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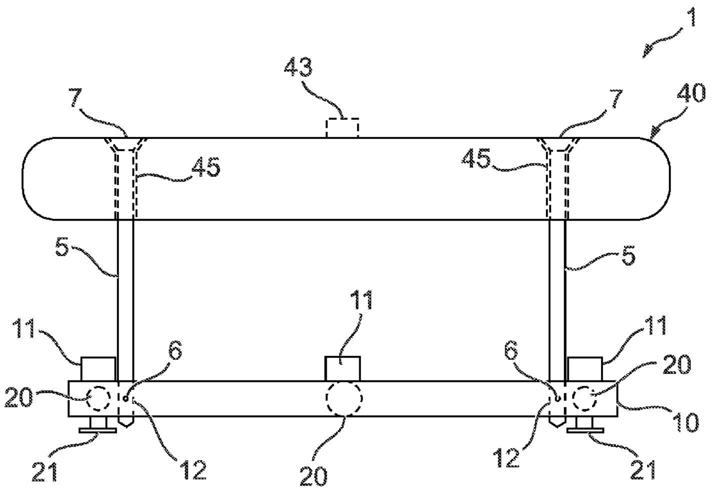

Fig. 6

(57) Abstract: A platform assembly comprising a marine energy harvester such as a tidal turbine (70) and a frame (1). The frame (1) has a chamber (40) for containing a buoyant fluid material and serving as a buoyancy device and is adapted to convert to a ballast device during installation of the platform assembly. The chamber (40) performs a dual purpose in providing buoyancy during deployment to an installation site and providing ballast acting on the platform assembly following installation of the platform assembly at the installation site. The chamber is movable relative to a base of the frame and has guide posts (5) adapted to guide the movement of the chamber (40) relative to the base (20). The guide posts (5) can optionally be removed from the frame (1) after conversion of the chamber (40) into a ballast device.

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FRAME FOR MARINE ENERGY HARVESTER

The present invention relates to a buoyancy frame and the use of such a frame in a method for the transportation, installation, and decommissioning of marine energy harvesters such as tidal turbines and wave energy converters

BACKGROUND OF THE INVENTION

The harnessing of energy in moving fluids using tidal turbines and wave energy converters etc. is a well-known concept. One embodiment of a tidal turbine takes the form of a nacelle containing generator components, to which a propeller-style rotary blade assembly is connected, the nacelle being connected to a supporting tripodal base. The rotation of the blades drives the generator. Alternatively, the base can have a single foot.

The nacelle and base are generally modular and transported in a separated state to the installation site, where the base is seated and ballasted or anchored in position before the nacelle is lowered onto it for connection of the two components. The tidal turbines are installed individually and due to their size, few can be carried at one time on a transportation vessel, making installation a costly and time-consuming process.

US Patent Application No. US 2014/0137789 is useful for understanding the present invention.

SUMMARY OF THE INVENTION

In accordance with a first aspect of the invention, there is provided a platform assembly comprising a marine energy harvester and a frame connected to the marine energy harvester, wherein the frame comprises at least one frame member adapted for attachment of at least one chamber adapted for containing a buoyant fluid material and serving as a buoyancy device, the chamber being adapted to convert to a ballast device during installation of the platform assembly.

In another aspect the invention provides a platform assembly comprising a marine energy harvester and a frame connected to the marine energy harvester, wherein the frame comprises at least one frame member adapted for attachment of at least one chamber adapted for containing a buoyant fluid material and serving as a buoyancy device, the chamber being adapted to convert to a ballast device during installation of the platform assembly; wherein the frame comprises at least one guide post which engages the chamber and wherein the chamber is movable relative to the frame along a path defined by the at least one guide post as the buoyancy of the chamber varies.

The invention also provides a frame for supporting a marine energy harvester, wherein the frame comprises at least one frame member adapted for attachment of at least one chamber adapted for containing a buoyant fluid material and serving as a buoyancy device, the chamber being adapted to convert to a ballast device during installation of the frame.

The marine energy harvester is optionally a tidal turbine, but other embodiments can incorporate a wave energy converter. The marine energy harvester is optionally an offshore marine energy harvester converting tidal stream motions into electrical energy. The marine energy harvester is optionally deployed in an undersea environment, but other examples can be deployed in rivers or other underwater environments.

The chamber optionally performs a dual purpose in providing buoyancy during deployment to an installation site and providing ballast acting on the platform assembly following installation of the platform assembly at the installation site.

Optionally the chamber is dimensioned to provide sufficient ballast for the platform assembly when flooded after installation, optionally with no additional ballasting works being necessary. Optionally the chamber can be increased in size to accommodate sufficient ballast material in the chamber (optionally flowable ballast material) with a suitably high specific gravity to provide sufficient ballast for the platform assembly without relying on other ballast being added to the platform assembly. Optionally the chamber can be increased in size to accommodate the additional ballast material optionally added to the frame members and optionally to compartments of the buoyancy chambers prior to load-out. Optionally the flowable ballast can be a liquid at the time of deployment (which can optionally set into a solid material after deployment) having a specific gravity of not less than seawater. In certain examples, separate ballast (grout, cement, iron ore etc.), which can optionally be flowable and/or settable after flowing, can be added to the chamber and/or the frame member. Optionally this separate ballast can be added prior to load-out. Optionally this separate ballast can be added to the chamber after installation of the platform assembly.

Optionally the frame comprises a base disposed between at least two frame members. Optionally the base comprises at least two base members, optionally disposed perpendicularly to and optionally extending between at least two frame members. Optionally the base members have fixtures such as lugs, sockets, threads or padeyes to connect a structure, optionally for supporting a power converter such as a tidal turbine nacelle, to the base members. Optionally the fixtures are spaced apart on the base members. Alternatively the support structure for the power converter can be formed integrally with the frame.

Optionally each frame member comprises at least one guide post which may optionally be releasably secured to the platform assembly. The guide post can for example be attached to the frame member. Optionally the guide post is permanently attached to the frame member, for example by welding. Optionally the guide post passes through the chamber, for example passing through a pipe or lined aperture that passes through the chamber, thereby securing the chamber to the frame member while buoyant.

Optionally the pipe through the chamber and the guide post can have alignment devices to assist in alignment and assembly of the pipe and the post; in one example, the pipe can be canted at one end. In one example the pipe is flared in a bellmouth shape at one or both ends of the pipe. Optionally the bellmouth of the pipe that is adjacent to the frame member engages the guide post to accommodate misalignment between the guide post and the pipe after the chamber has been placed onto the guide post. Optionally the guide post and pipe that receives the guide post engage at the opposite ends of the pipe. Other alignment mechanisms can be used. Optionally the alignment devices do not protrude beyond the outer surface of the chamber in the assembled platform assembly, although this is an option. The guide post can optionally be removed from the frame, optionally while the chamber is connected to or contiguous with the frame.

Optionally the guide post is received within a bore in the frame member. Optionally the bore is lined by a liner and the guide post is supported by the liner along at least a portion of the length of the aperture through the frame member, and optionally along the whole of the length of the frame member. The liner can comprise a tubular pipe welded into the bore through the frame member that acts to support the guide post across the diameter of the frame member. Optionally the guide post is releasably secured to the frame member by a latching device for example, with a guide pin, optionally more than one guide pin, which passes through the frame member and the guide post, and optionally through the pipe lining the aperture through the frame member. Optionally the guide post can be releasably secured to the frame by a hydraulic latch. Optionally the frame member and the guide post can incorporate alignment devices to assist in alignment and assembly of the frame member and the post.

Optionally a restraint device in the form of a cap is secured to the guide post optionally at the end of the guide post spaced away from the frame member to constrain the movement of the buoyancy device with respect to the guide post. Optionally the cap can have a canted surface with a larger diameter end that has a larger diameter than the lined aperture, for example, it can be conical, extending radially away from the post at a canted angle, and optionally engages with the adjacent bellmouth of the lined aperture through the buoyancy device. In another example, the cap can have a flat surface such as a plate optionally extending radially with respect to the post, beyond the diameter of the lined aperture, so that the engagement between the two can restrict relative movement. Optionally the pipe can have a flange that engages the plate. Optionally the restraint device is disposed on the top of the guide post, and engages the chamber only when the chamber is in the raised position at or near the top of the guide posts, i.e. when the chamber is acting as a buoyancy device and is filled with buoyant fluid. The canted surface of the restraint device interfaces between the guide post and the lined aperture in the chamber, which can usefully incorporate sufficient clearance between the two components to allow satisfactory tracking of the chamber down the guide post when the chamber is moving into the ballast position, and this can usefully have the effect of reducing or preventing relative movement between the post and the chamber when the restraint device is fully engaged.

Optionally the restraint device is located within the chamber. Optionally the restraint device is located at the top, or optionally at the bottom, of the guide post. Optionally the restraint device is located at the top, or optionally at the bottom, of the chamber. Optionally the restraint device is located externally to the chamber.

Optionally when the platform assembly is floating, the chamber is free to move along a path defined by the guide post, optionally as the buoyancy of the chamber varies. Optionally the chamber is movable from a first transportation configuration in which the chamber serves as a buoyancy device, and comprising a first position at the end of the guide post disposed away from the frame member; to a second installation configuration comprising a second position adjacent to or contiguous with the frame member. Optionally the chamber can occupy any position between the first and second positions during movement of the chamber or frame. Optionally the chamber comprises a buoyancy chamber. Optionally the buoyancy chamber is partially filled with fluids of varying density in order to increase or decrease the buoyancy of the chamber, and therefore the platform assembly. Optionally the buoyancy chamber is wholly filled with fluids, which can be of varying density.

Optionally the chamber comprises more than one compartment. Optionally, in different compartments, fluids of varying density can be contained, optionally an odd number of compartments, for example 3, 5, or more. Optionally the chamber has a larger central compartment, with a greater volume, with smaller compartments having lesser volume than the central compartment on either side. Optionally the compartments are equally sized. Optionally each compartment has its own flood and vent valves. Optionally only some of the compartments have flood and vent valves, for example, if a compartment is permanently ballasted it does not require valves.

Optionally the compartments disposed at either side of the main compartment are configured to contain ballast, for example seawater, or alternatively iron ore slurry, grout, cement, aggregate, or the like. Optionally, each of the outermost compartments is filled with ballast prior to load-out. Optionally the compartments of the chamber are symmetrically balanced around the centre of the chamber. Optionally the central compartment or compartments are at least partially filled with air. Alternatively or additionally, ballast can optionally be loaded into an inner compartment spaced away from the outermost end of the chamber and closer to a guidepost, optionally coincident with a guidepost, such that a guidepost passes through the compartment. Optionally the ballast in the chamber is symmetrically arranged around the centre of the chamber.

Incorporating compartments into the chamber controls the maximum submerged weight of the chamber when the central compartment is fully ballasted. As the density of the mediums is known, the descent of the chamber can be predicted and controlled by the rate of flooding of one or more compartments. Compartmentalisation and controlling the maximum submerged weight has advantages for contingency and intervention operations. For example, sizing the main compartment of the chamber such that when this compartment is fully flooded the submerged weight of the chamber is a manageable known amount (e.g. up to approximately 20t) allows for easier and more predictable intervention operations in the event that the chamber hangs-up on the guideposts and requires a contingency intervention with a winch from an installation vessel to pick-up the tank and lower it under support from the winch. The compartmentalisation of the chamber into compartments of known size, optionally each with its own valve(s), means that the winch needed to perform an intervention task can be smaller and simpler. In certain examples with compartments, the valves can be opened which can flood different compartments to full volume sequentially up to a limited volume of ballast with less reliance on ROV support. For example, the valves can be left to flood without necessarily requiring ROV control or even ROV attendance. This removes or mitigates the requirement of the ROV to shut off flood valves in a non-compartmentalised chamber as the chamber started to move. Compartmentalisation also has the advantage that during decommissioning, the venting of the chambers and the residual ballast after venting is predictable.

Optionally the chamber can be latched to the frame in the ballast configuration after installation.

Optionally the movement of the chamber relative to the frame during installation is controlled (for example limited) for at least a part of the path between the first and second positions by a control device, which can optionally be associated with the guide posts, and which controls the movement of the chamber relative to the frame in order to decelerate the chamber as it approaches the frame.

Optionally the control device can comprise a gas spring, hydraulic piston arrangement, a coiled spring or any other resilient device capable of absorbing velocity of the chamber and decelerating the chamber as it approaches the frame, thereby reducing the impact between the chamber and the frame upon contact. Optionally the control device can incorporate a telescopic section, for example a telescopic section of the guide post. Optionally the telescopic section can telescopically contract against a force applied by a spring, which can optionally be energised, e.g. by compression during the contraction of the telescopic section. Optionally the control device can comprise a hydraulic actuator, such as a hydraulic cylinder and piston arrangement, which can optionally be located in the guide post, and which can drive or control the change in configuration between extended and contracted configurations of the decelerator device. The control device can facilitate a soft landing by controlling the landing of the chamber on the frame. The installation vessel winch can then serve as a backup and in some examples, need not be used as the primary control for the movement of the chamber relative to the frame. The mechanism enabling controlled movement of the chamber can optionally be controlled by a remotely operated vehicle (ROV).

Optionally the control device can comprise a mechanical or hydraulic component associated with the guide post with a physical connection to the buoyancy tank such that the buoyancy tank when negatively buoyant would be subject to a controlled lowering into its ballast position.

Optionally the control device can be remote from the guide posts and a hydraulic/mechanical soft landing system can be incorporated into one or more of the chamber cradles.

Optionally the buoyancy device is converted to ballast for the platform assembly by wholly or optionally partially filling the buoyancy chamber with fluid of greater or equal density than the surrounding seawater.

Optionally each frame member comprises at least one cradle for the chamber when said device is filled with dense fluid to convert the chamber from a buoyancy device to a ballast device for the platform assembly. Optionally each cradle comprises a support, optionally an arcuate support, to retain the chamber when converted to ballast and this can help to resist rolling movement. Optionally the cradle comprises a structural web (optionally in the form of a tubular duct shaped to match the arcuate surfaces of the support and the frame member) which is optionally disposed under the support, which reinforces the cradle and helps to resist deformation of the cradle under the force of the ballast. Optionally the web and the support are supported by a support stub, optionally extending perpendicularly to the longitudinal axis of the frame member and optionally acting to support the chamber on the cradle.

Optionally the buoyancy device is lowered to a ballast position by the increase in weight of the device when wholly or partially filled with fluid of greater or equal density than the surrounding seawater. Optionally the buoyancy device is mechanically lowered to a ballast position. Optionally the buoyancy device is lowered using winches, typically from the installation vessel, optionally after ballasting. Optionally the buoyancy device is lowered or triggered to lower using hydraulic means. Optionally the buoyancy device is lowered by activating such hydraulic means remotely, for example by a remotely operated vehicle (ROV).

Optionally, where the chamber comprises multiple compartments, the central compartment of the chamber is dimensioned such that when the central chamber is optionally flooded with seawater ballast, optionally the chamber has a submerged total weight of approximately 20t. Optionally, in this example, there is no requirement for monitoring of or conducting the flooding of the chamber by an ROV. Optionally, descent of the chambers, optionally down at least one guide post, can be monitored by at least one monitoring device, such as an acoustic transceiver. Optionally depth readings are transmitted from the acoustic transceiver and monitored remotely.

Optionally the acoustic transceiver forms part of an acoustic telemetry system. Optionally a coded acoustic signal is sent from the installation vessel and received by the acoustic transceiver. Optionally the signal is sent from an ROV. Optionally the acoustic telemetry system comprises an electronic control pod connected to a solenoid operated hydraulic valve pack. Optionally when the coded acoustic signal is received by the acoustic transceiver, the transceiver transmits an electric signal to the electronic control pod. Optionally hydraulic power is supplied by a bank of charged accumulators, optionally connected into the hydraulic circuits. Optionally, the hydraulic circuits control actuation of the flood and vent valves on the chamber compartments.

Optionally other parameters can be monitored by readings from the acoustic transceiver, for example pitch, roll, or azimuth heading. Optionally these readings are monitored during the towing operation. Optionally they are monitored during the installation of the platform assembly. Optionally the readings are transmitted using at least one direct control umbilical. Optionally the direct control umbilical is directly connected to the electronic control pod. Optionally the direct control umbilical is installed on the platform assembly prior to load-out, and optionally routed to tugs. Optionally a direct control umbilical is pre-installed on at least one chamber, and optionally connected to the control pod. Optionally the umbilical is released and recovered by the installation vessel.

Optionally the compartmentalised chamber can be used in tandem with the winch system. Optionally the winch controls the initial descent of the chamber. Optionally the winch lowers the chamber onto the control device.

Optionally the telescopic cylinder assembly can be connected to the buoyancy device, which can optionally remain connected to the upper telescopic section of the post during movement of the chamber relative to the frame. Optionally this connection can be disconnected to facilitate recovery of guide posts, optionally after installation.

Optionally the guide posts are removably attached to the frame member, and can be removed from the frame member after the chamber is filled with ballast fluid and optionally when it is re-positioned and converted as a ballast device adjacent to the frame. Optionally the guide posts are secured to the frame by latch mechanisms and can be released by mechanical release of the latch mechanisms. Optionally the latch mechanisms are activated and de-activated by mechanical or hydraulic devices. Optionally the latch mechanisms can comprise hydraulic devices and are released by hydraulic means. Optionally the latch mechanisms securing the guide posts on the frame can be released by means of an ROV and are optionally removed from the frame by an ROV or by an installation vessel. Optionally the guide posts remain attached to the frame member after the chamber is filled with ballast fluid and optionally when it is re-positioned and converted as a ballast device adjacent to the frame. Optionally the guide posts are non-removably attached to the frame member.

Optionally the tidal turbine or other marine energy harvester is connected to at least one power umbilical, optionally with one or more (optionally independent and/or temporary) buoyancy devices attached along the length of the umbilical, for example at discrete locations on the umbilical which can be spaced apart on the umbilical to float the umbilical during towing. Optionally the power umbilical is connected at one end to a marine energy harvester, for example, to a tidal turbine nacelle with the opposite end of the umbilical left disconnected. Optionally the opposite end of the power umbilical is connected to a power distribution manifold after the installation of the platform assembly. In certain examples, the power umbilical can be connected in series between sequential marine energy harvesters being deployed. In other examples, the free ends of the power umbilicals can be connected to a power manifold in the field. The free end of umbilical can be stored on the frame, or adjacent frame, during deployment. In the event that power umbilicals are connected in series between sequential platform assemblies, the power umbilicals can optionally be connected between opposite (facing) sides of the frames, so that the marine energy converters in sequential platform assemblies are not in line with one another, but are spaced in a staggered arrangement with respect to one another, to ensure maximum clearance between the umbilical and the towline during towing operations. Optionally a bend restrictor can be incorporated into any power umbilical at, near to or remote from any frame of a platform assembly in order to maintain the power umbilical in a desired configuration and avoid damage to the umbilical.

