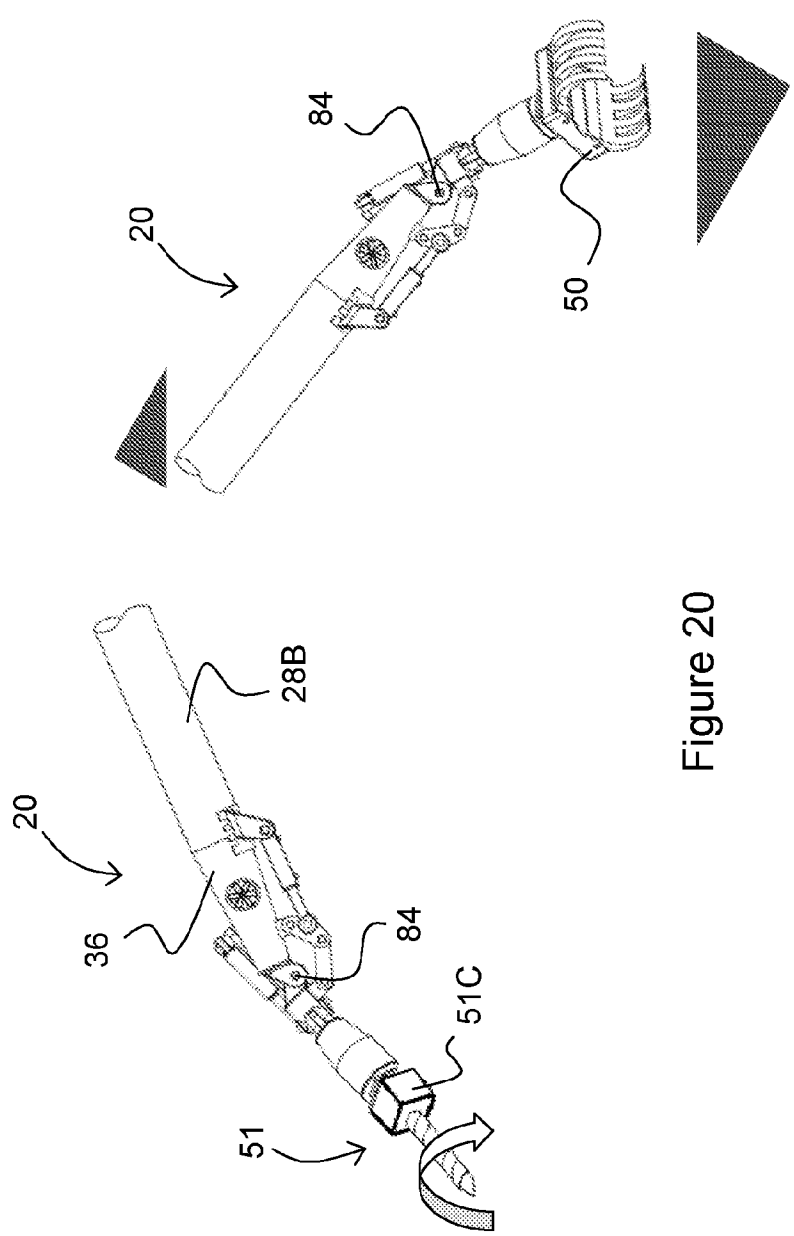


Figure 20

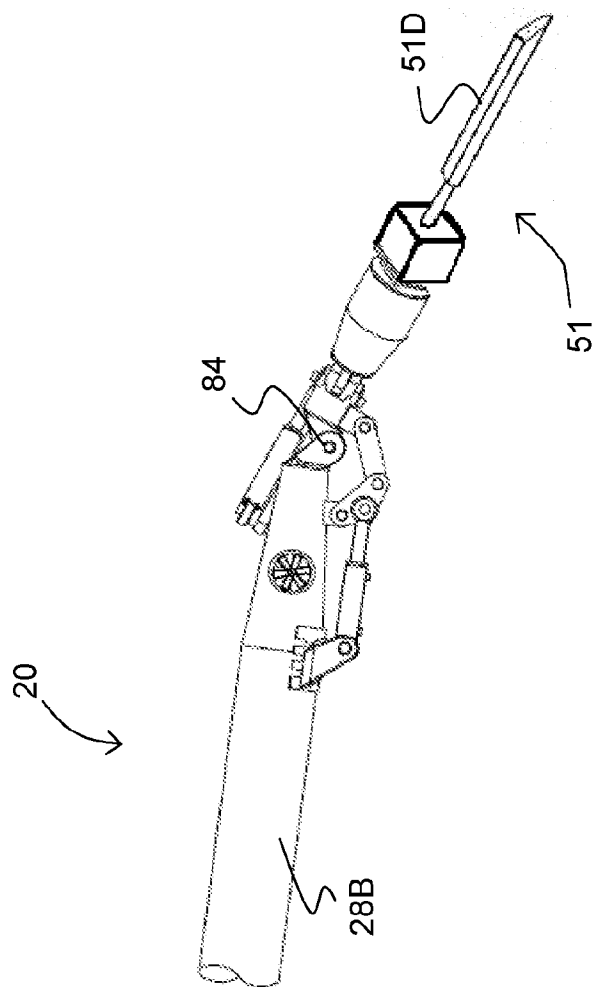


Figure 21

INTERNATIONAL SEARCH REPORT

International application No
PCT/NL2012/050066

A. CLASSIFICATION OF SUBJECT MATTER
INV. B63C11/52 B23D57/00 E02B17/04
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B63C B23D E02B F16L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 02/075059 A1 (TS TECNOSPAMEC S R L [IT]; MATTEUCCI FRANCESCO [IT]) 26 September 2002 (2002-09-26)	1-9,15, 16, 22-29, 31-33, 35-37, 39-45
Y	figures 8,1,3,4,7,9,10 -----	11-14
Y	WO 00/77306 A1 (EXCALIBUR ENGINEERING B V [NL]; DEN HARTOGH FRANS ARIEN [NL]; GELDER K) 21 December 2000 (2000-12-21)	11-14
A	figures 7,8 ----- -/-	1,24,25, 45



Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

30 May 2012

Date of mailing of the international search report

06/06/2012

Name and mailing address of the ISA/

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van Rooij, Michael

INTERNATIONAL SEARCH REPORT

International application No
PCT/NL2012/050066

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2010/131096 A1 (SAIPEM SPA [IT]; FONTOLAN MASSIMO [IT]) 18 November 2010 (2010-11-18) balloon fig.3 ,figures 1-4 -----	1-9, 11-17, 19, 21-33, 35-37, 39-45
X	WO 2004/070120 A1 (RAJALA PEKKA [FI]; LINDBERG VESA-MATTI [FI]) 19 August 2004 (2004-08-19) abstract; figure 1 -----	24-29, 31,32, 39,41, 44,45 1
A		
X	US 4 871 036 A (PARROTT GARY A [US]) 3 October 1989 (1989-10-03) figures 1,2,4 -----	24,45
X	US 5 042 959 A (TADATSU GUNKICHI [JP]) 27 August 1991 (1991-08-27) figures 1,2,12 -----	24,45
A		1,25,41, 44
