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(54) **A DETACHABLE SUCTION PUMP SKID**

(57) A detachable suction pump skid (3) for operation with a suction bucket (2) of an anchoring system for soft ocean floors. The suction pump skid (3) comprises a skid connection interface (22) for establishing a disconnectable rigid connection of the skid (3) to a trunk (15) of the suction bucket (2). The suction pump skid (3) further comprises a lid hoist mechanism (25) comprising a lid hoist actuator (35) connected to a lid holding tool (36), wherein the lid hoist actuator (35) is configured for raising and lowering a vertical position of the lid holding tool (36), wherein the lid holding tool (36) is configured for releasably holding a detached suction bucket trunk lid (26), and wherein the lid hoist mechanism (25) is configured for placing the detached suction bucket trunk lid (26) in or on an outlet opening (16) of the trunk (15). In addition, the suction pump skid (3) comprises a suction pump (18) coupled to a suction pipe (20) and configured for evacuating water from an interior of the suction bucket (2) via said trunk (15) and said suction pipe (20).

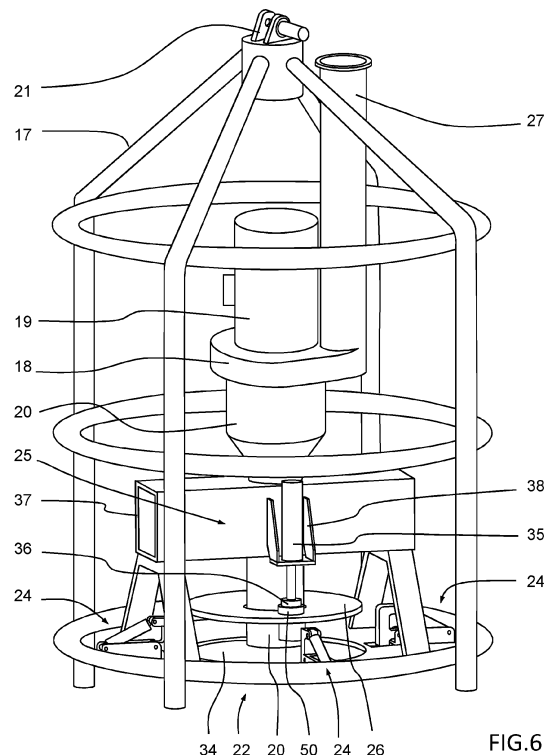


FIG.6

Description

TECHNICAL FIELD

[0001] The present disclosure relates to a detachable suction pump skid for operation with a suction bucket of an anchoring system for soft ocean floors. The disclosure further relates to a method for installing a suction bucket of an anchoring system on a soft ocean floor.

[0002] The anchoring system may for example be used as foundation for offshore wind turbines to generate electricity. Alternatively, the anchoring system may be used for constructing other types of offshore installations, such as wind farm control units, or offshore oil/gas platform, or the like. Moreover, the anchoring system may also be used as anchor for floating offshore platforms.

BACKGROUND

[0003] In the area of offshore anchoring system, bucket foundations have been used for decades within the offshore oil and gas industry for anchoring and fixed platform foundations. In the last couple of years, the concept has also been used for offshore wind Turbine (OWT) foundations.

[0004] However, the suction bucket has sometimes complex and costly equipment installed on the suction bucket for closing a water suction outlet in the suction bucket. Furthermore, after water evacuation from the suction bucket is completed, the water suction outlet generally needs to be closed and sealed by an underwater Remote Operated Vehicle (ROV).

[0005] Consequently, in the area of offshore anchoring system in form of a suction bucket jacket, for example for being used for offshore wind foundation, there is demand for further improvements in terms of cost-efficient equipment and faster and more convenient installation process.

SUMMARY

[0006] An object of the present disclosure is to provide a detachable suction pump skid, and associated method for installing a suction bucket of an anchoring system, that enables further improvements in terms of cost-efficient equipment and faster and more convenient installation process. This object is at least partly achieved by the features of the independent claims. The dependent claims contain further developments of the detachable suction pump skid.

[0007] According to a first aspect of the present disclosure, there is provided a detachable suction pump skid for operation with a suction bucket of an anchoring system for soft ocean floors. The suction pump skid comprises: a skid connection interface for establishing a disconnectable rigid connection of the skid to a trunk of the suction bucket; a lid hoist mechanism comprising a lid hoist actuator connected to a lid holding tool, wherein the

lid hoist actuator is configured for raising and lowering a vertical position of the lid holding tool, wherein the lid holding tool is configured for releasably holding a detached lid, and wherein the lid hoist mechanism is configured for placing the detached lid in or on an outlet opening of the trunk; and a suction pump coupled to a suction pipe and configured for evacuating water from an interior of the suction bucket via said trunk and said suction pipe.

[0008] According to a second aspect of the present disclosure, there is provided a method for installing a suction bucket of an anchoring system on a soft ocean floor. The method comprises: loading a detached trunk lid into a suction pump skid; releasably connecting the skid on a trunk of a suction bucket, and lowering the suction bucket to the ocean floor; fitting the lid in or on an outlet opening of the trunk; shifting a locking arrangement of the lid from an unlocked state to a locked state for fastening the lid to the trunk; activating a suction pump of the skid for evacuating water from the interior of the suction bucket via said trunk and a suction pipe of the skid; and releasing the skid from the trunk and lifting the skid out of the water.

[0009] In this way, it becomes possible to load a detached suction bucket trunk lid into the suction pump skid and subsequently using the suction skid for transporting, mounting and fastening the lid to the trunk, thereby eliminating the need for a ROV or similar type of underwater vehicle for closing and locking a suction bucket lid on a trunk of the suction bucket after completed water evacuation, thereby providing a faster and more convenient installation process.

[0010] Furthermore, the trunk of the suction bucket may also be provided with a less complex design, i.e. more cost-efficient equipment, because the trunk may be designed without an integrated suction bucket trunk lid. In addition, since the lid is detached from the suction bucket, e.g. not pivotally attached to the suction bucket, the type of lid may more easily be selected according to the specific circumstances of the installation.

[0011] In other words, having a detachable suction pump skid with integrated lid holding equipment for holding and installing a suction bucket trunk lid on the trunk of a suction bucket, a ROV-free operation for closing and locking the suction bucket trunk lid is accomplished, thereby enabling a faster installation at lower cost. Furthermore, the risk of ROV-downtime due to for example lack of clear ROV sight in muddy waters, and/or strong water currents, is eliminated.

[0012] Moreover, the integrated lid holding equipment of the suction pump skid may also be arranged to position the suction bucket trunk lid spaced apart from the trunk during a submerging state, i.e. when the suction bucket is lowered through the splash zone and down to the seabed, for providing large flow opening area of the trunk for ventilation of the suction bucket. After the suction bucket has self-penetrated the sea bed is certain distance, the integrated lid holding equipment of the suction pump skid may shift the lid to a closed and sealed position before

the suction operation can start, which involves operating a suction pump for evacuating water out from the suction bucket for lowering the suction bucket deeper into the seabed. Consequently, the suction pump skid according to the present disclosure enables the suction bucket to be provided with a single trunk for both self-ventilation and powered water evacuation, thereby reducing cost and time for manufacturing.

[0013] Further advantages are achieved by implementing one or several of the features of the dependent claims.

[0014] In some example embodiments, the skid connection interface comprises a moveable skid clamping mechanism operatively connected to a skid clamping actuator, wherein the skid clamping actuator is controllable for setting the skid clamping mechanism in an engaged operating position, in which a downwards facing seat of the skid is configured to be clamped against an upwards facing corresponding seat on the trunk by the skid clamping mechanism, and wherein the skid clamping actuator is controllable for setting the skid clamping mechanism in a disengaged operating position, in which the skid is free to move away from, or towards, the seat of the trunk. Thereby, the skid may be reliably remote connected and disconnected to/from the trunk.

[0015] In some example embodiments, that may be combined with any one or more of the above-described embodiments, the moveable skid clamping mechanism comprises a pivoting skid clamping member, and the skid clamping actuator is a linear actuator. This provides a reliable and cost-efficient clamping mechanism.

[0016] In some example embodiments, that may be combined with any one or more of the above-described embodiments, the skid comprises a closed hydraulic system including a tank for holding hydraulic fluid, a hydraulic pump, a hydraulic actuator, and a hydraulic valve arrangement fluidly connected to the hydraulic pump and hydraulic actuator for controlling motion of the hydraulic actuator. Thereby, the skid merely requires electrical power supply for being operational, such that a cost-efficient and user friendly skid is provided.

[0017] In some example embodiments, that may be combined with any one or more of the above-described embodiments, the closed hydraulic system includes an accumulator for storing high-pressure fluid. Thereby, clamping force is not lost merely because a temporary power loss, thereby providing improved operational safety.

[0018] In some example embodiments, that may be combined with any one or more of the above-described embodiments, the hydraulic pump of the closed hydraulic system is powered by an electric motor installed on the skid.

[0019] In some example embodiments, that may be combined with any one or more of the above-described embodiments, the suction pipe is configured for establishing fluid connection with a flow passage extending through the lid, and wherein the suction pump is config-

ured for evacuation of water from the interior of the suction bucket via said trunk, said flow passage through the lid and said suction pipe. By having a flow passage extending through the lid, the outlet of the trunk may function both as ventilation opening and suction opening, thereby eliminating the need for two separate openings.

[0020] In some example embodiments, that may be combined with any one or more of the above-described embodiments, the skid connection interface comprises a downwards facing seat configured for resting on an upwards facing corresponding seat of the trunk of the suction bucket, and wherein the downwards facing seat of the skid connection interface enables connection of the suction pump skid to the trunk at any relative angular position. Thereby, the mounting and connection of the skid on the trunk is simplified and may be performed faster and with less worker resources.

[0021] In some example embodiments, that may be combined with any one or more of the above-described embodiments, the skid comprises a downward facing conical guide arrangement for guiding the skid connection interface to a mating position on the trunk. Thereby, the mounting and connection of the skid on the trunk is simplified and may be performed faster and with less worker resources.

[0022] In some example embodiments, that may be combined with any one or more of the above-described embodiments, the skid has a valve actuator configured for engaging a valve control interface of a valve of the lid, and for controlling operating position of said valve. Thereby, a single lid may be used for both evacuation of water/mud from the suction bucket and subsequent closing and sealing of the trunk.

[0023] In some example embodiments, that may be combined with any one or more of the above-described embodiments, an end piece of the valve actuator is configured for engaging the valve control interface of said valve of the lid in connection with loading of the lid into the lid hoist mechanism. Thereby, an automatic operable connection between the valve actuator and the valve control interface may be accomplished upon loading of the lid in the skid.

[0024] In some example embodiments, that may be combined with any one or more of the above-described embodiments, the end piece of the valve actuator comprises a hole or recess configured to engage a vertical control pin of the valve control interface of the valve of the lid. Thereby, an automatic operable connection between the valve actuator valve and the control interface may be accomplished upon loading of the lid in the skid.

[0025] In some example embodiments, that may be combined with any one or more of the above-described embodiments, the end piece of the valve actuator comprises a vertical control pin configured to engage a hole or recess of the valve control interface of the valve of the lid. Thereby, an automatic operable connection between the valve actuator valve and the control interface may be accomplished upon loading of the lid in the skid.

[0026] In some example embodiments, that may be combined with any one or more of the above-described embodiments, the skid comprises a locking actuator configured for engaging a lock control interface of a lid locking arrangement, and for controlling operation of said lid locking arrangement. Thereby, the skid may fasten and lock the lid in the outlet opening of the trunk autonomously, without the need for a ROV or the like.

[0027] In some example embodiments, that may be combined with any one or more of the above-described embodiments, an end piece of the locking actuator is configured for engaging the lock control interface of the lid in connection with loading of the lid into the lid hoist mechanism. Thereby, an automatic operable connection between the locking actuator and the lock control interface may be accomplished upon loading of the lid in the skid.

[0028] In some example embodiments, that may be combined with any one or more of the above-described embodiments, the end piece of the locking actuator comprises a hole or recess configured to engage a vertical control pin of the lock control interface of the lid locking arrangement of the lid. Thereby, an automatic operable connection between the locking actuator and the lock control interface may be accomplished upon loading of the lid in the skid.

[0029] In some example embodiments, that may be combined with any one or more of the above-described embodiments, the end piece of the locking actuator comprises a vertical control pin configured to engage a hole or recess of the lock control interface of the lid locking arrangement of the lid. Thereby, an automatic operable connection between the locking actuator and the lock control interface may be accomplished upon loading of the lid in the skid.

[0030] In some example embodiments, that may be combined with any one or more of the above-described embodiments, the lid hoist mechanism comprises a vertically moveable lid manipulating fixture, wherein the at least one lid hoist actuator is connected to the lid manipulating fixture, and wherein the lid manipulating fixture carries the lid holding tool and the locking actuator. This provides a compact, flexible and cost-efficient design of the skid.

[0031] In some example embodiments, that may be combined with any one or more of the above-described embodiments, the lid holding tool comprises a moveable lid clamping mechanism operatively connected to a lid clamping actuator, wherein the lid clamping actuator is controllable for setting the lid clamping mechanism in an engaged operating position, in which a lid is configured to be gripped by the lid clamping mechanism, and wherein the lid clamping actuator is controllable for setting the lid clamping mechanism in a disengaged operating position, in which the lid is released from the lid clamping mechanism. Thereby, the skid can autonomously grip and release the lid, thereby providing a cost-efficient design with improved user-friendliness.

[0032] In some example embodiments, that may be combined with any one or more of the above-described embodiments, the lid clamping mechanism comprises a radially expanding clamping member configured for engaging an internal surface of a recess of the lid for gripping the lid, when the lid clamping mechanism is set in an engaged operating position. Thereby, the lid hoist mechanism may be connected to the lid without having to engage around the periphery of the lid, such that installation of the lid within a trunk is simplified.

[0033] In some example embodiments, that may be combined with any one or more of the above-described embodiments, the lid hoist actuator and/or skid clamping actuator and/or valve actuator and/or locking actuator and/or lid clamping actuator is a hydraulic actuator (cylinder-piston hydraulic actuator) or an electric actuator.

[0034] The disclosure also concerns an assembly comprising a detachable suction pump skid as defined above, and a detached lid that is releasably held by the lid holding tool of the skid, wherein the lid hoist mechanism and lid are configured for placing the detached lid in or on an outlet opening of the trunk.

[0035] In some example embodiments, that may be combined with any one or more of the above-described embodiments, the lid has a flow passage extending through the lid, and wherein the suction pipe is fluidly connected to the flow passage of the lid.

[0036] In some example embodiments, that may be combined with any one or more of the above-described embodiments, the lid has a holding interface that is engaged by the lid holding tool.

[0037] In some example embodiments, that may be combined with any one or more of the above-described embodiments, the lid has a locking arrangement that is moveable between an unlocked state, in which the lid is arranged to be removable from the trunk, and a locked state, in which the lid is arranged to be fastened to the trunk, and wherein the lid has a lock control interface that is engaged by the locking actuator of the skid.

[0038] In some example embodiments, that may be combined with any one or more of the above-described embodiments, the locking arrangement of the lid comprises at least one moveable locking member that is configured to be displaced radially outwards, in particular into an interior groove of the trunk, when the locking arrangement is moved from the unlocked state to the locked state.

[0039] In some example embodiments, that may be combined with any one or more of the above-described embodiments, the lid has a valve for controlling a flow area of the flow passage of the lid, wherein the valve has a valve control interface that is engaged by the valve actuator of the skid for controlling motion of the valve.

[0040] In some example embodiments, that may be combined with any one or more of the above-described embodiments, the valve is a gate valve.

[0041] In some example embodiments, that may be combined with any one or more of the above-described

embodiments, the assembly further comprises a suction bucket with a trunk.

[0042] In some example embodiments, that may be combined with any one or more of the above-described embodiments, the trunk has an interior locking groove configured to receive the locking element when the locking arrangement of the lid is moved from the unlocked state to the locked state.

[0043] According to a further aspect of the present disclosure, there is provided a detachable suction pump skid for operation with a suction bucket of an anchoring system for soft ocean floors. The suction pump skid comprises: a skid connection interface for establishing a disconnectable rigid connection of the skid to a trunk of the suction bucket; a lid hoist mechanism comprising a lid hoist actuator connected to a lid holding tool, wherein the lid holding tool is configured for releasably holding a detached suction bucket trunk lid, wherein the lid hoist mechanism is configured for placing the detached suction bucket trunk lid in or on an outlet opening of the trunk, wherein the skid connection interface comprises a downwards facing seat configured for resting on an upwards facing corresponding seat of the trunk of the suction bucket, and wherein the downwards facing seat of the skid connection interface enables connection of the suction pump skid to the trunk at any relative angular position; and a suction pump coupled to a suction pipe and configured for evacuating water from an interior of the suction bucket via said trunk and said suction pipe. This further aspect may be combined with any one or more of the above-described embodiments.

[0044] Further features and advantages of the invention will become apparent when studying the appended claims and the following description. The skilled person in the art realizes that different features of the present disclosure may be combined to create embodiments other than those explicitly described hereinabove and below, without departing from the scope of the present disclosure.

BRIEF DESCRIPTION OF DRAWINGS

[0045] The detachable suction pump skid, assembly and method according to the disclosure will be described in detail in the following, with reference to the attached drawings, in which

Fig. 1A-1D show schematically the main steps of a foundation installation,
 Fig. 2 shows a top view of the foundation before submerging,
 Fig. 3 shows a perspective view of a suction bucket,
 Fig. 4A-4B shows an example embodiment of the skid, and its connection to a trunk,
 Fig. 5 shows schematically the skid clamping mechanism used for connecting the skid to the trunk,

Fig. 6

Fig. 7

5 Fig. 8A-8C

Fig. 9A-9B

10 Fig. 10

Fig. 11

15 Fig. 12

Fig. 13-14

Fig. 15A-15B

20

Fig. 16

Fig. 17

25 Fig. 18A-18F

Fig. 19-21

30

DESCRIPTION OF EXAMPLE EMBODIMENTS

[0046] Various aspects of the disclosure will hereinafter be described in conjunction with the appended drawings to illustrate and not to limit the disclosure, wherein like designations denote like elements, and variations of the described aspects are not restricted to the specifically shown embodiments, but are applicable on other variations of the disclosure.

40 **[0047]** Detachable suction pump skids for operation with a suction bucket, also known as Suction Bucket Jacket (SBJ), of an anchoring system for ocean floors may be used for a variety of purposes, such as anchoring and fixed platform foundations, as well as offshore wind turbine foundations.

[0048] Figure 1A-1D schematically show some steps of an installation of an offshore wind turbine foundation 1 using a set of suction buckets 2 and associated detachable suction pump skids 3.