Optionally the platform assemblies can be installed in a staggered arrangement on the sea bed, which may be helpful in reducing turbulence for the later devices in the sequence, and thereby maximising output of the marine energy converters in the sequence. Optionally, when sequential platform assemblies are landed on the seabed, one of the tugs managing the towing array (e.g. the trailing tug) can apply an offset lateral force anchored against an installed turbine and land-out a second turbine with a lateral offset.

Optionally the frame includes at least one anchor point for securing a tow line from a lead boat to the platform assembly for deployment.

The present invention also provides a method of transporting and deploying a marine energy harvester at an installation site, the method comprising: connecting a marine energy harvester to a frame to form a platform assembly; launching the platform assembly into water, and floating the frame within the water by providing at least one buoyancy device attached to at least one frame member of the frame; towing the platform assembly to the installation site; lowering the platform assembly to its installation site on the seabed; and ballasting the platform assembly using dense fluid in the buoyancy device.

Optionally the frame can have a secondary buoyancy chamber, which can be filled with a buoyant fluid such as air. The secondary chamber optionally forms part of the frame, for example, a horizontal or vertical member on the frame, such as a nacelle support. The secondary buoyancy chamber advantageously does not move relative to the frame. The secondary chamber can have at least one (and optionally more than one) valve or other flow controller to permit adjustment of the buoyant fluid volume in the secondary chamber. The buoyancy can be controlled in the secondary chamber in order to trim or adjust the total buoyancy of the platform assembly, for example, when towing, and can be particularly useful in different phases of towing such as surface and submerged tow operations, when buoyancy requirements can be different. Additional buoyancy of the platform member during initial surface towing operations can raise the nacelle of the marine energy converter out of the water and provide a shallower draft for the platform assembly suitable for shallow water tows. Optionally the secondary member is flooded to control the buoyancy of the platform assembly. Optionally the secondary member is filled with buoyant fluid during surface towing operations.

Optionally the step of lowering the platform assembly to the seabed includes the step of reducing the buoyancy in a secondary, or optionally tertiary or more, buoyancy chamber acting on the frame. Optionally the step of lowering the platform assembly includes the step of increasing the density of a fluid in the secondary buoyancy chamber.

Optionally the frame can comprise a vibration controller, such as a strake or fairing acting as a vortex-induced vibration controller. VIV strakes or fairings can be incorporated on a frame member.

Optionally during load-out from a quay and prior to launch into the water, the chamber(s) are resting in the cradles on the frame members. The guide posts are secured to the frame at their bases, and have the restraint devices fitted and fixed to their upper ends, optionally above the chambers. The guide posts pass through the lined apertures in the chambers, and are releasably latched into the frame members. The marine energy harvester is optionally attached to the frame before launching into the water. During launch, optionally at least one crane, optionally two or more cranes with one on each side of the frame are connected by at least one winch line to the frame for lowering the frame into the water. Optionally as the platform assembly is lowered into the water, the chambers begin to move away from the frame members along a path defined by the guide posts and maintain buoyancy as the platform assembly sinks into the water. The platform assembly is usefully lowered in a level attitude by the crane or cranes, and the movement of the chambers on the guide posts and the speed of descent of the frame is controllable by varying the speed of the crane winches. The weight gradually transfers from the cranes to the chambers until winch line becomes slack, at which point, the buoyant chambers are maintaining flotation of the platform assembly with the frame supported in the water by the buoyant chambers, which are located at the top of the guide posts, held in place by the restraint devices in the form of the caps. The guide posts themselves are optionally latched into the frame members. The alignment devices stabilise the relative movement of the various parts (e.g. chambers & guide posts) and improve stability of the marine energy harvester supported by the frame.

Optionally during transfer when the chamber is floating, the bellmouths of the lined apertures through the chambers react with the conical restraint device on the guide post (or other alignment system) to increase stability of the buoyant chambers relative to the remainder of the platform assembly.

Optionally the load-out of the frame with/without the marine energy harvester could be performed from a dry dock facility, the frames being floated out when the dry dock is flooded. Optionally ballast chambers within the structural members of the frame may be filled with ballast, for example aggregate, cement, grout or similar, prior to load-out. Optionally, as the frames enter the water and the water level rises around the frame, the chambers float up the guide posts.

Optionally at least two platform assemblies are linked together by at least one tow line (optionally more than one tow line) and towed to the installation site at one time. Optionally several platform assemblies, e.g. three, four, or five etc. are linked together by a single tow line between each sequential pair and towed in a daisy-chain to the installation site. Optionally the platform assembly or assemblies are towed along the sea surface and submerged at the installation site. Optionally the platform assembly or assemblies are towed in a submerged state above the sea bed, and optionally below the wave affected zone; towing is optionally by a single tow vessel, and optionally by leading and trailing tow vessels. Optionally ballast devices such as clumpweights (e.g. chain) are attached to the or each of the tow lines between the platform assemblies. Optionally clumpweights are attached to the or each of the tow lines between the tow vessels and the platform assemblies, to form a submerged tow configuration optionally with at least one non-linear tow line (e.g. v-shaped) between sequential platform assemblies. Optionally the one or more tow lines to which the clumpweights are attached adopt a v-shaped configuration in the submerged tow configuration, with the nadir at the point of clumpweight attachment. Optionally this configuration assists with stability of the towed array of platform assemblies. Optionally this configuration acts as a motion damper to reduce impacts that would otherwise be transferred to the platform assemblies, and can minimise tow line movement and overall towing force. The configuration also increases compliance between platform assemblies in the towed array, as different assemblies in the array can move relative to one another more freely while being towed. The submerged towing arrangement also reduces fatigue on the components of the platform assemblies and the tow lines. Optionally the platform assemblies are towed in series. Towing the platform assemblies in series in the submerged configuration is particularly beneficial when connected by non-linear tow lines, for example v-shaped tow lines, that have ballast devices between sequential platform assemblies because adjacent platform assemblies in the series optionally tend to oscillate in the water in a sympathetic manner, e.g. in opposite directions. For example, when one platform assembly is ascending through the water column relative to the surface and the seabed, the adjacent assemblies in the series optionally tend to be descending. This contrary movement of adjacent assemblies in the series tends to even out loads on the tow lines, increases compliance and further reduces fatigue in the system. It also tends to limit the amplitude of movement of the assemblies, resisting the continued descent or ascent of any particular assembly or group of assemblies, which reduces drag and the risk of ascent of the platform assemblies into the wave affected zone (where collusion with floating debris on the surface is likely) or descent towards the seabed (where collision is likely with seabed formations).

Optionally the buoyancy devices are latched to the guide posts by a latch device during towing and optionally during lowering of the frame to the submerged substrate, preventing movement of the tanks up and down the axes of the posts. Optionally the latch can be deactivated after landing of the frame on the submerged substrate and before movement of the buoyancy devices. The restraint device at the top of the posts which allows sliding movement of the tanks down the posts, but resists disconnection of the tanks from the posts optionally retains the tanks on the posts in the event of deactivation of the latch. Optionally the buoyancy devices are latched to an upper portion of the guide posts.

Optionally once the platform assembly is at the installation site, the chamber(s) are at least partially filled with fluid of density not less than seawater. Optionally this partial filling with fluid of density not less than seawater may have been performed prior to towing. Optionally the fluid of density not less than seawater may be iron ore slurry or the like. Optionally the fluid of density not less than seawater may be grout, cement, aggregate or similar. Optionally both the chambers and ballast compartments in the structural members of the frame base may be at least partially filled with dense fluid such as iron ore slurry, grout, cement, aggregate or the like prior to towing.

The addition of ballast prior to load-out, and optionally the increased size of the buoyancy chambers, offers the advantage that the required height of the chambers to achieve stability of the platform assembly during towing, particularly during a submerged tow, is lowered. In this example, it then may be the case that the guide posts can be left in position post-installation rather than removed.

Optionally the filling of the chamber(s) with the higher density fluid is controlled remotely, optionally from an ROV or from the installation vessel. Optionally the fluid can be seawater, optionally admitted passively from the local environment around the platform assembly on the sea bed, or the fluid can be more dense than seawater, for example, drilling mud, and can optionally be pumped actively from a remote reservoir, which can optionally be on board the installation vessel. Optionally an ROV is utilised to open flood and vent valves on the chamber(s). Optionally the chamber(s) is only partially filled with the increased density fluid, to maintain some buoyancy. Optionally once the chamber(s) are partially-filled with fluid, the ROV closes the flood and vent valves.

The partial flooding of the chambers (normally by passive admission of seawater at this stage) reduces the buoyancy in the chambers, and the platform assembly becomes overall negatively buoyant and sinks to the submerged substrate at the installation site, optionally in a controlled manner. Optionally the platform assembly can be supported during the descent to the submerged substrate at the installation site by a winch, which can optionally be on the installation vessel. Optionally the rate of descent can be controlled by adjusting the buoyancy in the tanks. While the platform assembly as a whole is then negatively buoyant, the chambers themselves are optionally still positively buoyant. Hence, when in place on the submerged substrate, for example, on the seabed, the chambers are optionally still partially filled with buoyant fluid, are themselves positively buoyant and are therefore still at the upper ends of the guide posts, spaced away from the frame, and engaged with the restraint devices on the upper ends of the guide posts. Partial buoyancy in the chambers optionally stabilises the assembly and can be used to limit its speed of descent (or its weight) during lowering to the submerged substrate.

Instead of filling the buoyancy chambers with seawater or more dense fluid, in some examples, the buoyancy chambers can retain at least some of the buoyancy, and the change in buoyancy can be accomplished by reducing the buoyancy of a secondary buoyancy chamber on the frame, optionally by admitting seawater into the secondary chamber. Optionally the secondary chamber is static on the frame. Optionally the secondary chamber is symmetrically positioned on the frame. Optionally the secondary chamber can be flooded with a single valve operation. Optionally the secondary chamber can be flooded with more than one valve operation. Optionally

the different compartments or chambers can be flooded at different times. Optionally the secondary chamber is flooded to make the platform assembly negatively buoyant. Optionally the secondary chamber can comprise a frame member which can be reinforced internally to retain pressure. Optionally the secondary chamber can be connected to a frame member. Optionally the flooding operation can be carried out by remote acoustic actuation.
Optionally during the installation procedure, the ROV can dock with the platform assembly, optionally with a docking plate located on the frame of the platform assembly. Optionally the ROV thrust can be used to control the heading of the platform assembly during the landing operation. Optionally the ROV docking plate serves as a docking point for the ROV for control of the landing operation, and optionally a docking point for the ROV for the flooding and venting operations on a ballast/buoyancy chamber disposed within at least one of the structural members of the frame, for example the central structural member or members.

Once the platform assembly is in place on the submerged substrate, the chambers are then optionally converted from buoyancy devices to ballast devices by displacement of the buoyant fluid by denser fluids acting as ballast. Initially the chambers are lowered into their ballast configurations as follows: Optionally at least one winch is deployed over the side (or optionally an A-frame) of the installation vessel and at least one winch line is connected to rigging on the chamber, so that the chamber can be supported and controlled during the lowering of the chamber to the frame. Optionally the control device decelerates the chambers and provides a soft landing on the frame. Optionally a motion compensator device such as a cranemaster device can be provided in each winch line to reduce the effects of vessel heave on the lowering of the chamber towards the frame. Optionally at least one winch (optionally with a bridle rigging arrangement supporting both ends of the chamber but with the load centred between the chamber ends) is provided per chamber to more effectively control the lowering of the chamber towards the frame. Optionally an ROV is used to connect the winch line to the chamber. Optionally the winch line is connected to pre-installed rigging on the chamber and the line is initially left in a slack condition. Optionally an ROV reopens the flood and vent valves of the chamber(s) to continue flooding, optionally by seawater admitted from the surrounding environment, but optionally this could be done by pumping a more dense fluid from a local or remote reservoir. Optionally the position of the chamber is monitored, optionally by an ROV, and when the chamber becomes negatively buoyant and starts to move down the guide posts the slack is taken up on the winch. Optionally the winch line tension is used to assess the submerged weight of the chamber while maintaining the position of the chamber relative to the frame member.

Optionally once the chamber is negatively buoyant, and can sink under its own weight, the winch line is paid out and the chamber optionally moves down the guide posts towards the frame member. Optionally each chamber is flooded concurrently. Optionally each chamber is lowered via the winch individually. Optionally more than one (e.g. each) chamber is lowered concurrently. Optionally this movement is controlled by the payout rate of the winch line.

Optionally once the winch load reaches a given value, for example a predetermined value in a range of 5-20t, the ROV closes the flood and vent valves so that the chamber density does not increase any further which helps to avoid overloading the winch. Optionally the winch line is then paid out to lower the chamber down the guide posts until it is received by the cradles on the frame member. Optionally the winch is then disconnected and the ROV again opens the flood and vent valves to fully flood the chamber with the denser fluid. Optionally once the chamber is fully filled its use is then fully converted to ballast for the platform assembly and is then acting as a ballast device.

Optionally the second chamber is then flooded and lowered in exactly the same manner as the first chamber. Optionally the second chamber is initially flooded at the same time as the first chamber in order to ensure stability of the platform assembly. Optionally the ROV closes the flood and vent valves on the second chamber when it is still positively buoyant and located at the top of the guide post.

Optionally, in a scenario where a winch is not used, the chambers are initially lowered into their ballast configurations as follows: an ROV operates the flood and vent valves on the chamber, optionally on selected compartments within the chamber, optionally allowing the chamber to freely flood. Optionally the chamber reaches negative buoyancy and descends down the guide posts. Optionally the control devices act to decelerate the chamber, which is then optionally received by the cradles on the frame member, without surface intervention. Compartmentalised chambers optionally have separate flood valves on each compartment allowing each compartment to be flooded by sequentially opening each valve.

Once the platform assembly is in place on the submerged substrate, the chambers are then converted from buoyancy devices to ballast devices by displacement of the buoyant fluid by denser fluids acting as ballast. This can be seawater in some examples, but in some examples the fluid used for final ballasting is denser than the fluid in the surrounding environment, and advantageously displaces the seawater from the chambers. The denser fluid can be pumped or flowed actively or passively and is optionally delivered through a conduit connecting a flood valve on the chamber with a reservoir for the dense fluid, which can optionally be located on the installation vessel. Optionally the chambers are at least partially filled with fluids having different phases, for example, gravels or slurries, containing solid particulates in a liquid phase behaving overall as a flowable fluid, but comprising solids mixed with liquids. One example is iron ore gravel, which can be flowed into the chambers to ballast them during installation or on load out prior to deployment of the platform assembly into the water, and which could be deballasted partially on decommissioning by flowing the liquid phase out of the chambers and leaving at least some of the solid particulate material in place in the chamber.

Optionally one or more chambers are ballasted by pumping with drilling mud. Optionally one or more chambers are ballasted with cement. Optionally one or more chambers are ballasted by a fluid that remains in a fluid state during the operational lifetime of the tidal turbine and can be pumped out of one or more chambers during decommissioning of the platform assembly.

Optionally when the chambers are ballasted, and resting in the cradles on the frame member, the guide pins securing the guide posts and the guide posts themselves are released and removed from the frame member, and optionally recovered by the installation vessel. Optionally the chamber is connected to the frame member after removal of the guide posts. Optionally the chamber is connected to the frame member by a mechanical connection, optionally by a hydraulic connection. Optionally the chamber is connected to the frame member by a pin. Optionally the connection is lockable.

Optionally the installation vessel recovers the tow lines and clumpweights between the platform assemblies following installation.

Optionally the frame is supported on the submerged substrate, for example by mudmats disposed on the underside of the frame. Optionally the frame is landed directly onto the submerged substrate.

In another example, several frames, optionally with tidal turbines connected, optionally with power umbilicals connected, are loaded out onto a submergence vessel or barge. The frames are then optionally transported to an assembly site, optionally near to the installation site. Optionally the frames are offloaded at the assembly location and the platform assembly configured. Optionally the assembled platform assemblies are then towed by tugs to the installation site for installation. This method of assembly is envisaged as being useful in the event that, for example, the fabrication site of the frames is too distant from the installation site for a practical tow duration.

The present invention further provides a method of decommissioning a frame for supporting a marine energy harvester installed at a submerged installation site, the frame having at least one chamber adapted for containing a buoyant material and serving as a buoyancy device; the method comprising:
increasing the buoyancy of the platform assembly by decreasing the density of the fluid contained within the at least one chamber and raising the platform assembly above its submerged installation site; and
towing the frame to a decommissioning site.

Optionally, the method includes recovering a power converter optionally in the form of a nacelle and optionally recovering an umbilical from the frame by means of a decommissioning vessel, optionally before recovery of the frame. Optionally the method includes configuring tow lines and optionally ballast devices such as clumpweights between the frames as previously described in relation to the installation. Optionally the method includes mechanically connecting the chamber(s) to the frame before the step of towing the frame to the decommissioning site, optionally after removal of the guide posts, optionally after installation. Optionally the frames are submerged and connected in series during the towing step.

Optionally for decommissioning the installation procedure could be fully reversed and the full assembly, including power converter (e.g. nacelle) and umbilical, could be towed to the decommissioning site. Optionally the guide posts could be reinstalled and the buoyancy chambers could be raised above the frame, but in some examples, once the buoyancy chambers are contiguous with the frame and converted to ballast chambers during the installation procedure, they can be secured to the frame, optionally at that time, and can optionally remain in that secured contiguous configuration during decommissioning. Optionally the chambers can be secured to the frame during the decommissioning process.

Optionally the modular sections of the platform assembly e.g. the turbine nacelle and power umbilicals are disconnected from the frame and recovered by a decommissioning vessel before the platform is re-floated.

Optionally the decommissioning vessel installs tow lines and clumpweights between the platform assemblies (without nacelle and power umbilical), and these are optionally connected by the ROV.

Optionally the ROV launched from the decommissioning vessel connects fluid lines to the chambers and then opens valves to pump out a portion of the ballast fluid contained within the chambers and replaces the volume of fluid removed with air or with another fluid less dense than water. Optionally once a portion of the fluid is removed, the chambers are converted once again to buoyancy devices. Optionally once a portion of the fluid is removed, the ROV closes the valves. Optionally the ROV monitors the pumping operation and when the frame becomes positively buoyant and floats up off the seabed in a controlled manner the pumping operation is stopped and the ROV closes the valves. Optionally this operation is repeated for two, three, four or five platform assemblies. Optionally the buoyancy is controlled so that the frame floats above the seabed, but optionally below the wave affected zone.

