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DESCRIPTION

[0001] The present invention relates to a method and a device for disposing of a piece of unexploded ordnance (UXO) lying under water.

[0002] Experts assume that the German region of the North Sea and the Baltic Sea is polluted with over two million tons of UXO in a wide variety of different kinds and forms. Even after many decades, this UXO poses a significant hazard to shipping, fishing, and tourism, but also for example to ongoing use of marine areas by the offshore energy industry. In addition to potential explosions, however, the progressive corrosion of the generally metallic ordnance casings constitutes a latent hazard for humans and the marine environment.

[0003] UXO clearance methods known from the prior art are usually composed of several steps. In the following, we will consider large-format UXO in the frequently encountered forms such as moored mines, depth charges, bottom mines, or torpedoes. Current Explosive Ordnance Disposal (EOD) is composed of three phases, each of which uses specialized, high-grade, technically sophisticated equipment:

1. 1. Sounding,
2. 2. Identification of a respective UXO and excavation, and
3. 3. Clearing on site by detonation.

For safety reasons, a clearing of such UXO is carried out on site by detonation under water. If only because of the metallic remains of a piece of ordnance that are in principle left behind, this does not constitute complete disposal.

[0004] The outlined procedure requires operational carrier vessels, trained personnel including divers and, in addition to highly specialized technology, also appropriate weather; this method cannot be used all year long and generally can only be performed during daylight hours. In addition, civil and governmental stakeholders are equally involved in the overall process, with the corresponding advance planning. Despite the very high investment of time and money, known EOD always entail high risks for the people directly involved as well as enormous impacts on the environment due to the blast and fragmentation effect that accompanies a detonation, an extreme acoustic stress to marine mammals over hundreds of kilometers, and environmental risks due to an uncontrollable input of explosive residues and harmful chemical decomposition products of the transformed explosives to the environment.

[0005] US 2009/0223355 A1 teaches the use of water jet cutting for reducing the impact and the performance of a land mine. However, land mines are not the type and minor size of UXO usually found under water and in the sea.

[0006] DE 10 2013 004 445 B3 just discloses a method for recovering and defusing bombs lying on seabed. This method involves dismantling the bomb in a chamber by using a high-pressure water jet device, after introducing air into the space of said chamber under displacing

water.

[0007] The object of the present invention is to create a method and a corresponding device, which quite significantly reduce the harm to humans and the environment described non-exhaustively above by way of example in the course of clearing UXO done avoiding any detonation under water.

[0008] This object is attained according to the invention by means of the features of claim 1 in such a way that in a first step of a method for disposing of a UXO according to the invention, a UXO - which has been detected and been excavated sufficiently to permit an identification or typing, including determination of a spatial position and orientation and determination of a state or degree of preservation - is stabilized and, secured in this position and spatial orientation, is raised up from the sea bottom, and brought into a predetermined orientation and then immobilized. In a second step, the UXO is separated from the surrounding seawater by placing it into a closable chamber, which is emptied of seawater after it is closed. Then a casing of the UXO is cut open by means of water jet cutting in a pressurized or compressed-air atmosphere and then a complete removal of the explosive is carried out, likewise by means of water jet cutting. During this procedure, however, because of the use of the closable chamber, the UXO does not in principle have to be brought up to the surface of the sea while being defused, destroyed and disposed. In other words, the above-described complete delaboration of the respective UXO takes place inside the chamber under water. This has the advantage, among other things, of the fact that an ambient pressure does not change and there is therefore no fear of any negative impact on the charge. In addition, this also safely avoids detonation of hydrostatic detonation devices. A very important aspect, however, is that of the protection from fragmentation and from a shock wave, etc. in the event of an explosion under water by maintaining a safe distance from people. Finally, as remains of the UXO, only scrap that can be recycled and has been cleansed of other chemicals is removed from the chamber at the surface of the water whereas hazardous chemicals are removed separately. In this case, the use of the chamber according to the invention ensures that in principle, no further contamination of seawater or the marine environment with components of the ordnance can occur.

[0009] As an attainment of the above-mentioned object, a device according to the invention has at least one manipulator for immobilizing the UXO and for bringing it, once it has been raised up from the sea bottom, into a predetermined orientation in a chamber that can be closed and drained of water, in which a device is provided for cutting a casing of the UXO for subsequent complete removal of the explosive, possibly by washing it out.

[0010] Advantageous modifications are the subject of the respective dependent claims. According to them, the closable chamber is embodied as bell-shaped and is designed for a use of the device according to the invention in a coastal shallow water region with a depth of 0 to approximately 50 m and for accommodating large-format UXO, for example in the form of moored mines and depth charges of German design as well as British bottom mines of the Mark I through Mark IV types, among others.

[0011] For all of the various designs of explosive ordnance, after the step of establishing a predetermined orientation of the UXO inside the closed chamber, basically first, an immobilization is carried out, even of parts that are later cut off or cut out by means of water jet cutting, which takes place according to one embodiment through the known use of additional abrasive additives. Then, the UXO is dissected, paying particular attention to design-specific detonators that are provided and other explosive elements. For this purpose, in one embodiment of a device according to the invention, at least one additional manipulator is provided for ensuring the positioning of parts of a respective UXO and securing them in position, particularly detonators or bursting charges, etc. in or on severed parts of the casing of such a UXO.

[0012] In a preferred embodiment of the invention, parts of the explosive are removed from the chamber in an aqueous solution and/or in the form of a sludge or suspension. This can occur by means of pumping out. The solution or sludge is temporarily stored and/or disposed of separately, particularly on board a supply ship. After the chamber is cleansed of explosive residues and after the predominantly metallic remnants of the ordnance still contained in it are cleansed of explosive residues, they can be disposed of or undergo further processing as scrap either on board the supply ship or on land with little residual hazard. The chamber can then be immediately used again for disposing of another UXO.

[0013] Basically, the at least one detonator of the UXO, which generally contains chemicals and/or an explosive in a significantly lower quantity than a blasting charge or main charge, can be dealt with in the same way. The primary explosive or the booster charge, which is ignited by the detonator, is generally more explosive than an actual main charge of a piece of explosive ordnance, which is much larger in terms of quantity and volume. During the above-described delaboration, particular attention is paid to such parts in order, for example, to minimize mechanical impacts, even in the form of agitation or vibrations, as much as possible. If possible, for example, a booster charge, which is also referred to as a booster, is kept or stored separately inside the chamber while the main charge is being rinsed out. In one embodiment of a method according to the invention, a removal of the booster does not take place until the chamber is opened and the scrap has also been removed. After the removal from the chamber, this booster part is then separately destroyed in a separate explosion chamber on land, i.e. separately from the device described here. But a detonator is not installed in every device. Specifically in munitions that have been disposed of at sea in so-called DMM sites, the presence of an armed detonator is not all that common. Even these pieces of UXO without detonators, however, are extremely dangerous to people and the environment simply because of the large amount of explosives that they contain.

