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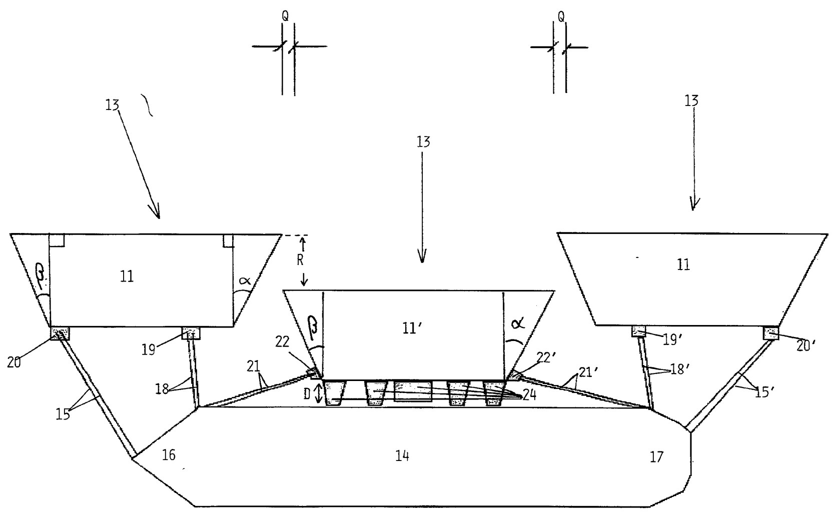
(54) HARBOUR PLANT FOR STORAGE, LOADING AND UNLOADING OF HYDROCARBON PRODUCTS AT SEA AND METHOD THEREOF

(57) This publication discloses a harbour plant (10) for storage, loading and unloading of hydrocarbon products at sea, comprising a number of units (9) being mutually placed on the seabed so that a harbour plant is formed. The units (9) are placed independently at a given distance apart in sideways direction and having a front surface along which a vessel is intended to be moored, forming passage(s) for parts of the waves, and being configured to dampen a part of the incoming waves while allowing other parts of the waves and current to pass through the harbour plant. The sideways distances between two neighbouring units (9) is governed by the frequency of the waves to be dampened and the frequencies of the waves allowed to pass in between the units (9).

The front surface of one of the units (9) is offset with a distance relative to the front surfaces of two neighbouring in a traverse direction away from said incoming waves, and/or that the units are configured in such way that the width of the passage between two neighbouring units increases or decreases in direction of the wave motion.



FIGUR 2

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Description

The Technical Field of the Invention

[0001] The present invention relates to transport of oil and gas at sea, more specifically a device as specified in the preamble of the independent claims.

[0002] In more detail, the invention relates to installation and operation of a harbour plant for storage and loading or unloading of hydrocarbons, such as liquefied natural gas at a distance from the shore in shallow waters, where the alternative is to build storage installations for liquefied natural gas on shore or as a moored, floating installation.

[0003] In particular, the invention relates to a harbour plant for storage, loading and unloading of hydrocarbon products at sea, comprising a number of units being mutually placed on the seabed so that a harbour plant is formed. The units are intended to be placed independently, in a spaced relation at a given distance D apart in sideways direction and having a front surface along and against which a vessel is intended to be moored. Further, the units form passage(s) for parts of the waves, and are configured to dampen a part of the incoming waves while allowing other parts of the waves and current to pass through the harbour plant, the sideways distances between two neighbouring units being governed by the frequency of the waves to be dampened and the frequencies of the waves allowed to pass in between the units.

[0004] The invention relates also to a method for establishing a mooring configuration for vessels, utilizing the storage unit(s) as basis for mooring, meeting the international requirements set out in international conventions, such mooring plant being intended to be placed on a coastal or offshore site, the mooring system being dimensioned to resist mooring forces and all other requirements of international mooring conventions.

[0005] In the following, the common designation of LNG (Liquefied Natural Gas) is used for natural gas that is cooled down to a liquid state. It is common to cool methane to about -161 degrees Celsius, but the invention is also applicable to other types of petroleum products, such as chilled gases such as ethane, methane, propane and butane. In addition, the invention can be used for storage, loading and unloading of oil and oil products.

Background of the Invention

[0006] Harbour sites for LNG- or large oil tankers are considered to be very hazardous. Therefore, it is not advantageous to place the sites in the vicinity of populated areas. At the same time, the biggest consumers of LNG are found in densely populated countries. A number of solutions has therefore been suggested to place LNG storage installations at sea.

[0007] Further, to transfer LNG, articulated arms or hoses that are well insulated and flexible are often used. The hoses are often in fact very rigid and very inflexible. The articulated arms move normally in one plane only and do not tolerate sideways movements. This requires that an LNG vessel must properly moored in protected harbours both during loading or unloading operations, lying leeward.

[0008] It has previously been proposed to provide harbour sites for LNG loading at sea that either float or are placed on the ocean bottom. The floating sites have the problem in common that the transfer of LNG between vessel and storage installation takes place between two floating, movable bodies. The dynamics put great demands on equipment and safety if the loading takes place side by side.

[0009] An alternative is to transfer LNG between the aft and bow of the two floating bodies, but this is considerably more difficult than corresponding, prior art loading operations for oil, and the method places great demands on the equipment. If in addition these vessels are allowed to rotate, the storage vessel for LNG must be equipped with a complex underwater swivel system for LNG.