Optionally the frame comprises releasable ballast weights, optionally for use in the decommissioning process. Optionally release of the ballast weights during decommissioning compensates for incomplete venting of the chamber(s), and optionally ballast/buoyancy compartments within the frame.

Optionally at least one tow vessel then tows the frames in series in a submerged or a surface configuration, optionally with v-shaped tow lines as previously described, in the same manner as described in the installation of the platform assemblies.

In one example during decommissioning the power converter (e.g. the nacelle) and umbilical can be removed by a decommissioning vessel, and the ballast chambers can be mechanically connected to frame to enable recovery of the frame and the chambers together. The guide posts can optionally be removed after installation and can be recovered as one of the installation steps. Likewise, the mechanical connection between the ballast chambers and the frame can be completed at installation.

Optionally several recovered frames are towed in a series linked daisy-chain back to the quayside. Optionally the modular sections of the platform assembly, e.g. the turbine nacelle, are disconnected from the frame before recovery, and parts of the platform assembly are recovered separately.

Examples of the invention will be described with reference to a tidal turbine device, but the examples are suitable for use with other types of marine energy harvester such as wave energy converters.

The various aspects of the present invention can be practiced alone or in combination with one or more of the other aspects, as will be appreciated by those skilled in the relevant arts. The various aspects of the invention can optionally be provided in combination with one or more of the optional features of the other aspects of the invention. Also, optional features described in relation to one example can optionally be combined alone or together with other features in different examples of the invention.

Various examples and aspects of the invention will now be described in detail with reference to the accompanying figures. Still other aspects, features, and advantages of the present invention are readily apparent from the entire description thereof, including the figures, which illustrates a number of exemplary constructions and aspects and implementations. The invention is also capable of other and different examples and aspects, and its several details can be modified in various respects, all without departing from the spirit and scope of the present invention. Accordingly, the drawings and descriptions are to be regarded as illustrative in nature, and not as restrictive. Furthermore, the terminology and phraseology used herein is solely used for descriptive purposes and should not be construed as limiting in scope. Language such as "including," "comprising," "having," "containing," or "involving," and variations thereof, is intended to be broad and encompass the subject matter listed thereafter, equivalents, and additional subject matter not recited, and is not intended to exclude other additives, components, integers or steps. Likewise, the term "comprising" is considered synonymous with the terms "including" or "containing" for applicable legal purposes.

Any discussion of documents, acts, materials, devices, articles and the like is included in the specification solely for the purpose of providing a context for the present invention. It is not suggested or represented that any or all of these matters formed part of the prior art base or were common general knowledge in the field relevant to the present invention.

In this disclosure, whenever a composition, an element or a group of elements is preceded with the transitional phrase "comprising", it is understood that we also contemplate the same composition, element or group of elements with transitional phrases "consisting essentially of", "consisting", "selected from the group of consisting of", “including”, or "is" preceding the recitation of the composition, element or group of elements and vice versa.

All numerical values in this disclosure are understood as being modified by "about". All singular forms of elements, or any other components described herein are understood to include plural forms thereof and vice versa. References to directional and positional descriptions such as upper and lower and directions e.g. “up”, “down” “front”, “rear”, “upper”, “lower” etc. and related terms are to be interpreted by a skilled reader in the context of the examples described and are not to be interpreted as limiting the invention to the literal interpretation of the term, but instead should be as understood by the skilled addressee.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 shows a schematic front view of the frame with guide posts, chambers not shown;

Figure 2 shows a schematic top view of the frame of figure 1;

Figure 3 shows a schematic side view of the frame of figure 1;

Figure 4 shows a schematic front view of the frame with chambers in their first buoyant configuration;

Figure 5 shows a schematic top view of the frame with chambers in position and optional releasable ballast weights;

Figure 6 shows a schematic side view of figure 4 and optional acoustic transceiver assembly;

Figure 7 shows a schematic front view of the frame with chambers in an interim negatively buoyant configuration as they move towards the base of the guide posts;

Figure 8 shows a schematic side view of figure 7;

Figure 9 shows a schematic front view of the chambers in the ballast position with the guide posts in place;

Figure 10 shows a schematic side view of figure 9;

Figure 11 shows a schematic front view of the frame with the chambers in the ballast position with the guide posts removed and integrated flared bellmouths within the pipe through the bore in the chamber;

Figure 12 shows a schematic side view of figure 11 and an illustration of the optional feature of buoyancy/ballast compartments within the chamber;

Figure 13 shows a schematic front view of the platform assembly comprising the frame, chambers and tidal turbine;

Figure 14 shows a schematic front view of an alternative embodiment of the frame with telescopically retracting guide posts;

Figure 15 shows a schematic side view of figure 14;

Figure 16 shows a cross-section of the mud mat and cradle assembly;

Figure 17 shows a perspective view of a frame with an example of a tidal turbine support structure connected to it with a representation of the span of the turbine blades when fitted, the frame in a partially submerged position with the chambers maintaining buoyancy;

Figure 18 shows an example of a surface tow of several platform assemblies with lead and trail tugs;

Figure 19 shows an example of a submerged tow of several platform assemblies with power umbilicals between platform assemblies, and clumpweights attached to the towlines;

Figure 20 shows a schematic front view of an alternative embodiment of the invention with an internal interface between the guide posts and the chambers;

Figure 21 shows a schematic top view of the apparatus of figure 20 with an alternative example of ballast/buoyancy chambers forming some of the frame base members;

Figure 22 shows a schematic side view of figure 21

Figure 23a-c shows alternative interfaces between the guide posts and the chambers.

DETAILED DESCRIPTION OF THE INVENTION

Referring to figures 1-3, a first schematic example of a frame 1 for transporting, installing and decommissioning tidal turbines is shown without chambers acting as buoyancy devices. Four guide posts 5 are positioned with two connected to each frame member 10. The guide posts pass through bores 12 in the frame member 10 and are each secured by guide pins 6, or by some other attachment mechanism such as a latch device, bayonet mechanism, etc. The frame shown in these figures is illustrative in nature and in ordinary use the guide posts would be connected to the frame and would be passing through chambers acting as buoyancy devices. Each frame member 10 comprises a plurality of cradles 11, for example three cradles, for the chambers when they are seated at the bottom of the guide posts 5. The frame 1 is optionally supported on the sea bed by mudmats 21 located at each end of the frame members 10. A cross-section of a mudmat 21 and cradle 11 is shown in Figure 16, with the cradle supported by a structural web 11w above a support stub 11s. The frame base 20 is disposed between the frame members 10 with a plurality of base members, for example three base members, extending perpendicularly to the longitudinal axis of the frame members 10. Two of the base members have bores 73 or other fixtures for receiving and retaining a tripodal support structure for a tidal turbine nacelle. Optionally the support structure for the nacelle is welded to the base members. Optionally the frame base 20 can have a different arrangement of bores or other attachment means to accommodate different styles of support structure, for example a single stem. The arrangement and type of fixtures such as the bores 73 can be varied in different examples.

Components of the platform assembly can incorporate or comprise a vortex-induced vibration controller such as a VIV strake or fairing. VIV strakes or fairings can be incorporated on the frame 1, for example, on a frame member 10, or on components of the base 20, particularly the peripheral components of the base 20.

The guide posts 5 each have a conical restraint device 7 disposed at their upper ends that interface with the chambers as they move, either through changes in buoyancy or movement of the frame 1 or platform assembly once the tidal turbine is connected. The restraint devices 7 provide a canted surface optionally in the form of a cone, which engages with a part of the chamber as will be described below. When the platform assembly is under tow to the installation site, the effects of the drag on each chamber also leads to interfacing of the chambers with the guide post 5, which acts to retain the chambers on the platform assembly and resists separation.

Figure 2 shows the optional inclusion of a static secondary buoyancy device 20s centrally and symmetrically positioned over the centre of gravity of the frame, within one of the frame base members 20. The secondary buoyancy device is not represented in the remaining figures as it may not feature in all embodiments of the invention. The secondary buoyancy device 20s may be contained within one of the frame base members 20, or it may form a frame base member itself.

The reader will appreciate that the various descriptions of above, below, front, rear and sides etc. in this disclosure are mentioned in the context of the orientation of the examples described in the figures, but these features are not intended to be limiting and can be modified in other examples of the invention.

Figures 4-6 show the chambers acting as buoyancy devices in the form of cylindrical tanks 40 at their first, buoyant configuration. Each frame member 10 has a tank 40 disposed above it to maintain balance of the frame 1 and the platform assembly when the tidal turbine is connected. The tanks 40 have a bore 45 through which the guide post 5 passes. The bore 45 terminates in a flared or canted interface in at least one end and is lined along its length by a pipe. Optionally the interface extends beyond the bore 45, and can optionally be welded to the end of the pipe through the bore 45, for example in the form of a flared bellmouth. In this example the interface is integrated within the bore 45 and does not extend beyond the outer surface of the tank 40. These pipes and interfaces react with the guide post 5 to allow for minor misalignment during movement of the tanks 40. The pipes through the bores 45 and the corresponding interfaces also assist with the restraint of the tanks 40 when the platform assembly is under tow.

Figure 5 shows the optional inclusion of removable ballast weights 25 centrally and symmetrically positioned on either side of the frame. The removable ballast weights 25 are not represented in the remaining figures as they may not feature in all embodiments of the invention. The releasable ballast weights 25 can be used in the decommissioning process. Release of the ballast weights 25 during decommissioning can compensate for incomplete venting of the tanks 40, and optionally ballast/buoyancy compartments within the frame 1.

Figure 6 shows the optional inclusion of at least one acoustic telemetry system 43 attached to the top of a tank 40. The acoustic telemetry system 43 is not represented in the remaining figures as it may not feature in all embodiments of the invention. The acoustic telemetry system 43 can comprise an acoustic transceiver, an electronic control pod connected to a solenoid operated hydraulic valve pack, and a bank of charged accumulators, connected into the hydraulic circuits. Descent of the tanks 40 down the guide posts 5 can be monitored by the acoustic transceiver 43, with depth readings being transmitted from the transceiver 43 and monitored remotely.

A coded acoustic signal is sent from an installation vessel or an ROV and received by the acoustic transceiver. Optionally, when the coded acoustic signal is received by the acoustic transceiver, the transceiver transmits an electric signal to the electronic control pod. Hydraulic power is supplied by the bank of charged accumulators and consumed by the hydraulic circuits to control actuation of the flood and vent valves on the tanks 40.

Optionally when the tanks 40 are in the buoyant configuration, they can be connected to the top of the guide post 5 by a latching device and held in place during tow, although this is not essential and in some cases, buoyant tanks can be forced against restraint devices on the tops of the guide posts by the buoyant force alone, without any requirement for a mechanical latching device. Optionally the tanks 40 are connected to the guide posts by a hydraulically operated latch. Optionally the tanks 40 are connected with a temporary mechanical connection such as a pin.

Optionally the connection is released, for example, by an ROV prior to flooding of the tanks 40 at installation.

In this configuration the tank 40 is at least partially filled with a fluid that is less dense than sea water, e.g. air. When the frame is out of the water the tanks 40 are resting in the cradles 11 on the frame member 10, at the bottom of the guide posts 5.

The platform assembly is deployed by first lowering the frame 1 into water from e.g. a quay. Optionally, two (or more) cranes are used to lower the frame, one on each side of the frame. The frame 1 is connected to the cranes by winch lines which pay out and support the frame as it is lowered, maintaining the balance of the frame as the chambers move away from the frame along a guided path corresponding with the axes of the guide posts. The support structure for the tidal turbine or other marine energy harvester is connected to the frame 1 optionally during the frame fabrication or on the quayside or after it has stabilised in the water. Finally, the nacelle is lowered onto the support structure to complete the platform assembly, although this can also be done on the quayside. Optionally the overall frame, support structure and tidal turbine assembly is buoyant. Power umbilicals are optionally connected to the nacelle on the quayside or once the turbine has been assembled in the water. Optionally the load-out of the frame with/without the tidal turbine assembly could be performed from a dry dock facility, the frames being floated out when the dry dock is flooded.

Once the platform assembly 50 is complete (Figure 17) a tow line 91 is connected to the frame. Optionally a tow line 91 can be connected to each frame member 10, or frame base 20, or tank 40, to maintain balance. Optionally the tow line can be connected to the marine energy harvester on each platform assembly. The tow line stretches between the platform assembly and a lead tug, optionally an installation vessel. Optionally, as shown in Figures 18 and 19, several platform assemblies 50 can be connected together by tow lines 91 to create a daisy-chain of assemblies 50 being towed behind the lead tug 90. A trail tug can optionally be included at the end of the towed configuration. This allows for the installation of several tidal turbines in a single tow, reducing the number of return trips the tugs needs to make between the quay and the installation site.

The series of platform assemblies are towed on or below the surface to the installation site. The platform assemblies can be towed to the installation site with the tanks 40 partially flooded, provided that the overall buoyancy of each platform assembly is not negative, and sufficient to prevent the assembly from sinking. The buoyancy during towing can be sufficient to maintain the tanks 40 on the surface, but this is not necessary, and in some cases, it is advantageous to tow the series of assemblies submerged (but optionally at a stable and consistent depth) optionally below the wave affected zone. Optionally the tow is on the surface in shallow water, upon reaching deeper water clumpweights 91c (e.g. chain) are introduced into the tow lines 91 (Figure 19) to enable the platform assemblies to be submerged. Optionally in the submerged tow the clumpweights induce a “V-shape” into the tow lines between the platform assemblies and between the tugs and platform assemblies. The function of this “V-shape” is to introduce compliance in the tow lines and to minimise the transfer of tow vessel motions to the platform assemblies during the tow. Thus the tanks 40 are themselves buoyant, and maintain the buoyancy of the overall platform assembly until the installation point is reached. When submerged the buoyant tanks 40 will generally be located at the tops of the guide posts 5, with the remainder of the assembly suspended below the tanks 40. The platform assemblies in the series can be at the same or different depths. The depth of the platform assemblies can optionally vary during the tow and is dependent upon the tow line configuration, and optionally sequential assemblies in the series adopt different depths at the same time. Also, the platform assemblies in the series are optionally towed out of line with one another in the series, so that they are landed in installation sites that are not aligned, and this is advantageous because the flow of fluid past and through the marine energy converters on the frames can thereby be enhanced. Optionally the platform assemblies can be installed in a staggered arrangement on the sea bed, which may be helpful in reducing turbulence for the later devices in the sequence, and thereby maximising output of the marine energy converters in the sequence. Optionally, when sequential platform assemblies are landed on the seabed, one of the tugs managing the towing array (e.g. the trailing tug) can apply an offset lateral force anchored against an installed turbine and land-out a second turbine with a lateral offset.

When the installation site is reached, the tow lines are paid out to bring the platform assemblies close to the seabed, the tanks 40 are at least partially flooded with seawater in order to make the platform assembly negatively buoyant and position it onto the seabed in a controlled manner. Optionally instead of flooding the tanks 40, which can optionally retain the same buoyancy without loss of buoyant fluid, one or more secondary buoyancy chambers 20s containing buoyancy fluid such as air during launch and towing operations can be flooded with seawater at the installation site, while the tanks 40 retain at least some (or all) of their buoyant fluid. The secondary buoyancy chamber(s) can optionally comprise a portion of a structural member of the frame which can optionally be symmetrically arranged on the frame, and can be fixed in position on the frame. An installation vessel optionally deploys an ROV to perform the valve operations for the flooding operation.

Optionally the platform assembly can be allowed to sink freely from the tow depth to the seabed under the control of the buoyancy in the tanks 40 and without any winch control, but in some examples, the platform assembly can be lowered to the seabed by a winch from the installation vessel, which can bear part or all of the load. It is advantageous that at least some of the load is borne by buoyancy in the tanks 40, to reduce the load on the winch.

When the platform assembly is correctly positioned on the seabed, a winch line is deployed over the side of the installation vessel and is connected to one tank 40 and left in a slack condition. Optionally, two winch lines can be connected to the same tank. When in place on the submerged substrate, the tanks 40 are normally disposed at the tops of the guide posts 5, as they still retain some residual buoyancy.

When the platform assembly is in place on the seabed, with the tanks 40 still partially buoyant and with the winch lines connected between the installation vessel and the tanks 40, the tanks 40 are flooded (optionally completely) with seawater as the ROV opens the valves. Optionally the tanks are flooded in stages. One tank 40 is partially flooded such that it retains some buoyancy, and at that point, the ROV closes the valves to retain that partial buoyancy within the first tank. Immediately before the flooding stage, the tank 40 is optionally still buoyant and positioned at the top of the guide post. At this stage of the process, the winch line has optionally already been attached to rigging on the tanks 40, optionally before flooding of the tanks commenced, although in some cases, the winch line can be connected after the tank 40 is partially flooded. Optionally the rigging has been preinstalled at the quayside. Optionally the tank 40 has a connection point moulded or fixed into it for the winch line. An ROV can also be used to connect the winch line to the tank 40.

The winch line is left slack during the flooding until the tank 40 starts moving down the guide post, after the tank 40 has become negatively buoyant. The winch line movement is detected by the winch control and the winch line is then recovered by the installation vessel at the surface until substantially all slack is taken up and it is bearing the load of the tank 40. Optionally, a motion damper is connected in the winch line to reduce the effects of vessel heave on the tank lowering operation. An ROV is optionally used to open the flood and vent valves of the tank 40 to permit ingress of seawater into the tank 40. The winch line tension can be used to gauge the volume filled while maintaining the position of the tank 40 relative to the frame member 10 close to or at the tops of the guide posts 5. Once the winch load has reached a threshold which can vary in different examples, but in this case is in the range 5t-20t, e.g. 5-10t and optionally close to 10t, the ROV closes the valves to stop the flooding operation, so that the load on the winch then remains relatively constant. The winch then lowers the tank 40 into its cradle supports 11 in a controlled manner. The load carried by the winch is reduced because of the residual buoyancy in the partially filled tank 40 (although the tank is still negatively buoyant at this point). The amount of buoyancy is controlled by closing the flooding valves at the required time. Figures 7 and 8 show the tanks 40 disposed at a halfway point of the guide posts 5. The tanks 40 have been partially filled with the dense fluid and at this stage are negatively buoyant and are moving down the guide posts 5.

Once the tank 40 has been lowered into contact with the cradle supports 11 on the frame, the ROV can open up the flood and vent valves on the tank 40 to fully flood it with seawater. The same operation is then repeated to lower the second tank 40 into its cradle supports.