50 **[0049]** An offshore wind turbine foundation 1 is first transported on water 4 to a desired installation site using some type of cargo transport vessel. With reference figure 1A, a lifting platform 5, such as floating lifting platform or seabed supported lifting platform, thereafter lifts the foundation 1 using a lifting crane 9 or the like to the desired installation position.

[0050] The foundation 1 may have various alternative designs. For example, the foundation 1 may include a

rigid support structure made of metal or other type of rigid material. The foundation 1 may have a top support surface 6 arranged for supporting an offshore wind turbine, and a plurality of bottom support feet 7 arranged for anchoring and supporting the foundation to the seabed 8, for ensuring that the offshore wind turbine will remain standing primarily in a vertical position. Each bottom support feet 7 may be provided with suction bucket 2 for anchoring in the seabed 8.

[0051] Figure 2 shows schematically a top view of an example embodiment of a foundation 1 resting on a transport vessel 11 next to a lifting platform 5. The foundation 1 may of course alternatively be transported by the lifting platform 5 itself.

[0052] The foundation 1 has a top support surface 6 and three bottom support feet 7, each rigidly connected to an individual suction bucket 2 having an suction pump skid 3 detachably installed thereon.

[0053] The suction bucket 2 has circumferential continuous side wall, in particular a circular side wall, a top wall closing the upper surface of the suction bucket 2, and an open lower side facing the seabed. As a result, the suction bucket may first self-penetrate the seabed to a certain extent upon being lowered to the seabed, and subsequently made to further embed into the seabed by evacuating the water/mud that is trapped within the suction bucket 2. Consequently, the suction bucket includes a trunk with a through opening for enabling further evacuation of water/mud from the suction bucket. The trunk, i.e. suction bucket interface, is arranged for receiving a suction pump skid 3 for pumping out water/mud from the interior of the suction bucket until the suction bucket has become embedded sufficiently deep into the seabed.

[0054] Each suction pump skid 3 may be connected to the lifting platform 5 via a power supply cable 10 for powering the pump and/or control actuators of the suction pump skid. In some example embodiments, the suction pump skid 3 may also be connected to the lifting platform 5 via a fluid pipe for conveying pumped out water/mud from the suction bucket to the lifting platform 5.

[0055] The installation of the suction pump skid 3 on the associated trunk of the suction bucket 2 is typically performed before lifting the foundation 1 from its transportation vessel.

[0056] Figure 1B shows the foundation 1 after the lifting platform has lowered the foundation 1 through the water 4 to the seabed 8. The suction bucket then stands on the seabed after a certain level of self-penetration into the seabed 8.

[0057] With reference to figure 1C, thereafter the suction pump of the suction pump skid starts operating for evacuating water and/or mud from the interior of the suction bucket 2, and the resulting under pressure within the suction bucket 2, in combination with the weight of the foundation 1, then causes the suction bucket to penetrate further into the seabed until the suction bucket has become sufficiently embedded into the seabed, as showed in figure 1C.

[0058] The operation of the suction pump skid 3 of each individual bottom support foot 7 may for example be individually controlled by a central electronic controller based on feedback signal received from an inclinometer or the like, for ensuring that the foundation remains in a vertical position during and after completed installation.

[0059] With reference to figure 1D, after the foundation has reached its desired installation position, the suction pump skids 3 are disconnected from the trunks of the suction buckets and lifted on board the lifting platform 5 and the crane 9 may be disconnected from the foundation 1.

[0060] Figure 3 shows schematically a perspective view of suction bucket 2 having circumferential continuous side wall 12, in particular a circular side wall, a top wall 13 closing the upper surface of the suction bucket 2, and a lower side 14 that is open and arranged to face the seabed 8.

[0061] A bottom support foot 7 of a cylindrical leg of a foundation 1 is illustrated being fastened to the top wall 13 of the suction bucket 2. Furthermore, a trunk 15 with a suction outlet 16 is fastened on the top wall 13 of the suction bucket 2. A suction pump skid 3 is lowered towards the trunk 15 for connection thereto, for subsequently pumping out water from the suction bucket via the suction outlet 16 after having lowered the suction bucket 2 to the seabed 8.

[0062] Figure 4A schematically shows a suction pump skid 3 being lowered towards the trunk 15 of a suction bucket 2 for connection thereto. Figure 4A shows schematically one example embodiment of the interior of the suction pump skid 3, namely including a rigid frame 17 having a top connection structure 21 for enabling lifting and manoeuvring of the suction pump skid 3 by means of a lifting wire or the like. The suction pump skid 3 further includes a suction pump 18 operationally connected to a motor 19 and configured for evacuating water from an interior of the suction bucket 2 via a suction pipe 20 that is connected to the suction pump 18.

[0063] The suction pump skid 3 further comprises a skid connection interface 22 for establishing a disconnectable rigid connection of the skid 3 to the trunk 15 of the suction bucket 2. The skid connection interface 22 includes for example a downwards facing seat arranged for abutting and resting against an upwards facing corresponding seat 23 of the trunk 15. The skid connection interface 22 also comprises a moveable skid clamping mechanism 24 arranged for temporarily clamping and fastening the suction pipe skid 3 to the trunk 15 during installation of the suction bucket 2.

[0064] It is desirable to have a large opening in the trunk during the initial phase of the submersing state of the suction bucket 2, also referred to as the ventilation phase, because this reduces the risk of unwanted tilting of the foundation caused by trapped air bubbles within the suction bucket. Furthermore, this ventilation phase of the installation process may also be performed faster with a large trunk opening. Hence, the suction bucket

trunk lid 26 must be sufficiently opened or offset from the opening of the trunk 15 during at least the ventilation phase, but preferably also while lowering the suction bucket down to the seabed, for avoiding reduction of the ventilation rate. After the suction bucket jacket has self-penetrated the seabed, the trunk needs to be closed and sealed before the suction operation using the suction pump skid can start. Finally, after the suction operation is completed, the suction outlet used by the suction pump skid also needs to be closed and sealed.

[0065] In the prior art, this is solved by having a moveable lid fastened to the trunk, and having the lid in an open state during installation, and using a ROV for closing and sealing the open lid after removal of the suction pump skid from the suction bucket.

[0066] The suction pump skid according to the present disclosure solves the problem of providing a ROV-free installation of the suction bucket by providing the suction pump skid with an integral lid hoist mechanism 25 that is arranged for gripping and manoeuvring a detached suction bucket trunk lid 26 in connection with installation of the suction bucket 2. Specifically, the lid hoist mechanism 25 enables loading of a detached suction bucket trunk lid 26 into the suction pump skid 3 prior to mounting of the suction pump skid 3 on the trunk of the suction bucket. The suction bucket trunk lid 26 is loaded to a dedicated ventilation position, in which the suction bucket trunk lid 26 is located sufficiently far away from the trunk opening for enabling good ventilation of the suction bucket during submersion phase.

[0067] Furthermore, the lid hoist mechanism 25 also provides selective displacement of the detached suction bucket trunk lid 26 from said ventilation position to a closing position, i.e. a position in which the suction bucket trunk lid 26 closes and seals the outlet opening of the trunk, as well as selective detachment of the suction pump skid from the trunk 15 while the suction bucket trunk lid 26 remains in a locked state in the outlet opening 16 of the trunk 15.

[0068] Consequently, the suction pump skid 3 according to the disclosure provides a ROV-free operation for installation of a suction bucket 2 on a seabed, including closing and locking of the suction bucket trunk lid 26 in or on the trunk opening 16.

[0069] The suction pump skid 3 further comprises a pump outlet pipe 27 for evacuating water and/or mud exiting the suction pump 18, as well as a downward facing conical guide arrangement 28 for guiding the skid connection interface to a mating position on the trunk, i.e. a position in which the skid connection interface is concentric with the mating position on the trunk, thereby simplifying mounting of the suction pump skid 3 on the trunk 15.

[0070] The suction pump 18 and its design, together with the design, placement and implementation of the motor 19, suction pipe 20, pump outlet pipe 27, as schematically illustrated in figure 4A, can of course be varied to a large extent without departing from the scope of the independent claims.

[0071] Figure 4B schematically shows a perspective view of the suction pump skid 3 in mounted state on the trunk 15.

[0072] Figure 5 shows schematically a cross-section of the skid connection interface 22 of the suction pump skid, as well as the trunk 15. The skid connection interface 22 comprises a downwards facing seat 29 configured for resting on an upwards facing corresponding seat 23 of the trunk 15 of the suction bucket 2, and the downwards facing seat 29 of the skid connection interface 22 enables connection of the suction pump skid 3 to the trunk 15 at any relative angular position. In other words, the downwards facing seat 29 of the skid connection interface 22 is arranged for allowing the suction pump skid 3 to be connected to the trunk 15 at any angular position of the suction pump skid 3 around a central axis of the downwards facing seat 29.

[0073] The downwards facing seat 29 of the skid connection interface 22 may thus for example have a continuous annular surface, as showed in figure 5, or alternatively a discontinuous annular surface, or any type of rotation-symmetric shape that enables connection of the suction pump skid to the trunk at any relative angular position.

[0074] Furthermore, the detached suction bucket trunk lid 26 has for example a circular circumferential shape for enabling said connection of the suction pump skid to the trunk at any relative angular position.

[0075] Figure 5 also shows an example embodiment of the moveable skid clamping mechanism 24 more in detail. Specifically, according to some example embodiments, the skid connection interface 22 comprises a plurality of individual moveable skid clamping mechanisms 24, each operatively connected to an individual skid clamping actuator 30, wherein each skid clamping actuator 30 is controllable for setting the associated skid clamping mechanism 24 in an engaged operating position, in which the downwards facing seat 29 of the skid 3 is configured to be clamped against the upwards facing corresponding seat 23 of the trunk by the plurality of skid clamping mechanisms 24, and wherein each skid clamping actuator 30 is controllable for setting associated skid clamping mechanism 24 in a disengaged operating position, in which the skid 3 is free to move away from, or towards, the seat 23 of the trunk 15.

[0076] As illustrated in figure 5, in some example embodiments, each moveable skid clamping mechanism 24 comprises a pivoting skid clamping member 31, and the skid clamping actuator 30 is a linear actuator. A first end of the clamping actuator 30 is attached directly or indirectly to the rigid frame 17 of the skid and the other end of the clamping actuator 30 is attached to a first pivot joint 32 of the clamping member 31, while a second pivot joint 33 of the clamping member 31 is attached directly or indirectly to the rigid frame 17 of the skid. Consequently, linear motion of clamping actuator 30 results in pivoting motion of the clamping member 31.

[0077] In the example embodiment of figure 5, the skid

comprises four clamping mechanisms 24 distributed around a central opening 34, defined by the annular downwards facing seat 29, in the bottom region of the skid 3.

[0078] The clamping actuator 30 may for example be a hydraulic, electric or pneumatic operated actuator.

[0079] Figure 6 shows schematically a further example embodiment of the suction pump skid 3 according to the disclosure with more details about for example the lid hoist mechanism 25. In figure 6, a detached suction bucket trunk lid 26 is temporarily hold by the lid hoist mechanism 25 in the ventilation position in the suction pump skid 3.

[0080] For manoeuvring the detached suction bucket trunk lid 26, e.g. gripping, lifting, holding, lowering and releasing the detached suction bucket trunk lid 26, the lid hoist mechanism 25 comprises a lid hoist actuator 35 connected to a lid holding tool 36, wherein the lid hoist actuator 35 is configured for raising and lowering a vertical position of the lid holding tool 36, wherein the lid holding tool is configured for releasably engaging a holding interface 50 of a detached suction bucket trunk lid 26.

[0081] The lid hoist actuator 35, which for example be a hydraulic, electric or pneumatic operated linear actuator, is directly or indirectly fastened to the rigid frame 17 of the skid 3. In the example embodiment of figure 6, the skid is provided with a support cradle 37 that is rigidly connected to the rigid frame 17, and the lid hoist actuator 35 is rigidly fastened to the support cradle 37 via a support bracket 38.

[0082] In the example embodiment of figure 6, the support cradle 37 also supports the suction pipe 20, suction pump 18, motor 19, ump outlet pipe 27, suction pipe 20.

[0083] The lid holding tool 36 of the lid hoist mechanism 25, as well as the corresponding holding interface 50 of a detached suction bucket trunk lid 26, may have various alternative designs. For example, the lid holding tool 36 may be a moveable clamp that may be controlled to clamp and release of portion of the suction bucket trunk lid 26. Alternatively, the lid holding tool 36 may include a projection that positively engages a recess of the suction bucket trunk lid 26, or oppositely. Still more alternatively, as schematically illustrated in figure 6 and figure 7, the lid holding tool 36 may include a radially expanding clamping member that is configured for engaging a holding interface 50 in form of a recess in the suction bucket trunk lid 26 for gripping the lid. Said recess of the suction bucket trunk lid 26 may for example be provided by fastening an attachment cup 39 to the suction bucket trunk lid 26, wherein the cup 39 is open towards an upper side and closed towards a lower side.

[0084] In other words, the holding interface 50 may comprise a recess 60 in the suction bucket trunk lid 26 configured for being engaged by the lid hoist mechanism 25 of the suction pump skid 3, in particular by an expanding clamping member 46 of the lid hoist mechanism 25, for holding the suction bucket trunk lid 26 while the lid 26 is being placed in or on said outlet opening 16 of the trunk

15 by said lid hoist mechanism 25.

[0085] With reference to figure 7, which shows the suction bucket trunk lid 26 in perspective view from below, the suction bucket trunk lid 26 further comprises a central through hole 40 configured for direct or indirect sealing engagement with an exterior surface of the suction pipe 20 of the skid, thereby enabling pumping out the remaining water and/or mud from the suction bucket 2 while the lid 26 is attached and locked to the trunk.

[0086] Moreover, in those embodiments in which the lid 26 is arranged for being inserted into the outlet opening 16 of the trunk 15, the lid may be provided with a radially exterior seal 41 arranged for sealing engagement with the radially interior surface of the trunk 15.

[0087] Consequently, the disclosure thus concerns a detachable suction pump skid 3 for operation with a suction bucket 2 of an anchoring system for soft ocean floors, wherein the suction pump skid 3 comprises a skid connection interface 22 for establishing a disconnectable rigid connection of the skid 3 to a trunk 15 of the suction bucket 2. The suction pump skid 3 further comprises a lid hoist mechanism 25 having a lid hoist actuator 35 connected to a lid holding tool 36, wherein the lid hoist actuator 35 is configured for raising and lowering a vertical position of the lid holding tool 35, wherein the lid holding tool 36 is configured for releasably holding a detached lid 26, and wherein the lid hoist mechanism 25 is configured for placing the detached lid 26 in or on an outlet opening 16 of the trunk 15. The suction pump skid 3 further comprises a suction pump 18 coupled to a suction pipe 20 and configured for evacuating water from an interior of the suction bucket 2 via said trunk 15 and said suction pipe 20.

[0088] The suction pipe 20 is thus configured for establishing fluid connection with a flow passage extending through the lid 26, and wherein the suction pump 18 is configured for evacuation of water from the interior of the suction bucket 2 via said trunk 15, said flow passage through the lid 26 and said suction pipe 20.

[0089] Figures 8A-C show an example embodiment of the lid holding tool 36 of the skid configured for engagement with an attachment cup 39 of the lid 26. The lid holding tool 36 is thus arranged for being attached to the lid hoist actuator 35 of the skid, for example via a threaded aperture 42 on a top side of the lid holding tool 36. Similarly, the attachment cup 39 is arranged for being fastened to the lid 26, for example by means of fasteners clamping an exterior flange 43 of the attachment cup 39 against the lid 26.

[0090] Figure 8A shows the lid holding tool 36 prior to engagement with attachment cup 39, in a released state. The lid holding tool may comprise a moveable lid clamping mechanism 44 operatively connected to a lid clamping actuator 45, wherein the lid clamping actuator 45 is controllable for setting the lid clamping mechanism 44 in an engaged operating position, in which an attachment cup 39 of a lid 26 is configured to be gripped by the lid clamping mechanism 44, and wherein the lid clamping

actuator 45 is controllable for setting the lid clamping mechanism 44 in a disengaged operating position, in which the attachment cup 39 of the lid 26 is released from the lid clamping mechanism 44. In figure 8A, the clamping actuator 45 is set in a release state and the clamping mechanism 44 is set in the disengaged operating position.

[0091] Figure 8B shows the lid holding tool 36 being inserted into the attachment cup 39, but with the clamping actuator 45 still being set in the release state and the clamping mechanism 44 still being set in the disengaged operating position.

[0092] Figure 8C shows the lid holding tool 36 inserted into the attachment cup 39 and with the clamping actuator 45 set in engaged state and the clamping mechanism 44 set in the engaged operating position.

[0093] The lid clamping mechanism 44 comprises radially expanding clamping members 46 configured for engaging an internal surface of a recess of the lid 26 for gripping the lid 26, when the lid clamping mechanism 44 is set in an engaged operating position.

[0094] The lid holding tool 36 and the attachment cup 39 may have a cylindrical overall shape, and the clamping members 46 may be pivotally attached to a frame structure 49 of the lid holding tool 36 for providing a radially outwards pivotal motion.

[0095] The lid clamping actuator 45 may be a linear actuator, for example a hydraulic, electric or pneumatic operated actuator, wherein an actuator piston 47 and associated piston rod 48 is arranged to engage the clamping members 46 for making them pivot outwards, as illustrated in figure 8C.

[0096] The attachment cup 39 may be provided with a partly undercut internal surface for ensuring positive locking and engagement between the attachment cup 39 and the clamping members 46 in their radially expanded state.

[0097] Figure 9A schematically shows an example embodiment of a suction bucket trunk lid 26 for being fitted in or on an outlet opening 16 of a trunk 15 of a suction bucket 2 of an anchoring system for soft ocean floors according to the present disclosure, wherein the suction bucket trunk lid 26 comprises a locking arrangement 51.

[0098] Figure 9A shows the lid with the locking arrangement in an unlocked state, i.e. the locking arrangement 51 is not configured to be in engagement with a corresponding locking groove of the trunk.

[0099] Figure 9B shows the lid according to figure 9A, but with the locking arrangement in a locked state, i.e. the locking arrangement 51 is configured to be in engagement with a corresponding locking groove of the trunk 15.

[0100] Figure 10 shows a schematic cross-sectional view along cut A-A in figure 9B, when the suction bucket trunk lid 26 is positioned in the outlet opening 16 of a trunk 15, and with the locking arrangement 51 in a locked state, i.e. with the locking arrangement 51 in engagement with a corresponding locking groove of the trunk 15.

[0101] The locking arrangement 51 is moveable between an unlocked state, in which the suction bucket trunk lid 26 is arranged to be removable from the trunk 15, and a locked state, in which the suction bucket trunk lid 26 is arranged to be secured to the trunk 15, and the locking arrangement 51 has a lock control interface 52 for shifting the locking arrangement 51 from the unlocked state to the locked state, and the suction bucket trunk lid 26 is a detached unit.