[0010] To reduce the problems associated with the dynamics of the floating bodies during loading operations, it has been proposed to install large, rectangular steel or concrete structures on the seabed, functioning as artificial harbours, where a continuous steel or concrete wall is intended to form a protection for incoming waves. Typical depths of water proposed are 8-30 metres. This type of large construction is intended to be built away from populated areas and at the same time functioning as a breakwater for the LNG ships during loading and unloading operations.

[0011] The problem can be reduced by moving the ship over onto the leeward side of the harbour construction, but calculations and basin experiments have shown that the harbour construction which forms a continuous barrier must be built to be very large if one is to obtain a significant shielding effect when waves and swells come during one period from a particularly unfavourable angle. This is due to the well-known effect that ocean waves will be bent around both sides of such a construction and a focal point will arise some distance behind the leeward side where the bent waves meet. At this focal point, the height of the waves can actually be higher than the incoming waves.

[0012] A large harbour construction placed on the ocean bottom, which shall act as a shield from the waves, will therefore be very costly. Different forms for these types of harbour sites for LNG built in concrete that shall shield the ships from the waves during loading operations have been suggested. One suggested shape is, for example, to build the construction as a horseshoe and let the LNG ships load/unload inside this. This will reduce the dynamics considerably, but the harbour site will be even more costly than a harbour site in the shape of a rectangle.

[0013] NO 126927 describes a harbour site comprising a number of units that are afloat or sunk and otherwise constructed for placement on the seabed. Each unit comprises a base, load-carrying structure and moveable wave-breaking elements that can be moved according to need.

[0014] US 3,958,426 describes a harbour site comprising a number of units placed apart on the seabed, so that at least one straight mooring location is formed. The units are provided with fenders and wave dampening devices.

[0015] Applicants own publication WO2006/041312 discloses a harbour plant for storage, loading and unloading hydrocarbons such as LNG at sea, the whole content of which hereby being included by the reference. The harbour comprises three units built from steel or concrete, placed on the seabed. The units are placed in sidewise relation in-line. The harbour is configured to dampen the waves, the vessel being intended to lie on the leeward side of the mooring.

[0016] US 2004/0011424 discloses a unit for transferring a fluid between a carrier and a harbour plant consisting of a number of separated piled structures as strong points in the mooring system. In particular, this publication relates to the fluid transfer system, such fluid transfer system consisting of rigid pipe lined and pivotable joints. It should be appreciated, however, that the publication also indicates a mooring system. According to the harbour plant disclosed the vessel id moored on the windward side of the harbour plant.

[0017] FR 2252 450 relates to a floating sea dampening device serving as a breakwater formed by a number of trapezoidal platforms of different size, which when assembled, form an approximately trapezoidal assembly with a narrowed end facing the direction of the incoming waves.

[0018] US 4,712,944 discloses a plurality of inflatable and floatable buoyant members configured and connected on slack lines adaptable to yielding to high tide and storm conditions and in which the lines are secured to anchor member. By positioning the buoyant member in the path of the sea waves and by minute adjustments of buoyancy, maximising of dissipation of the waves is achieved.

[0019] US 2,044,795 relates to an oceanic harbour for landing of sea-planes. The harbour consists of a series of piers or pontoons, immovably located in, and resting upon the bed of the ocean where the gaps provided between the piers are closed by a mobile baffle or barrier, flexibly connected to the piers. A series of avenues or openings are arranged between isolated piers. The piers have an octagonal footprint or a rectangular footprint and each of the series of interconnected piers are aligned, sideways spaced apart.

[0020] Calculations and basin tests have, however, shown that an LNG carrier can in fact be exposed to increased movements if moored on the windward side of these types of rectangular harbour sites. This exposure is due to swell and waves being reflected from the harbour wall and will be caught between the LNG ship and the harbour construction. In some cases, this can lead to a form of standing waves between the harbour wall and the LNG ship, something which can increase the movements of the vessel.

[0021] Hence there is a need for a harbour plant providing mooring conditions where the vessel is lying leeward and where the movement of the vessel due to sea conditions is eliminated, or at least greatly reduced, providing as safe mooring and loading conditions as possible. Further, there is a need for dampening the waves and reducing the effects of waves and currents on the moored vessel as much as possible.

Summary of the Invention

[0022] According to a first aspect of the present invention, there is provided a harbour plant for storage, loading and unloading of hydrocarbon products at sea, comprising a number of units being mutually placed apart on the seabed with at least three units forming a harbour site having a front surface along which a vessel is intended to be moored, the units being placed independently at a given distance apart in sideways direction, the units forming a passage or passages for parts of the waves, and being configured to dampen a part of the incoming waves, while allowing other parts of the waves and current to pass through the passage or passages between neighbouring units, the sideways distances between two neighbouring units being governed by the frequency of the waves to be dampened and the frequencies of the waves allowed to pass in between the units,
characterized in that the front surface of middle unit of said three units is offset with a distance (R) relative to the front surfaces of two neighbouring units (9) in a traverse direction with respect to the longitudinal direction of the plant, away from said incoming waves, and that R is in the range of 2 to 60 meters.