Figures 9-14 show the tanks 40 in the second configuration after being fully flooded with seawater. Here the tanks 40 are resting on the cradles 11 and acting as ballast for the platform assembly in place on the seabed. The installation vessel then optionally pumps the dense ballast fluid into the tanks 40 to increase the ballast in the tanks 40. In the ballasting process, the winch line is disconnected and the ROV optionally connects fluid lines to the tanks 40 and opens valves to pump a denser fluid into them to complete the ballasting operation. The ballasting step and the flooding step can each be omitted. For example, the tanks 40 can simply be flooded with seawater without being filled with denser ballasting fluid, or can be filled with denser ballasting fluid without being flooded with seawater. However, the two steps are useful in combination, as the movement of the tanks 40 is more controllable if they are filled or partially filled with seawater during the flooding process, and then only ballasted with dense fluid after they are contiguous with the frame.

The tanks 40 have now been converted to serve as ballast devices instead of buoyancy devices.

The dense ballast fluid can be seawater, but is optionally drilling mud, cement, or another fluid that is no less dense than water (e.g. more dense than water), in order to convert the use of the tanks 40 from buoyancy devices to ballast devices, when the assembly is in place at the installation site and stably located on the submerged substrate. Optionally the fluid can be of a kind that remains fluid throughout the operational lifetime of the tidal turbine, in order for the fluid to be pumped back out of the tanks for decommissioning of the turbine and to return the tanks 40 to their buoyant state. Optionally the fluid can be a suspension of particulates comprising a dense solid and a liquid. Optionally the dense solid can remain in the tanks after decommissioning, while the fluid can be pumped out.

Optionally the tanks 40 may have more than one compartment 40c, 40e, 40m contained therein for ballasting and buoyancy. Figure 12 shows the optional inclusion of compartments 40c, 40e, 40m. In the illustrated example, there are five compartments 40c, 40e, 40m contained within the tank 40, with a central compartment 40m, and the four remaining compartments 40c, 40e symmetrically placed on either side of the central compartment 40m. The compartments 40c, 40e, 40m are not represented in the remaining figures as they may not feature in all embodiments of the invention.

Optionally the central compartment 40m has a greater volume than the other compartments 40c, 40e. Optionally the compartments 40c, 40e, 40m are equally sized. Optionally each compartment 40c, 40e, 40m has its own flood and vent valves. Optionally only some of the compartments 40c, 40e, 40m have flood and vent valves, for example, if a compartment is permanently ballasted it does not require valves.

Optionally the compartments 40c, 40e disposed at either side of the main compartment are configured to contain ballast, for example seawater, or alternatively iron ore slurry, grout, cement, aggregate, or the like. Optionally, each of the outermost compartments 40c is filled with ballast prior to load-out. Optionally the compartments 40c, 40e of the chamber are symmetrically balanced around the centre of the chamber 40m. Optionally the central compartment 40m (or compartments) is at least partially filled with air.

Optionally when the tanks 40, acting as ballast devices, are resting in the cradles 11 on the frame member 10 and full of dense ballast fluid, the guide pins 6 securing the guide posts 5 and the guide posts 5 themselves can be removed from the frame member 10, and can be recovered by the installation vessel. Figures 11 and 12 show the removal of the guide posts 5 from the frame member 10 and tanks 40. The tanks 40 are now acting as ballast devices for the platform assembly. The disconnection of the guide posts 5 is optionally performed by the ROV, through mechanical or hydraulic means. Optionally once the guide posts 5 have been removed, the ROV enables a mechanical connection to connect the tank 40 to the frame member 10. Optionally the connection is a hydraulic latch. Optionally the connection is in the form of a pin.

Figure 13 shows an example of the platform assembly 50 with the tidal turbine 70 in place. The nacelle 71 is connected to the support structure 72, in this case a tripod. The support structure 72 is in turn connected to the frame base 20. The tanks 40 are in the ballast position, resting in the cradles 11 on the frame members 10.

Figures 14 and 15 show an alternative embodiment of the frame 101 with telescopically retracting guide posts 105. These guide posts 105 optionally provide a soft landing to a tank approaching the cradles 111. Optionally this soft landing requires no operator intervention. Optionally the guide posts 105 can be hydraulically retracted. When the tank 40 is buoyant, it floats at the top of the posts engaging with the restraint devices 107 at the top of each post 105, and when the tank 40 loses buoyancy during the flooding or ballasting steps, it moves closer to frame members

110 to rest in the cradles 111and the guide post sections 105 telescopically collapse inside one another, and together inside the bore of the tank 40. Optionally the tank 40 can be latched to the tops of the posts 107. The collapse of the telescopic sections of the guide posts 105 is controlled by a hydraulic piston and cylinder arrangement inside the guide posts, which acts as a resilient spring device decelerating the tank 40 as it approaches the cradles 111. Optionally the deceleration is only needed at the last stage of the movement, to prevent damaging collisions at high speeds between the tank 40 and the cradles 111. Other types of deceleration device can be used. Optionally the control device can be incorporated within the cradles 111.

Once the tidal turbine has reached the end of its operational lifetime, it must be decommissioned by removal from the installation site and recovery back to land. The decommissioning process can optionally be substantially the reverse of the installation process.

For the decommissioning process, a decommissioning vessel can recover any power converter (e.g. a nacelle) on the frame and any power umbilical as a separate step in the decommissioning process. Optionally the decommissioning vessel then connects two or more frames together in a series arrangement, with interconnecting tow lines and clumpweights as previously described, while the frames are still static on the seabed. If desired, the guide posts 5 can optionally be re-inserted into the tanks 40, currently acting as ballast, and secured by guide pins 6, and in some cases the tanks 40 can be raised above the frame 20 in the step of towing the frame to the decommissioning site, but in some examples, the guide posts 5 are not needed in the decommissioning process, and the tanks 40 remain immovably secured to the frame during the whole of the decommissioning process.

An ROV can be deployed from the decommissioning vessel to open the valves of the tanks 40, and optionally to connect fluid lines. The decommissioning vessel pumps out a portion of the fluid contained within the tank 40 and replaces the volume of fluid removed with air or with another fluid that is more buoyant than seawater. This can be done by displacement of the dense ballast fluid from the tanks by the pumping of the air into the tanks 40, or by separate pumping steps for each fluid. Optionally once a portion of the ballast fluid is removed and the tank 40 has recovered at least a portion of its buoyancy, the tank 40 is converted once again to a buoyancy device. At a suitable point, when the desired amount of buoyancy has been recovered by the tank 40, the ROV optionally closes the valves. The buoyancy in the tank 40 is controlled at this stage until the frame lifts off the seabed in a controlled manner, for example restrained by clumpweights and towlines. It is often desirable for the frame as whole to be negatively buoyant when ascending to the surface, as this is more controllable, for example under the control of a winch from the installation vessel. Hence, the tanks 40 are not completely filled with buoyant fluid at this stage, but instead their buoyancy is increased to an extent that they can be towed to the quayside in a similar but reversed process to the installation.

Optionally a winch line is attached to the frame either through connection to a preinstalled rigging on the tank, or a connection point moulded into or attached to the tank. Alternatively the winch line can be attached to a point on the frame 1. Optionally the ROV assists in the attachment of the winch line to the frame 1. After connection to the frame 1, the winch line is recovered until all slack is taken up.

Once the winch is connected to the frame, the ROV again opens the valves. The decommissioning vessel commences pumping out more fluid and replacing the volume removed with air until the tanks 40 reaches the desired level of buoyancy for the ascent off the seabed. During the pumping process the winch line is steadily being recovered to take up slack and maintain support and balance. Optionally the winch line has a motion compensator. In most examples the guide posts are not re-installed on the frame for decommissioning, and the tanks 40 remain immovably secured to the frame during the decommissioning process.

The frame 1 is then optionally lifted towards the surface by the winch on the installation vessel, which lifts only a part of the load as the tanks increase the buoyancy of the overall frame 1, so the crane on the installation vessel can have a reduced capacity. In some examples the frame 1 can be re-floated under the force of the buoyancy alone provided by the tanks 40, without using a crane. In either event, the force applied to the frame 1 during the ascent is controlled so that the speed of ascent is maintained within desired parameters. The frame 1 can floated to the surface and surface towed to a decommissioning site, or can be floated towards the surface, but can be maintained below the surface by clumpweights etc, and can be towed at depth.

In another example, instead of being lifted by a winch during decommissioning, the tanks 40 are filled with sufficient buoyancy to float the frame 1 without any external lifting forces from the surface, and the depth and rate of ascent of the frame is controlled by towlines 91 and clumpweights 91c installed between the frames, and by adjusting buoyancy in the tanks 40. Optionally the tanks 40 are secured onto the frames 1 by a mechanical connection, which can be made up during installation and checked before decommissioning.

Once the frame 1 is re-floated to the desired towing depth, which may be on the surface or partially or wholly submerged, e.g. where at least some of the frame 1 e.g. the base, is below the wave affected zone, at least one (optionally two or more) tow line 91 is attached, optionally to the frame base 20, or on the frame members 10, or tanks 40. Optionally more than one tow line can be attached to maintain stability of the frame 1 when under tow. Independent chambers 92b are optionally attached to the power umbilical 92 connected to the tidal turbine for buoyancy during towing. Optionally, several frames are connected together in series with at least one tow line, and are towed in a daisy-chain behind the lead boat to the recovery location.

Optionally the turbine structure remains on the frame 1 during re-floating of the platform assembly. Optionally the platform assembly is towed to the recovery or decommissioning location. At the recovery location, for example a quay, any separable modular sections of the platform assembly, e.g. the turbine nacelle, are optionally disconnected from the frame 1 and each part of the platform assembly is recovered. However, in some examples, the components of the power converter, the support and the frame can be recovered separately from the installation site.

In one example described with reference to the drawings, optionally the frame 1 can be lifted using at least one crane, optionally more than one crane, into water at the quayside. The tidal turbine nacelle 70 and the power umbilical 92 are then optionally lifted onto the frame, with the whole assembly being positively buoyant. Alternatively, a dry dock facility can be used to load out at least one frame 1, optionally multiple frames, e.g. at least 2, 3, 4 or more. The tidal turbine nacelle 70 and the power umbilical 92 are optionally lifted onto the frame 1 at the quayside after the frame has been loaded out. Optionally, the platform assembly 50 comprising the frame 1, tidal turbine nacelle 70 and power umbilical 92 is configured at the dry dock location prior to load out.

The platform assembly 50 is rendered buoyant by at least one buoyancy tank 40, optionally at least two buoyancy tanks. Optionally the frame base 20, 220 contains at least one static buoyancy member 20s, 220s (see Figures 2, 21) forming a part of the frame base 20,220 and being configured with at least one valve allowing the static buoyancy member to be flooded to assist in making the platform assembly negatively buoyant during installation. The static buoyancy member does not typically receive ballast fluid, but can be used to fine tune the amount of buoyancy for landing the frame during installation, or for trimming the frame when towing. Optionally more than one static buoyancy member can be incorporated on the frame, for example, in one of the uprights extending from the plane of the base 20, 220. This can be partially flooded for towing operations, e.g. surface towing operations. Thus in this example, the tanks 40, 240 are not flooded before landing the frame on the seabed, but optionally the tanks 40, 240 retain full or at least partial buoyancy. Optionally the static buoyancy member being flooded to sink the frame to the seabed is symmetrically disposed on the frame centre of gravity. Flooding the single static buoyancy member during the installation step and sinking to the seabed advantageously means that the frame 1, 201 can be more stable during the descent to the seabed, as the buoyant force acting on it is optionally more controllable and optionally more symmetrically disposed on the frame. The static buoyancy member can be balanced on the frame and can have just enough flooded weight to take the assembly onto the seabed. Optionally the buoyancy of the static member can be less than the tanks 40, 240, for example, around 20-30t, and the buoyancy tanks 40,240 can have a buoyancy when full of buoyant fluid in the order of several hundred tonnes each. Hence, flooding the static buoyancy member but maintaining the buoyancy of the tanks 40, 240 simply tips the balance of the overall frame by a small amount enough to make the frame overall just slightly negatively buoyant.

The flooding of the static buoyancy member 20s, 220s is thus optionally used to land and position the frame on the seabed, whereas the buoyancy tanks 40, 240 are used post landing to stabilise the assembly as they are flooded with dense fluid and converted into ballast tanks.

In shallow water the platform assemblies 50 are optionally towed in series in a surface tow configuration. In deep water, the towlines 91 are optionally reconfigured by the addition of clumpweights 91c to the towlines. The addition of clumpweights 91c submerges the platform assemblies and they are then optionally towed in series in the submerged configuration to the installation site. Optionally the depth of the platform assemblies under tow can be varied by varying the towline configuration and towing speed.

Once the platform assemblies 50 have been towed to the installation site, the lead and trail towlines 91 are optionally paid out until the clumpweights 91c land on the seabed. Optionally, at least one static buoyancy member in the frame base is then flooded to make the platform assembly overall negatively buoyant. At least one buoyancy tank 40 is initially partially flooded during installation such that the tank 40 remains buoyant at the upper portion of the guide posts 5. Optionally at least two buoyancy tanks are flooded concurrently. Optionally during concurrent flooding a control device is utilised to decelerate the tanks and provide a soft landing on the frame.

Optionally the installation vessel comprises a winch that can optionally be connected to at least one buoyancy tank 40 during flooding of the tank. The winch line optionally maintains the position of the tank until flooding is halted to limit the load on the winch and the winch line can be paid out to lower the buoyancy tank onto the cradles 11 in a controlled fashion. This method can optionally be repeated for more than one buoyancy tank.

The remaining platform assemblies 50 of the tow are optionally installed laterally relative to the first platform assembly and to one another. The trail tug optionally applies lateral force onto the towline such that it reacts against the first installed platform assembly.

The buoyancy tanks 40 on each platform assembly 50 are ballasted, optionally with dense fluid or with solid slurry, to complete the installation. Optionally flooding the buoyancy tanks 40 with seawater may be sufficient to complete the ballasting operation. Optionally the towlines 91 and clumpweights 91c are then recovered. Optionally the power umbilicals 92 are configured.

During decommissioning, the decommissioning vessel optionally recovers the tidal turbine nacelle 70 and the power umbilical. The vessel then optionally configures the towlines 91 and clumpweights 91c between the frames 1. The vessel optionally pumps out the ballast from the ballast tanks until the frame returns to positive buoyancy. Optionally, once this process has been repeated for all frames to be towed, the frames are returned to the decommissioning site.

Figures 20-22 show another example of the invention which is essentially the same as has been described above, and with corresponding reference numerals increased by 200. In this example, the frame 201 comprises static buoyancy members 220s within the central fore-aft structural member of the frame base 220. In this example, the frame members 210 are landed directly onto the submerged substrate.

Figure 23a-c shows three possible examples of the interface between the restraint device 7 of the guide post 5 and the bore 45 of the tank 40. Figure 23a shows the restraint device 7a in the form of a flared bellmouth external to the bore 45a of the tank 40a, with the guide post 5a passing through the bore. Figure 23b shows the restraint device 7b interfacing with a canted surface within the bore 45b of the tank 40b, towards the top of the bore 45b. Figure 23c shows another example of the interface with the restraint device 7c interfacing with a canted surface of the bore 45c located near or at a central axis of the tank 40c. Any of these examples of the interface may be used with any of the examples of the platform assemblies described herein.

1. A platform assembly comprising a marine energy harvester and a frame connected to the marine energy harvester, wherein the frame comprises at least one frame member for attachment of at least one chamber adapted for containing a buoyant fluid material and serving as a buoyancy device, the chamber being adapted to convert to a ballast device during installation of the platform assembly.

2. A platform assembly as claimed in claim 1, wherein the frame comprises at least one guide post which engages the chamber.

3. A platform assembly as claimed in claim 2, wherein the chamber is movable relative to the frame along a path defined by the at least one guide post as the buoyancy of the chamber varies.

4. A platform assembly as claimed in any one of claims 2-3, wherein the guide post is removably connected to the frame and can be removed from the frame when the chamber contains ballast without removing the chamber from the frame.

5. A platform assembly as claimed in any one of claim 2-4, wherein the guide post passes through a lined orifice in the chamber.

6. A platform assembly as claimed in claim 5, wherein the lined orifice in the chamber incorporates sufficient clearance between the guide post and the chamber to allow satisfactory tracking of the chamber down the guide post when the chamber is moving into the ballast position.

7. A platform assembly as claimed in any one of claims 2-6, wherein the guide post extends perpendicularly from the frame, and has at least one canted surface which engages with a surface on the chamber to control alignment between the chamber and the guide post.

8. A platform assembly as claimed in any one of claims 2-7, wherein the frame member comprises at least one bore that receives the guide post.

9. A platform assembly as claimed in claim 8, wherein the bore supports the guide post across the diameter of the frame member.

10. A platform assembly as claimed in claim 8 or claim 9, wherein the guide post is secured to the frame member with at least one guide pin.

11. A platform assembly as claimed in any one of claims 8-10, wherein the guide post is secured to the frame member with a latch mechanism.

12. A platform assembly as claimed in any one of claims 8-11, wherein the guide post is permanently secured to the frame member.

13. A platform assembly as claimed in any one of claims 2-12, including a restraint device adapted to be secured to the guide post to constrain the chamber on the frame.

14. A platform assembly as claimed in claim 13, wherein the restraint device has a conical canted surface which engages with a canted surface on the chamber to resist separation of the chamber from the frame.

15. A platform assembly as claimed in claim 14, wherein the canted surface of the restraint device interfaces between the guide post and the lined orifice in the chamber.

16. A platform assembly as claimed in any one of claims 2-15, wherein the chamber is movable relative to the frame along a path defined by the axis of the at least one guide post as the buoyancy of the chamber varies.

17. A platform assembly as claimed in any preceding claim, wherein the frame comprises a base disposed between at least two frame members.

18. A platform assembly as claimed in claim 17, wherein the base comprises at least two base members disposed perpendicularly to and extending between at least two frame members.

19. A platform assembly as claimed in any preceding claim, wherein the marine energy harvester comprises a support structure, and wherein the frame is provided with fixtures to connect the support structure of the marine energy harvester to the base members, the fixtures being spaced apart on the base members.

20. A platform assembly as claimed in any preceding claim, wherein the frame includes at least one anchor point for securing a tow line to the platform assembly for towing the platform assembly through water during deployment.

21. A platform assembly as claimed in any preceding claim, wherein the chamber contains a buoyant fluid and serves as a buoyancy device during deployment of the platform assembly to the installation site, and is converted to a ballast device at the installation site by wholly or partially filling the chamber with a ballast fluid having a higher density than the buoyant fluid in order to decrease the buoyancy of the chamber at the installation site.

22. A platform assembly as claimed in any preceding claim, wherein the chamber is converted to ballast by wholly or partially filling the chamber with fluid of density no less than the surrounding seawater.