[0014] In a particularly preferred embodiment of the invention, the chamber, along with the manipulators, is situated in or on a support element, which is optionally connected via a cable connection with the aid of a platform at the surface of the water, e.g. a ship, a floater, or a pontoon, is lowered over a detected UXO, and is positioned in a stationary fashion, or the support element is erected on at least three legs over the UXO. The first of these approaches

is used at depths of 0 to approximately 50 m and primarily in munitions dumping zones with a correspondingly high density and overlapping of a plurality of pieces of UXO. With pieces of UXO lying in an isolated position and/or at greater depths of even more than 50 m, the second approach with a support element standing on legs is preferably used. Once established, a stationary position in solid contact with the sea bottom reduces the positioning and control effort on board the transport and supply ship.

[0015] In any case, it is preferable for the device to be embodied as a largely self-sufficient processing unit for underwater delaboration of UXO in a shallow water or coastal region. A device according to the invention is thus preferably operated autonomously, i.e. controlled by people who are always at a safe distance. Correspondingly, a device that has been lowered over a detected UXO via a cable connection and has been positioned in a stationary fashion is controlled as an autonomous vehicle from a supply ship. A support element standing on legs is controlled by cable from a ship that is generally an oceangoing vessel; the ship stays at a sufficient safety distance from the device while procedures are being carried out inside the device.

[0016] In an important modification of the invention, in the preparatory step of excavating and stabilizing the UXO, a pasty cement mixture is deposited in, on, or around the UXO. The cement mixture used is characterized by the fact that at a respective depth of the relevant UXO, it has a density that corresponds to that of the surrounding water and thus does not have any inherent buoyancy and exhibits a good adhesion in or to the material of the UXO. By admixing fibers, it is possible to adjust a mechanical reinforcement of the cement mixture. Other additives of the cement mixture, in addition to achieving a time-controlled setting of the cement mixture, also give it the lowest possible solubility in the surrounding seawater. On the whole, the use of the cement mixture pursues the objective of a stabilization of the UXO in the sense of a mechanical reinforcement of the corroded structure of the UXO. Alternatively or in addition, the cement mixture can also be used for a mechanically reliable attachment of a hook or some other element with a definite form for grasping and positioning the UXO.

[0017] It is particularly advantageous to use a gripper with soft cushions, which produce a contact of the gripper with the UXO. This achieves an at least partial embrace of a housing of the UXO with the most uniform possible distribution of the action of force in order not to destroy a structure of the UXO that may possibly have been weakened by corrosion. Otherwise, the UXO would fracture, which at the very least, would increase the number of individual parts to recover and could cause an escape of the explosive or other chemicals or even cause detonation of the UXO. The goal is to achieve a stable and safe handling of the UXO for orientation and correct positioning in the chamber or a receptacle inside the chamber.

[0018] In a modification of the invention, a receptacle is embodied as an adapter in order to adapt to a number of ordnance designs. This adaptation takes place, among other things, by adapting to different diameters and heights, as well as keeping certain regions unobstructed in a definite way in order in particular to keep detonators of a respective UXO freely accessible to a manipulator-guided WAS device for disarming by means of detachment or in order to reliably

avoid mechanical, physical contact since otherwise, it could set off the UXO.

[0019] Other features and advantages of embodiments according to the invention are explained in greater detail below with reference to exemplary embodiments based on the drawings. The drawings schematically show the following:

Figs. 1a and 1b:

perspective depictions of two basic use types of a support element to which are attached a chamber and manipulators;

Figs. 2a - 2h:

are perspective depictions of individual process steps of the exemplary embodiment according to Fig. 1a;

Figs. 3a - 3d:

are sectional depictions of the closed chamber, with different UXO or parts thereof held in an adapter;

Figs. 4a - 4e:

are lateral sectional depictions to illustrate a sequence of the method; and

Fig. 5:

is a top view of a support element to which are attached a chamber and manipulators as well as drive units.

[0020] Throughout the different drawings, the same reference numerals are always used for the same elements or method steps. The invention will be explained below in detail in a non-limiting way, essentially only with regard to a use of a device for disposing of a large-format UXO essentially in the form of a so-called moored mine.

[0021] Methods and corresponding devices will be described below, which, when used as part of clearing a large-format UXO, should quite significantly reduce the hazards involved and harm to people and the environment. Figs. 1a and 1b are perspective depictions of a device 1 adapted to two basic types of use. In this case, the device 1 has a respective support element 2, embodied here as a triangular frame structure with a chamber 3 mounted in it and in this instance, a total of four manipulators 4, 5, 6, 7 attached to it. The various tasks performed by these manipulators 4, 5, 6, 7 and their correspondingly adapted equipment will be discussed below with reference to, among others, the sequences of Figs. 2a - 2g and 4a - 4e. For the sake of comprehensibility, a depiction of additional auxiliary and preparatory units and storage spaces for consumables, etc. that are provided on the support element 2, has been omitted here. Further, the manipulators 4, 5, 6, 7 are attached to the device 1 here. However, they can be separated from the device 1 establishing independent units that are only called on demand respectively.

[0022] The exemplary embodiments of Figs. 1a and 1b differ essentially only with regard to the type of positioning over a previously detected UXO 8. The device 1 according to the exemplary embodiment in Fig. 1a is lowered in a manner not shown in detail here from an unmanned

floaters by means of three cables 9 in a shallow water region of up to approximately 50 m in depth and is held over the position of the UXO 8 in a stable fashion. For safety reasons, therefore, a control team is located a sufficiently large distance away in order to perform monitoring- and possibly also control procedures. In the case of an accidental detonation of a large-format UXO 8, the people are always safe. This is particularly necessary when used in dumping zones since in them, various pieces of UXO are placed in a large quantity and high density, randomly and even on top of one another on the surface of the sea floor or in the sea floor. In such regions, an erroneous contact can trigger a chain reaction, making it crucial to avoid any additional bottom contact or contact with the sea bottom BO.

[0023] By contrast, the device 1 according to the exemplary embodiment in Fig. 1b, with an otherwise identical design, instead of being positioned by means of cables 9, is positioned by means of three legs 10 with only a suggested possibility of length adjustment ΔL , by means of which the support element 2 is positioned like a tripod over the detected UXO 8, which is lying isolated at a greater water depth, and the support element is leveled by means of a length compensation of at least one of the legs 10. The support element 2 is aligned essentially horizontally as part of a position correction.

[0024] In a manner that is not shown, the device 1 according to Fig. 1b is connected via a cable to a manned supply ship, also not shown in detail, which is staffed with monitoring and control teams and, after the device 1 has been successfully positioned, is stationed remotely for the safety reasons mentioned previously. In the present exemplary embodiment, in addition to a function for supplying the device with energy and operating supplies, which will be explained in detail below, and for waste disposal, the cable also serves as a mechanical positioning means and as a traction mechanism for raising and lowering the device 1 on board the supply ship, which is generally an oceangoing vessel.