[0023] In embodiments, the units are configured in such way that the width (Q) of the width of the passage between two neighbouring units increases or decreases in direction of the wave motion

[0024] In embodiments, the footprint of the displaced unit is trapezoidal, where the parallel side surfaces are perpendicular to the predominant direction of the waves.

[0025] In embodiments, the minimum width (q) of the passage corresponds to approximately ¼-½ times the wavelength of the wavelength that is desired to damp.

[0026] In embodiments, an angle (α) between one of the two parallel sides of the unit and at least one of the slanted sides is in the range 0 to 30 degrees.

[0027] In embodiments, the distance between two neighbouring units and/or the laterally offset distance between two units is such that there is no visual opening in the passage.

[0028] In embodiments, the mean sideways distance between the units is about 20 metres when the units are placed at a water depth of 18 metres.

[0029] In embodiments, the units are arranged so that two or more mooring places are formed, and where said mooring places form an angle in relation to each other, such as 90 degrees.

[0030] In embodiments, the minimum width Q of the passage between two neighbouring units corresponds to approximately 1/4 - 1/2 times the wavelength of the wavelength to be dampened.

[0031] In embodiments, the units are provided with means for protecting the units from damages caused by collision, said means comprising elements projecting out from surfaces facing vessels, said means also preferably serving as anchoring points for a vessel intended to be moored along the harbour plant and also preferably contribute to a wave breaking effect.

[0032] In embodiments, the means for collision protection is configured to extend down through waterline when in installed position.

[0033] According to a second aspect of the present invention, there is provided a method for constructing and placing of a harbour site according to the first aspect, **characterized in** that it comprises the following steps: based on wave frequencies to be dampened and allowable frequencies to pass between the units, calculating the distances between the units, placing at least three units such that they stand on their own weight on a seabed and are spaced a distance apart sideways aligned across the direction of the predominating direction of the incoming waves, forming openings between two neighbouring units in the direction of the incoming waves, so that the harbour site dampens a part of the incoming waves while other waves pass through the harbour site, and laterally displacing one of the at least three units in a direction of the incoming wave with respect to the neighbouring unit(s).

[0034] In embodiments, the distance between the units is determined with the help of the following steps: measuring the wave height in a desired area over a period of time, creating a wave spectrum of measured wave heights, calculating a statistical distribution of the wave spectrum determining the average wave height according to the normal distribution of the wave spectrum, and determining the distance between the units according to the value of the average wave height.

[0035] An object of the present invention is to provide an improved harbour plant with incorporated and integrated storage units and an improved method for establishing such harbour plant providing a safe haven for vessels during offshore loading and unloading, for example of hydrocarbons such as LNG.

[0036] A further object of the present invention is to provide an improved harbour plant where the mooring conditions for large vessels, for example for transport of LNG, are optimized, eliminating, or at least reducing the effects of wind, waves and current on the moored vessel, thus also providing wind shielding for the moored vessel.

[0037] A still further object of the present invention is to provide an improved harbour plant where the criteria and international standards for mooring large vessels are met, thereby satisfying the relevant requirements and standards. Reference is made to the following relevant standards, the content of which being included by the reference:

- BS 6349 - Harbour Facilities
- OCIMF - Mooring Equipment Guidelines (2008)
- SIGGTO - Site Selection and Design for Ports and Jetties (1997)

[0038] Another object of the present invention is to provide an improved harbour plant with protecting means associated therewith, protecting the moored vessel form impacts and collision caused by drifting vessels, more or less without manoeuvrability.

[0039] Yet another object of the present invention is to provide an improved harbour plant allowing a part of the waves to pass more or less unhindered, while the remaining part of the waves are dampened.

[0040] Another object of the invention is to provide an improved bottom-located harbour site at sea which can store, load or unload LNG directly between vessel and harbour site where the effect of the movements of the ship is minimised in a simple and cost-effective way.

[0041] It is also an object of the invention to provide an improved flexible and bottom-located harbour site for LNG at sea which can be built as several smaller units, where each unit may be lowered down onto the seabed individually, resting due to gravity, so that all the units finally form a harbour site with mooring points in a desired direction, alternatively in several different directions.

[0042] Another object of the invention is to provide an improved harbour site where the wave dampening is best for medium wave frequencies, for example, for waves up to 8-10 seconds frequency, where it might be required for the ship to be able to operate.

[0043] Moreover, it is an object of the invention that in such time-limited, extreme weather conditions, such as hurricanes with high waves, where a vessel will find it difficult to operate in a harbour, the largest waves will pass through the harbour site, the effect and the influence on the harbour site of these extreme environmental forces thereby being reduced significantly in that the extreme energy passes through the harbour site.

[0044] Yet another object of the invention is to enable building of each of the units of the harbour site at reasonable price and efficiently and as complete as possible at a traditional construction site, preferably at a dockyard with the use of a dry dock. Thereby, the costly finishing work at sea will be minimised. After final outfitting at the building site, each of the units is brought or towed to the installation location, finally to be lowered down with the use of known techniques.

[0045] A further object of the present invention is to provide an improved harbour site which can be placed on the ocean bottom at a pre-calculated, relative distance which maximises the wave-dampening effect, and that the units can be given a shape giving the best wave-dampening effect possible, so that the LNG vessel has advantageous movements during loading/unloading operation at the harbour site.