23. A platform assembly as claimed in any preceding claim, wherein the chamber is converted to ballast by wholly or partially filling the chamber with solid material in fluid slurry.

24. A platform assembly as claimed in any preceding claim, wherein the at least one frame member comprises at least one cradle adapted to support the chamber on the frame when the chamber contains ballast.

25. A platform assembly as claimed in claim 24 wherein the or each cradle comprises a support in the form of an arcuate support member connected to the frame member to retain the chamber on the frame member when converted to a ballast device.

26. A platform assembly as claimed in any preceding claim, wherein the chamber is lowered from a buoyancy device position into a ballast device position by the decrease in buoyancy of the chamber when wholly or partly filled with fluid of density no less than the surrounding seawater.

27. A platform assembly as claimed in any preceding claim, wherein the chamber is mechanically lowered to a ballast position.

28. A platform assembly as claimed in any preceding claim, wherein at least one guide post is removably attached to the frame member, and wherein after the chamber is filled with ballast and lowered into a ballast device position by following a path defined by at least one guide post, the at least one guide post is removed from the frame member.

29. A platform assembly as claimed in any preceding claim, incorporating a control device adapted to control the movement of the chamber relative to the frame member.

30. A platform assembly as claimed in claim 29, wherein the control device is associated with at least one guide post.

31. A platform assembly as claimed in claim 30, wherein the control device is associated with at least one cradle.

32. A platform assembly as claimed in any preceding claim, wherein the marine energy harvester is connected to at least one power umbilical with independent temporary buoyancy devices attached to the umbilical to float the umbilical during at least one phase of towing.

33. A platform assembly as claimed in any preceding claim, wherein the frame comprises at least one secondary buoyancy chamber, which is configured to contain a buoyant fluid, and configured to be flooded with a fluid with a higher density.

34. A platform assembly as claimed in claim 33, wherein the secondary buoyancy chamber is symmetrically arranged on the frame.

35. A platform assembly comprising a marine energy harvester and a frame connected to the marine energy harvester, wherein the frame comprises at least one frame member for attachment of at least one chamber adapted for containing a buoyant fluid material and serving as a buoyancy device, the chamber being adapted to convert to a ballast device during installation of the platform assembly, wherein the frame comprises at least one guide post which engages the chamber, wherein the chamber is movable relative to the frame along a path defined by the at least one guide post as the buoyancy of the chamber varies.

36. A method of transporting and deploying a marine energy harvester at an installation site on a submerged substrate, the method comprising:
connecting the marine energy harvester to a frame, to provide a platform assembly, the frame having at least one chamber adapted for containing a buoyant material and serving as a buoyancy device;
flowing a buoyant fluid into the chamber;
launching the platform assembly into water and supporting the platform assembly in the water by means of the buoyant fluid in the chamber;
towing the platform assembly to the installation site;
conveying the platform assembly to the installation site; and
ballasting the platform assembly against the submerged substrate by increasing the density of fluid in the chamber.

37. A method as claimed in claim 36, the frame further having at least one guide post which engages the chamber and wherein the method includes moving the chamber along a path relative to the frame as the buoyancy of the chamber varies.

38. A method as claimed in claim 36 or 37, wherein the platform assembly is connected by at least one tow line to at least one other platform assembly such that more than one platform assembly is towed to the installation site.

39. A method as claimed in any one of claims 36 -38, wherein the platform assembly is towed with power umbilicals pre-configured.

40. A method as claimed in any one of claims 36-39, wherein the frame comprises at least one secondary buoyancy chamber containing a buoyant fluid, and wherein the method comprises increasing the density of fluid in the secondary buoyancy chamber to lower the platform assembly onto the seabed.

41. A method of decommissioning a frame for a marine energy harvester installed at a submerged installation site, the frame having at least one chamber adapted for containing a buoyant material and serving as a buoyancy device; the method comprising:
increasing the buoyancy of the frame by decreasing the density of the fluid contained within the chamber and raising the frame above its submerged installation site; and
towing the frame to a decommissioning site.

42. A method as claimed in any one of claims 36-41, wherein the chamber is movable from a first transportation configuration comprising a first position at the end of the guide post disposed away from the frame member; to a second installation configuration comprising a second position adjacent to the frame member.

43. A frame for supporting a marine energy harvester, wherein the frame comprises at least one frame member adapted for attachment of at least one chamber adapted for containing a buoyant fluid material and serving as a buoyancy device, the chamber being adapted to convert to a ballast device during installation of the frame.

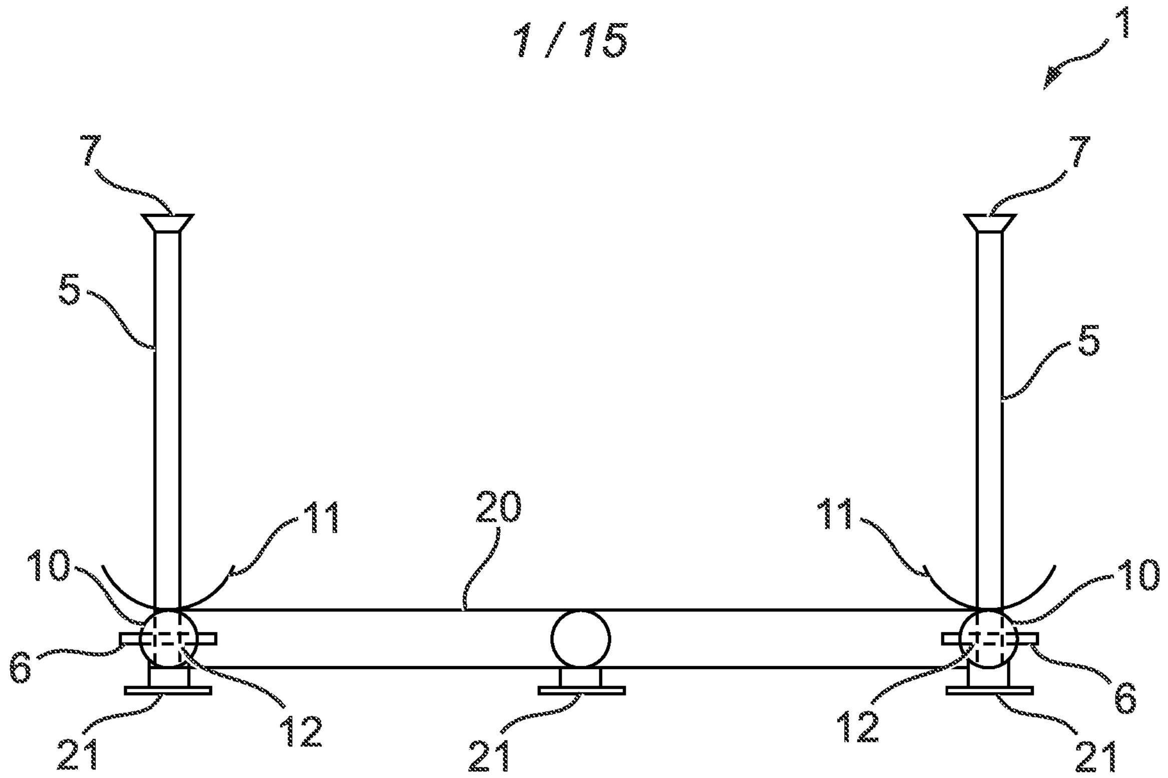
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Fig. 1

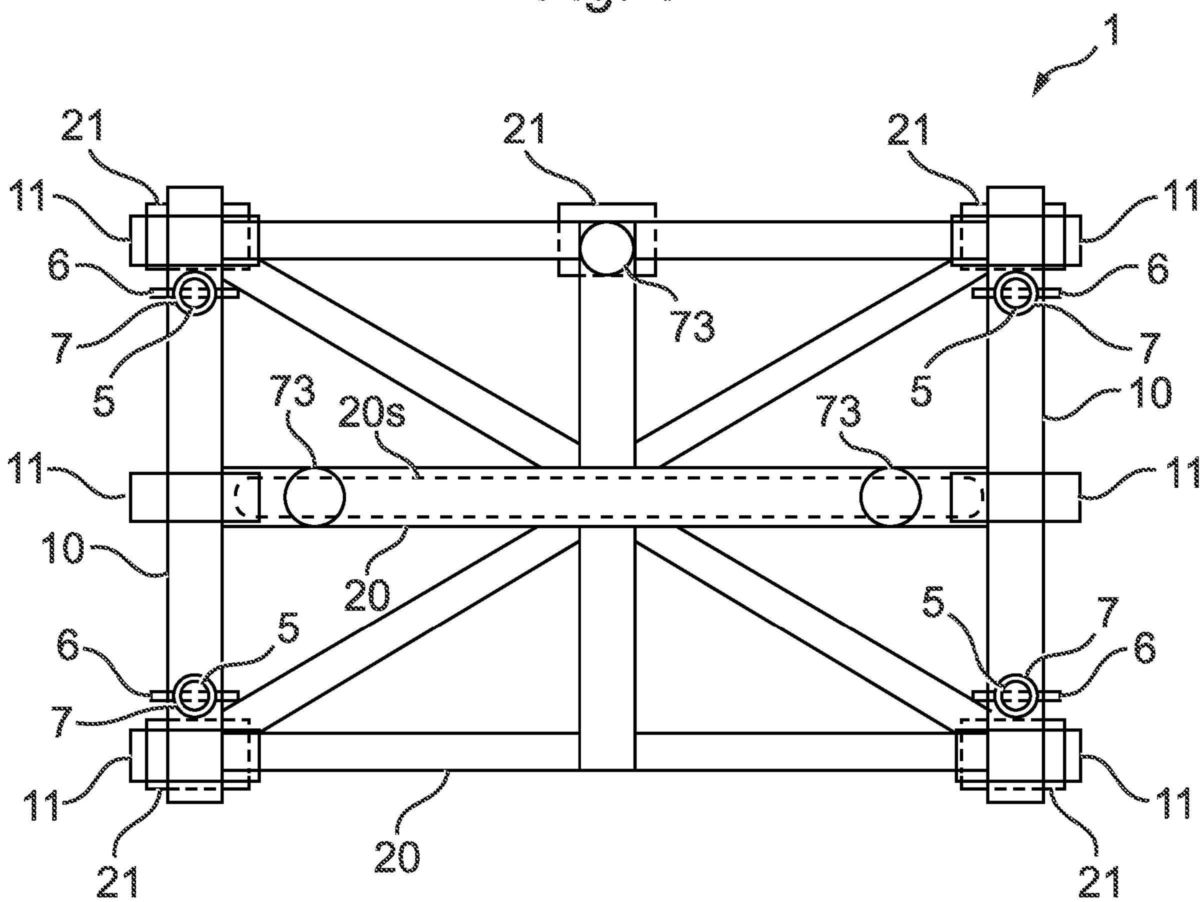
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Fig. 2

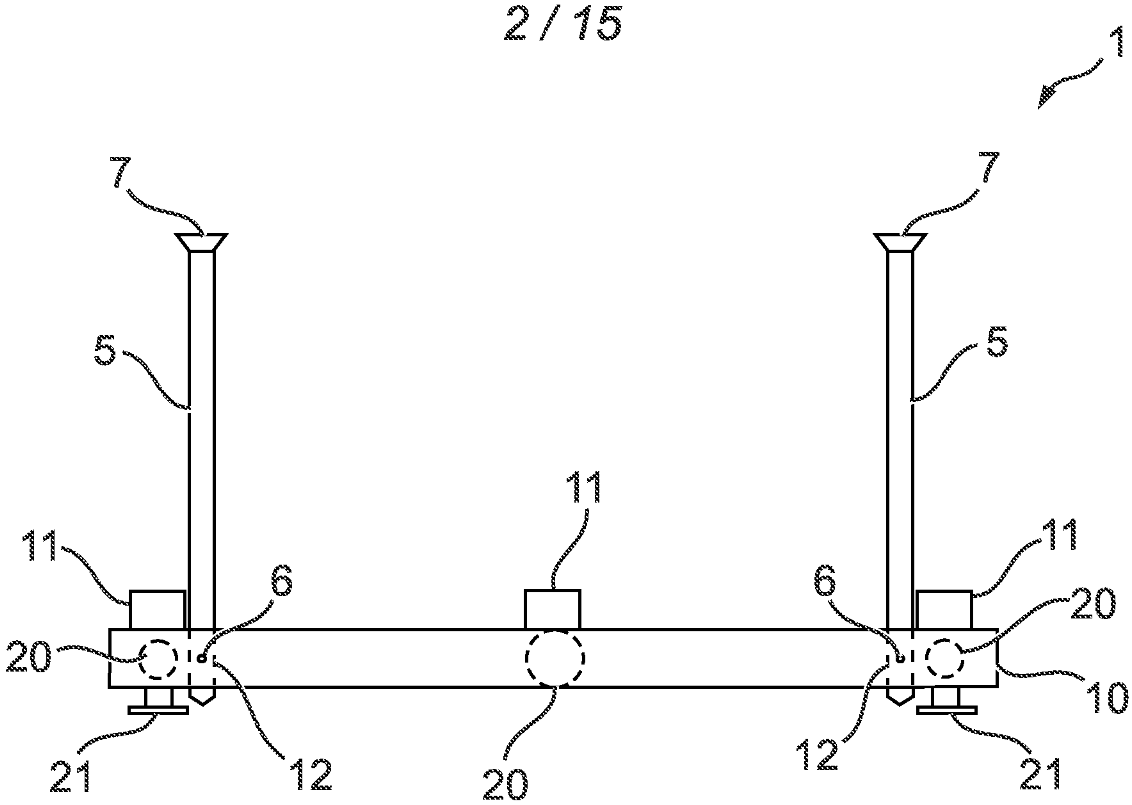

Fig. 3

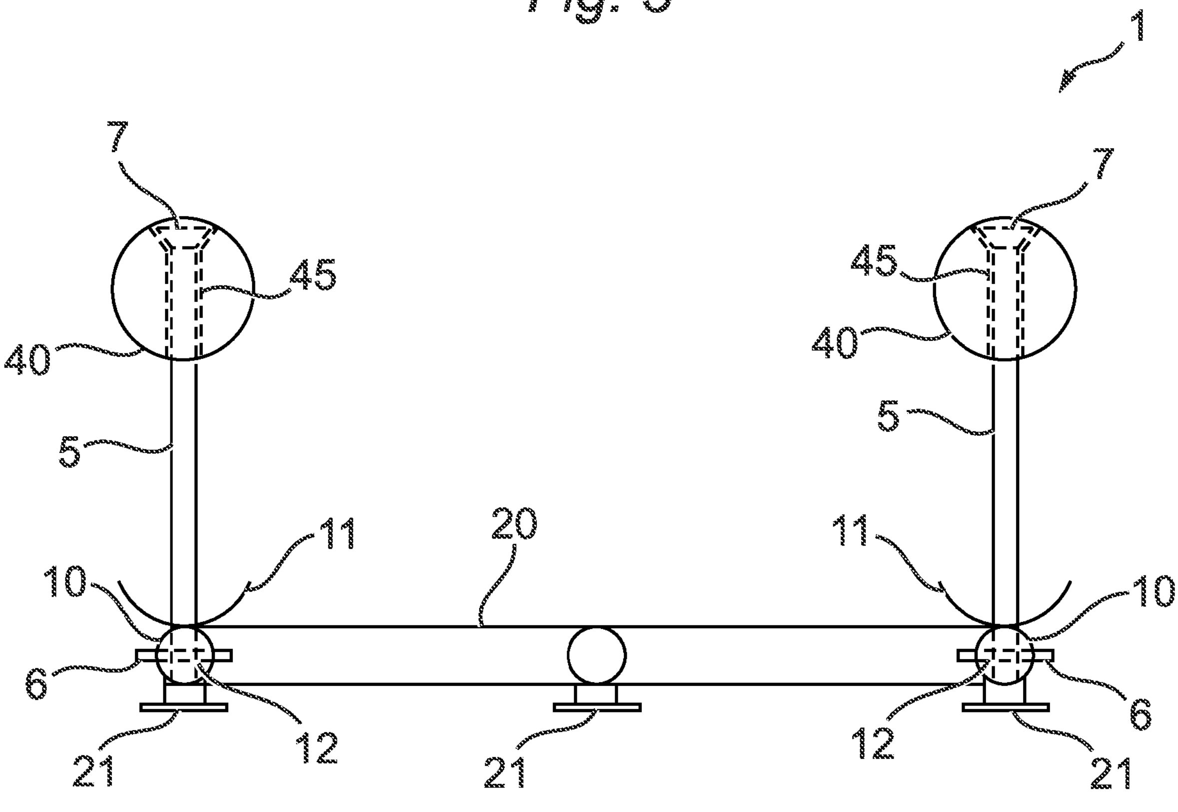

Fig. 4

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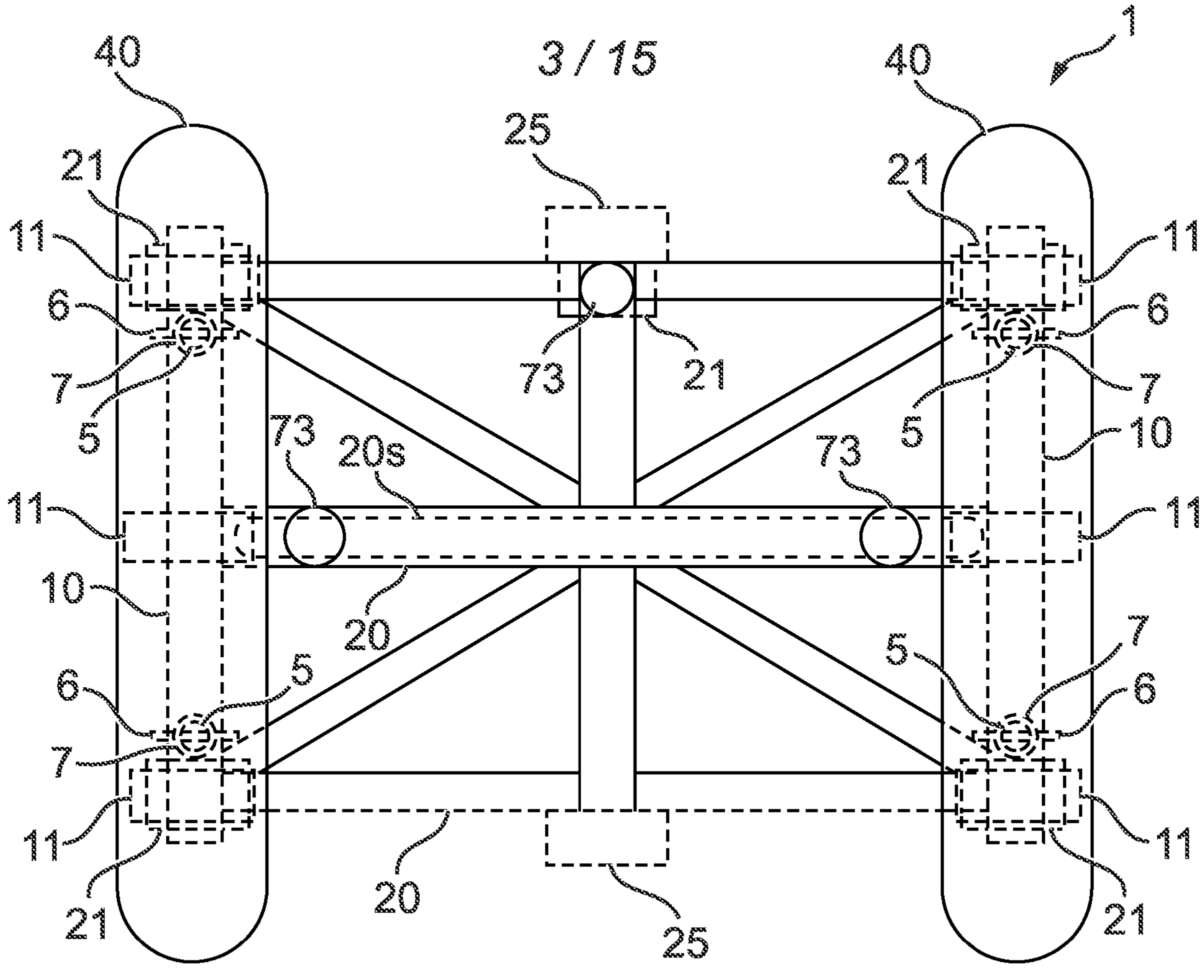
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Fig. 5