[0025] In each of the devices 1 shown, the chamber 3 is embodied as the actual centerpiece for a complete elimination of a UXO 8 without direct environmental harm. An upper tool is embodied as bell-shaped and has a large opening that is always oriented straight down toward a surface of a sea bottom BO. This opening is adjoined by a frame that can be lowered in a precisely vertical fashion, with an adapter 11 for accommodating the UXO 8. The chamber 3 is closed by means of a cover 12 that is mounted in pivoting fashion.

[0026] Based on the perspective depictions in Figs. 2a - 2h, individual process steps of the exemplary embodiment according to Fig. 1a will now be described, which also occur identically in the exemplary embodiment according to Fig. 1b: in continuity with the drawing in Fig. 1a, in Fig. 2a, the device 1 is positioned at a particular working height H above one of the pieces of UXO 8 and is also held there by means of the cable 9 during the subsequent processing steps in a stable fashion with regard to its x and y coordinates. The UXO 8 is resting on the sea bottom BO and is still partially covered with sediment and/or overgrowth. For further excavation and cleaning of the UXO 8 with as little contact as possible, the manipulator 4 is equipped with digging, cleaning, and/or suction means 13, which, with the use of imaging devices that are not shown in detail, are used to excavate the UXO 8 until it can be identified with regard to its

design type and it is possible to exactly determine its spatial position and orientation. This step is very important simply because sunken moored mines, depending on their design, can have different types of detonation devices 14 distributed over different locations. And these detonation devices 14 can even be still so sensitive that merely touching one of these detonation devices 14 could cause the UXO 8 to explode.

[0027] Finally, in this method step, a mechanical state of the UXO 8 must also be investigated by means of the imaging devices of the manipulator 4, which have an ability beyond that of conventional optical camera processes, to reliably provide usable images under difficult conditions and despite a significant clouding of the surrounding water by the above-mentioned excavation and cleaning work. Particularly a sunken moored mine as the UXO 8 to be handled here must have a leak in an outer casing that otherwise serves as a float in order, due to the flooding of the float, to sink to the sea bottom. If this leak was caused for example due to shelling, then a mechanical basic structure of the UXO 8 may already have been weakened solely by this to such an extent that this UXO 8 could break into several pieces already during an excavation or an attempt to immobilize it in its current position on the sea bottom. As a result, explosive could also come into contact with the surrounding water or the UXO 8 could even explode. The same is basically true for a continued corrosion of the metal parts by the seawater and plant or animal growth with mussels, barnacles, and algae.

[0028] To secure and stabilize in the sense of a mechanical reinforcing of the as a rule significantly corroded structure of the UXO 8, the manipulator 4 also has a device 15 for producing and definitely positioning, metering, and outputting a mechanical immobilization material. This immobilization material - in the form of liquefied paraffins, thermoplastic- or thermosetting plastics and foams, or cement - can be placed into the UXO 8 and/or around the UXO 8, even at least partially surrounding it. After a certain amount of time, the above-mentioned substances have hardened to the point that they effectively prevent the UXO 8 from collapsing during the subsequent fastening and removal from the sea bottom by means of a gripper as an essential component of the manipulator 5 and are able to withstand this stress.

[0029] In the present exemplary embodiment, a cement is advantageously used, which has the special feature that it can be adjusted by means of its composition so that it does not create any inherent buoyancy on the UXO 8 under water and adheres well, even to corroded metal. In addition, the still pasty cement does not dissolve in the surrounding seawater as it is being applied and also does not wash out.

[0030] Alternatively (and in a manner not shown in detail), through the use of an immobilization material in the form of the above-described cement, it is possible to attach or embed a hook. Since the cement has such a good adhesion, even to corroded metals that it firmly bonds to them the moment it is applied, the cement can be used to glue a holding element in place, e.g. in the form of a hook. A hook of this kind can, after a resilient hardening is achieved, be used for grasping and positioning the UXO 8. According to this alternative, it is thus also possible to use small grippers.

[0031] After the completion of the preparatory method steps performed using imaging monitoring, including a precise excavation, identification of the type and position of the relevant UXO 8, stabilization and reinforcement or mechanical encapsulation of the casing, a manipulator 5 takes over from the previously active first manipulator 4 in the processing sequence. Consequently, the UXO 8 in Fig. 2b is embraced and lifted by a gripper 16 of the manipulator 5. This procedure is also monitored by means of imaging equipment on manipulator 4. For secure fastening and subsequent positioning, the gripper 16 has cushioned inner surfaces, by means of which a force acting on the casing of the UXO 8 is distributed over comparatively large areas and is thus reduced as much as possible. At the same time, this reliably prevents the UXO 8 from slipping in the gripper 16 or even being dropped.

[0032] In the approach to the process step shown in Fig. 2c, the whole device 1 has been raised up by an amount ΔH . Thanks to this change in height ΔH above the surface BO of the sea bottom, it is now possible in the method step shown in Fig. 2d to open the chamber 3 by lowering a bottom part 17 of the chamber 3 without this part being able to touch the surface BO of the sea bottom or even another possibly adjacent UXO 8'. The bottom part 17 includes an internal receptacle 18 of the adapter 11. The gripper 16 is then pivoted by the manipulator 5 so that the UXO 8 assumes a predetermined orientation and correspondingly, after completion of the positioning, is transported by the manipulator 5 in the correct position into the corresponding receptacle 18 of the adapter 11 of the bottom part 17 and is accommodated therein, see Fig. 2e.

[0033] The bottom part 17 is attached to the chamber 3 by means of a so-called Sarrus mechanism 19 by means of which the bottom part 17 is guided relative to the chamber 3 in a high-precision linear fashion. This precise linear guidance is considered necessary for a number of reasons: on the one hand, it must always be possible to reliably close the chamber 3 with the bottom part 17. On the other hand, however, once a precise positioning of the UXO 8 in the receptacle 18 of the adapter 11 has been set, it must be maintained as precisely as possible so that after the gripper 16 is withdrawn and the bottom part 17 is closed, it is possible to no longer provide a manipulator for a readjustment of the orientation of the UXO 8. An incorrect positioning would thus require in a time-consuming reopening of the chamber with a lowering of the bottom part 17 for a re-manipulation by means of the manipulator 5 with its gripper 16 accompanied by monitoring with the imaging equipment of the manipulator 4.

[0034] Fig. 2f shows the device 1 in a closed state, i.e. one in which an opening of the chamber 3, which is oriented downward and toward the surface BO of the sea bottom, is securely closed by the bottom part 17. The UXO 8 is now exactly positioned on or in a receptacle 18 of the adapter 11 on the inside of the chamber 3. Then, the UXO 8 is removed from the water so to speak by pumping out and/or displacing the seawater contained in the chamber 3. A gas pressure prevailing in the chamber 3 thus essentially corresponds to the water pressure at this working depth.