[0046] Moreover, an object of the invention is to provide a harbour plant enabling mooring hawsers between the vessel and the mooring to lead downwards from the vessel towards the mooring point on the harbour plant with an angle of at least 2 degrees, preferably with a larger angle according to international standards. It should be appreciated that the mooring points should be arranged in the vicinity, but above the sea level, to also allow smaller vessel to be moored to the plant and still maintain said downward lead on the mooring lines or hawsers.

[0047] It is also an object of the present invention to provide a harbour plant shielding the moored vessel from wind forces, caused by wind coming from any directions, but most commonly from the same direction as the incoming waves.

[0048] The objects of the present invention are achieved by an improved harbour plant and a method for establishing such harbour plant as further defined by the independent claims. Embodiments, alternatives and variants of the invention are defined by the dependent claims.

[0049] According to the invention, the front surface of one of the units is offset with a distance Z relative to the front surfaces of two neighbouring units in a transverse direction away from said predominating direction of incoming waves, and that R is a distance in the range of a distance 0 to Z, where Z is the length of offset central unit

[0050] The distance Z may preferably be equal to the length of the largest vessel to be moored along a longitudinal side of the central, offset unit.

[0051] The units are configured in such way that the width of the passage between two neighbouring units increases or decreases in direction of the wave motion.

[0052] The offset distance of said unit may preferably be in the range 2 to 60 metres, and the footprint of the displaced unit may preferably trapezoidal, where the parallel side surfaces are perpendicular to the predominant direction of the waves. Further, the units may be configured in such way that a width of the passage between two neighbouring units decreased in direction of the incoming wave. Also, the footprint of the two neighbouring units may preferably, but not necessarily be is trapezoidal.

[0053] According to one embodiment of the invention, the minimum width (Q) of the passage corresponds to approximately ¼-½ times the wavelength of the wavelength that is desired to dampen.

[0054] Further, an angle (α) between one of the two parallel sides of the unit and at least one of the slanted sides of a unit may be in the range 0 to 30 degrees. Optionally, the angle (α) may be different for one of the side walls of a unit.

[0055] According to another embodiment or variant of the invention, the distance between two neighbouring units and/or the laterally offset distance between two units may preferably be such that there is no visual opening in the passage, perpendicular to the front face of the unit. The mean sideways distance may preferably be between around 20 metres when the units are placed at a water depth of 18 metres.

[0056] According to another embodiment, the units may be arranged so that two or more mooring points are formed, and where said mooring points form an angle in relation to each other, such as 90 degrees.

[0057] The units may be provided with means for protecting the units from damages caused by collision, said means comprising elements projecting out from surfaces facing vessels, said means also preferably serving as anchoring points for a vessel intended to be moored along the harbour plant and also preferably contribute to a wave breaking effect. The means for collision protection may be configured to extend down through waterline when in installed position.

[0058] The height of the mooring platform should be arranged above the sea level, at a low, but safe height, providing flexibility for mooring a wide range of different sized vessels.

[0059] According to the present invention, a method for constructing and placing of a harbour site is also provided. The method comprises the following steps:

- placing at least three units standing on their own a distance apart so that the harbour site dampens a part of the incoming waves while other waves pass through the harbour site,
- displacing one of the at least three units in a lateral direction with respect to the neighbouring unit(s), and calculating the distance between the units according to which wave frequencies one wishes to dampen and which frequencies one wishes to pass between the units. Said distance between the units may preferably be determined by the following steps:
    - measuring the wave height in a desired area over a period of time,
    - creating a wave spectrum of measured wave heights,
    - calculating a statistical distribution of the wave spectrum
- determining the average wave height according to the normal distribution of the wave spectrum, and determining the distance between the units according to the value of the average wave height.

[0060] An advantage with placing the units in the harbour site according to the invention a distance apart from each other will be that the required parts of the wave spectrum can be dampened while waves which can lead to extreme strain on the harbour site will travel through. Thus, the units which the harbour site is composed of can be built cheaper and easier, at the same time as one achieves dampening of the parts of the wave spectrum where it is relevant for the ships to operate near or at the harbour site.

[0061] It is also an advantage of the present invention that the waves are dampened efficiently by breaking and cancellation effects which are due, among other things, to reflection from many walls and one thus avoids that the wave energy is deflected and appears at focal points other places in the vicinity of the harbour site.

[0062] In addition, it is a great advantage construction wise and economically that the harbour site is fabricated in smaller units. Thus, several workshops can compete for the construction that will, to a large extent, be able to be fabricated in traditional shipyards. In addition, the installation will be much less hazardous.

[0063] A further advantage according to the present invention is that the units constituting the harbour site for LNG according to the invention can be lowered down to the ocean bottom, be removed, be moved and be replaced to form new individual configurations as required using known techniques.

[0064] The units according to the invention forming the harbour site are placed apart at a required distance. The distance between the units is decided by the wave frequencies intended to be dampen and the frequencies allowed to pass between the units. This distance can be calculated with known methods or be found by means of basin experiments.

[0065] By placing the units a distance apart both sideways and in the prevailing direction of waves, the effect of a build-up of wave energy between harbour wall and side of the ship is avoided. In particular, stationary waves which may be created between a continuous structure and the side of a ship due to reflections between the vertical sides are avoided or at least substantially reduced. Detrimental and extreme parts of the wave energy will thus slip between the units. Since the wave energy is in this way partially is broken up and partially pass between the units, an advantageous cancellation effects and thereby a reduction of the wave energy in the area around the harbour site and the ship is provided.