[0102] A suction bucket trunk lid 26 that is a detached unit means herein that the lid 26 is a separate part that is free to become separated from the trunk as soon as the locking arrangement 51 is set in the unlocked state. In other words, the lid 26 is not pivotally, or otherwise, attached to the trunk, when the locking arrangement 51 is set in the unlocked state. This enables transportation of the detached lid 26 by the suction pump skid 3 to the trunk 15, and subsequent mounting and locking of the lid 26 to the trunk.

[0103] The suction bucket trunk lid 26 comprises a holding interface 50 configured for being engaged by the lid hoist mechanism 25 of the suction pump skid 3 for holding the suction bucket trunk lid 26 while the suction bucket trunk lid 26 is being placed in or on said outlet opening 16 of the trunk 15 by said lid hoist mechanism 25, and the lock control interface 52 of the locking arrangement 51 is configured for being engaged by a locking actuator of the suction pump skid 3 for shifting the locking arrangement 51 from the unlocked state to the locked state.

[0104] Accordingly, the skid comprises a locking actuator configured for engaging the lock control interface 52 of said lid locking arrangement 51, and for controlling operation of said lid locking arrangement 51.

[0105] Consequently, the suction pump skid 3 controls the position of the locking arrangement as long as the lid 26 is carried by the skid 3, thereby eliminating the need for a separate ROV or the like for actuating the locking arrangement 51 of the lid 26.

[0106] With reference to figure 9A-B and figure 10, the locking arrangement 51 does not protrude outside of a periphery 54 of the suction bucket trunk lid 26, in a plane of the lid 26, when the locking arrangement 51 is set in the unlocked state, but the locking arrangement does protrude outside of a periphery 54 of the suction bucket trunk lid 26 when the locking arrangement 51 is set in the locked state.

[0107] Consequently, the lid 26 is free to move in and out from the outlet opening of the trunk 15 as long as the locking arrangement 51 is set in the unlocked state, but the lid 26 is locked in the outlet opening of the trunk 15 when the locking arrangement 51 is set in the locked state. Others said, the locking arrangement 51 is configured to engage an interior groove 55 of the trunk 3 when the locking arrangement 51 is moved from the unlocked state to the locked state.

[0108] The locking arrangement 51 comprises at least one moveable locking member 56 that is configured to

be displaced outwards or inwards in a plane of the suction bucket trunk lid 26 when the locking arrangement 51 is moved from the unlocked state to the locked state.

[0109] In the example embodiments of figure 9A-9B and 10, the moveable locking member 56 is configured to be displaced outwards in a plane of the suction bucket trunk lid 26 when the locking arrangement 51 is moved from the unlocked state to the locked state. Specifically, the at least one moveable locking member is configured to be displaced outwards into an interior groove of the trunk when the locking arrangement is moved from the unlocked state to the locked state. However, in other embodiments the lid and trunk may be designed for having the moveable locking member 56 being displaced inwards in a plane of the suction bucket trunk lid 26 when the locking arrangement 51 is moved from the unlocked state to the locked state. Specifically, the at least one moveable locking member may thus be configured to be displaced inwards under a trunk flange or trunk collar when the locking arrangement is moved from the unlocked state to the locked state.

[0110] The locking arrangement comprises at least two locking members that are pivotally fastened to the suction bucket trunk lid, and wherein displacement of the lock control interface for shifting the locking arrangement from the unlocked state to the locked states results in pivotal outwards motion of each locking member in a plane of the lid.

[0111] In the example embodiments of figures 9A-9B, the locking arrangement comprises two, in particular curved, elongated locking members 56, wherein each locking member 56 is pivotally fastened to the suction bucket trunk lid at a first end region of the locking member 56 and connected to the lock control interface 52 via a linkage arm 57 at a second end region of the locking member 56, wherein displacement of the lock control interface 52 for shifting the locking arrangement from the unlocked state to the locked states results in pivotal outwards motion of each locking member 56 in a plane of the lid 26.

[0112] In particular, each locking member 56 is pivotally fastened to the suction bucket trunk lid at a first pivot point 58 at the first end region of the locking member, and the first end second end regions of each locking member 56 are located on opposite end regions of the lid 26 for providing relatively elongated locking members 56.

[0113] The radially outer shape of the curved elongated locking members 56 may have a form that conforms with a circular periphery of lid 26, in particular over at least 20% of the circumference of lid 26, for having a large surface area of the locking members 56 entering the locking groove 55 of the trunk 15, and thus providing a relatively large and distributed effective locking engagement of the locking members 56 with the locking groove 55.

[0114] As mentioned above, the locking arrangement 51 may be provided with a locking mechanism in form of

one or more linkage arms 57 that ensures shifting of the locking members 56 from between the locked and unlocked state in response to displacement of the lock control interface 52. In the example embodiment of figures 9A-9B, the lock control interface 52 is provided on an individual linkage member 59, and each locking member 56 is connected to the individual linkage member 59 via a separate linkage arm 57. In other words, one end region of each linkage arm 57 is pivotally connected to the individual linkage member 59, and the other end region of each linkage arm 57 is pivotally connected to a locking member 56.

[0115] For further improved locking engagement of the locking arrangement 51, the individual linkage member 59 may be arranged to be displaced in a direction towards the periphery 54 of the lid when shifting the locking arrangement 51 from the unlocked state to the locked state, such that a portion of the individual linkage member 59 may protrude and enter into the locking groove of the trunk when locking arrangement 51 in locked state.

[0116] With reference to for example figures 9A-9B and 10, in some example embodiments, the suction bucket trunk lid 26 is provided with a flow passage 61 extending through the lid 26 for enabling evacuation of water from the interior of the suction bucket 2 via said flow passage through the lid 26. Specifically, the suction bucket trunk lid 26 is configured for establishing a fluid connection between a suction pipe 20 of a suction pump skid 3 and the flow passage 61 of the suction bucket trunk lid 26 for enabling evacuation of water from the interior of the suction bucket 2 via said trunk 15, said flow passage 61 through the lid 26 and said suction pipe 20.

[0117] Thereby, there is no need for a separate large ventilation hole in the suction bucket for the submersion step, and a separate smaller water evacuation hole in the suction bucket for connection with the suction pump. Instead, a single relatively large outlet opening 16 is provided in the trunk 15, and a smaller water evacuation hole for connection with the suction pump is provided in the lid, thereby eliminating one hole in the suction bucket and thus enabling reduced manufacturing cost.

[0118] The suction bucket trunk lid 26 may be provided collar 89 surrounding the flow passage 61 extending through the lid 26 for providing improved direct or indirect connection and sealing with the suction pipe 20 of the skid.

[0119] In certain implementations of the suction bucket 2, it is desirable to be able to close and seal the suction bucket 2 after completed installation on the seabed 8. Consequently, in some example embodiments, the suction bucket trunk lid 26 may be provide with a valve 62 for controlling a flow area of the flow passage 61 extending through the suction bucket trunk lid 26, and in particular for being able to close the flow passage 61 through the lid 26.

[0120] As illustrated in figures 9A-9B and 10, the valve 62 may be a gate valve, i.e. having flat valve member that is slidably mounted in a valve housing 63 between

first and second positions, wherein a hole 64 in the valve member coincides with the flow passage 61 in the first position, as shown in figure 9A, thereby setting the valve in an open state, and wherein the hole 64 in the valve member is offset from the flow passage 61 in the second position, as shown in figure 9B and figure 10, thereby setting the valve in a closed state.

[0121] Furthermore, the valve 62 has a valve control interface 65 for controlling motion of the valve 62.

[0122] Figure 11 shows schematically a perspective view of part of the lid hoist mechanism 25, according to one example embodiment of the suction pump skid 3. This part combines several different features and functionalities of the lid hoist mechanism 25 into a single unit that is vertically displaceable by means of the lid hoist actuator 35.

[0123] Specifically, the single unit may include lid manipulating fixture 66 that carries various components of the lid hoist mechanism 25. The lid manipulating fixture 66 may for example be a plate. In the example embodiment of figure 11, the lid manipulating fixture 66 carries two lid holding tools 36, a locking actuator 53 and a valve actuator 67. The lid manipulating fixture 66 may also be provided with a collar 68 for slidable engagement with the suction pipe 20 of the skid 3.

[0124] The lid manipulating fixture 66 may for example be vertically displaceable by two lid hoist actuators 35, each being connected to a threaded aperture 42 of a lid holding tool 36 that is secured to the lid manipulating fixture 66. However, the lid hoist actuators 35 may of course be connected to the lid manipulating fixture 66 by other means.

[0125] The valve actuator 67 may be a linear actuator, and the valve actuator 67 may be hydraulically, electrically or pneumatically operated. A first end 69 of the valve actuator 67 is fastened to the lid manipulating fixture 66 and a second end of the valve actuator 67 has a moveable end piece 70.

[0126] Consequently, with reference to figure 12, which shows the lid manipulating fixture 66 positioned on top of the lid 26, the skid 3 has a valve actuator 67 configured for engaging the valve control interface 65 of a valve 62 of the lid 26, and for controlling operating position of said valve 62. Specifically, the end piece 70 of the valve actuator 67 is configured for automatically engaging the valve control interface 65 of said valve 62 of the lid 26 in connection with loading of the lid 26 into the lid hoist mechanism 25, i.e. in connection with lowering the lid manipulating fixture 66 on the detached lid 26 for gripping and loading the lid 26 into the skid 3.

[0127] For example, the valve control interface 65 of said valve 62 may comprise a vertical control pin, and the end piece 70 of the valve actuator 67 may comprise a hole or recess 71 configured to engage the vertical control pin of the valve control interface 65 of the valve of the lid 26. This arrangement may of course be reversed, so that the valve control interface 65 of said valve 62 may comprise a hole or recess, and the end piece 70

of the valve actuator 67 may comprise a vertical control pin configured to engage the hole or recess of the valve control interface 65 of the valve 62 of the lid 26.

[0128] The locking actuator 53 may be a linear actuator, and the locking actuator 53 may be hydraulically, electrically or pneumatically operated. A first end 72 of the locking actuator 53 is fastened to the lid manipulating fixture 66 and a second end of the locking actuator 53 has a moveable end piece 73.

[0129] Consequently, with reference to figure 12, the skid 3 has a locking actuator 53 configured for engaging the lock control interface 52 of the locking arrangement 51 of the lid 26, and for controlling operating position of said locking arrangement 51. Specifically, the end piece 73 of the locking actuator 53 is configured for automatically engaging the lock control interface 52 of said locking arrangement 51 in connection with loading of the lid 26 into the lid hoist mechanism 25, i.e. in connection with lowering the lid manipulating fixture 66 on the detached lid 26 for gripping and loading the lid 26 into the skid 3.

[0130] For example, the lock control interface 52 of said locking arrangement 51 may comprise a vertical control pin, and the end piece 73 of the locking actuator 53 may comprise a hole or recess 74 configured to engage the vertical control pin of the lock control interface 52. This arrangement may of course be reversed, so that the lock control interface 52 of said locking arrangement 51 may comprise a hole or recess, and the end piece 73 of the locking actuator 53 may comprise a vertical control pin configured to engage the hole or recess of the lock control interface 52 of the lid.

[0131] With reference to figure 13, in some example embodiments, the lid 26 includes a locking arrangement 51 and a flow passage 61, as described above with reference to figure 9A-9B, but is free from any features associated with the valve 62. Such a lid may be used in suction bucket installations where there is no need to close the flow passage through the lid after completed installation.

[0132] Moreover, a lid without a valve may also be used in combination with a valve lacking a flow passage 61, as schematically showed in figure 14. In such an implementation, the suction bucket trunk lid 26 of figure 13 is first used during the installation of the suction bucket, as described above. However, the suction pump skid 3 does not release the lid 26 after completed installation, but rather unlocks the lid 26 from the trunk 15 and loads the lid 26 into the skid 3 before disconnecting the skid 3 from the suction bucket 2. The skid 3 may thereafter be used again for transporting a lid without a flow passage 61, such as a lid according to, or similar to figure 14, down to the installed suction bucket 2, and for installing the lid 26 in the trunk 15 and shifting the locking arrangement 51 to the locked state, and subsequently releasing the lid 36 and disconnecting the skid 3 from the trunk 15.

[0133] Still more alternatively, a ROV of similar type of underwater vehicle may be used for transporting the lid without a flow passage 61, such as a lid according to, or

similar to figure 14, down to the installed suction bucket 2, and for installing the lid 26 in the trunk 15 and shifting the locking arrangement 51 to the locked state.

[0134] The locking arrangement 51 of the lid 26 may have various forms and designs, depending on the circumstance. For example, figure 15A-15B show schematically a further embodiment of the locking arrangement 51 of the lid 26, wherein figure 15A shows the lid with the locking arrangement in the unlocked state, and wherein figure 15B shows the lid with the locking arrangement in the locked state.

[0135] The locking actuator 53 is here operatively connected to a ring member 75 for generating a small rotational motion of the ring member 75 in response to actuation of the locking actuator 53. The locking arrangement comprises three individual locking members 56 distributed around the circumference to the lid 26, wherein each locking member 56 is slidably arranged in a radial direction within a locking member housing 76. Each locking member 56 is connected to the ring member 75 via a linkage arm 57, such that rotational displacement of the ring member 75 induced by the locking actuator 53 results in radial motion of the locking member 56, as illustrated by the dotted line arrows in figure 15B.

[0136] In the embodiment of figure 15A-15B, the locking actuator 53 is schematically showed located on the lid, but the locking actuator 53 is typically mounted on the skid 3, in particular on a lid manipulating fixture 66, as described above with reference to figures 11 and 12. Furthermore, the valve 62 and associated parts, such as the valve control interface, etc., may be included into the lid 26 of figures 15A-15B if required.

[0137] The present disclosure also concerns an assembly comprising a detachable suction pump skid 3 as described above in combination with a detached circular lid 26 that is releasably held by the lid holding tool 36 of the skid 3, wherein the lid hoist mechanism 25 and lid 3 are configured for placing the detached lid 3 in or on an outlet opening 16 of the trunk 15.

[0138] The present disclosure also concerns an assembly comprising a trunk 15 of a suction bucket 2 for an anchoring system for soft ocean floors, and a detached lid 26 as described above, wherein the suction bucket trunk lid 26 is removable from the trunk 15 in the unlocked state of the locking arrangement 51, and wherein the suction bucket trunk lid 26 is secured to the trunk 15 in the locked state of the locking arrangement 51.

[0139] The present disclosure also concerns an assembly comprising a detached lid 26 as described above, and a suction pump skid 3 comprising a lid hoist mechanism 25, wherein the lid hoist mechanism 25 comprises a lid hoist actuator 35 connected to a lid holding tool 36, wherein the lid hoist actuator 35 is configured for raising and lowering a vertical position of the lid holding tool 36, wherein the lid holding tool 36 holds the detached lid 26, and wherein the lid hoist mechanism 25 is configured for placing the detached lid 26 in or on the suction opening 16 of the trunk 15.

[0140] In those implementations of the suction pump skid in which the various actuators of the skid are hydraulic actuators, the skid 3 may comprise a self-contained closed hydraulic system, thereby eliminating the need for hydraulic connection between the skid and the lifting platform 5. In other words, the skid would merely require an electric power supply from the lifting platform 5, or some other source.

[0141] For example, figure 16 shows schematically how such a self-contained hydraulic system of the suction bucket skid 3 could be accomplished. For example, the closed hydraulic system of the skid 3 could include a tank 77 for holding hydraulic fluid, a hydraulic pump 78, an electric motor 79 for powering the hydraulic pump 78, an accumulator 80 for storing high-pressure fluid, a hydraulic valve arrangement 81 fluidly connected to the hydraulic pump 78 and tank 77 and arranged for controlling a set of hydraulic actuators.

[0142] The hydraulic valve arrangement 81 may have a stacked sectional or monoblock valve arrangement including for example first to fifth stacked valve sections 82, 83, 84, 85, 86, each including a directional control valve having a first work port A and a second work port B, each fluidly connected to one or more hydraulic actuators.

[0143] The directional control valve of the first valve section 82 may for example be fluidly connected with a set of skid clamping actuators 30.

[0144] The directional control valve of the second valve section 83 may for example be fluidly connected with a locking actuator 53.

[0145] The directional control valve of the third valve section 84 may for example be fluidly connected with a valve actuator 67.

[0146] The directional control valve of the fourth valve section 85 may for example be fluidly connected with two lid hoist actuators 35, and the directional control valve of the fifth valve section 86 may for example be fluidly connected with two lid clamping actuators 45.

[0147] An ECU 87 may be operationally connected to the electric motor 79 and the directional control valves of the hydraulic valve arrangement 81 for controlling operation of the suction pump skid 3.

[0148] An example embodiment of a method for installing a suction bucket 3 of an anchoring system on a soft ocean floor will be described below with reference figures 18A-F, which shows operating status of an example embodiment of the suction pump skid in relation to a detached lid and a trunk of the suction bucket 2.

[0149] The example embodiment of the suction pump skid of figures 18A-F will first be briefly described with reference to figure 17, which schematically shows an enlarged version of the same simplified suction bucket skid 3, here carrying a suction bucket trunk lid 26 installed in an outlet opening 16 of a trunk 15 of a suction bucket 3.

[0150] Specifically, the assembly of figure 17 shows a schematic view of a skid 3 having a frame 17 with a conical guide arrangement 28 facing downwards, a skid

clamping mechanism 24 controlled by skid clamping actuators 30, a suction pipe 20 fluidly connected to a suction pump 18, a motor 19 operationally connected to the pump 18, lid hoist actuators 35 for vertically displacing a lid manipulating fixture 66 that carries a lid holding tool 36. The assembly of figure 17 further includes a lid 26 with a locking member 56 and a trunk 15 of a suction bucket.

[0151] A first phase of the method for installing a suction bucket 3 of an anchoring system on a soft ocean floor is illustrated in figure 18A, which shows the skid being lowered towards a lid 26 that is stored on a lid fixture 88 located on the lifting platform or the like. This step is thus a preparation step for loading the lid into the skid 3. When the skid is resting on the lid fixture 88, the lid manipulating fixture 66 is lowered, the lid holding tool 36 grips the lid 26, and the lid manipulating fixture 66 is raised again together with the lid.

[0152] The next phase, illustrated in figure 18B involves lifting the skid with loaded lid to the suction bucket, and subsequent connection of the skid 3 on a trunk 15 of the suction bucket 2.

[0153] Figure 18C shows the skid in connected state on the trunk using the skid clamping mechanism 24 and skid clamping actuators 30, and with the lid located in a ventilation position, i.e. in a position relatively far away from the outlet opening 16 of the trunk 15 for ensuring high air and/or water flow capacity during a submersion sequence, i.e. during lowering of the suction bucket to the seabed. Hence, after connection of the skid to the trunk of the suction bucket, the suction bucket with skid set in the operating state of figure 18C is submersed and positioned on the seabed.