[0035] In the transition between Figs. 2f and 2g, the device 1 is raised further out of the water or the sea. During this, the third manipulator 6 is in use on the inside of the chamber 3. After a

check of a position of the UXO 8 and/or its detonation devices 14, a metallic outer hull or casing of the UXO 8 is opened by means of water jet cutting with the addition of abrasives. An explosive contained in the UXO 8 is completely removed by using another tool employing liquefaction by means of water conveyed into the chamber 3 from the outside, i.e. likewise essentially by means of water jet cutting and rinsing. Components of the explosive are removed from the chamber 3 in an aqueous solution and/or in the form of sludge or suspension. In this case, this suspension is pumped out in order to be temporarily stored and/or disposed of separately outside the chamber 3, in this exemplary embodiment on the floater or some other supply unit at the surface of the water.

[0036] In the transition to the illustration in Fig. 2g, there is already no longer any casing of a UXO 8 visible inside the chamber 3. In this case, the UXO 8 has already been cut into smaller pieces and the explosive has been transformed into a suspension and pumped out. After this, all that is left behind in the chamber 3 is parts of the casing of the UXO 8, which, as non-hazardous scrap, can largely be supplied to normal recycling, without having to comply with further safety regulations, while the severed detonators 14 etc. can be separately stored, disarmed, and only after this, likewise disposed of as metal scrap.

[0037] Fig. 2h shows a scene out of the water, in which the scrap remaining in the chamber 3 is ejected by opening or pivoting the cover 12 while the bottom part 17 of the chamber 3 is lowered to release the adapter 11. The remaining metallic remnants can therefore fall out of the chamber 3 in order to be collected at the surface of the water on board a supply ship or the like. This assures that in addition to chemical impurities from explosive residues, metal parts are also prevented from falling back into the sea. After the cover 12 is closed and the bottom part 17 has been lifted to close the chamber 3, the device 1 can be lowered directly back into the sea in order to dispose of the next UXO 8' and the above-described cycle begins again with a corresponding placement of the device 1 over a detected UXO 8'.

[0038] The illustrations in Figs. 3a - 3d show sectional depictions of the closed chamber 3 with different large-format pieces of UXO 8 or parts 8", 8''' thereof accommodated in standardized receptacles 18 of the adapter 11. Fig. 3a is a side view of a UXO 8 to be subsequently handled, which is embodied in the form of a moored mine that is oriented in a precisely vertical fashion and secured in a standardized receptacle 18 of the adapter 11. A moored mine of this kind, taking into account the buoyancy under water, weighs approximately 400 kg, which must be securely grasped and moved by the 2nd manipulator 5. A moored mine, as an essentially spherical body, measures about 1.10 m in diameter and contains approximately 300 kg of explosives as a main charge and approximately 1 kg of explosive as a priming or booster charge.

[0039] Fig. 3b shows a UXO 8 embodied in the form of a depth charge secured in another standardized receptacle 18 of the adapter 11. A depth charge, with a weight of approximately 100 kg under water, has the outer form of a section of a cylinder with a diameter of approximately 50 cm and a length of 0.6 m. A depth charge contains approximately 140 kg of explosive as a main charge and approximately 1 kg of explosive as the main priming charge.

[0040] And finally, Figs. 3c and 3d show a holding of two parts of a bottom mine that has been pre-treated by being divided into thirds for subsequent handling with removal of the explosive, securing of the detonation devices, and final disposal of the remaining purely metallic remains. A bottom mine likewise constitutes a cylindrical section, which, with a diameter of approximately 50 cm corresponds to the diameter of a depth charge. It is thus possible to use the same adapter 11 in the bottom part 17 of the chamber 3 to accommodate both kinds of UXO 8. In addition, however, a bottom mine has an overall length of approximately 1.5 m. With a total weight of approximately 300 kg under water, a bottom mine contains a total weight of almost 350 kg of explosive as a main charge and approximately 4 kg of explosive in a priming charge. In one disposal method, a bottom mine is dissected so that the individual pieces to be separated from the explosive correspond approximately to the dimensions of a depth charge. By means of holders, not shown in detail here, inside of the chamber 3, it is also possible to carry out a disarming and disposal of an entire bottom mine with sufficient positional securing to even prevent a tilting inside the chamber 3. This also prevents the explosive and cutting waste from escaping into the surrounding water during the severing process.

[0041] The chamber 3 is in fact embodied as a pressure vessel in order, after one of the pieces of UXO 8 mentioned above by way of example has been received, to be able to ensure drainage in a compressed-air atmosphere, even at depths of approximately 50 m. A disarming of the UXO 8, however, always takes place by means of opening an outer casing and subsequently removing the explosive of at least one respective main charge by cutting and/or washing-out and transporting it in the form of a suspension out of the chamber 3. Through various safety measures, the possibility of an explosion occurring inside the chamber 3 is thus precluded as much as technically possible. As a result, the chamber 3 does not have to be embodied in the form of an explosion-protected explosion chamber, which would have to be able to withstand a detonation of 300 to 400 kg of TNT and explosives of this nature. Consequently, the chamber 3 essentially only has to be dimensioned with a view to the maximum use depth under water and the formats and outer dimensions of the UXO 8 to be accommodated therein. In addition, there must always be sufficient room inside the chamber 3 to accommodate the explosive/water suspension produced during the washing-out procedure as well as cut-off parts of the outer casing. In a manner not shown in detail here, water for cutting open and separating the outer casing and for washing out the explosive is supplied to the chamber 3 from the outside at high pressure, with or without the addition of additional abrasively acting substances, in this case, preferably from reservoirs on the support element 2. Waste water produced by these work procedures is continuously removed from the chamber 3 by means of a separate, closed circuit and is separately stored and/or prepared. Consequently, even as part of a dissection and washing-out procedure, no seawater can be contaminated with explosive and/or no metal parts of the bottom mine are left behind in the sea or get into the sea in the form of cuttings of the casing.

[0042] The series of Figs. 4a - 4e, in the form of lateral sectional depictions, shows an above-described processing sequence once again. In this case, Fig. 4a shows a state after completion of the excavation of the UXO 8, at the transition from the above-described Fig. 1b

to Fig. 1c. In this step, the gripper 16 has securely surrounded the UXO 8, which is possibly mechanically reinforced by means of cement, while the first manipulator 4 is already in a definite passive position on the frame 2. In the approach to Fig. 4b, the device 1 has already completed the height change ΔH for the opening of the chamber 3 through a lowering of the bottom part 17 of the chamber 3 by means of a drive cylinder 20 in order to set the UXO 8 secured in the gripper 16 into a receptacle 18 of the adapter 11 in a defined orientation. This step has been completed in the illustration shown in Fig. 4c. Then the manipulator 5 also switches into a passive position so that the chamber 3 can be closed through the action of the Sarrus mechanism 19, see Fig. 4d. Then, the water contained in the chamber 3 is pumped out or is pushed out through the introduction of compressed air so that an internal pressure in the chamber 3 is built up, which corresponds to a current water depth. Then the manipulator 6, accompanied by image-based monitoring, starts the process of opening or cutting open a casing of the UXO 8 by means of water jet cutting and separate handling of severed parts by means of a manipulator 7 for handling e.g. the at least one detonator 14 of the UXO 8, in this case, likewise by means of water jet cutting in cooperation with the manipulator 6. Inside the chamber 3, the manipulators 6 and 7 assist each other in the delaboration like two hands, with the tasks of the cutting and washing out always remaining the duty of the manipulator 6. Image-producing monitoring devices, e.g. in the form of camera systems and sensors inside the chamber 3, are not shown in the drawing.