[0066] By adjusting the distance between the units, it is possible to achieve an optimisation of the parts of the incoming frequency of the waves to be dampen. This is achieved by reflection of the incoming waves from walls and bottom of the units in several directions, whereupon a cancellation of the waves is obtained. In addition, a purposeful, approximately chaotic flow pattern, corresponding to stirring, between the units is produced, removing energy from the waves with a subsequent reduction of the movement response of the vessel.

[0067] For longer wavelengths, for example, swells with a period above 15-16 seconds, the wave reflections from the units will be smaller, and the energy that lies in this part of the wave spectrum will pass between the units. Waves with this wavelength are normally formed in connection with storms and hurricanes and then the ship will normally not be able to operate because of the wind. Hence the vessel will thereby not be moored in the harbour site.

[0068] The friction and thereby the wave dampening can be increased in that the units are fitted partially with sharp edges. In certain parts of the wave spectrum, a non-linear dampening is provided, thus removing energy that affects the ship.

[0069] A favourable form of the units will be to expand the volume of the units below the surface of the water, where a stowing of the waves can be provided so that the waves break, also contributing sometimes to wave dampening and reducing the waves on the leeward side of the harbour site. The shape and form of the structure below water can be varied dependent on the surroundings and which wave periods to be dampened. Favourable shapes could be an inclined surface corresponding to a beach, a built-up structure with sharp edges, a structure which is partially hollow or full of holes etc.

[0070] The distance on the seabed between the units will be decided by the wave spectra that occur at the installation location and by the chosen wave spectra to be dampen, causing favourably effects on the movements of the LNG ship. Calculations of a possible shape of a harbour site have shown that a quadratic or trapezoidal shape of the units and with a distance of 40 meters apart between the units, placed at a water depth of 18 metres and with no expansion of the volume below the sea level, will dampen waves with wavelengths less than 80 metres. At the same time, calculations have shown that large waves with a wavelength above 200 metres will pass with minimum loss of energy.

[0071] Calculations has also shown that by alternatively expanding the volume below the sea level, capture and removal of more energy from the waves, both from shorter and longer wavelengths, will be possible. Further dampening affecting the movements of the vessel in a favorable way can thereby be achieved by, for example, by increasing the volume of the units below sea level, for example, from 5-10 meters depth and down to the ocean bottom. This increase of volume can be limited to the volume between the units and be omitted along the mooring face where the LNG ship is moored. The increase of volume can be combined with securing a good and sound foundation of the units on the seabed. The units must, however, be configured so that waves are not reflected towards the LNG vessel, causing detrimental and undesired movements.

[0072] Parts of the wave spectrum can also be dampened, for example, by introducing outwardly extending sharp edges corresponding to bilge keels on ships. It is natural that these sharp edges are possibly introduced in the space between the units and not where the LNG ship shall be moored. A series of possible means having wave dampening effects have been described in the literature, such as hollow spaces in walls, ribs, and the like. The present invention offers the possibility of introducing these types of means at a harbour site for LNG in a very cost-effective way.

[0073] By providing a harbour site comprising several units installed near each other on the seabed, the LNG vessel can easily be moored and operate along the harbour site. If the LNG ship lies at the windward side of a harbour site according to the invention, reflection of waves towards the ship and the unfavourable, stationary waves produced between the ship and the harbour wall, are avoided.

[0074] Alternatively, the LNG ship can be moored on the leeward side of the harbour site according to the invention. A pre-estimated part of the wave energy will be able to pass between the units and it will be possible to dampen some of the wave energy. In this way forming of a dangerous focal point for the waves on the leeward side is avoided at the same time as the wave energy on the leeward side results in reduced and favourable ship movements.

[0075] By taking into account the local wave spectrum, it may be possible to achieve considerable dampening when the distance between the units is optimal, at the same time as the underwater structure of each of the units is configured with means for dampening of wave energy.

[0076] A particularly advantageous configuration of the harbour site according to the invention will be to arrange the units so that several mooring areas are formed and that these mooring areas form an angle with respect to each other, for example, of 90 degrees. It is possible to adjust the angle and positioning to known wave directions at the installation location of the harbour site. By being able to moor the LNG ship so that the waves come in alongside the ship, the movements of the ship will, in general, be in the form of heaving and stamping, giving considerably lower movements and dynamic forces midship where the loading and unloading operations of LNG will take place.

[0077] The harbour site for LNG vessels according to the invention can, if required, also be configured as a U or a V, if one wishes to protect the harbour operations themselves as much as possible and moor the ship in a more protected area where the waves are dampened to a desired extent. This is particularly effective if the underwater part of the units is formed as wave-dampeners, preferably in the direction towards the neighbouring units.

[0078] The units making up the harbour site will preferably be provided with a number of skirts of steel or concrete to be forced down into the seabed, contributing to a stable construction against the seabed. According to a preferred embodiment, the skirts have a cylindrical shape with a circular cross-sectional area in the horizontal plane, intended to be penetrated into the seabed. The skirts will contribute to the stability of the units against tiling and vertical and horizontal displacement.