[0154] Figure 18D shows a subsequent phase involving preparing for initiating suction phase using the suction pump of the skid. The skid remains clamped to the trunk using skid clamping mechanism 24, but before the suction phase can begin, the lid must be lowered into the outlet opening of the trunk and locked in this position using the locking arrangement including the locking member 56.

[0155] Figure 18E shows the subsequent suction phase using the suction pump for evacuating water/mud from the interior of the of suction bucket 2 for the purpose of lowering the suction bucket further into the seabed. Water/mud is thus sucked out from the suction bucket using the motor 19, suction pump 18, suction pipe 20, and flow passage 61 in lid 26. The skid remains clamped to the trunk using skid clamping mechanism 24.

[0156] Figure 18F shows subsequent release of the lid from the lid holding tool, as well as release of the skid from the trunk. If the lid has a valve, the valve may be closed by means of a valve actuator of the lid manipulating fixture 66 before the skid is released from the trunk.

[0157] An example embodiment of a method for installing a suction bucket 3 of an anchoring system on a soft ocean floor will be described below with reference to figure 19, which shows the main steps of the method. The method includes a first step S1 of loading a detached

trunk lid into a suction pump skid, in particular by means of the lid hoist mechanism of the skid. The method further includes a second step S2 of releasably connecting the skid on a trunk of a suction bucket, in particular by means of the moveable skid clamping mechanism, and subsequently lowering the suction bucket to the ocean floor using for example a lifting crane or the like. After the suction bucket has come to rest on the seabed, the method includes a third step S3 of fitting the detached lid in or on an outlet opening of the trunk, in particular by means of the lid hoist mechanism. The method further includes a fourth step S4 of shifting the locking arrangement of the lid from an unlocked state to a locked state, in particular by means of a valve actuator of the skid, for fastening the lid to the trunk. The method additionally includes a fifth step S5 of activating the suction pump of the skid for evacuating water from the interior of the suction bucket via said trunk and the suction pipe of the skid, and in particular also via a flow passage extending through the lid, for the purpose of further embedding the suction bucket into the seabed. Finally, after having reached an acceptable installation position of the suction bucket, the method includes a sixth step S6 of releasing the skid from the trunk, in particular by setting clamping actuator in non-engaged state, and lifting the skid out of the water.

[0158] In those embodiments in which the lid has a valve, an intermediate step S5* of closing said valve could be performed between the fifth and sixth steps S5, S6, as indicated by the dotted lines in figure 19, for the purpose of closing the flow passage through the lid.

[0159] The disclosure also concerns a method for mounting a suction bucket trunk lid on a trunk of a suction bucket of an anchoring system on a soft ocean floor. This method will be described below with reference to figure 20, which shows the main steps of the method. The method includes a first step S10 of loading a detached suction bucket trunk lid into a suction pump skid, in particular by means of a lid hoist mechanism of the skid. The method further includes a second step S20 of releasably connecting the skid on a trunk of a suction bucket, in particular by means of the moveable skid clamping mechanism, and in particular before lifting or submerging the suction bucket. The method includes a third step S30 of fitting the suction bucket trunk lid in or on a suction opening of the trunk, in particular by means of the lid hoist mechanism. Finally, the method includes a fourth step S40 of shifting a locking arrangement of the suction bucket trunk lid from an unlocked state to a locked state, in particular by means of a valve actuator of the skid, for detachably fastening the lid to the trunk.

[0160] The disclosure also concerns a method for installing a suction bucket of an anchoring system on a soft ocean floor that is based on the previous described method for mounting a suction bucket trunk lid on a trunk of a suction bucket. This method thus includes the first to fourth steps S10-S40 described above with reference to figure 20, but additionally including an intermediate step

S25 of lowering the suction bucket to the ocean floor performed after the second step S20 of releasably connecting the skid on a trunk of a suction bucket and before the third step S30 of fitting the suction bucket trunk lid in or on a suction opening of the trunk. The method further includes a fifth step S50 of activating a suction pump of the skid for evacuating water from the interior of the suction bucket via said trunk and a suction pipe of the skid, as well as a sixth step S60 of releasing the skid from the trunk and lifting the skid out of the water.

[0161] In those embodiments in which the lid has a valve, an intermediate step S55 of closing said valve could be performed after the fifth step S50 of activating a suction pump of the skid for evacuating water from the interior of the suction bucket, and before the sixth step S60 of releasing the skid from the trunk and lifting the skid out of the water, as indicated by the dotted lines in figure 21, for the purpose of closing the flow passage through the lid.

[0162] It will be appreciated that the above description is merely exemplary in nature and is not intended to limit the present disclosure, its application or uses. While specific examples have been described in the specification and illustrated in the drawings, it will be understood by those of ordinary skill in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the present disclosure as defined in the claims. Furthermore, modifications may be made to adapt a particular situation or material to the teachings of the present disclosure without departing from the essential scope thereof.

[0163] Therefore, it is intended that the present disclosure not be limited to the particular examples illustrated by the drawings and described in the specification as the best mode presently contemplated for carrying out the teachings of the present disclosure, but that the scope of the present disclosure will include any embodiments falling within the foregoing description and the appended claims. Reference signs mentioned in the claims should not be seen as limiting the extent of the matter protected by the claims, and their sole function is to make claims easier to understand.

REFERENCE SIGNS

[0164]

1. Foundation
2. Suction bucket
3. Suction pump skid
4. Water
5. Lifting platform
6. Top support surface
7. Bottom support feet
8. Seabed
9. Crane
10. Power supply cable
11. Transport vessel

12. Side wall
13. Top wall
14. Lower side
15. Trunk
16. Outlet opening of trunk
17. Rigid frame
18. Suction pump
19. Motor
20. Suction pipe
21. Top connection structure
22. Skid connection interface
23. Upwards facing corresponding seat
24. Skid clamping mechanism
25. Lid hoist mechanism
26. Suction bucket trunk lid
27. Pump outlet pipe
28. Conical guide arrangement
29. Downwards facing seat
30. Skid clamping actuator
31. Pivoting skid clamping member
32. First pivot joint
33. Second pivot joint
34. Central opening of skid
35. Lid hoist actuator
36. Lid holding tool
37. Support cradle
38. Bracket
39. Attachment cup
40. Central hole of lid
41. Lid seal
42. Threaded aperture
43. Flange of attachment cup
44. Lid clamping mechanism
45. Lid clamping actuator
46. Expanding clamping members
47. Piston
48. piston rod
49. Frame of lid holding tool
50. Holding interface of lid
51. Locking arrangement
52. Lock control interface
53. Locking actuator
54. Periphery of lid
55. interior groove of the trunk
56. Locking member
57. Linkage arm
58. First pivot point
59. Linkage member
60. Recess in lid
61. Flow passage in lid
62. Valve
63. Valve housing
64. Opening in valve member
65. Valve control interface
66. Lid manipulating fixture
67. Valve actuator
68. Collar of lid manipulating fixture
69. First end of valve actuator

70. End piece of valve actuator
 71. Hole or recess
 72. First end of locking actuator
 73. End piece of locking actuator
 74. Hole or recess
 75. Ring member
 76. Locking member housing
 77. Hydraulic fluid tank
 78. Hydraulic pump
 79. Electric motor
 80. Accumulator
 81. Hydraulic valve arrangement
 82. First valve section
 83. Second valve section
 84. Third valve section
 85. Fourth valve section
 86. Fifth valve section
 87. ECU
 88. Lid fixture
 89. Collar of lid

Claims

1. A detachable suction pump skid (3) for operation with a suction bucket (2) of an anchoring system for soft ocean floors, the suction pump skid (3) comprises:

a skid connection interface (22) for establishing a disconnectable rigid connection of the skid (3) to a trunk (15) of the suction bucket (2),
 a lid hoist mechanism (25) comprising a lid hoist actuator (35) connected to a lid holding tool (36), wherein the lid hoist actuator (35) is configured for raising and lowering a vertical position of the lid holding tool (36), wherein the lid holding tool (36) is configured for releasably holding a detached suction bucket trunk lid (26), and wherein the lid hoist mechanism (25) is configured for placing the detached suction bucket trunk lid (26) in or on an outlet opening (16) of the trunk (15),
 a suction pump (18) coupled to a suction pipe (20) and configured for evacuating water from an interior of the suction bucket (2) via said trunk (15) and said suction pipe (20).

2. The detachable suction pump skid (3) according to claim 1, wherein the skid connection interface (22) comprises a moveable skid clamping mechanism (24) operatively connected to a skid clamping actuator (30), wherein the skid clamping actuator (30) is controllable for setting the skid clamping mechanism (24) in an engaged operating position, in which a downwards facing seat (29) of the skid (3) is configured to be clamped against an upwards facing corresponding seat (23) on the trunk (15) by the skid clamping mechanism (24), and wherein the skid

clamping actuator (30) is controllable for setting the skid clamping mechanism (24) in a disengaged operating position, in which the skid (3) is free to move away from, or towards, the upwards facing corresponding seat (23) of the trunk (15).

3. The detachable suction pump skid (3) according to claim 2, wherein the moveable skid clamping mechanism (24) comprises a pivoting skid clamping member (31), and the skid clamping actuator (30) is a linear actuator.

4. The detachable suction pump skid (3) according to any of the preceding claims, wherein the suction pipe (20) is configured for establishing fluid connection with a flow passage extending through the suction bucket trunk lid (26), and wherein the suction pump (18) is configured for evacuation of water from the interior of the suction bucket (2) via said trunk (15), said flow passage (61) through the suction bucket trunk lid (26) and said suction pipe (20).

5. The detachable suction pump skid (3) according to any of the preceding claims, wherein the skid connection interface (22) comprises a downwards facing seat (29) configured for resting on an upwards facing corresponding seat (23) of the trunk (15) of the suction bucket (2), and wherein the downwards facing seat (29) of the skid connection interface (22) enables connection of the suction pump skid (3) to the trunk (15) at any relative angular position.

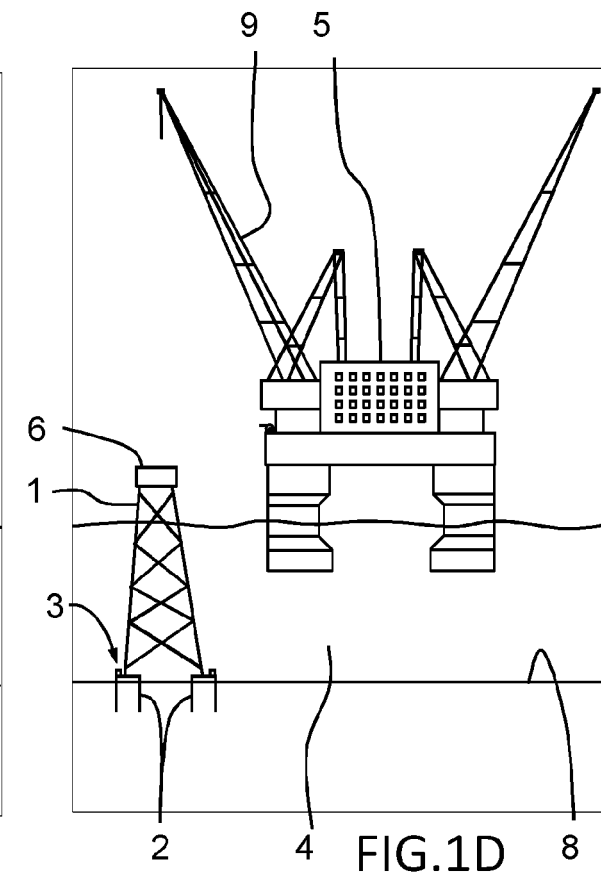
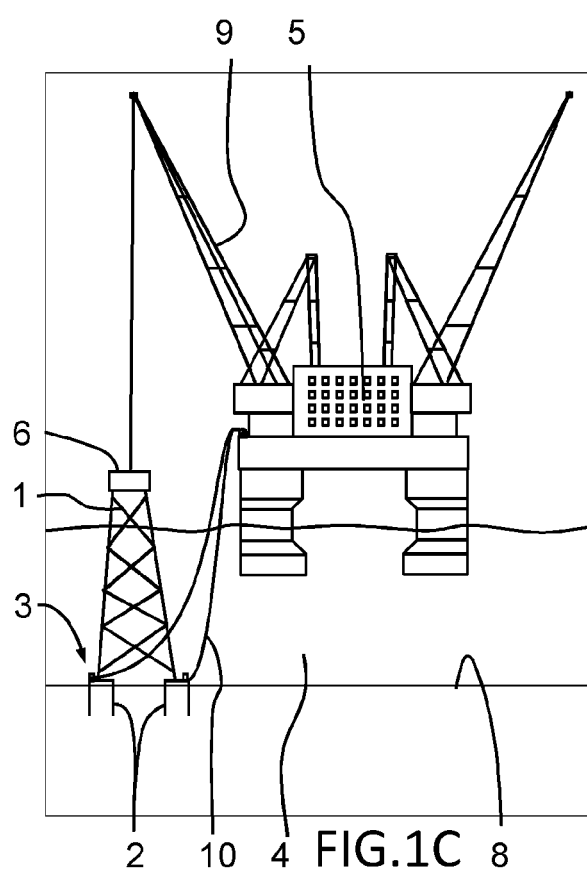
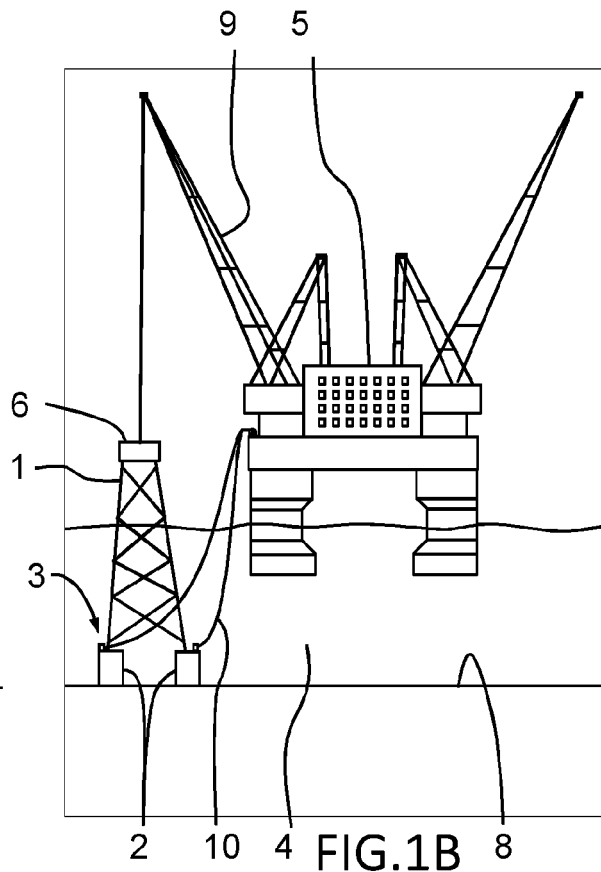
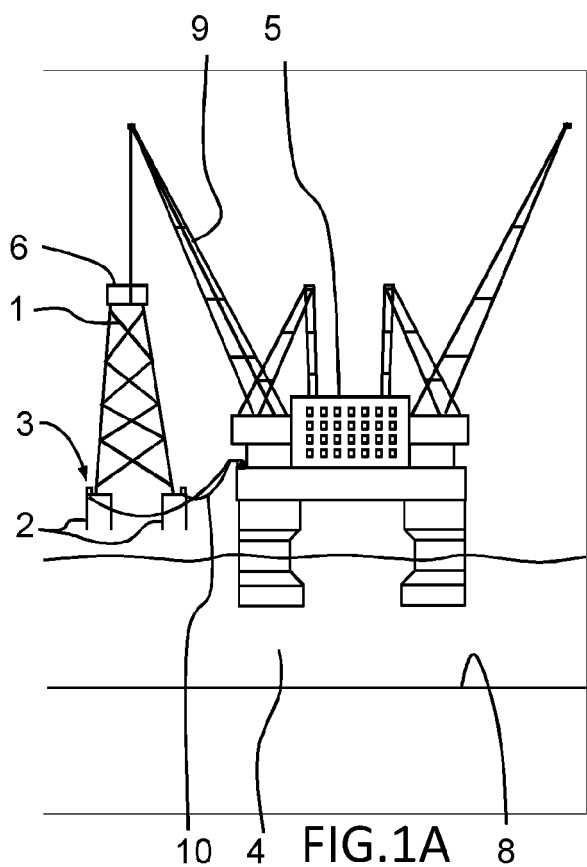
6. The detachable suction pump skid (3) according to any of the preceding claims, wherein the skid (3) comprises a downward facing conical guide arrangement (28) for guiding the skid connection interface (22) to a mating position on the trunk (15).

7. The detachable suction pump skid (3) according to any of the preceding claims, wherein the skid (3) has a valve actuator (67) configured for engaging a valve control interface (65) of a valve (62) of the suction bucket trunk lid (26), and for controlling operating position of said valve (62).

8. The detachable suction pump skid (3) according to claim 7, wherein an end piece of the valve actuator (67) is configured for engaging the valve control interface (65) of said valve (62) of the suction bucket trunk lid (26) in connection with loading of the lid (26) into the lid hoist mechanism (25).

9. The detachable suction pump skid (3) according to any of the preceding claims, wherein the skid (3) comprises a locking actuator (53) configured for engaging a lock control interface (52) of a lid locking arrangement (51), and for controlling operation of said lid locking arrangement (51).

10. The detachable suction pump skid (3) according to claim 9, wherein an end piece of the locking actuator (53) is configured for engaging the lock control interface (52) of the suction bucket trunk lid (26) in connection with loading of the lid (26) into the lid hoist mechanism (25). 5
11. The detachable suction pump skid (3) according to claim 9 or claim 10, wherein the lid hoist mechanism (25) comprises a vertically moveable lid manipulating fixture (66), wherein the at least one lid hoist actuator (35) is connected to the lid manipulating fixture (66), and wherein the lid manipulating fixture (66) carries the lid holding tool (36) and the locking actuator (53). 10 15
12. The detachable suction pump skid (3) according to any of the preceding claims, wherein the lid holding tool (36) comprises a moveable lid clamping mechanism (44) operatively connected to a lid clamping actuator (45), wherein the lid clamping actuator (45) is controllable for setting the lid clamping mechanism (44) in an engaged operating position, in which a suction bucket trunk lid (26) is configured to be gripped by the lid clamping mechanism (44), and wherein the lid clamping actuator (45) is controllable for setting the lid clamping mechanism (44) in a disengaged operating position, in which the suction bucket trunk lid (26) is released from the lid clamping mechanism (44). 20 25 30
13. The detachable suction pump skid (3) according to claim 12, wherein the lid clamping mechanism (44) comprises a radially expanding clamping member (46) configured for engaging an internal surface of a recess (60) of the suction bucket trunk lid (26) for gripping the lid (26), when the lid clamping mechanism (44) is set in an engaged operating position. 35
14. An assembly comprising: 40
- a detachable suction pump skid (3) according to any of the preceding claims, and
- a detached suction bucket trunk lid (26) that is releasably held by the lid holding tool (36) of the skid (3), wherein the lid hoist mechanism (25) and lid (26) are configured for placing the detached lid (26) in or on an outlet opening (16) of the trunk (15). 45 50
15. A method for installing a suction bucket (2) of an anchoring system on a soft ocean floor, the method comprises:
- loading a detached suction bucket trunk lid (26) into a suction pump skid (3), 55
- releasably connecting the skid (3) on a trunk (15) of a suction bucket, and lowering the suction bucket (2) to the ocean floor, fitting the suction bucket trunk lid (26) in or on an outlet opening (16) of the trunk (15), shifting a locking arrangement (51) of the suction bucket trunk lid (26) from an unlocked state to a locked state for fastening the lid (26) to the trunk (15), activating a suction pump (18) of the skid (3) for evacuating water from the interior of the suction bucket (2) via said trunk (15) and a suction pipe (20) of the skid (3), and releasing the skid (3) from the trunk (15) and lifting the skid (3) out of the water.