[0043] After an opening of the casing, the explosive of a main charge contained in the UXO 8 is removed through liquefaction using separately supplied water, likewise essentially by means of water jet cutting carried out by the manipulator 6. In this case, the tool used for this purpose is correspondingly changed for the purpose of producing an aqueous suspension. The suspension produced is pumped out of the chamber 3 or is pushed out of the chamber by compressed air, through a separate drain valve, and into a closed disposal circuit. The chamber 3 is then cleansed of explosive residues by rinsing with water. At this point, the only things remaining inside the chamber 3 are the cut-off parts of the former casing of the UXO 8 and separately contained detonators 14, not shown in detail here. For the corresponding handling of the scrap parts or sections of the outer casing of the UXO 8, the manipulator 7 is provided inside the chamber 3 and, after the opening of the chamber 3, the manipulator 6 is provided in the outer region.

[0044] Fig. 4e shows a process step in which now, through a simple pivoting of the cover 12 provided at the bottom by means of a drive cylinder 21, the remaining parts that have been cut off from the casing of the UXO 8 - as comparatively safe pieces metallic scrap 22, which have been cleansed of chemicals - are dumped out of the chamber 3 into a container that is not in the sea. The detonators 14, which generally contain comparatively small quantities of explosive, are separately removed from the chamber 3 and disposed of, provided that it was not possible for them to be correspondingly positioned by the manipulator 7 and cut open by the manipulator 6 and separated from the explosive contained therein by being washed out. In the latter case, these detonators 14 are also disposed of or recycled as metal scrap 22 of the outer casing of the UXO 8, without increased safety requirements.

[0045] Fig. 5 is a top view of the frame-shaped support element 2 with the chamber 3 and manipulators 5, 6, 7, 8 affixed to it as well as drive units and the like of the Sarrus mechanism 19 of the bottom part 17 of the chamber 3. This design is identical in the exemplary embodiments shown in Figs. 1a and 1b. In areas with a high density of UXO 8, the variant according to Fig. 1a is used simply due to the basic lack of contact with the bottom. With this variant, individual pieces of UXO 8 can be gradually removed, even from conglomerations, and disarmed and disposed of without additional stresses or contact resulting in an increased explosion danger. Autonomous units in the form of unmanned floaters with a high positioning precision with reference to geo-coordinates are available, which can maintain an exact depth position under water by means of winch systems, even when there are waves and when in shallow water regions.

[0046] As an essential element, the above-described device 1 includes the chamber 3, which is embodied as a bell-shaped pressure hull that is open toward the sea bottom BO and that can be opened and closed in a definite way by means of a Sarrus mechanism 19. The chamber 3 is adapted to a series of different standard formats of large-format pieces of UXO 8 with correspondingly high contents of hazardous and environmentally harmful explosives and offers a correspondingly dimensioned open interior for accommodating them and supporting them in a mechanically stable fashion even during processing by means of manipulators 6, 7 provided inside the chamber, with accompanying image-based monitoring and/or lighting. The interior of the chamber 3 is also embodied for collecting and temporarily accommodating aqueous suspensions of abrasive substances and metallic pieces from the high-pressure water jet cutting and the washing-out of the explosive of a respective main charge of the UXO 8. Apart from a pressure load during drainage by means of compressed air, even at depths of approximately 50 m below the surface of the water, and the static load due to the additional weight of the UXO 8, the chamber 3 does not have to have any further mechanical reinforcement since the chamber 3 is in particular not embodied as a detonation chamber. External and internal safety systems prevent detonation of any UXO 8 or of any detonators, detonation devices 14, or bursting charges that have been severed from it. In this way, the chamber 3 also offers a unit that can be positioned and transported well, is of a manageable weight, and is of a size that can be maneuvered both under water at the surface of the water.

[0047] A device 1 of the above-described type can be used as a compact, complete system for delaboration of even large-format pieces of UXO 8, which is not just for use in shallow marine regions and lakes. Advantageously, a device 1 can also be used on land, e.g. with positioning by means of a crane, for basically separating explosives and other parts of pieces of UXO 8 from the environment surrounding the chamber 3. Delaboration of UXO can be carried out with the greatest possible protection of people and the environment in pools of water e.g. below a ground water level, without excessive pumping-out, but also in a dry excavation pit. A device 1 that has been described in a number of embodiments therefore constitutes a universally usable tool, which can be used to a large extent independently of the weather, the day of the week, the time of day, the light conditions, etc. and can operate autonomously.

Reference Numeral List

[0048]

- 1 device
- 2 support element / support platform
- 3 chamber
- 4 1st manipulator
- 5 2nd manipulator
- 6 3rd manipulator
- 7 4th manipulator
- 8 piece of unexploded ordnance / UXO
- 9 cable
- 10 leg
- 11 adapter in a frame, lowered for accommodating the UXO 8
- 12 cover for closing the chamber 3, mounted in pivoting fashion
- 13 digging and suction means as well as imaging devices
- 14 detonation device of the UXO 8
- 15 device for producing and definitely outputting a mechanical immobilization material / cement
- 16 gripper with cushioned inner surfaces
- 17 bottom part of the chamber 3
- 18 standardized receptacles of the adapter 11 for different large-format UXO 8
- 19 Sarrus mechanism

20	drive cylinder for the bottom part 17
21	drive cylinder for tilting of the cover 12
22	metal scrap / cut-off parts of the outer casing of the UXO 8
BO	surface of the sea bottom
ΔL	length adaptation / length compensation
H	working height for the 1 st and 2 nd manipulators 4, 5 above a UXO 8
ΔH	height change for the opening of the chamber 3

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- [US20090223355A1](#) [0005]
- [DE102013004445B3](#) [0006]

Patentkrav

1. En fremgangsmåde til bortskaffelse af en ueksploderet blindgænger UXO (8), der ligger under vand, hvor den detekterede UXO (8) placeres i et lukbart

5 kammer (3), og kammeret (3) tømmes for havvand efter lukning, og en kapsling af UXO (8) åbnes ved hjælp af vandstråleskæring, **kendetegnet ved, at** UXO (8) udgraves til identifikation og typebestemmelse, herunder bestemmelse af en rumlig position og retning og bestemmelse af en tilstand og grad af bevaring, og stabiliseres og løftes derefter op fra havbunden og bringes i en forudbestemt
10 retning, og inden i kammeret (3) adskilles UXO (8) så fra det omgivende havvand, og indkapslingen af UXO (8) skæres, og et eksplosiv, der findes deri, fjernes helt.