[0079] Alternatively, each of the units can possibly be positioned on the seabed using known techniques, alternatively be placed on top of a pre-installed base, positioned on the seabed.

[0080] It should also be appreciated that each unit of the plant is given a substantial height, also proving wind protection for a moored vessel.

[0081] According to one embodiment of the invention, the distance between the offset central unit and at least one of the neighbouring units should be Q meter where Q should be in the range from 0 meter to Z meter, Z being preferably minimum 25% of the length of the largest vessel to be moored along the leeward side of the offset central unit. With such dimensions and with the mooring configuration according to the present invention, the moored vessel is prevented from pivoting about the offset central unit when subjected to wind, current or waves from any direction. This is advantageously, in particular for loading or de-loading LNG, since such loading system is based on rigid steel pipes and pivotable joints.

Short Description of the Drawings

[0082] The device according to the invention can be explained in more detail in the following description with reference to the enclosed figures, wherein:

Figures 1 shows schematically a view seen from above of an embodiment of the harbour site according to the invention; where three units are placed a distance apart on the seabed, the middle one being positioned in a retracted position with regard to the wave direction;

Figure 2 shows schematically a view seen from above of a second embodiment of the harbour site corresponding to the embodiment shown in Figure 1, but where the units forming the harbour plant having a trapezoidal foot print;

Figure 3 shows schematically a view seen from above of a third embodiment of the harbour site corresponding to the embodiment shown in Figure 1, wherein the units forming the harbour plant are provided with additional mooring and/or wave breaking or damping means;

Figure 4 shows schematically a vertical section in longitudinal direction of the units shown in Figure 3, seen along the line 4-4 in Figure 3;

Figure 5 shows a side view of an ocean installation where the units are configured to provide two mooring positions, the two mooring positions being arranged at an angle with respect to each other;

Figure 6 shows schematically a side view of a unit provided with ice breaking buffering structures on two opposite sides of a unit;

Figure 7 shows schematically a side view of a plant unit according to the present invention, also indicated schematically a vessel moored to the unit, the Figure indicating the direction of the mooring hawser; and

Figure 8 shows schematically another configuration of the units forming the plant.

Detailed Description of the Figures

[0083] It should be noted that in the following description of the embodiments shown in the Figures, the same reference numbers are used for identical or similar structures and features.

[0084] Figures 1 shows schematically a view seen from above of an embodiment of the harbour site 10 according to the invention. The harbour site shown comprises three identical units 11,11', configured to rest stably on a seabed 12 due to gravity. The three units 11,11' are placed a distance Q apart on the seabed 12, the middle unit 11' also being positioned in a retracted position in respect to the two other units 11 with a retracted distance R, the middle unit 11' being retracted in a same direction as the general, predominant direction 13 of the waves the waves. As further shown in Figure 1 a vessel 14 is moored along the middle unit 11' on the leeward side of the units 11,11'. The mooring system used for mooring the vessel 14 to the units 11,11' comprises one or more forward mooring line 15 extending from the bow 16 of the vessel 14 to a fore mooring point 20 at the far leeward corner of one of the units 11. The one or more hawsers 15 have a forward lead, i.e. forming an oblique angle with the longitudinal axis of the vessel 14 in fore direction. Likewise, one or more aft mooring line 15' extend between the stern 17 of the vessel 14 and an aft mooring point 20' at the far leeward corner of the adjacent unit 11, forming a lead in aft direction of the vessel 14, such lead also forming an oblique angle with the longitudinal direction of the vessel 14. Further, the mooring system comprises forward brest mooring lines 18 extending from the bow region 16 of the vessel to the adjacent unit 11, the direction of the one or more hawsers being more or less perpendicular with respect to the front of the adjacent unit 11, the forward brest mooring line 18 being connected to a mooring point 19 in the middle region of the adjacent unit 11. Likewise, a corresponding one or more aft brest mooring lines 18 extend between the stern region 17 and an aft mooring point 19' on the adjacent unit 11, the hawser direction being more or less perpendicular to the front side of the adjacent unit 11. The mooring system comprises also one or more fore spring mooring lines 21 extending from the bow region 16 towards a mooring point 22 on the adjacent leeward corner of the retracted middle unit 11', providing a lead in aft direction of the vessel, the fore spring mooring lines 21 forming an acute angle in rear direction of the vessel. Correspondingly one or more aft spring mooring lines 21' extend from the stern region 17 of the vessel to a mooring point 22' on the adjacent leeward corner of the middle, retracted unit 11', the lead being in forward direction.

[0085] The units 11 may be provided with collision dampers 23 rigidly fixed to the surface of the units 11, intended to face the vessel 14 when in moored position. It should be noted that the Figure shows two variants of such dampers 23. These will be described in more detail below in connection with Figure 4. The dampers 23 may serve as reinforced support points for the mooring points 19,20,22.

[0086] The middle unit 11', on the face intended to face the vessel 14 in moored position, is provided with strong dampers 24, securing a distance D between the hull of the vessel 14 and the structural wall of the middle unit 11'.

[0087] It should be appreciated that although the Figure discloses a middle unit 11' retracted in a same direction as the incoming predominant waves direction, the middle unit 11' may be displaced in opposite direction, i.e. in a direction towards the predominant wave direction. Further, it should be appreciated that the mooring system may have another configuration and/or another number of hawsers, etc. Further, also the various mooring points may differ without deviating from the inventive idea.