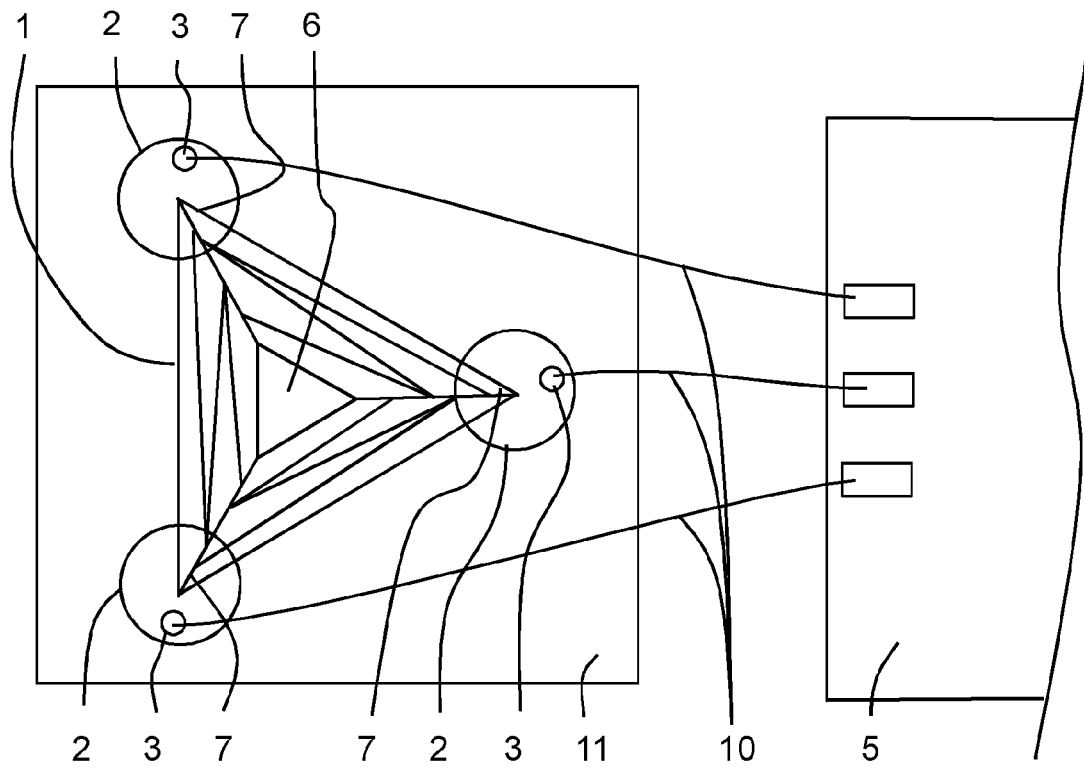


FIG. 2

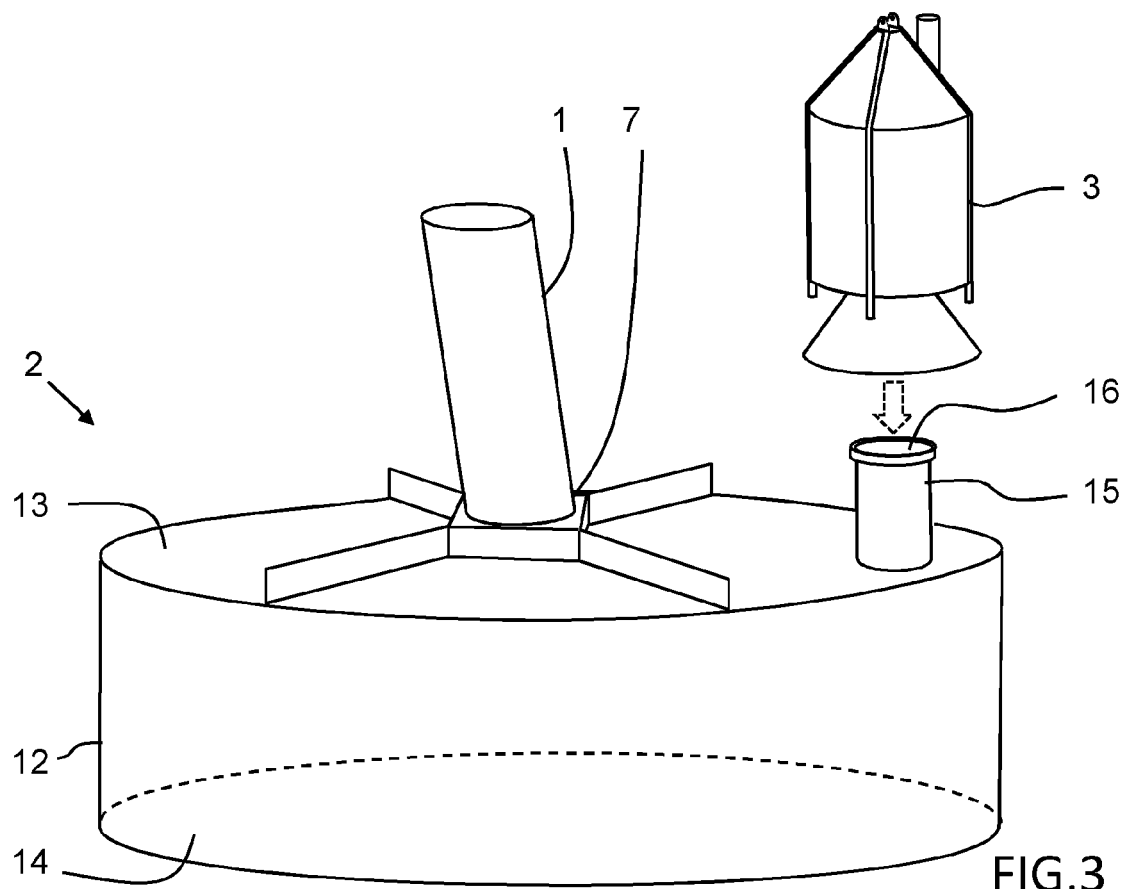


FIG. 3

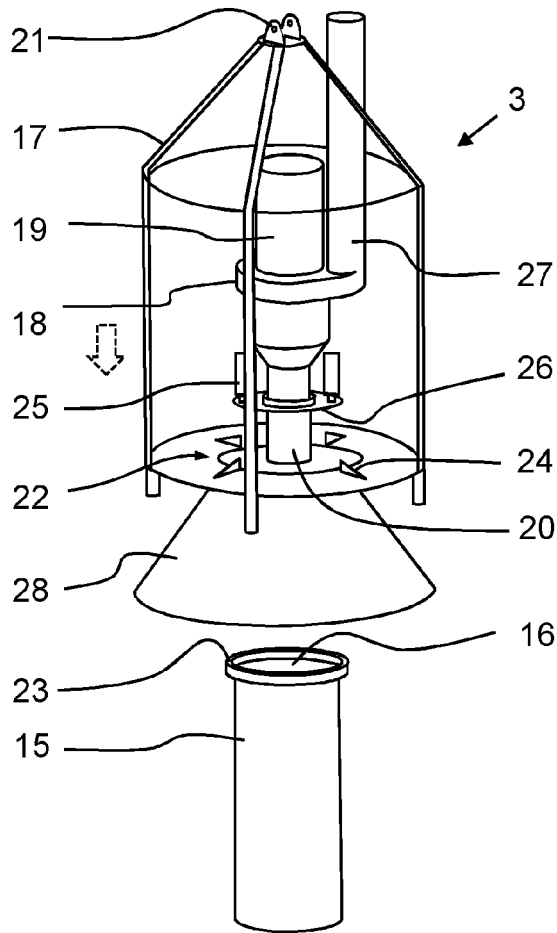


FIG. 4A

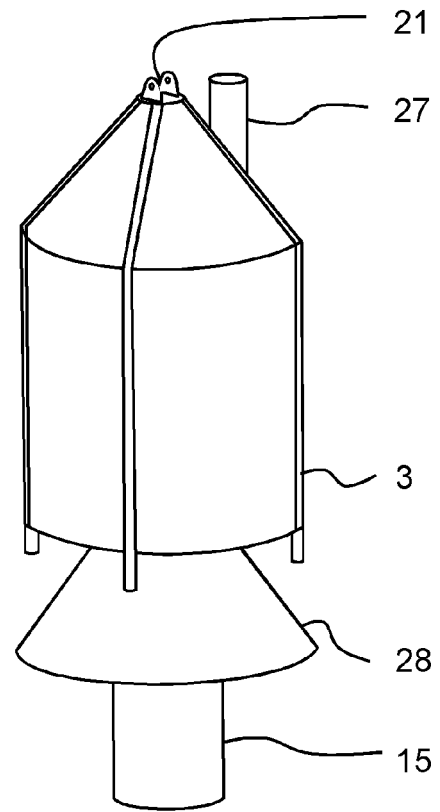


FIG. 4B

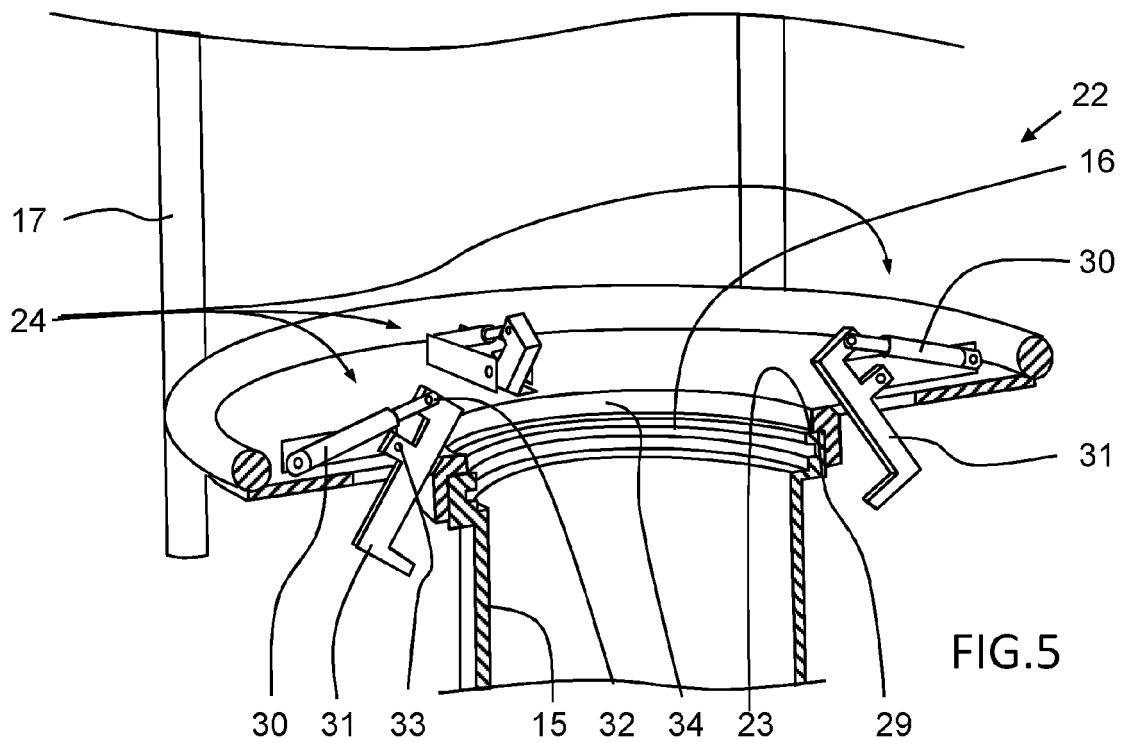


FIG. 5

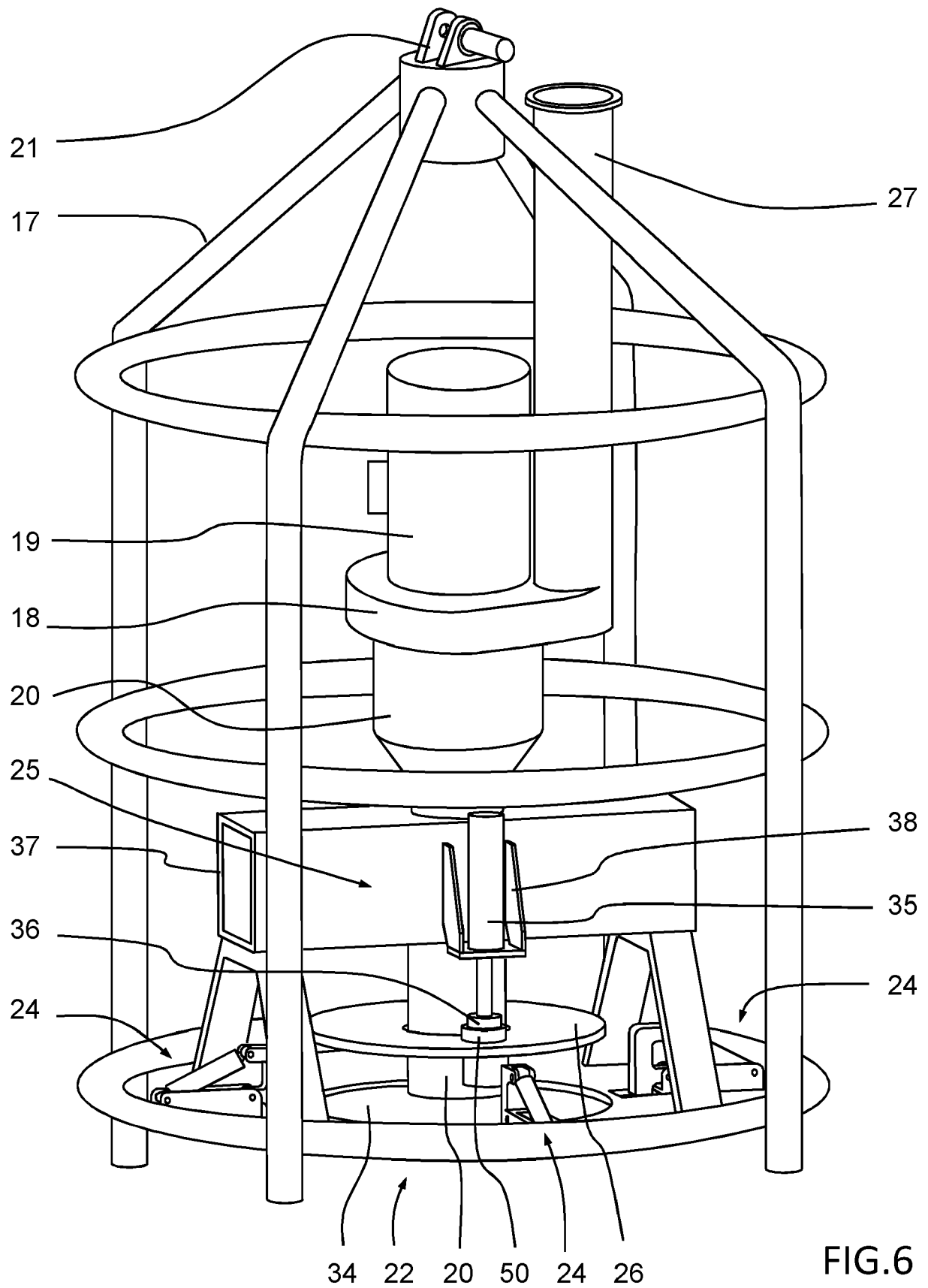