2. Fremgangsmåden i henhold til det foregående krav, **kendetegnet ved, at**
15 den komplette fjernelse af eksplosivet finder sted gennem likvefaktion ved hjælp af forsynet vand, ligeledes fortrinsvis ved hjælp af vandstråleskæring, og dele af eksplosivet fjernes fra kammeret (3) i en vandig opløsning og/eller i form af slam eller suspension eller pumpes ud og opbevares midlertidigt og/eller bortskaffes separat.

20

3. Fremgangsmåden i henhold til ét af de foregående krav, **kendetegnet ved, at** efter trinnet til etablering af en forudbestemt retning af UXO (8) inden i det lukkede kammer (3) før vandstråleskæringen, udføres basalt set først en mekanisk immobilisering af UXO (8) og/eller dele, der skal skæres af.

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4. Fremgangsmåden i henhold til ét af de foregående krav, **kendetegnet ved, at** der bruges en cement til stabilisering i form af en mekanisk forstærkning af den korroderede struktur af UXO (8) og/eller for at fastgøre en krog til efterfølgende at gribe fat i og positionere UXO (8).

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5. En anordning til bortskaffelse af en ueksploderet blindgænger UXO (8), der ligger under vand, i et lukbart kammer (3), der omfatter midler til

vandstråleskæring til at åbne UXO (8), hvor anordningen er specielt udformet til at udføre en metode i henhold til ét af foregående krav, **kendetegnet ved, at** anordningen (1) har mindst én manipulator (4), der er udstyret med midler til gravning, rengøring, midler til identifikation og typebestemmelse af UXO (8) og/eller sugemidler (13), og en manipulator (5) til immobilisering af UXO (8) og til at bringe UXO (8), der er blevet løftet op fra havbunden (BO), i en forudbestemt stilling i et kammer (3), der kan lukkes og tømmes for vand, og inden i kammeret (3) findes mindst én anordningsmanipulator (6) til at skære en indkapsling på UXO (8) op og til at fjerne eksplosivet helt.

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6. Anordningen i henhold til det foregående krav, **kendetegnet ved, at** det lukkbare kammer (8) er udformet som en dykkerklokke eller klokkeformet og er designet til en brug af anordningen (1) i et lavvandet, kystnært område med en dybde på 0 til ca. 50 m.

15

7. Anordningen i henhold til ét af de to foregående krav, **kendetegnet ved, at** ved hjælp af en adapter (18), er kammeret (3) udformet til at kunne rumme UXO (8) i stort format i form af forankrede miner og dybvandsbomber af tysk design samt britiske bundminer af typen Mark I til og med Mark IV, blandt andre.

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8. Anordningen i henhold til ét af de foregående krav 5 til og med 7, **kendetegnet ved, at** kammeret (3) er forbundet med et dæksel (12) ved hjælp af en Sarrus-mekanisme (19) til nøjagtig styring under lukning.

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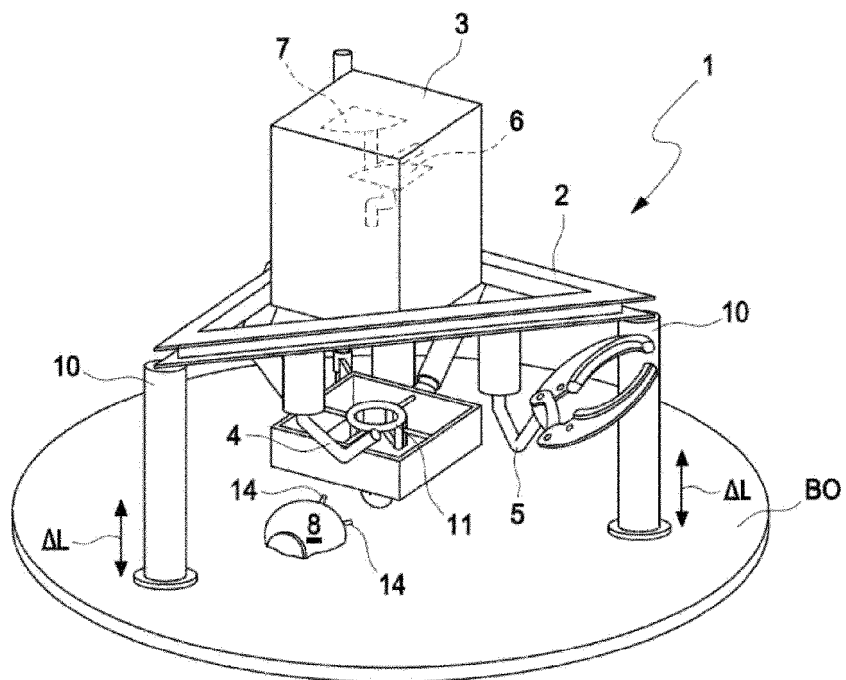
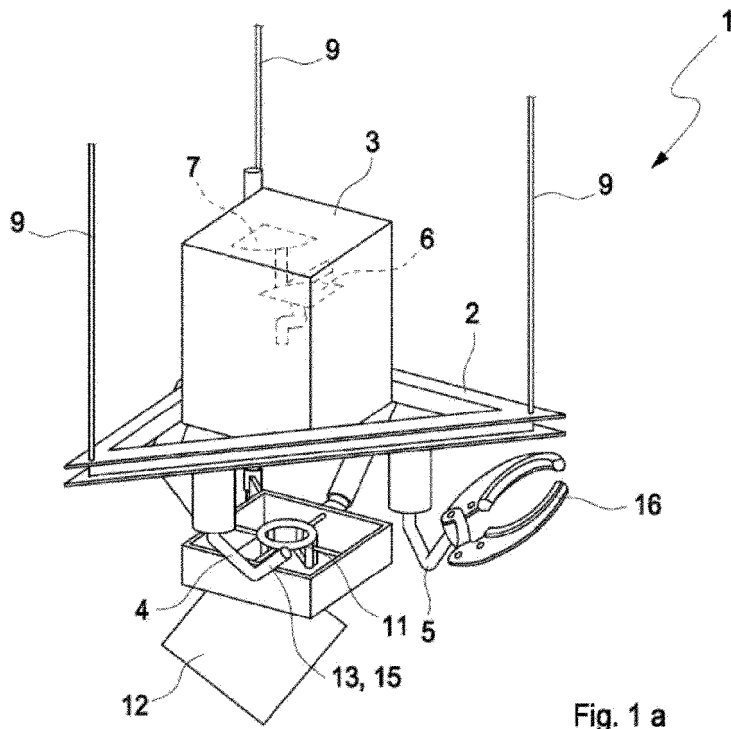
9. Anordningen i henhold til ét af de foregående krav 5 til og med 8, **kendetegnet ved, at** kammeret (3), sammen med uafhængigt kontrollerbare manipulatorer (4, 5, 6, 7), er placeret i eller på et støtteelement (2) og den første manipulator (4) desuden omfatter midler (13) en billeddannelsesenhed og/eller en anordning (15) til produktion og endelig afgivelse af et mekanisk

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immobiliseringsmateriale.