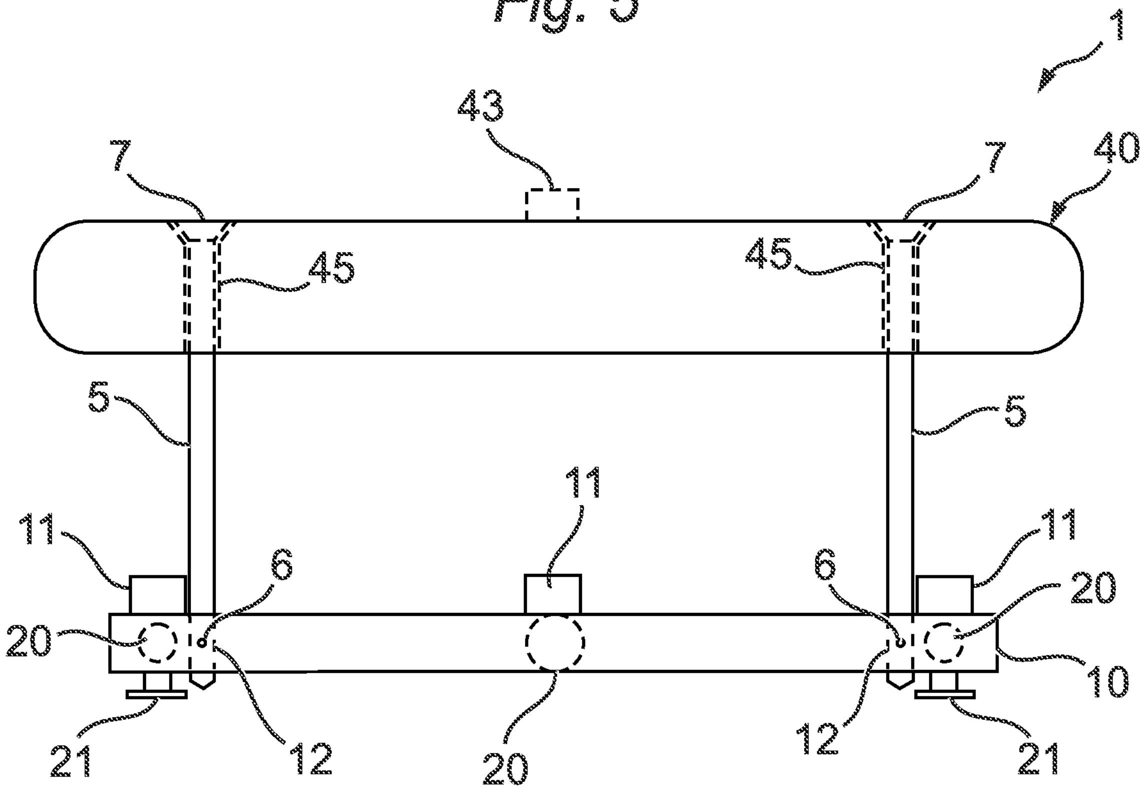
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Fig. 6

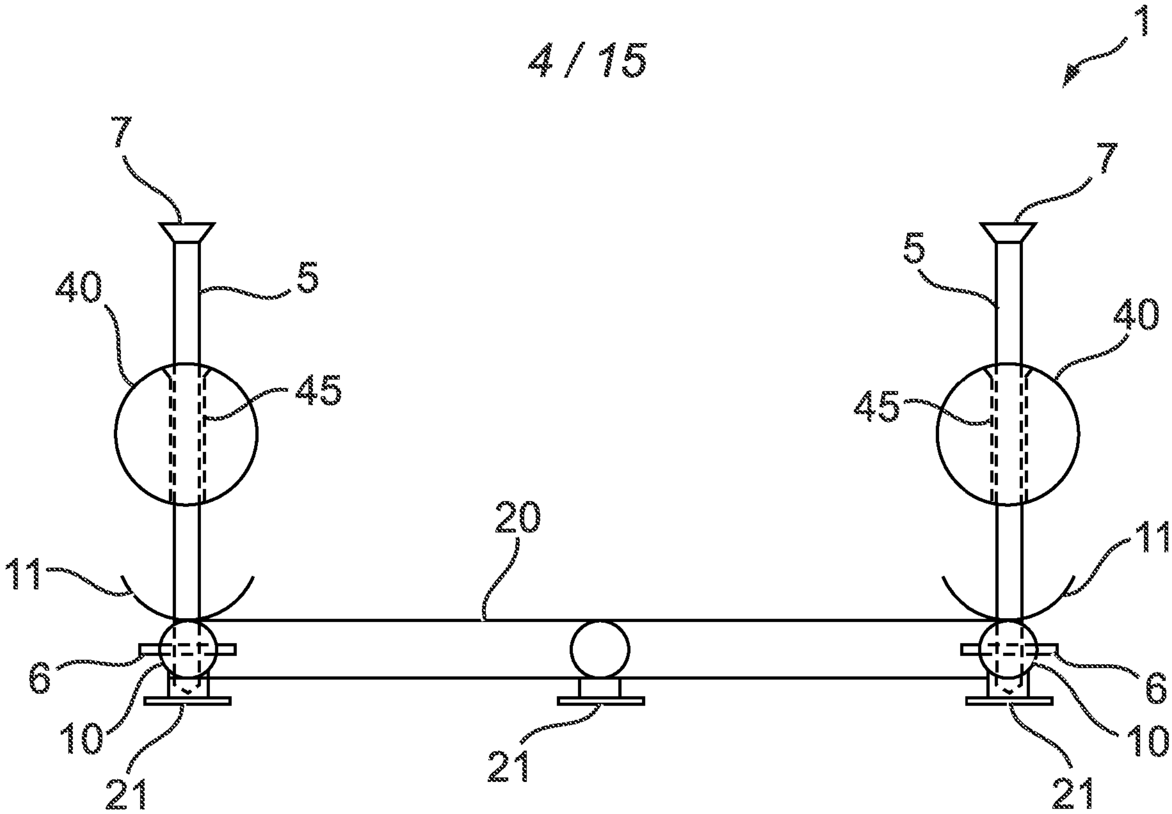
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Fig. 7

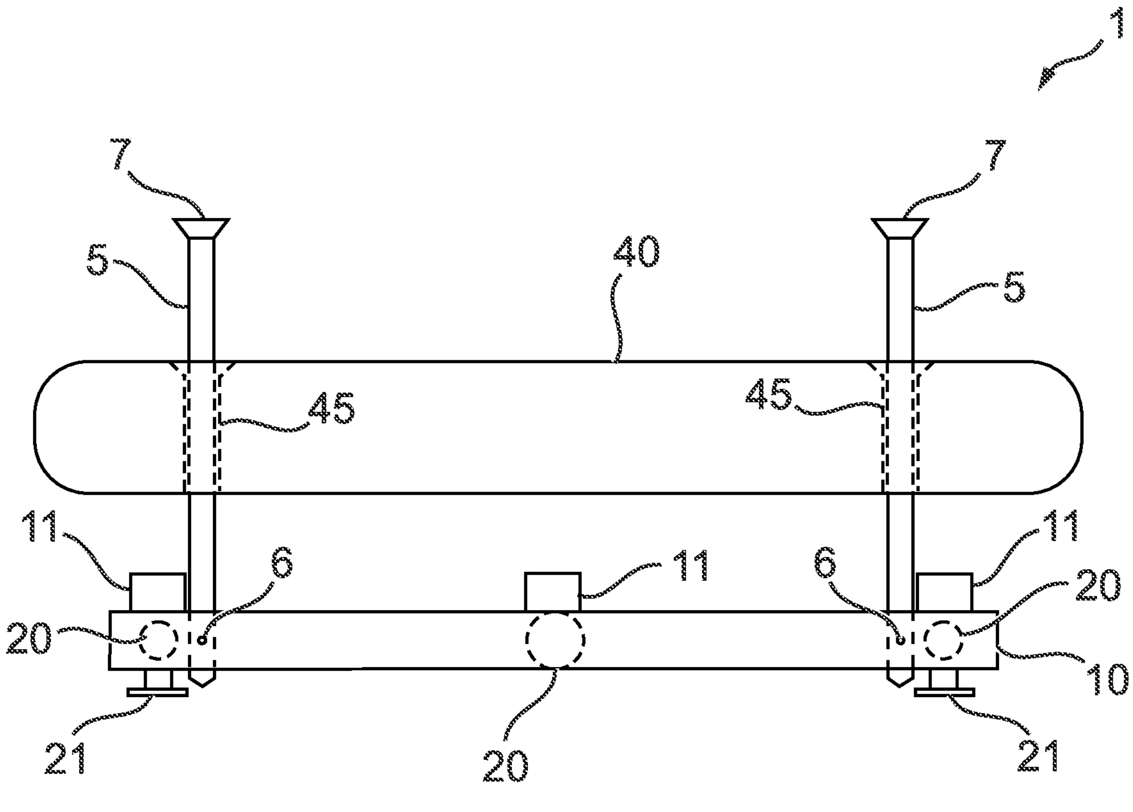
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Fig. 8

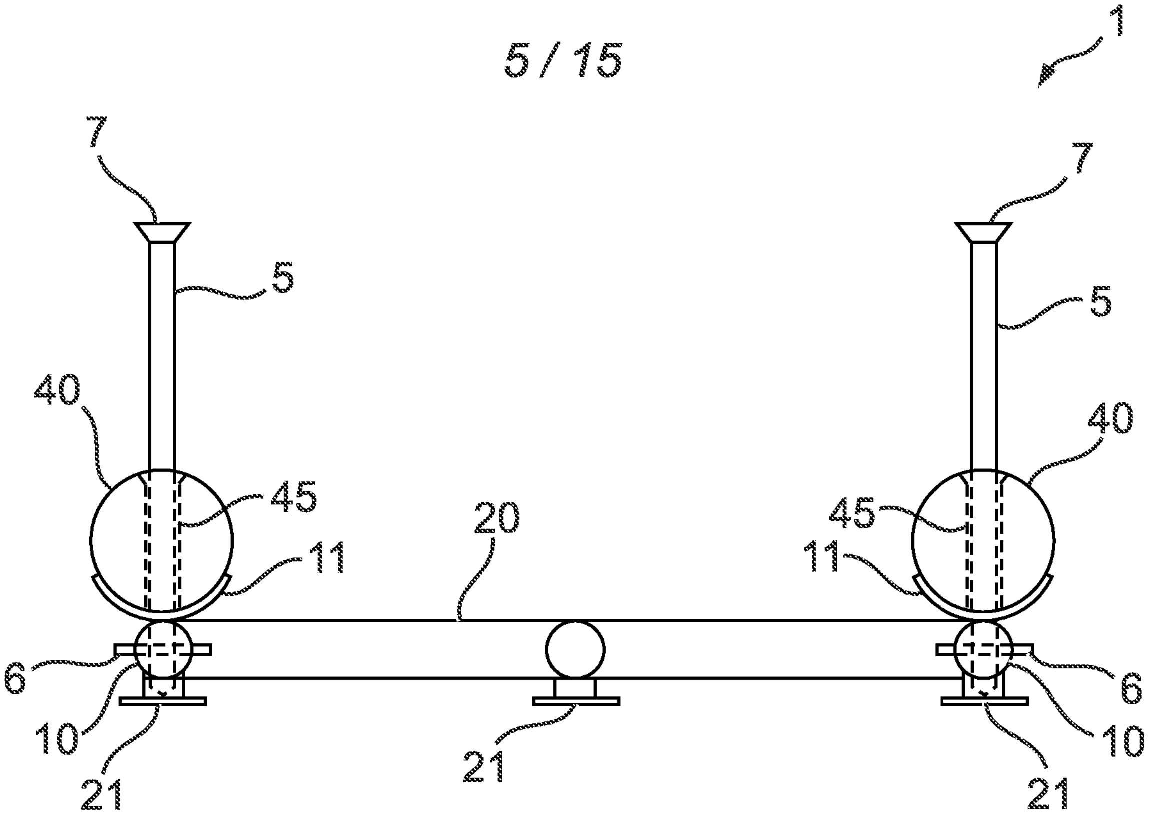
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Fig. 9

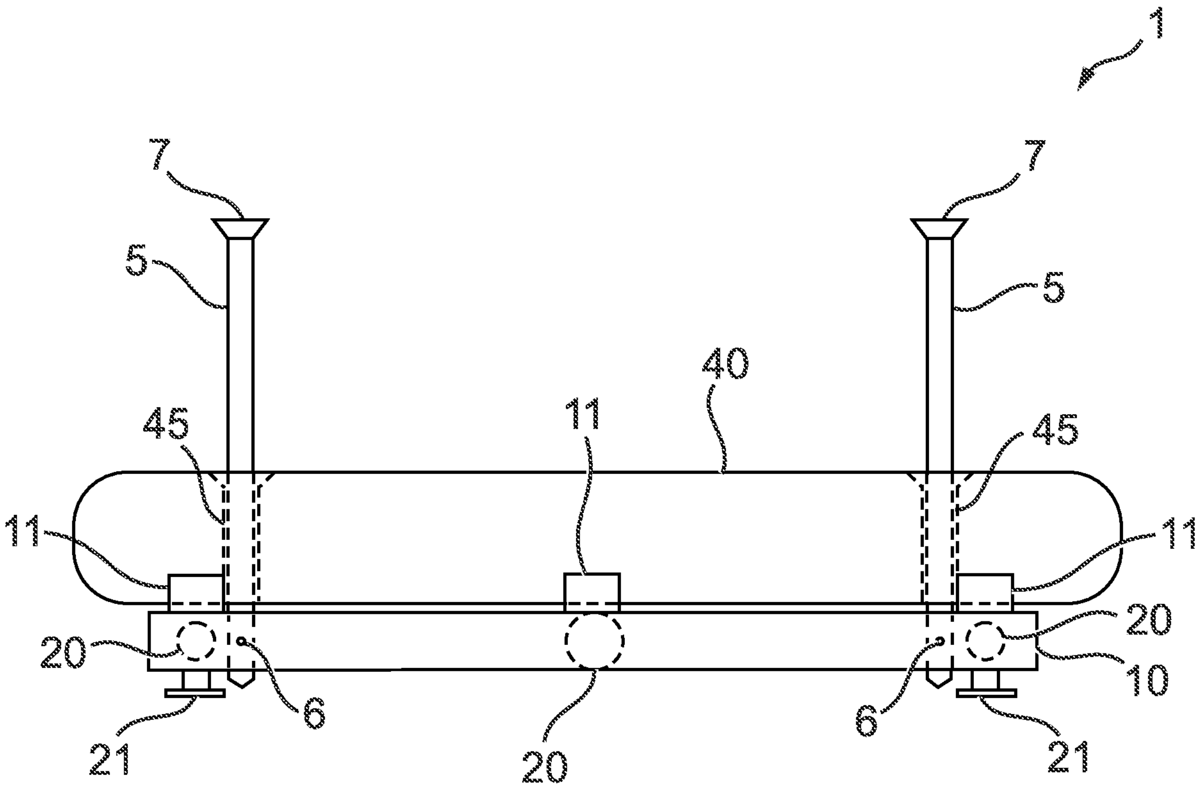
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Fig. 10