FIG.6

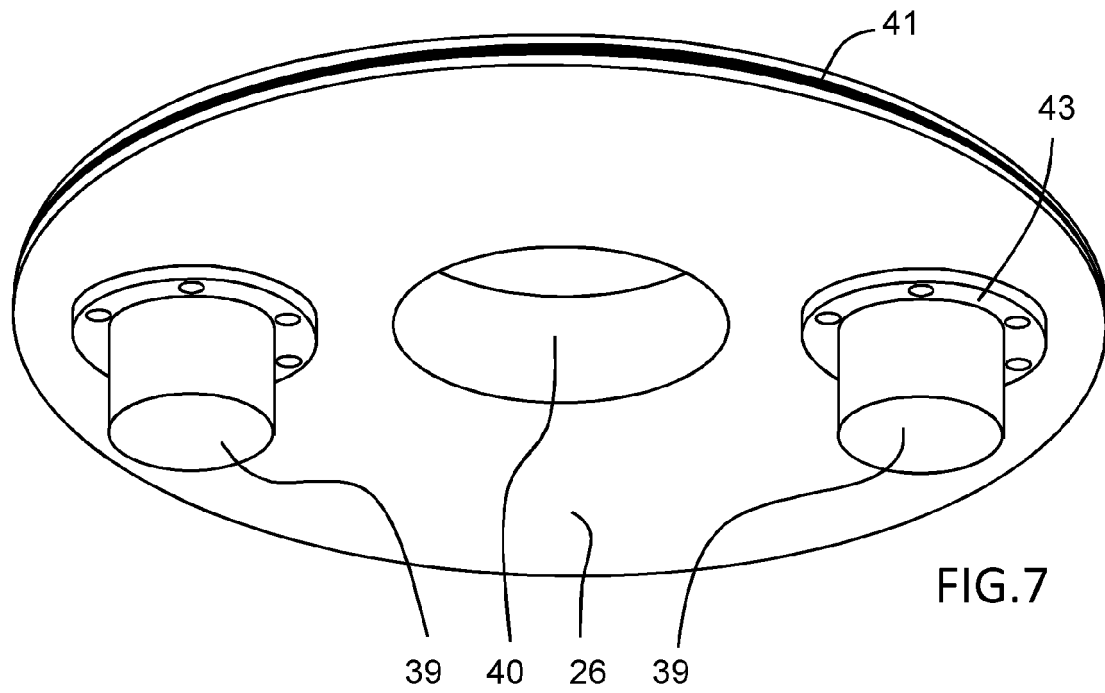


FIG. 7

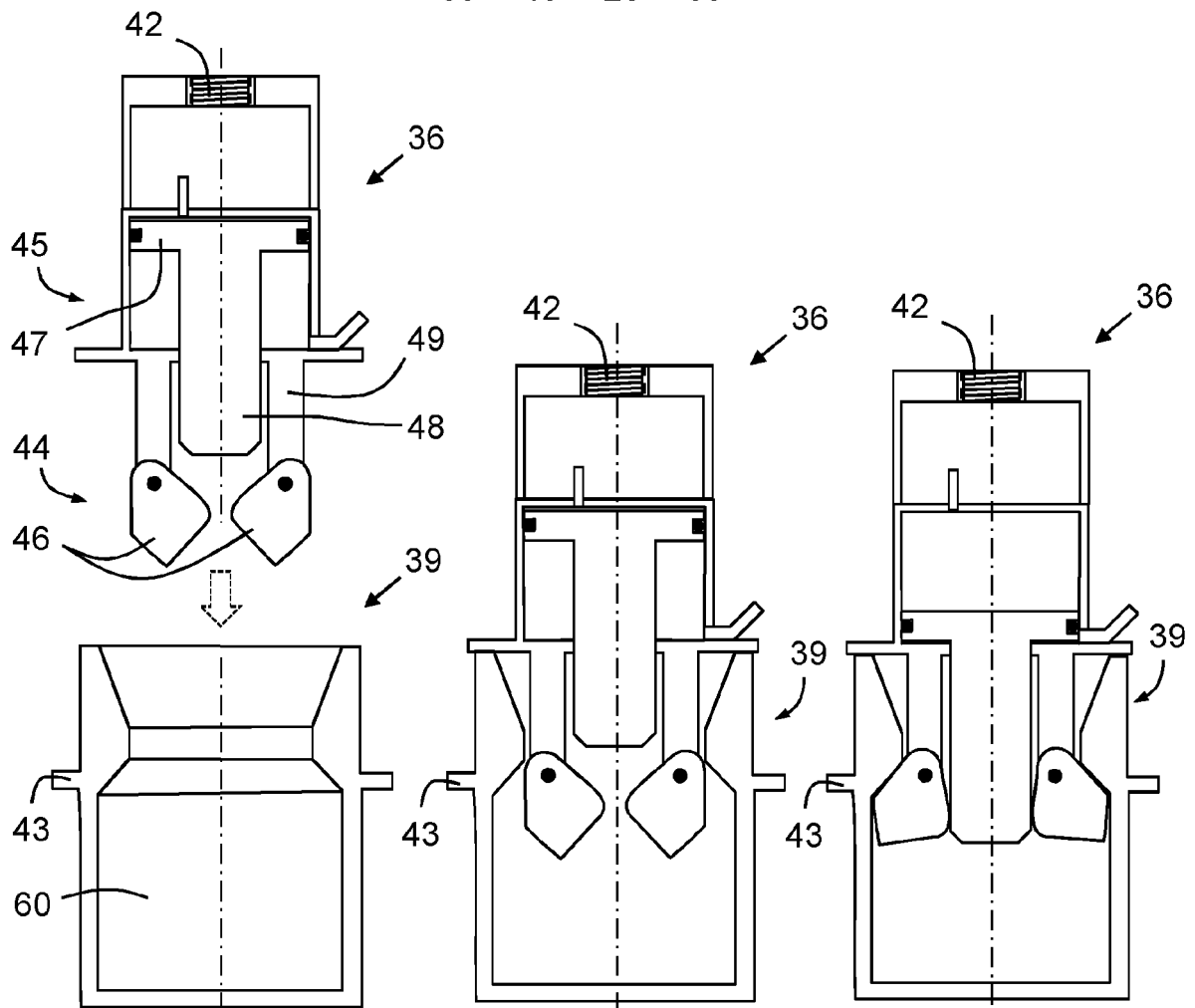
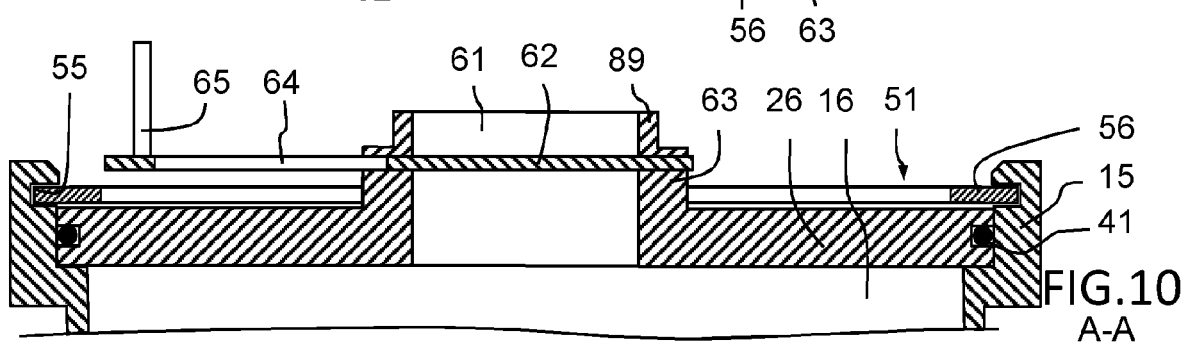
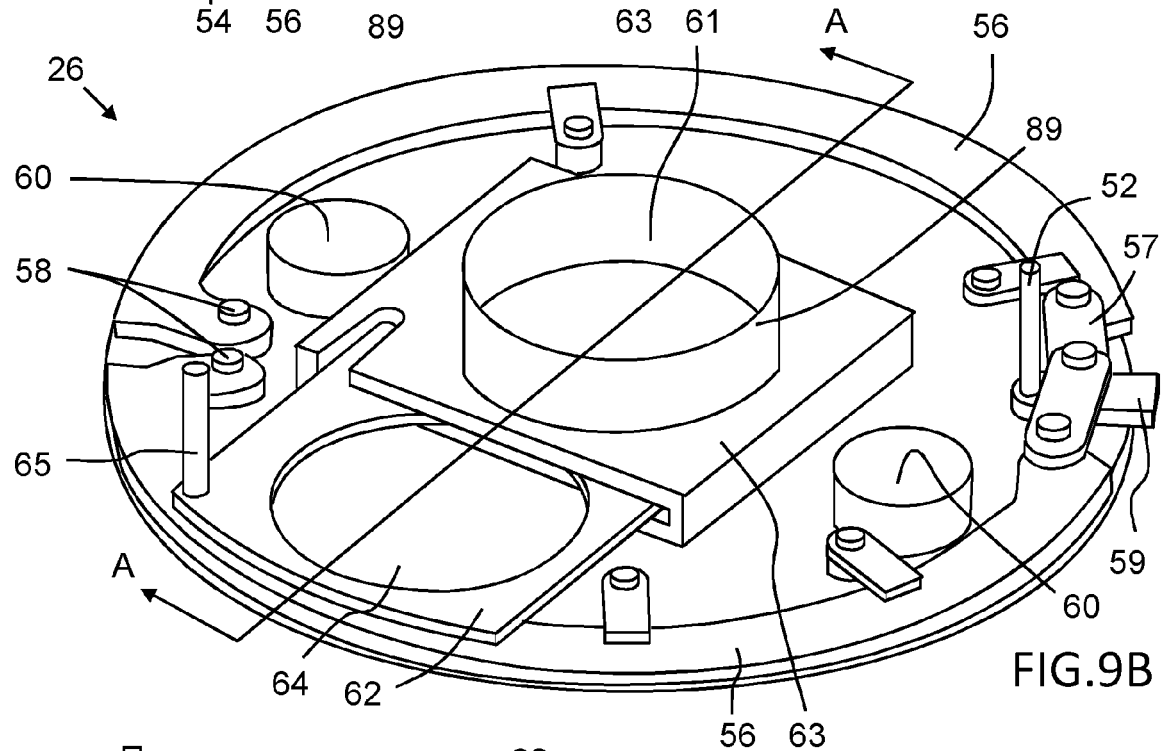
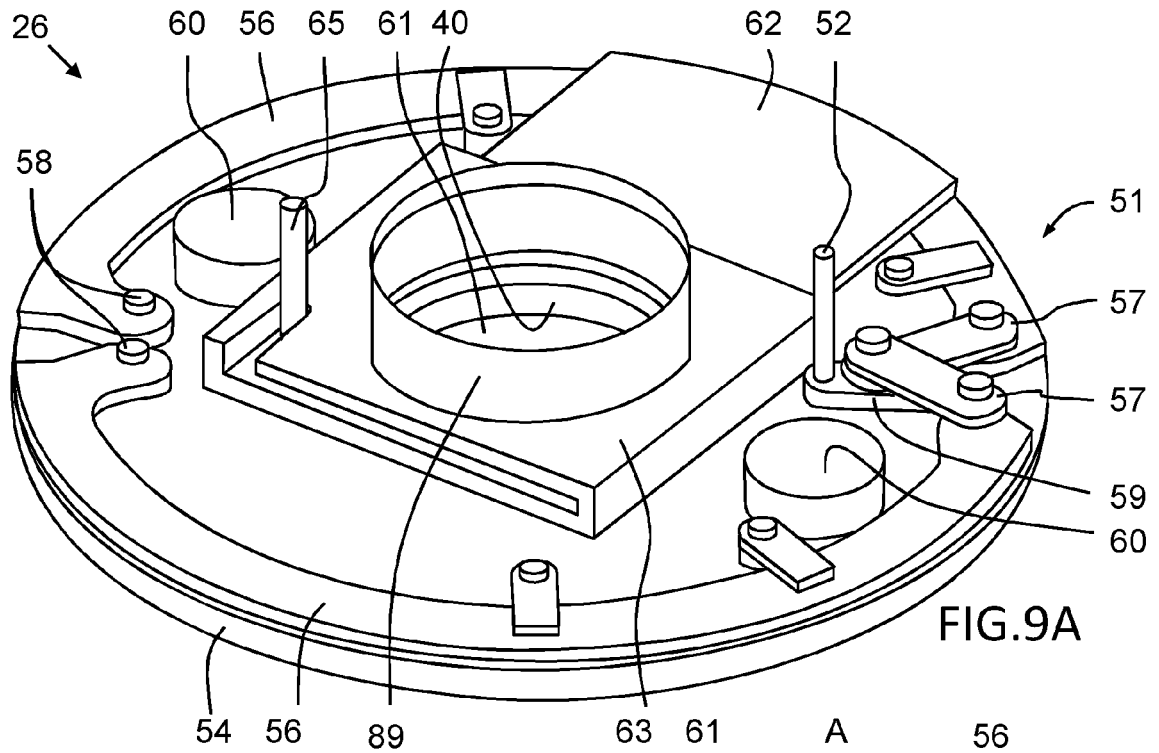
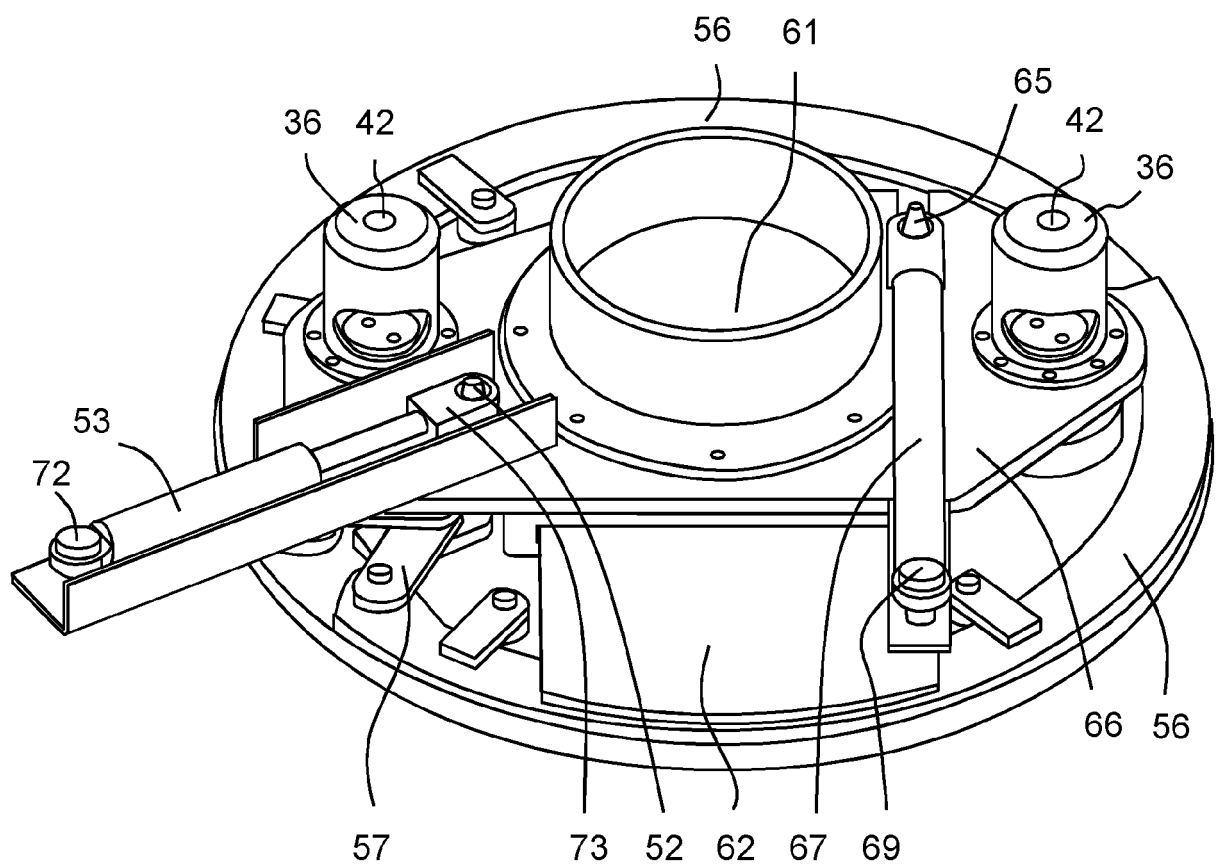
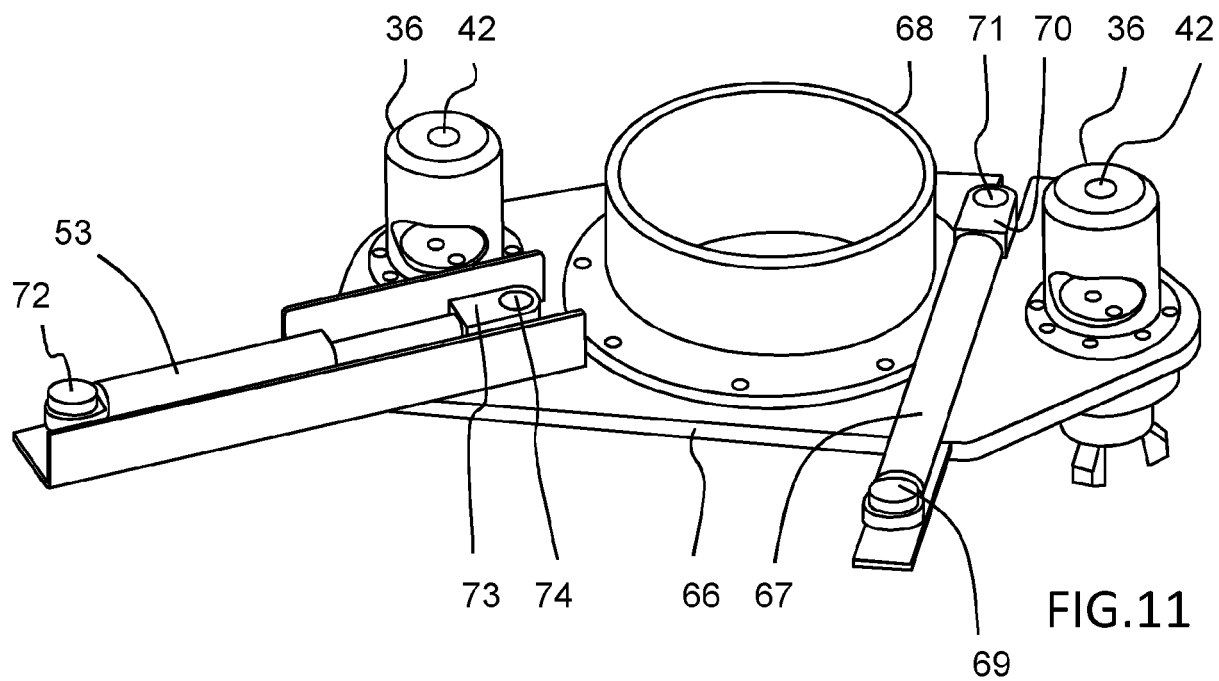