10. Anordningen i henhold til ét af de foregående krav 5 til og med 9,
kendetegnet ved, at mindst én manipulator (5) har en griber (16) med en blød
pude til omgivelse af et hus eller en indkapsling på UXO (8) til stabil og sikker
retningsplacering og positionering og til transport af UXO (8) til det lukbare og
5 tømbare kammer (3).

DRAWINGS



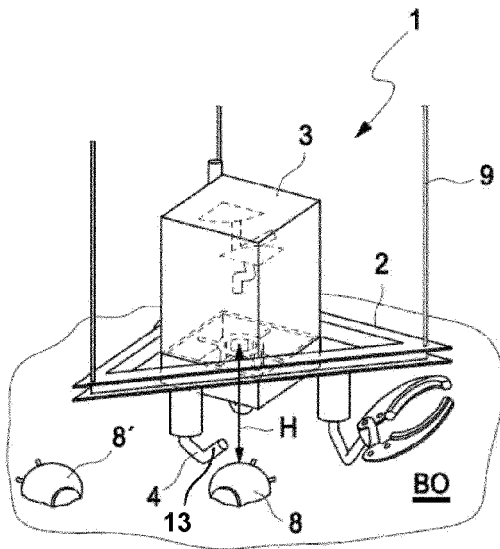


Fig. 2 a

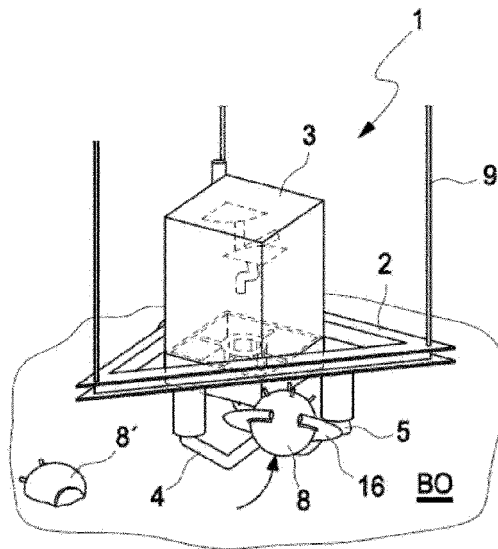


Fig. 2 b

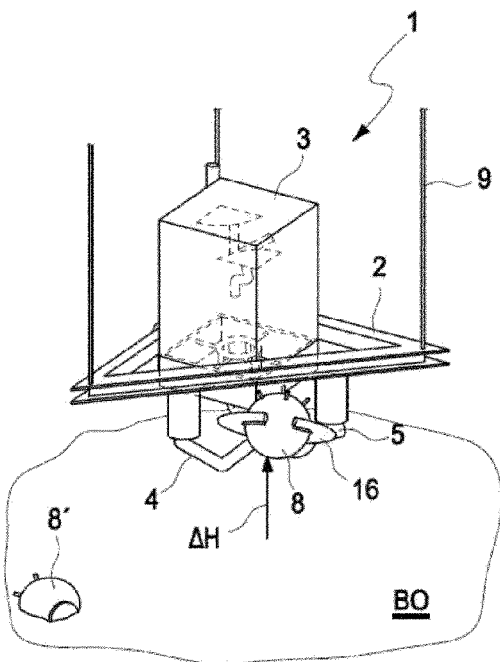


Fig. 2 c