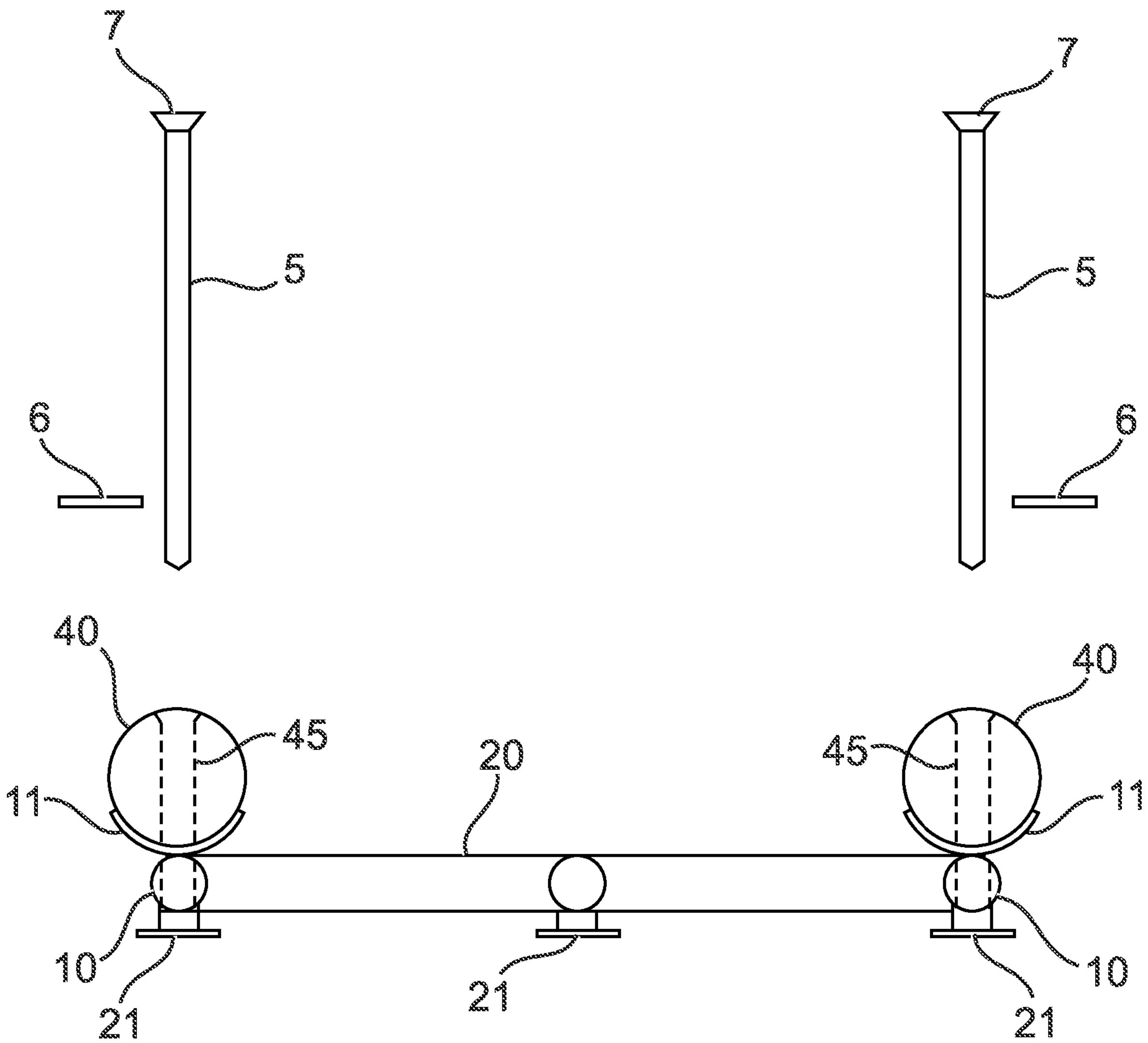

Fig. 11

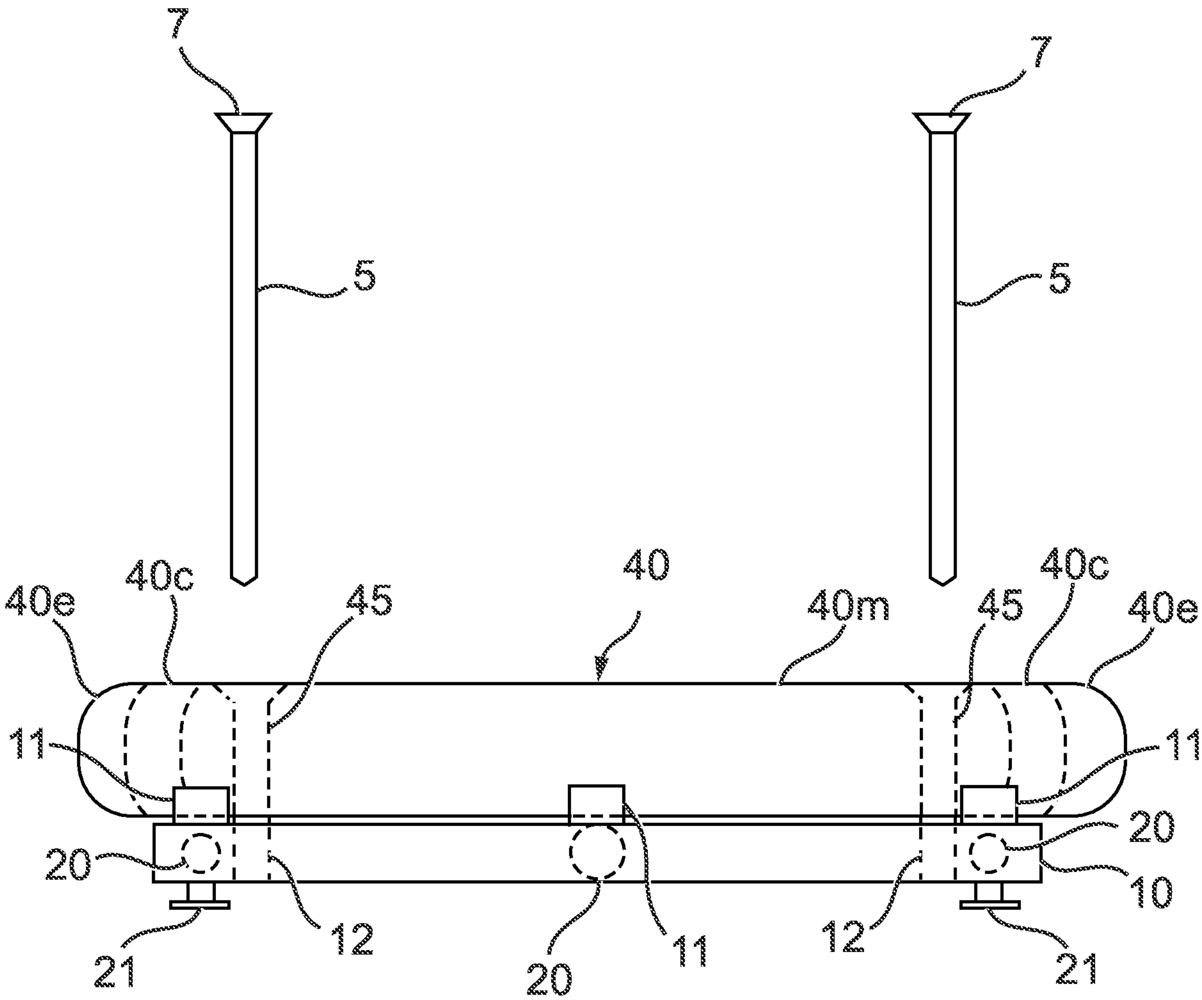

Fig. 12

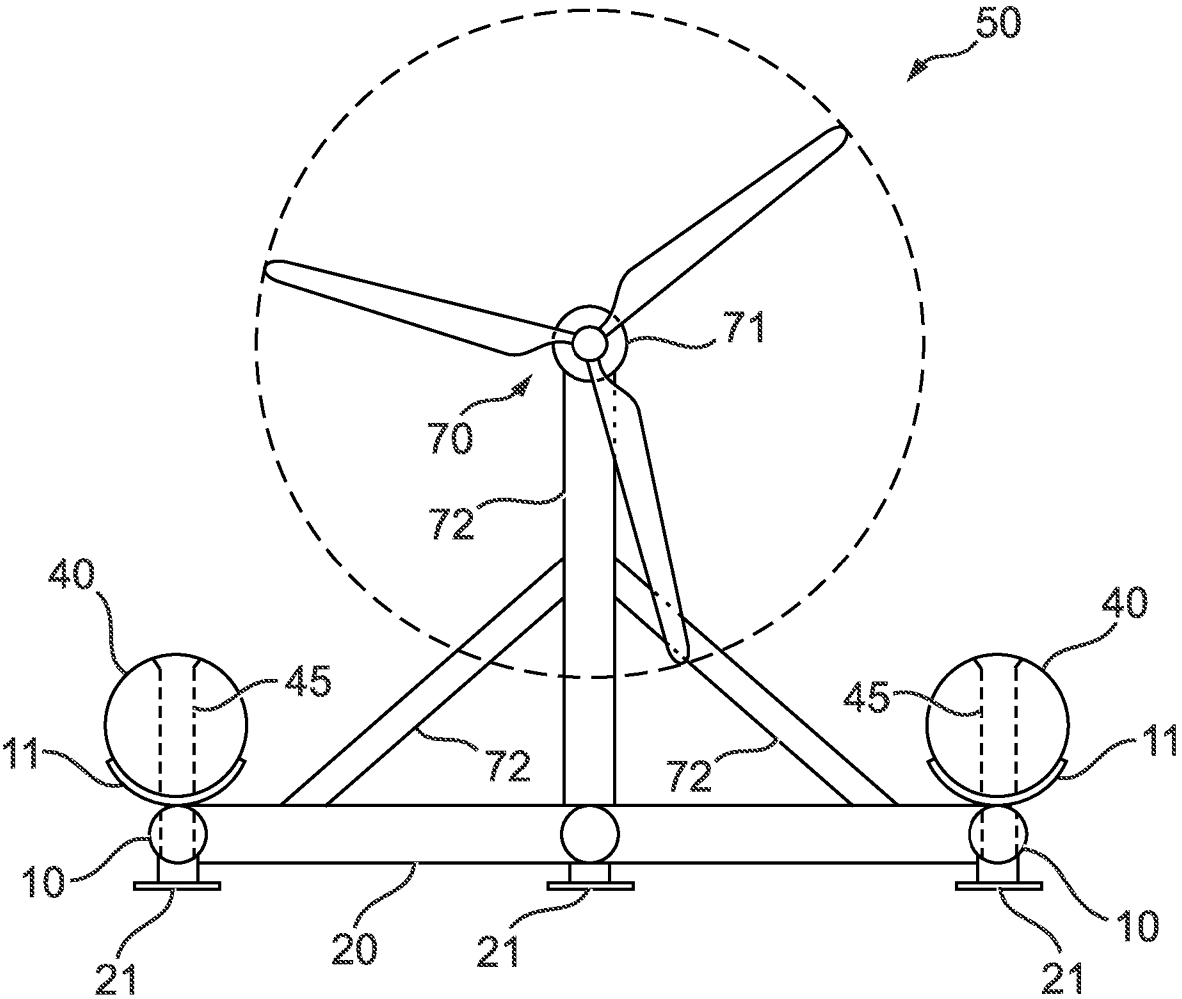

Fig. 13

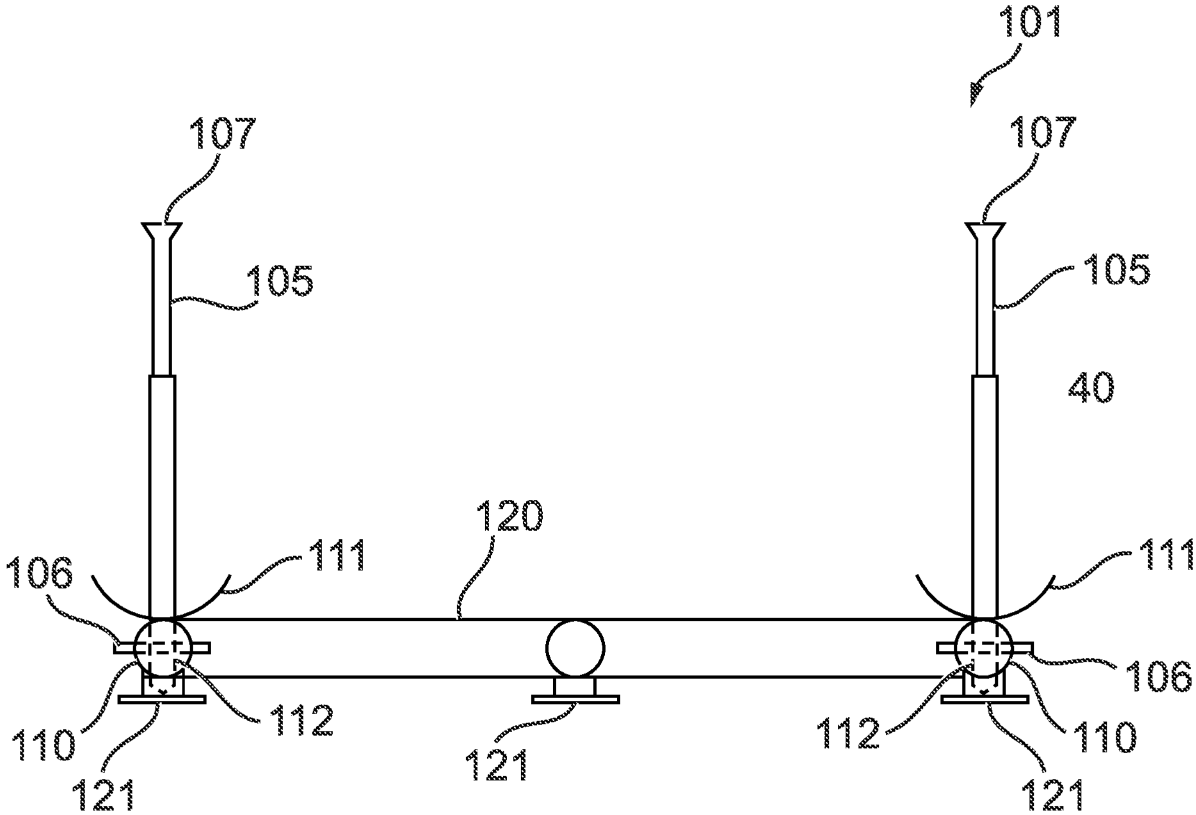
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Fig. 14

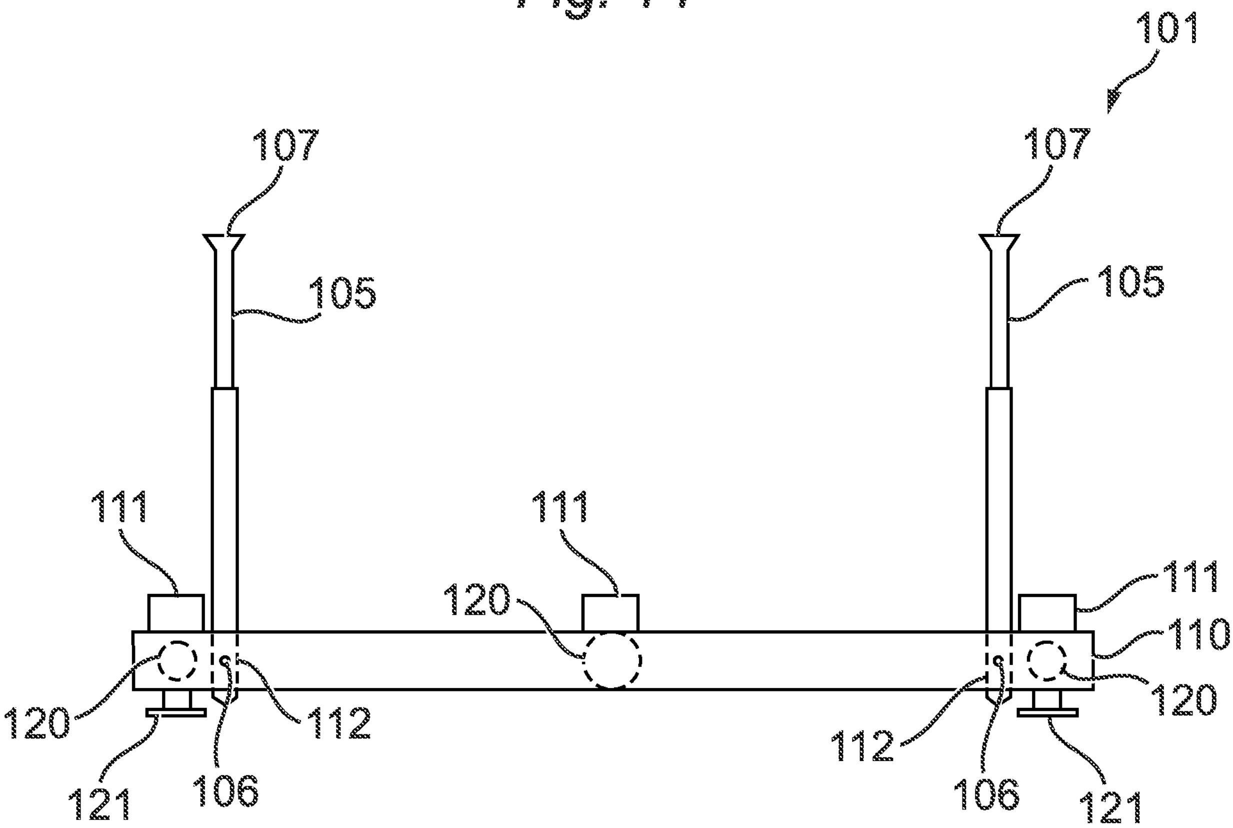
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Fig. 15