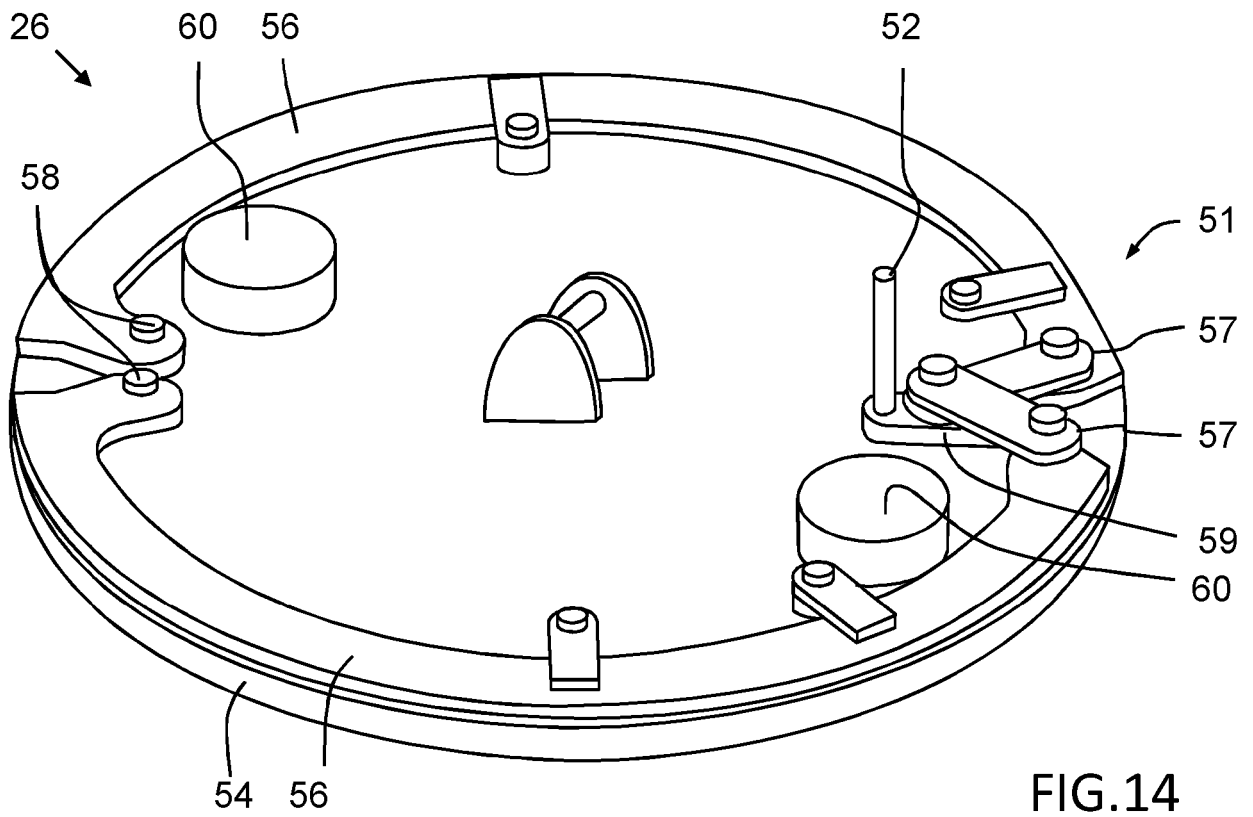
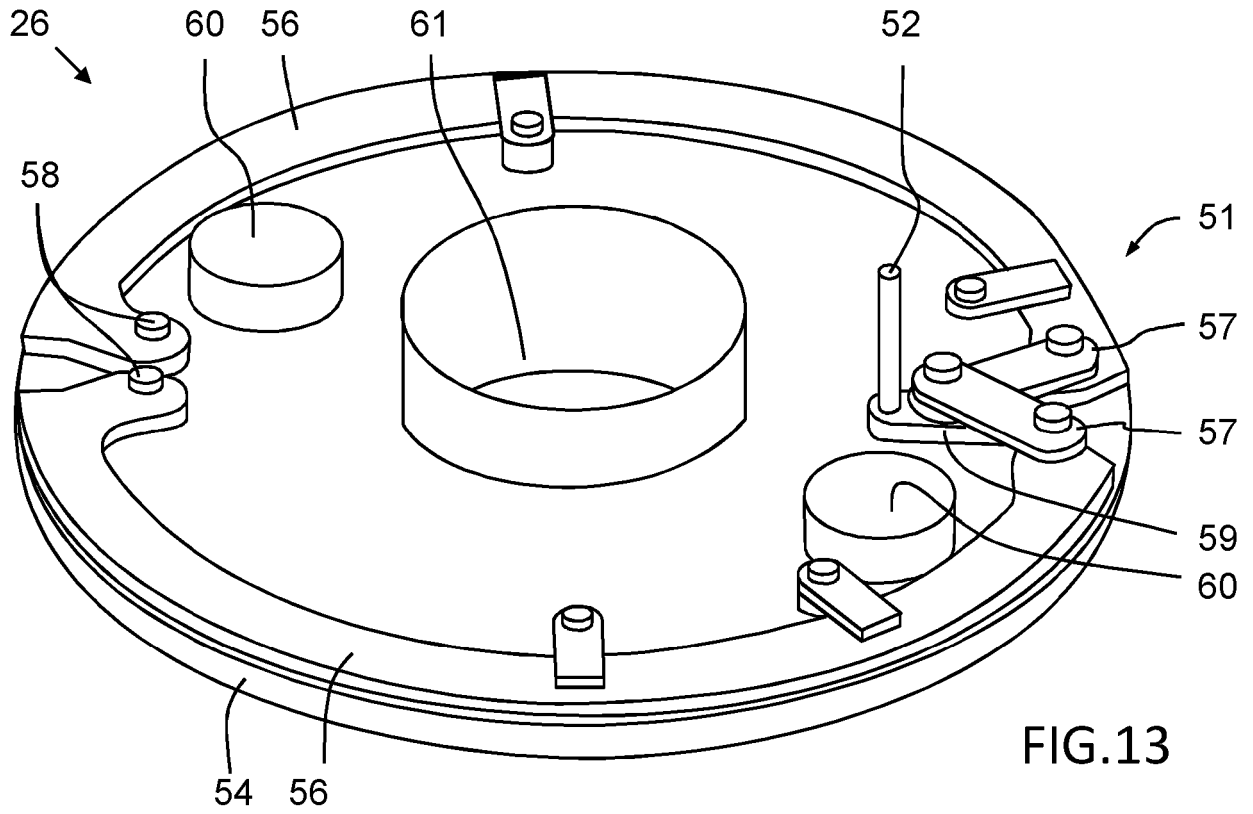
FIG. 8A

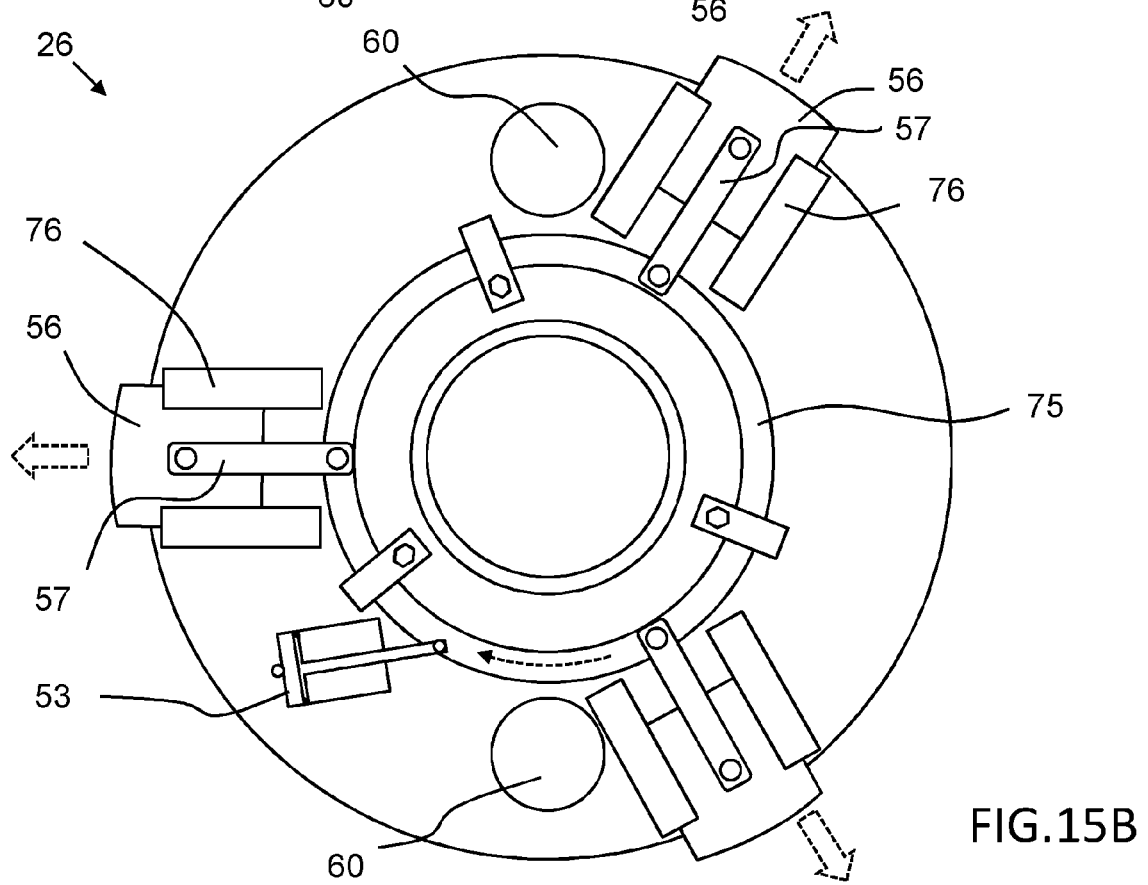
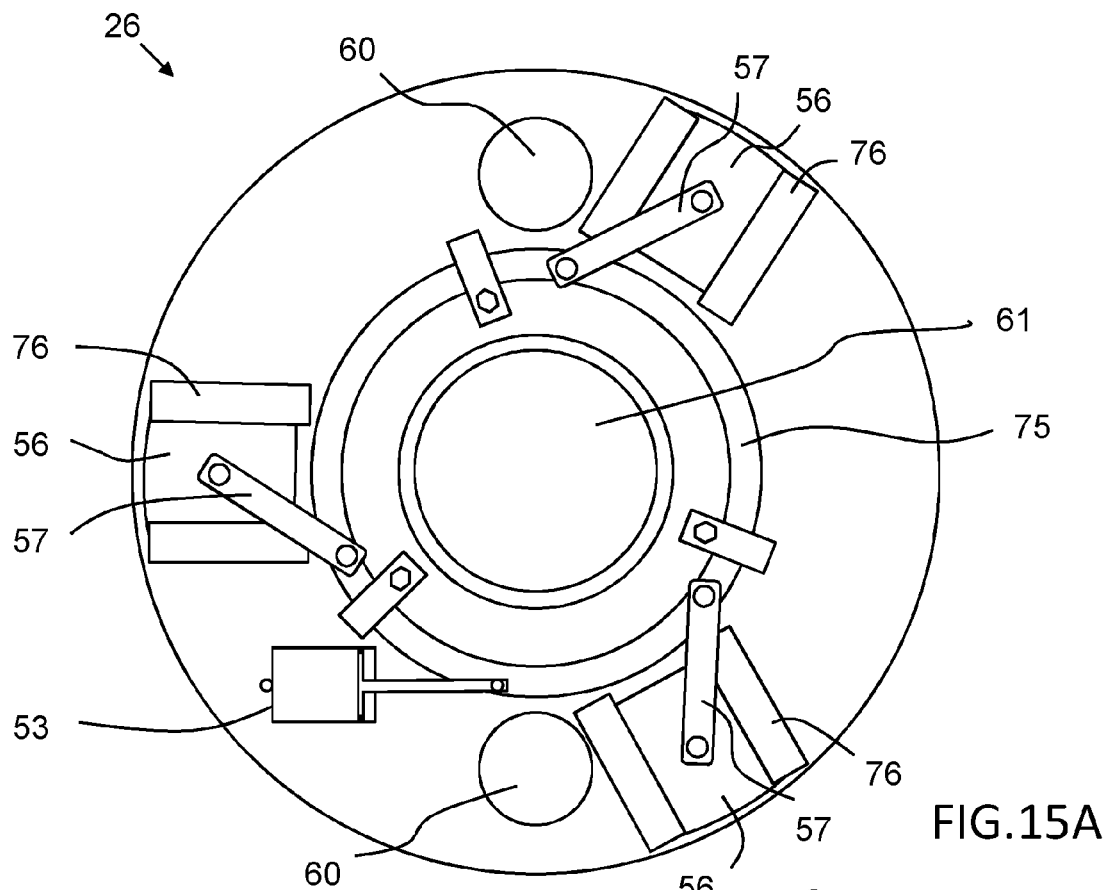
FIG. 8B