[0088] Figure 2 shows schematically a view seen from above of a second embodiment of the harbour site 10 corresponding to the embodiment shown in Figure 1, but where the units 11,11' forming the harbour plant 10 having a trapezoidal foot print. The mooring configuration and the mooring points 19,19', 20,20', 22,22', including the collision dampers 24 correspond to the ones shown in Figure 1.

[0089] Due to the trapezoidal foot print of the units 11.11', the embodiment shown provide a passage between two adjacent units which has a small opening (Q) upstream the waves and an increasing opening in downstream prevailing direction of the waves. It should be appreciated, however, that the units 11,11' may be placed in a closer spaced relation, leaving a reduced, or actual no visual sightline in the wave direction. Alternatively, the units may be placed in a configuration where the shorter sides of the trapezoids of the units 11,11' face the waves. According to such embodiment the opening between two adjacent units 11,11' is largest in upstream direction of the waves, the opening being narrower in direction away from the wave direction.

[0090] The trapezoidal shape may be regular, i.e. the acute angle α formed between the front side and one of the side surfaces, are equal. Alternatively, one of the side surface may form an angle β with the front side, where β differs from α.

[0091] As for the embodiment shown in Figure 2, the angle α and β may be adjusted depending on required maximum wave breaking effects. The variation in the reflection and diffraction caused by the alteration of the angle α and β changes the interference pattern of the approaching waves. This results in an effective reduction of the wave height or causes increased wave breaking, resulting in a reduction of the propagated wave energy. Moreover, the direction of the waves propagating between the units will be altered, resulting in a change of region effectively "shadowed" by the structure. Further both the distance Q and R may also be adjusted for the same purposes. The adjustment of the angle α and Q and R will increase or widen the wave direction (wave protection angle) and give the harbour design a wider range of reflection angles to create damping effects. The distances and angles can be tuned towards the predominant wave pattern and direction for maximum protection of the harbour operation.

[0092] Figure 3 shows schematically a view seen from above of a third embodiment of the harbour site 10 corresponding to the embodiment shown in Figure 1, wherein the units 11,11' forming the harbour plant 10 are provided with additional mooring and/or wave breaking or damping means, while Figure 4 shows schematically a vertical section in longitudinal direction of the units 11,11', shown in Figure 3, seen along the line 4-4 in Figure 3. Again, the mooring configuration being identical with the ones shown in Figures 1 and 2, the difference being the types of collision dampers used. The various dampers are disclosed in more details in Figure 4. Two types of dampers may be used. One damper, type A, is of a type extending down through the water line 25, projecting outwards from the side and/or the front walls of the units 11,11'. In addition to functioning as a collision damper, the dampers A,B may also dampen the effects of the waves and/or also function as supports for the mooring points 19,19',20,20',22,22'. Alternatively, or in addition, the dampers may be of a type projecting outwards from the units 11,11' on the front and/or side walls of the units 11,11', the dampers (type B) being terminated above the sea level 25. Said type B dampers may also be used for supporting the mooring points 19,19',20,20', 22, 22'. Type B dampers are terminated above the sea level 25.

[0093] As also indicated in Figure 4, the units 11,11' may be provided with tanks for storage of hydrocarbons, such as for example LNG. From a safety point of view, only the wing units 11, may be provided with such tanks. It should be appreciated that the mooring system 10 according to the present invention also may be provided with means, such as loading systems, cranes, etc.

[0094] Figure 5 shows a side view of an ocean installation where the units 11,11' are configured to provide two mooring positions, the two mooring positions being arranged at an angle with respect to each other._The harbour site for LNG vessels according to the invention can, if required, also be configured as a U or a V, if one wishes to protect the harbour operations themselves as much as possible and moor the ship in a more protected area where the waves are dampened to a desired extent. This is particularly effective if the underwater part of the units is formed as wave-dampeners, preferably in the direction towards the neighbouring units.

[0095] The dampers A,B or the units 11,11' may also be provided with mooring fenders so that it is possible to safely moor the LNG ships 14 to the harbour site 10 by means of the mooring arrangement. The mooring fenders can be made from known, flexible materials according to known techniques. However, they do not have to comprise the mooring arrangement, as an alternative embodiment can be that the mooring installation is placed a distance from the harbour site itself.

[0096] Figure 6 shows schematically a side view of a mooring and storage unit 11, resting on the seabed due to its own weight, possibly with additional ballast and the weight of the plant, equipment and stored fluid. As indicated in the Figure, the plant unit 11 is provided with ice breaking buffering structures 26 arranged in the region of the water line 25 on two opposite sides of a unit 11. The ice breaking buffering structure 26 may have an inclined upper and/or lower surface, configured for breaking up the ice and possibly securing an oblique impact between the broken ice and the vertical walls of the unit 11. The free end of the ice breaking buffering structure 26 may be positioned slightly below the sea level.

[0097] Moreover, as indicated, the unit 11 may also be provided with storage tanks for hydrocarbons, for example insulated storage tanks for LNG.

[0098] The unit shown is also provided with a mooring point 20 arranged above the highest expected tidal height and below the top surface 27 of the unit, thus enabling a negative lead of an angle α' for the mooring hawsers (not shown) extending between vessel 14 and the plant unit 11. It should be appreciated that although the reference number 20 is used for the mooring point, said indicated mooring point may be any one of the mooring point required for safely mooring the vessel 14 to the plant.