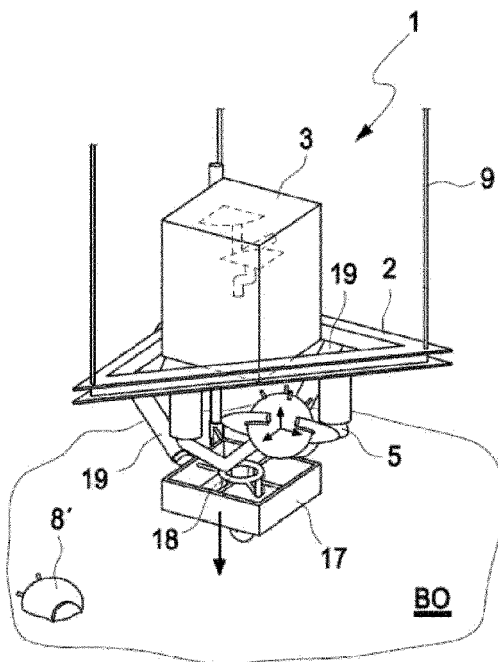


Fig. 2 d

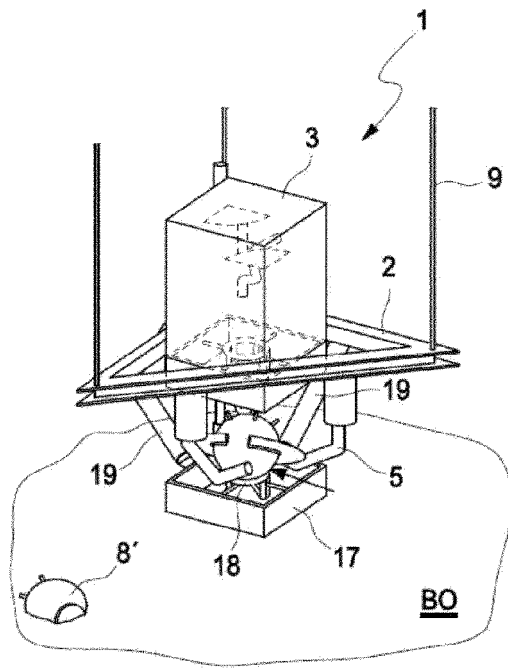


Fig. 2 e

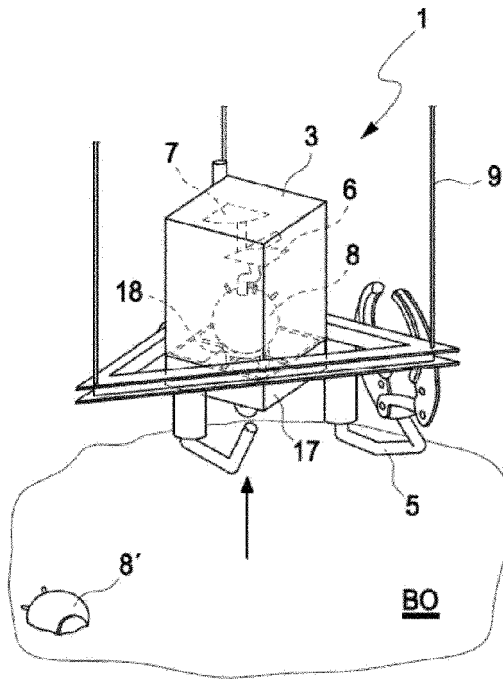


Fig. 2 f

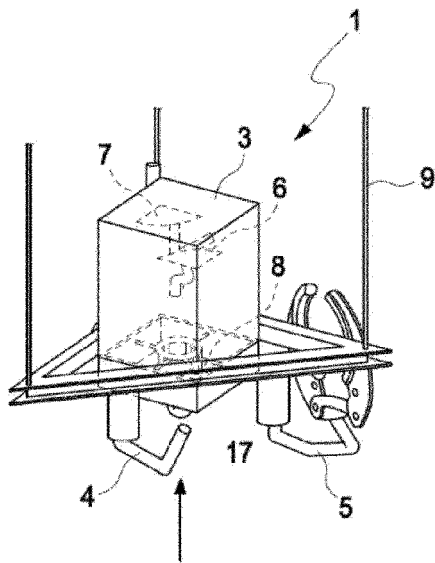


Fig. 2 g

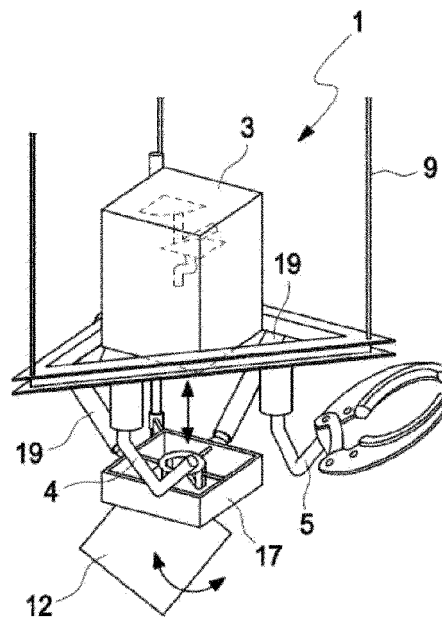


Fig. 2 h

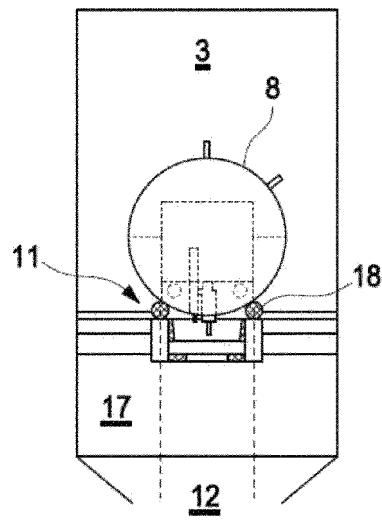


Fig. 3 a

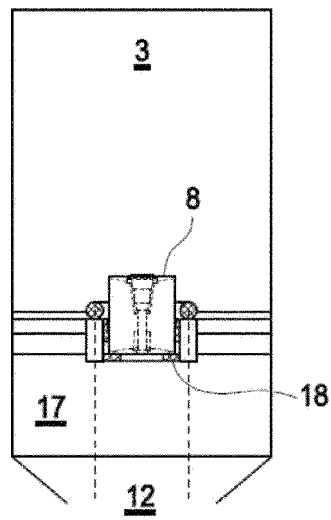


Fig. 3 b

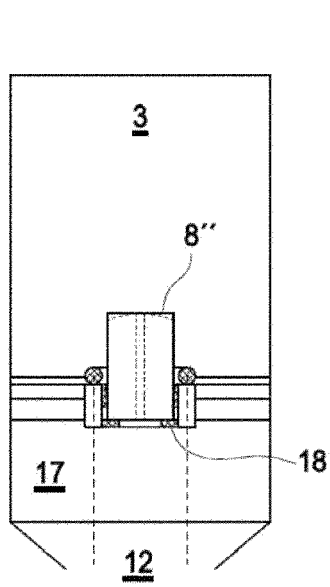


Fig. 3 c

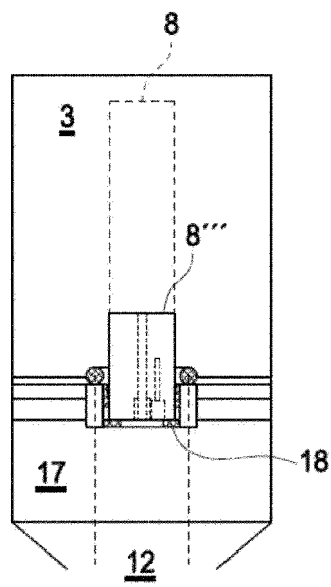


Fig. 3 d

Fig. 4e

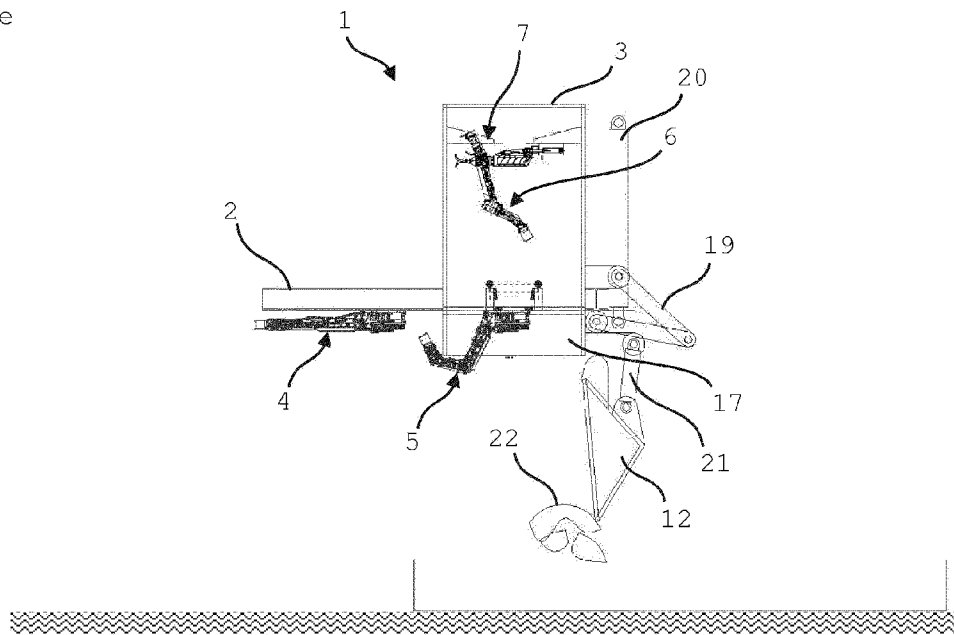


Fig. 5