FIG. 8C









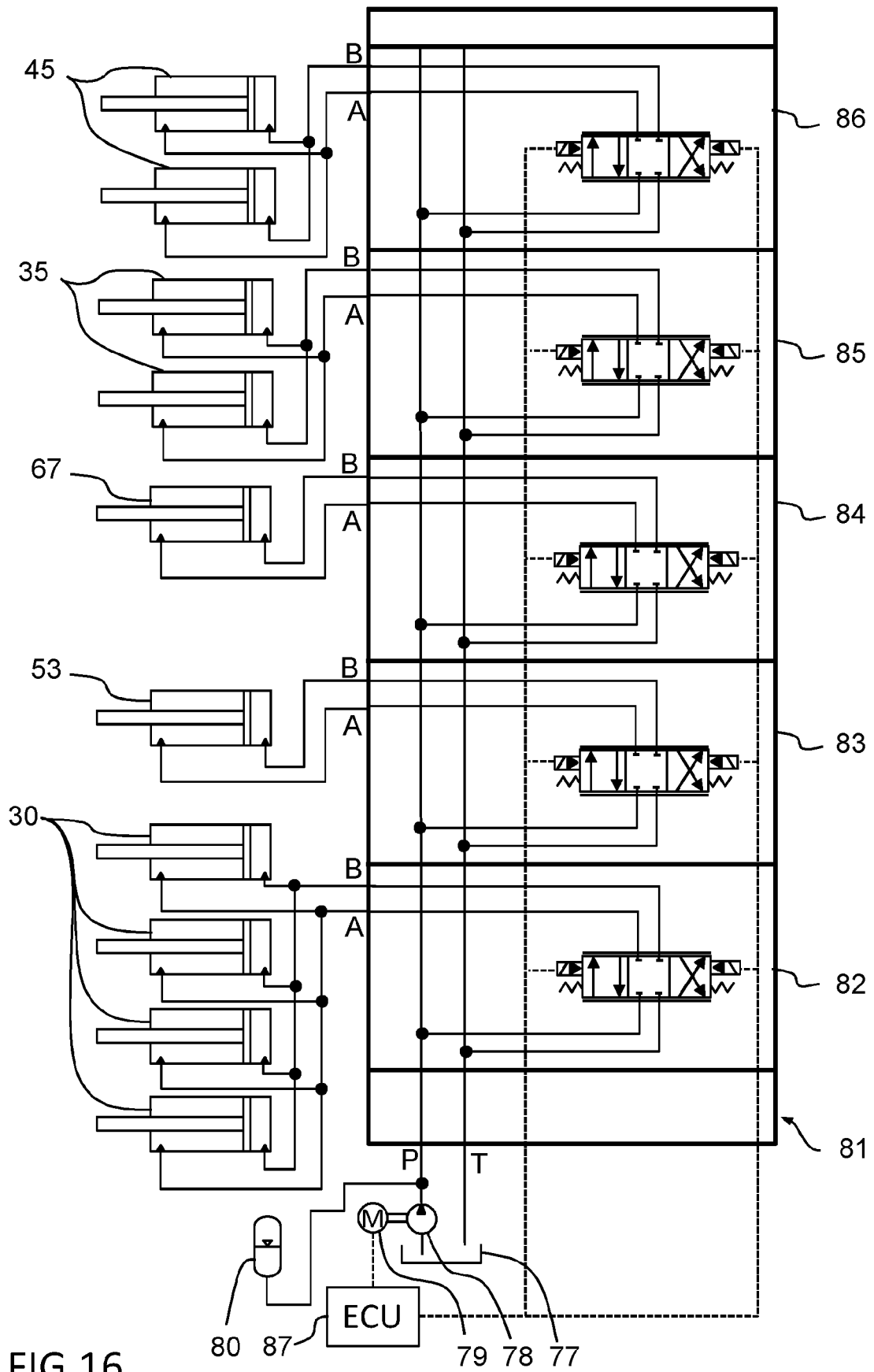


FIG.16

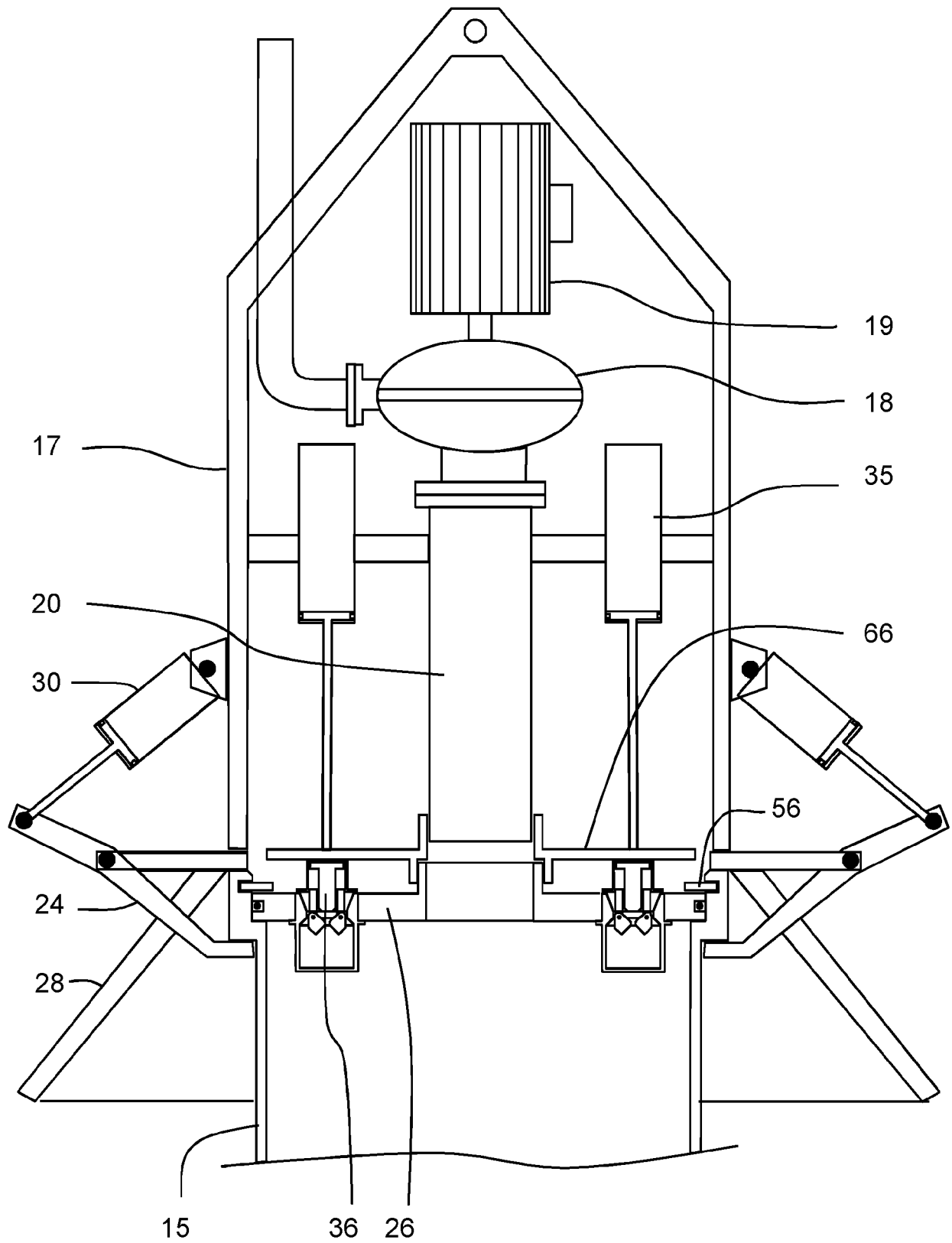


FIG.17

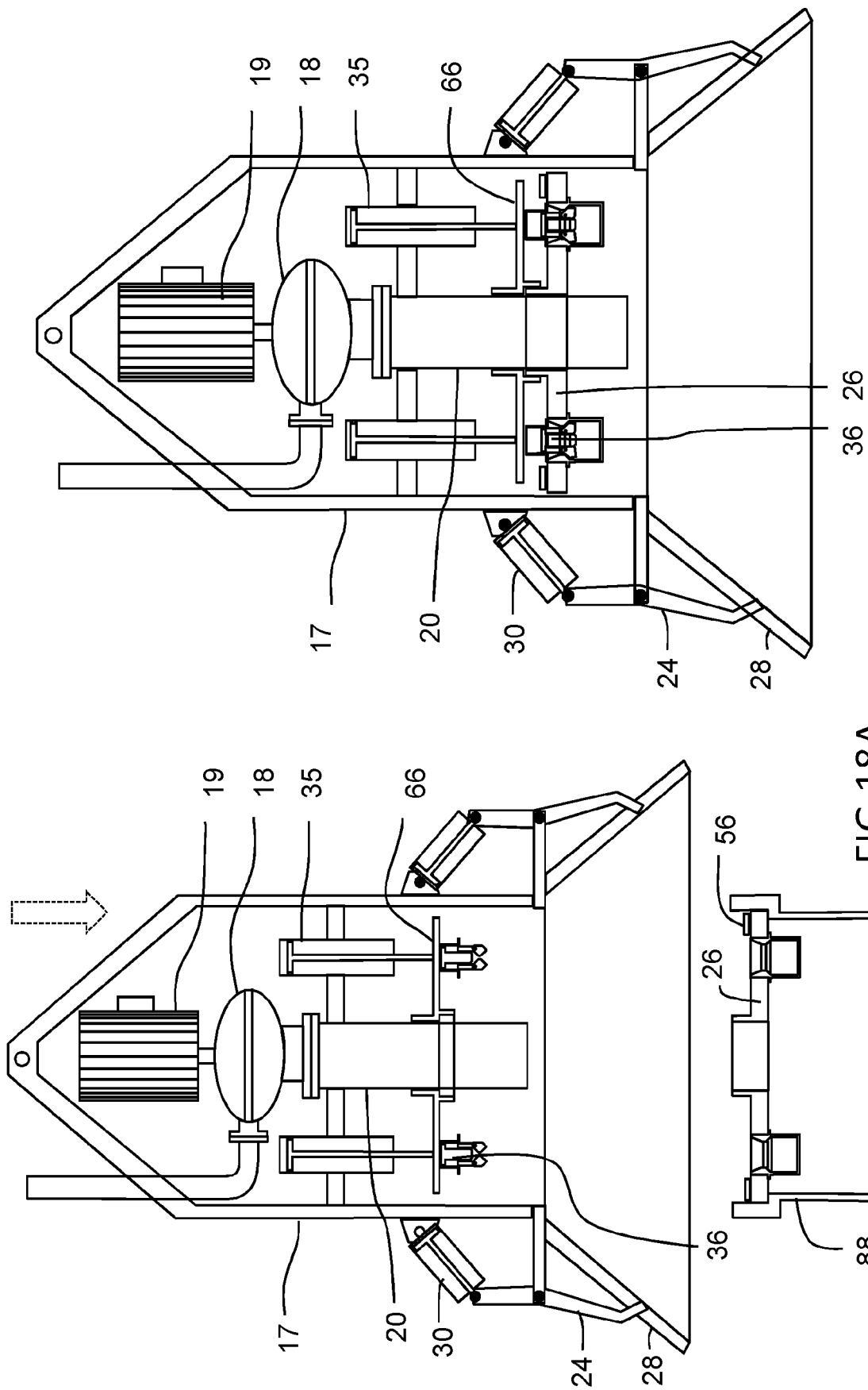
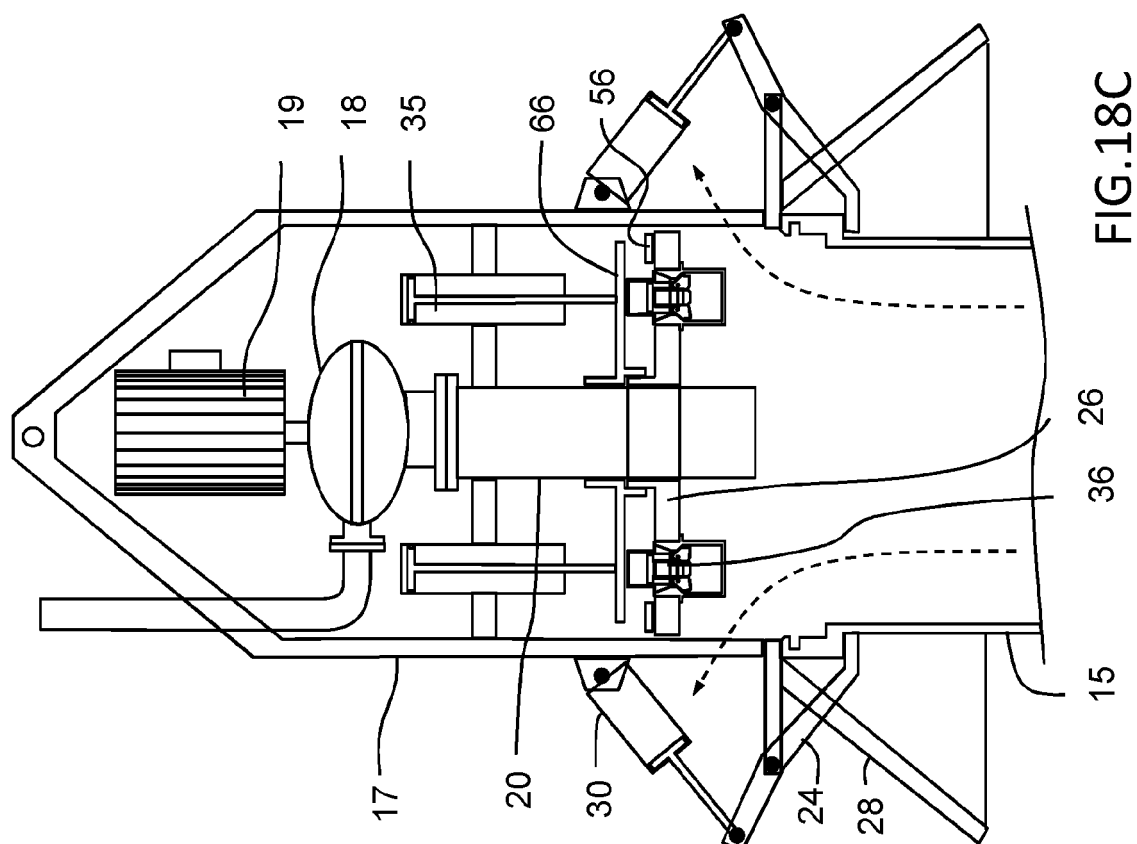
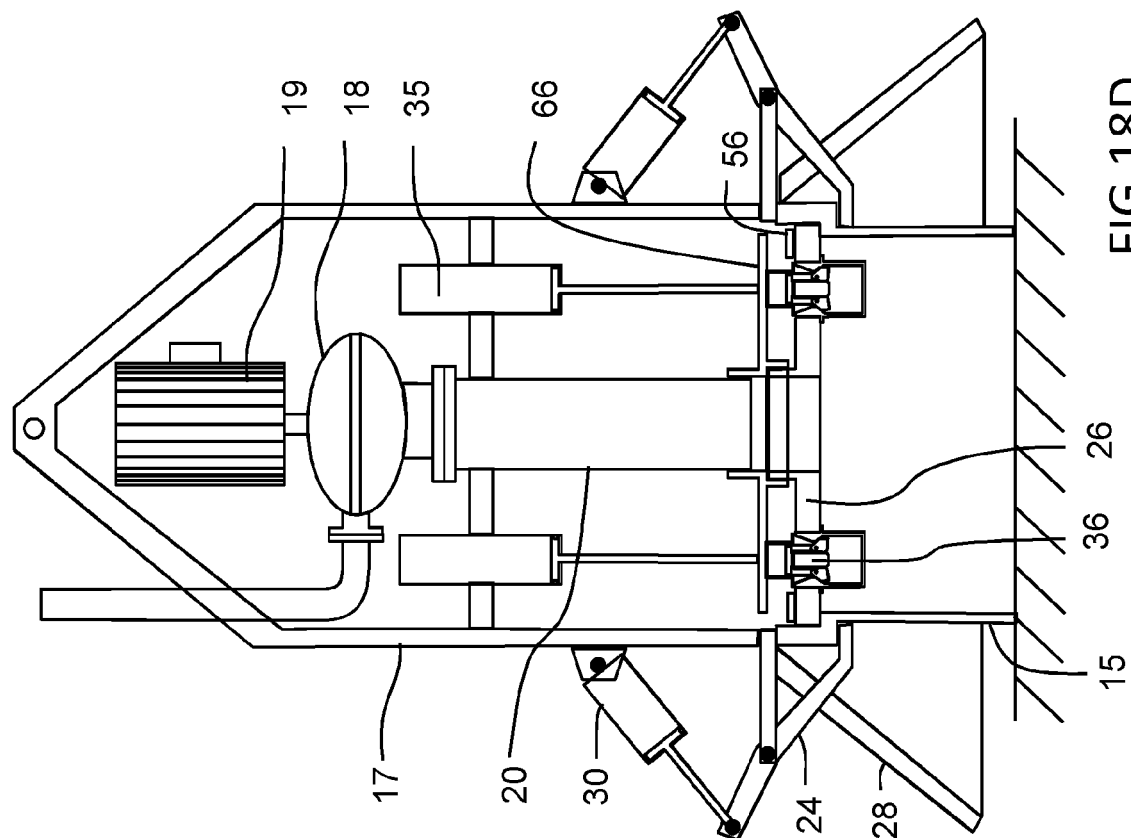
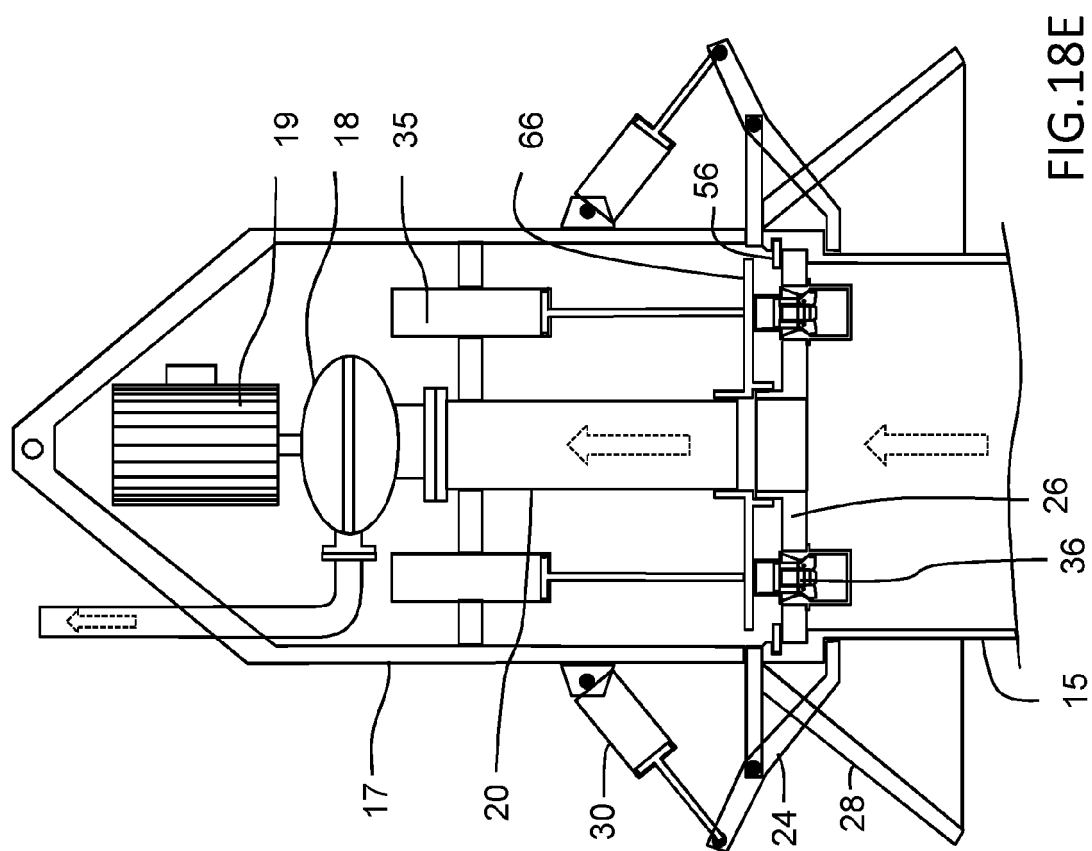
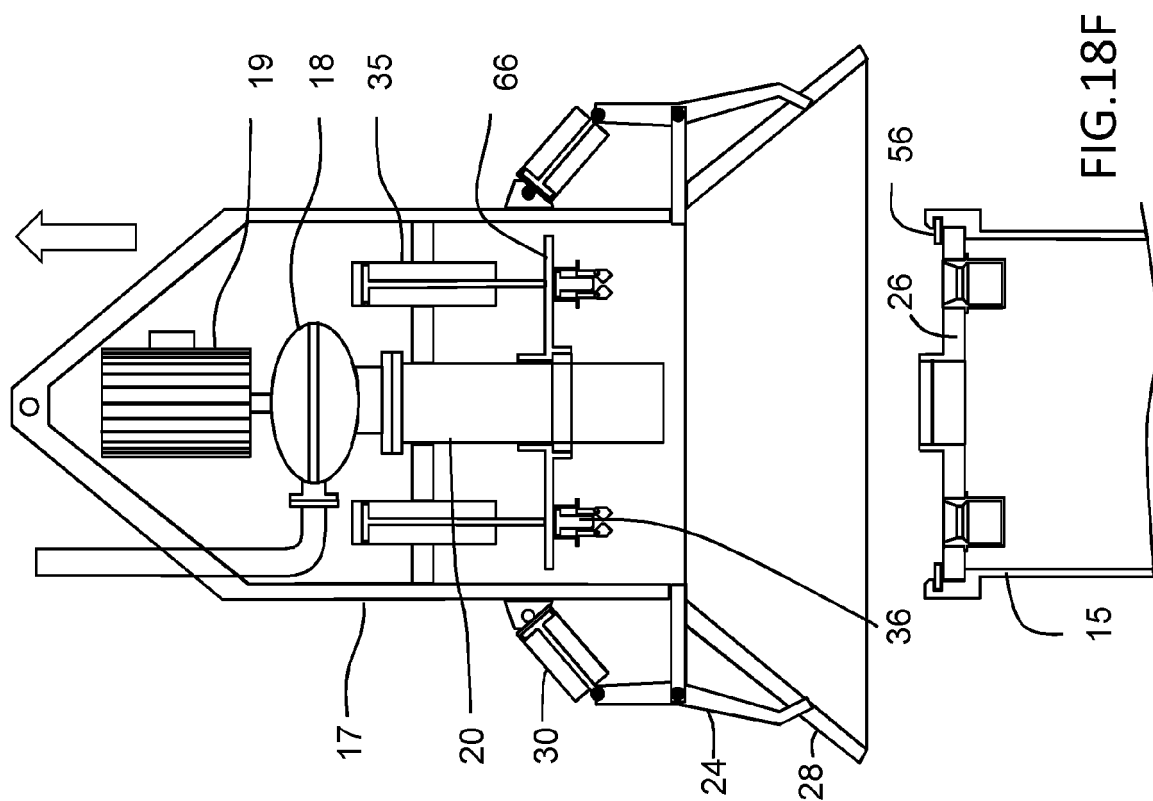


FIG.18B

FIG.18A





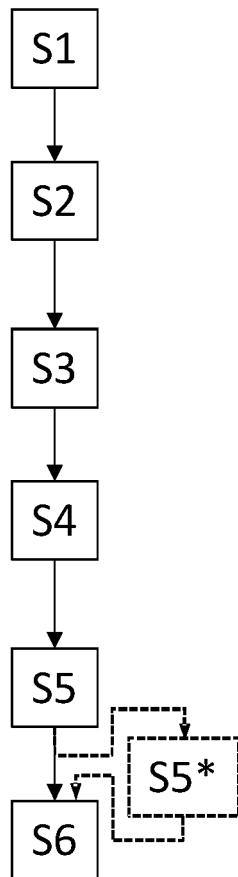


FIG.19

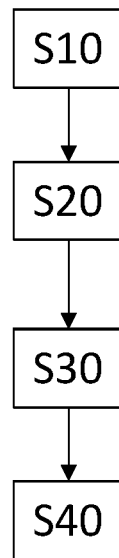


FIG.20

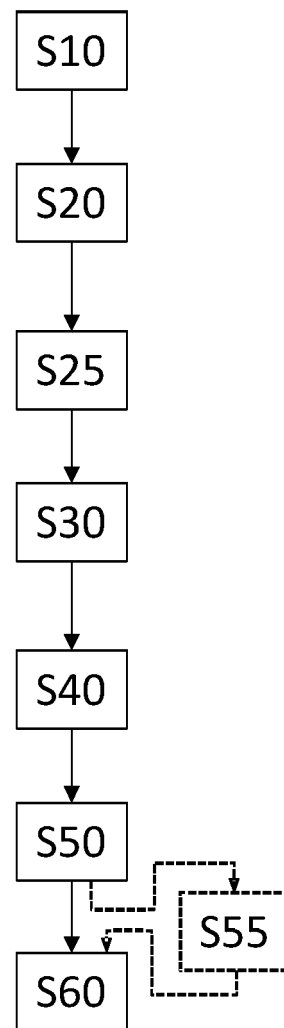


FIG.21



EUROPEAN SEARCH REPORT

Application Number

EP 22 18 3600

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 9 868 492 B1 (MOHRFELD AUSTIN T [US]) 16 January 2018 (2018-01-16)	15	INV. E02D27/52
A	* column 4, line 65 - column 12, line 63; figures 1-5 *	1-14	
A	WO 2007/063130 A2 (SINGLE BUOY MOORINGS [CH]; ALHAYARI SAMY [FR]) 7 June 2007 (2007-06-07) * the whole document *	1-15	
A	EP 3 315 670 A2 (SPT EQUIPMENT BV [NL]) 2 May 2018 (2018-05-02) * the whole document *	1-15	
			TECHNICAL FIELDS SEARCHED (IPC)
			E02D E02B
The present search report has been drawn up for all claims			
Place of search		Date of completion of the search	Examiner
Munich		2 December 2022	Geiger, Harald
CATEGORY OF CITED DOCUMENTS			
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document			
T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 22 18 3600

5 This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
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02-12-2022

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