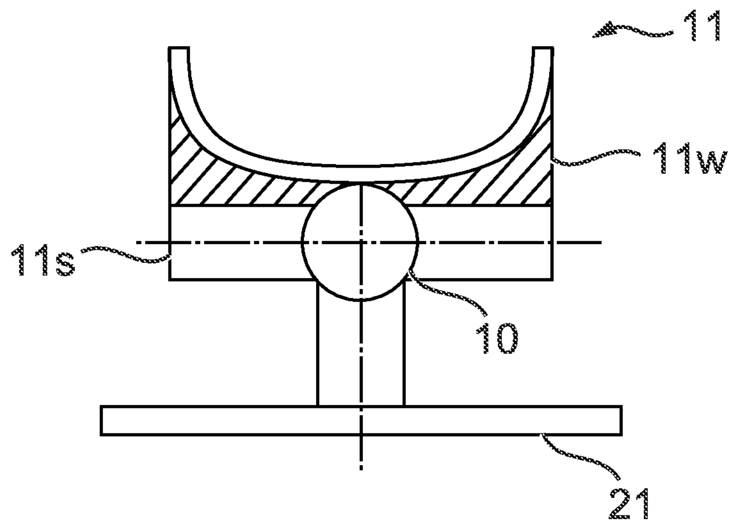

Fig. 16

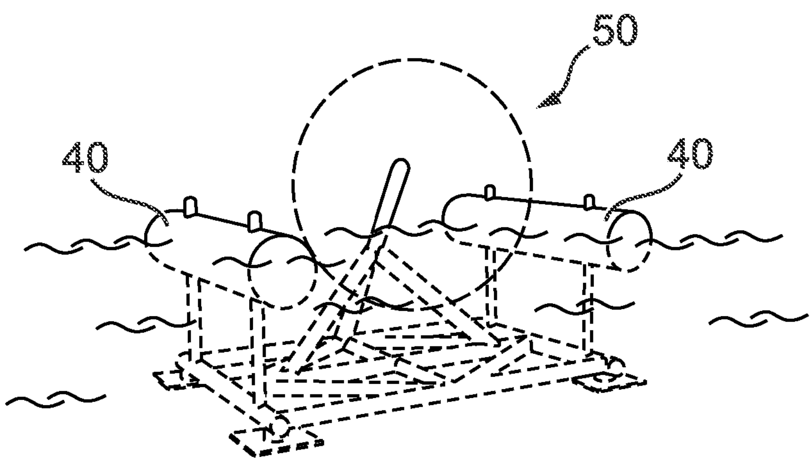

Fig. 17

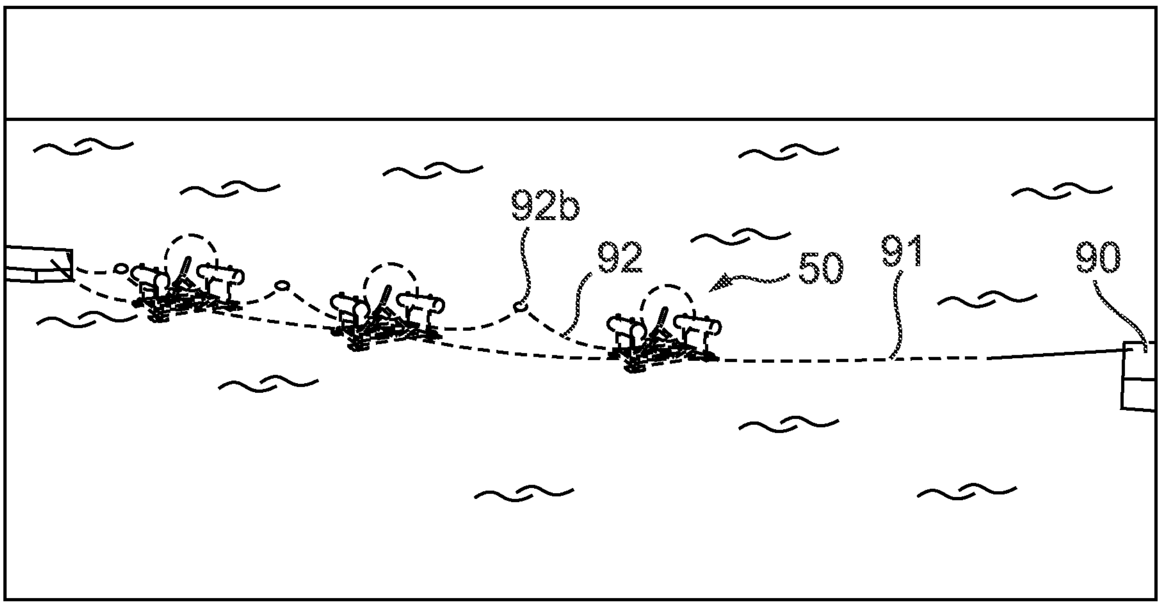

Fig. 18

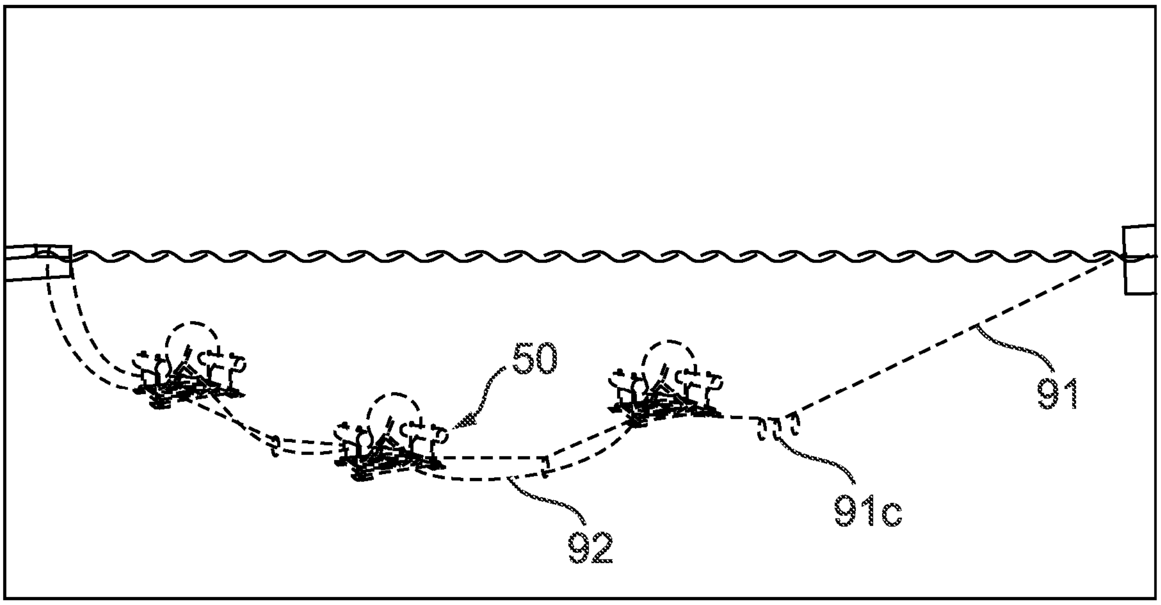

Fig. 19

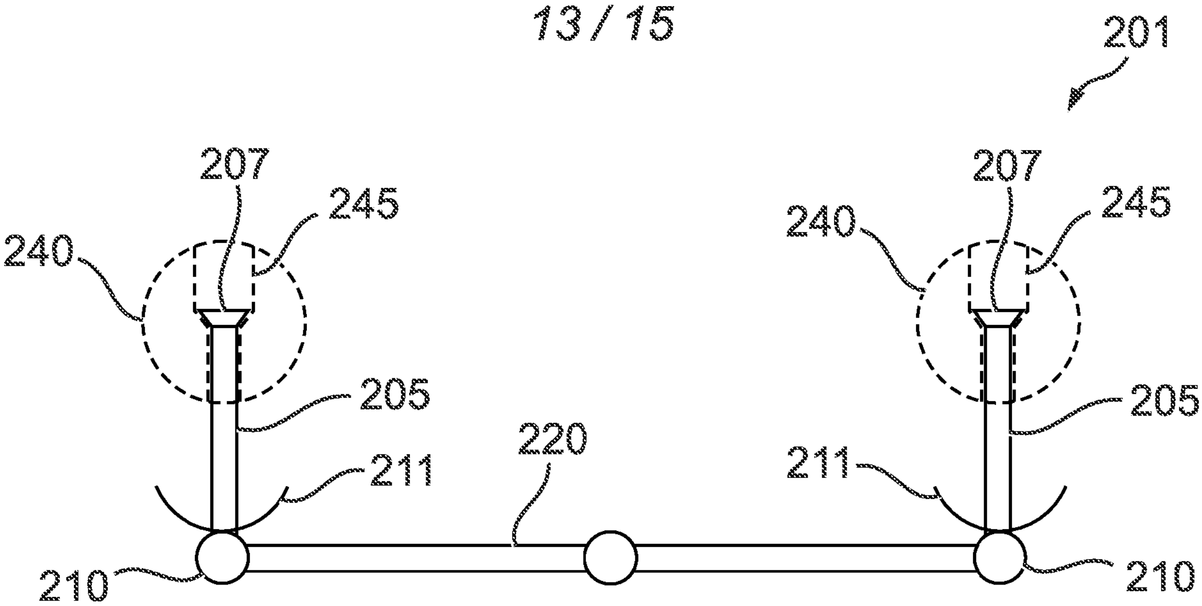
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Fig. 20

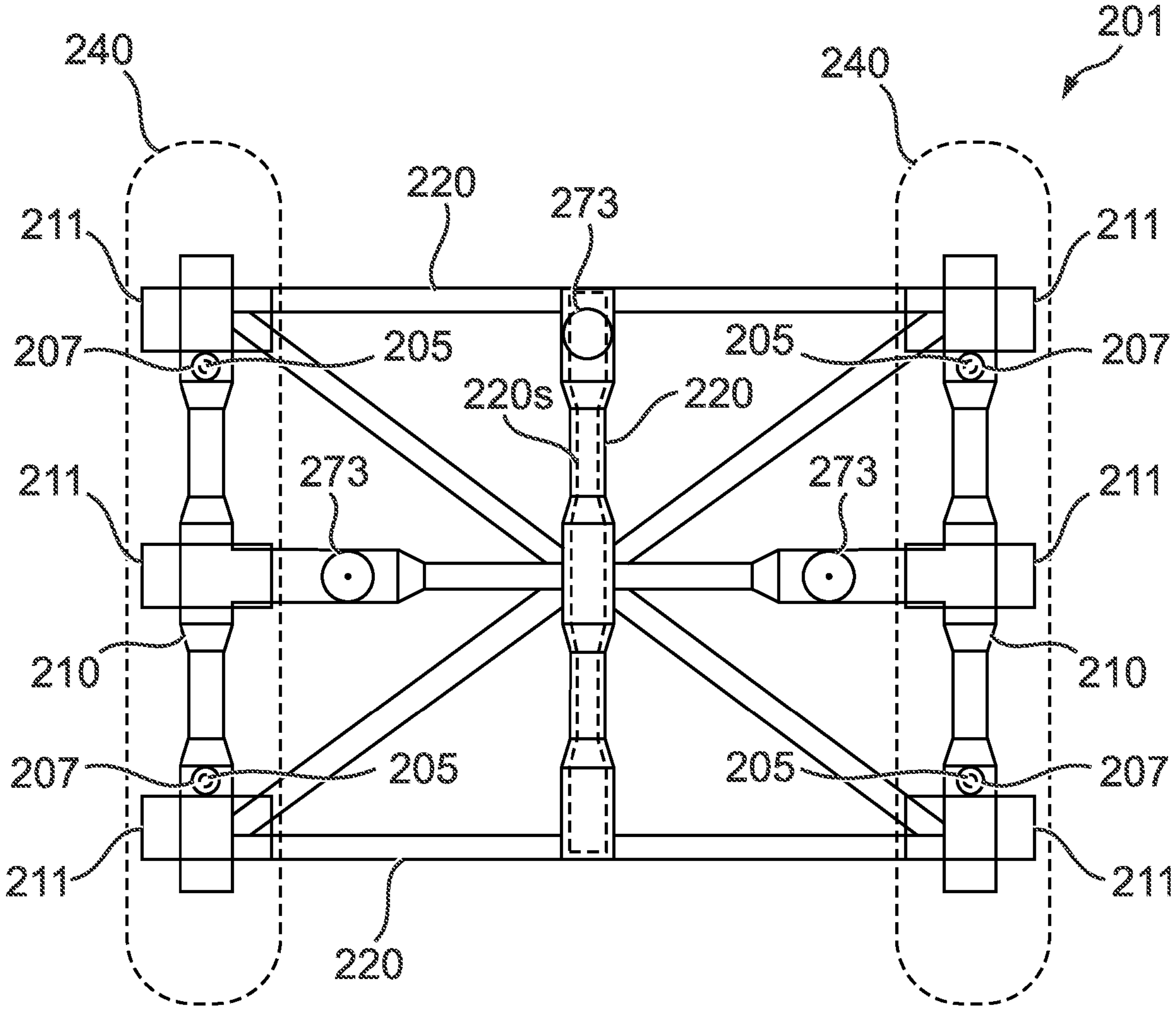
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Fig. 21

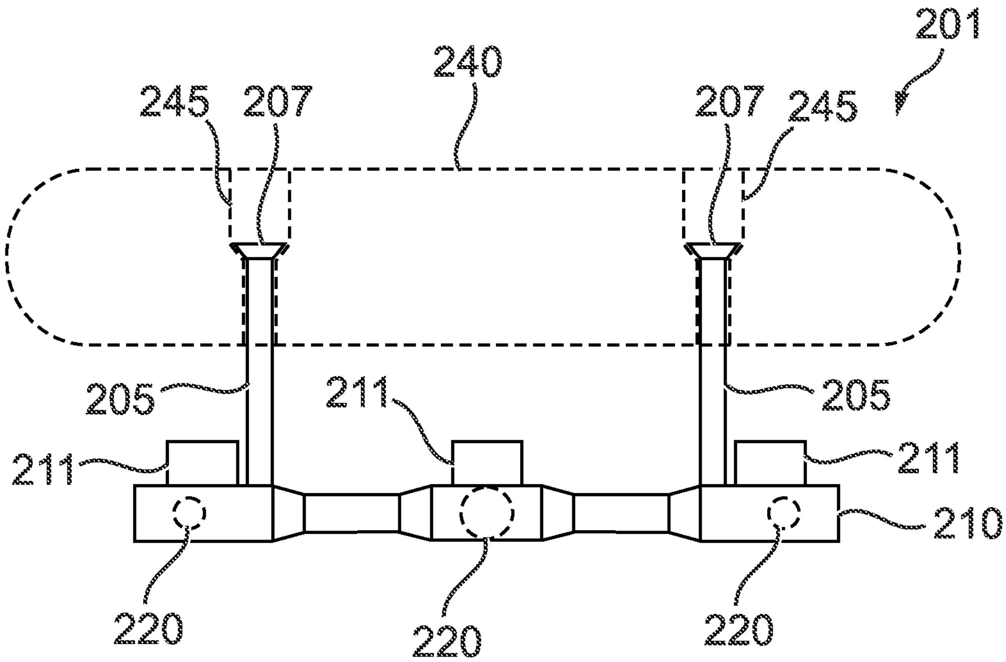

Fig. 22

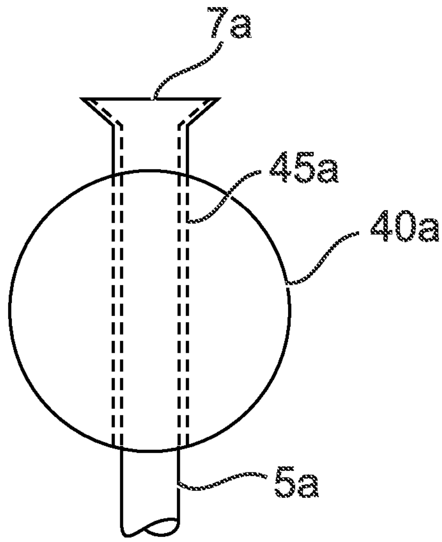

Fig. 23a

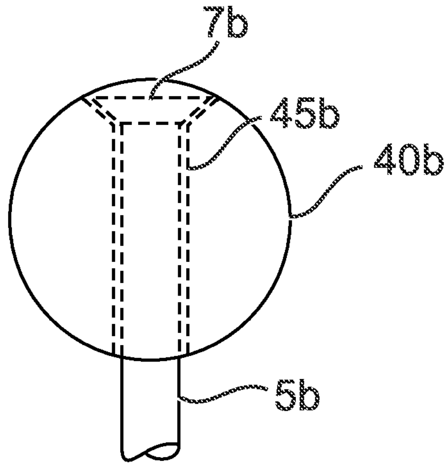

Fig. 23b

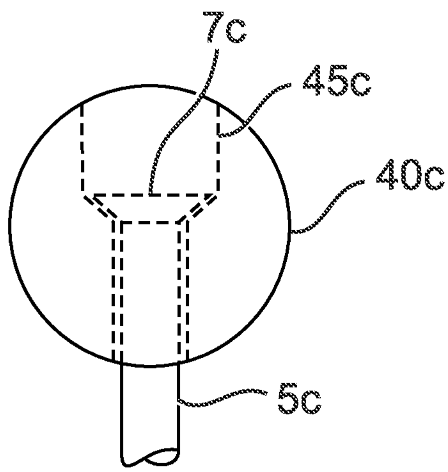

Fig. 23c

PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference P171585.WO.01	**FOR FURTHER ACTION** see Form PCT/ISA/220 as well as, where applicable, item 5 below.	
International application No. PCT/GB2016/050904	International filing date *(day/month/year)* 31 March 2016 (31-03-2016)	(Earliest) Priority Date *(day/month/year)* 8 May 2015 (08-05-2015)
Applicant BAIRD SUBSEA LTD		

This international search report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This international search report consists of a total of 4 sheets.

[X] It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**
   a. With regard to the **language,** the international search was carried out on the basis of:
      [X] the international application in the language in which it was filed
      [ ] a translation of the international application into ______________________, which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1(b))
   b. [ ] This international search report has been established taking into account the **rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91 (Rule 43.6*bis*(a)).
   c. [ ] With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, see Box No. I.

2. [ ] **Certain claims were found unsearchable** (See Box No. II)

3. [ ] **Unity of invention is lacking** (see Box No III)

4. With regard to the **title,**
   [X] the text is approved as submitted by the applicant
   [ ] the text has been established by this Authority to read as follows:

5. With regard to the **abstract,**
   [ ] the text is approved as submitted by the applicant
   [X] the text has been established, according to Rule 38.2, by this Authority as it appears in Box No. IV. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority

6. With regard to the **drawings,**
   a. the figure of the **drawings** to be published with the abstract is Figure No. 6
      [ ] as suggested by the applicant
      [X] as selected by this Authority, because the applicant failed to suggest a figure
      [ ] as selected by this Authority, because this figure better characterizes the invention
   b. [ ] none of the figures is to be published with the abstract

Box No. IV Text of the abstract (Continuation of item 5 of the first sheet)

A platform assembly comprising a marine energy harvester such as a tidal turbine (70) and a frame (1). The frame (1) has a chamber (40) for containing a buoyant fluid material and serving as a buoyancy device and is adapted to convert to a ballast device during installation of the platform assembly. The chamber (40) performs a dual purpose in providing buoyancy during deployment to an installation site and providing ballast acting on the platform assembly following installation of the platform assembly at the installation site. The chamber is movable relative to a base of the frame and has guide posts (5) adapted to guide the movement of the chamber (40) relative to the base (20). The guide posts (5) can optionally be removed from the frame (1) after conversion of the chamber (40) into a ballast device.

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2016/050904

A. CLASSIFICATION OF SUBJECT MATTER
INV. F03B13/26 F03B17/06 E02B17/00
ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F03B E02B

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

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

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2014/205603 A1 (TIDAL HARNESS LTD [CN]) 31 December 2014 (2014-12-31) paragraphs [0007], [0008], [0024] - [0027], [0030], [0035], [0047] - [0050] figures 1,15 -----	1-43
A	WO 2010/143967 A2 (SEATOWER AS [NO]; RAMSLIE SIGURD [AU]; KARAL EVA [NO]) 16 December 2010 (2010-12-16) page 1, column 24 - page 3, column 20 page 5, line 34 - page 6, line 8 page 9, line 6 - line 8 figures 4,11,12 -----	1-43
A	US 2014/145445 A1 (RICHER YVES [CA] ET AL) 29 May 2014 (2014-05-29) abstract figure 9 -----	1-43

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
1 July 2016	11/07/2016

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Lux, Ralph

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/GB2016/050904

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2014205603 A1	31-12-2014	CA 2916763 A1	31-12-2014
		CN 105339651 A	17-02-2016
		GB 2531460 A	20-04-2016
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US 2014145445 A1	29-05-2014	US 2014145445 A1	29-05-2014
		WO 2012103654 A1	09-08-2012