A	US 7 351 010 B1 (KELLY JOHN M [US] ET AL) 1 April 2008 (2008-04-01) figures 10,12 -----	1,24,25, 41,44,45
A	US 4 445 804 A (ABDALLAH MOHAMED G [US] ET AL) 1 May 1984 (1984-05-01) figures 2a,5a,6,7 -----	1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/NL2012/050066

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 02075059	A1	26-09-2002	BR 0208194 A 23-03-2004
		CN 1531616 A 22-09-2004	
		DE 60208353 T2 03-08-2006	
		DK 1373645 T3 22-05-2006	
		EP 1373645 A1 02-01-2004	
		IT GE20010026 A1 20-09-2002	
		NO 20034218 A 22-09-2003	
		UA 79928 C2 10-08-2007	
		US 2004069103 A1 15-04-2004	
		WO 02075059 A1 26-09-2002	
WO 0077306	A1	21-12-2000	AU 771609 B2 01-04-2004
		AU 5578900 A 02-01-2001	
		BR 0011647 A 29-06-2004	
		DK 200101874 A 25-01-2002	
		GB 2365907 A 27-02-2002	
		NL 1012314 C2 15-12-2000	
		NO 20016106 A 13-02-2002	
		US 6550411 B1 22-04-2003	
		WO 0077306 A1 21-12-2000	
WO 2010131096	A1	18-11-2010	AU 2010267740 A1 08-12-2011
		EP 2430346 A1 21-03-2012	
		EP 2430347 A2 21-03-2012	
		WO 2010131096 A1 18-11-2010	
		WO 2011001231 A2 06-01-2011	
WO 2004070120	A1	19-08-2004	FI 20030164 A 05-08-2004
		WO 2004070120 A1 19-08-2004	
US 4871036	A	03-10-1989	NONE
US 5042959	A	27-08-1991	AU 609633 B2 02-05-1991
		AU 3933489 A 15-02-1990	
		CA 1312350 C 05-01-1993	
		DE 3926225 A1 15-02-1990	
		FR 2636038 A1 09-03-1990	
		GB 2221711 A 14-02-1990	
		IT 1232431 B 17-02-1992	
		JP 1733784 C 17-02-1993	
		JP 2053693 A 22-02-1990	
		JP 4018117 B 26-03-1992	
		NL 8902043 A 01-03-1990	
		US 5042959 A 27-08-1991	
US 7351010	B1	01-04-2008	NONE
US 4445804	A	01-05-1984	NONE