[0099] .Figure 7 shows schematically a side view of a plant unit 11 according to the present invention, also indicated schematically a vessel 14 moored to the unit 11, the Figure indicating the vertical orientation and direction of any one of the mooring hawser 15, 15', 18,18' 21, 21'. The vessel 14 moored to the plant is indicated by a cross sectional view through the vessel 14.

[0100] As indicated in Figure 7, the height of the plant unit 11 may be so high that the hull of the vessel 14 more or less is shielded by unit 11.

[0101] Figure 8 shows schematically another configuration of the units 11 forming the plant. According to this configuration, the configuration of the units shown in Figure 2 is used. In addition, another unit 11' is added, the orientation being such that a shelter is established, preventing waves coming from a direction more or less parallel with the longitudinal direction of the three units 11. It should be appreciated that the mooring lines, mooring points etc. is not shown. Such gear and equipment may be a duplicate of the ones shown in the other Figures. The Figure also indicates as an option an end of a pier 28 for access from ashore to the plant. The bridges between the pier and the plant unit 11 and between the various plant units 11 are not shown.

[0102] The units 11,11' may be constructed at the harbour site 10, build at a remote construction site, towed and placed on the ocean bottom 12. The units 11,11' and the harbour site 10 are formed according to the local environmental conditions such as depth of water, type of ocean bottom, wave formations and where possible, negative effects from environmental forces such as waves, wind and current are minimised. Dependent on desired mooring direction and position for the LNG ship 14, the units 11,11' are placed on the ocean bottom in a desired configuration such that the desired loading conditions for the LNG ship are the best possible according to operative and safety considerations.

[0103] The shape of the units 11,11' into an installed harbour site 10 is adapted to the local wave spectrum at the installation location so that waves that lead to movements of the ships during operations at the harbour site 10 are dampened as much as possible, while other waves are permitted to pass the harbour site 10.

[0104] Adjustments to the waves can be achieved by setting the units 11,11' at a distance from each other on the ocean bottom. Small waves will be dampened by short distances and big waves will be dampened by large distances, respectively. Calculations have shown that it is particularly favourable to use a distance between the units 9 that approximately correspond to ¼-½ times the wavelength of the waves that one wishes to dampen.

[0105] To determine which waves one wishes to dampen, one can start with a wave spectrum in the form of wave height and wave frequency. Then it can be useful to represent a number of waves over time with the help of a wave spectrum, for example, by measuring maximum height of each wave. By using a statistical distribution, such as significant values of said wave spectrum, one can determine which type of wave frequencies and wave heights is wanted, in the main, to dampen. With significant values, it is meant the mean value of the third of the waves that is highest over a 20 minute period (for measuring the wave height). Other forms of statistical distribution can also be used and as this is known for a person skilled in the art they are not described further herein.

[0106] The size of the base of the unit can be adapted to achieve the best possible wave dampening. It is advantageous that the upper part of the base is placed below the ocean surface itself, so that a form of a bank is created between the upper part of the base and the ocean surface. Calculations have shown that it is particularly advantageous to place the unit(s) 11,11' around half a wave height below the ocean surface in relation to wave height and associated wavelength one wishes to dampen. An example of this will be that if the wave height one wishes to dampen is 8 metres, then it is advantageous to place the top of the base approximately 4 metres below the sea level 25. To achieve such a distance between the sea level 25 and base, the size of the base is adjusted accordingly.

[0107] The appearance of the base also has an influence on the dampening of the waves around the harbour site 10. It is an advantage that the base has a quadratic form in the horizontal plane, where it will, in such an example, only be necessary to carry out changes in the height to adapt the base in relation to the ocean surface. However, it shall be mentioned that other appearances of the base can be applied, and they are described in more detail later in the description.

[0108] The base of the units11.11' can also be formed in a number of ways dependent on aims, needs and wishes.

[0109] The units 11,11' may have a relatively large and voluminous base (not shown) where these bases are placed relatively near each other. By this formation and placing of the units 11.11', a harbour site 10 functioning as a wave dampener or wave breaker for the desired parts of the wave spectrum, for example, waves with periods of less than 10 seconds. At the same time, the longer period swells will be able to slip through the harbour site 10 if this is desired. In addition, it will be possible to reduce the effect of unfavourable ocean streams.

[0110] If stronger dampening is required, the units 11,11' may be formed with more inclined sidewalls and be placed closer to each other. The units 11,11' and the bases can be formed with rougher or perforated surfaces, sharp edges, protrusions, etc., if one wishes increased interaction with, and further dampening of, the waves (not shown).

[0111] The units 11,11' do not need to lie in a straight line in relation to each other but can be placed at a desired angle in relation to each other as shown in figure 5. This is advantageous if one wishes to avoid negative effects of, for example, swells that come from varying directions. During loading and unloading operations, it is particularly disadvantageous to get in strong waves and swells in the midship direction. This gives large heaving and rolling movements for the LNG ship14, at the same time as the ship can be forced against the mooring location, something which is highly undesired during loading and unloading operations of LNG.

[0112] By mooring the LNG ship 14 in another direction, the strong waves or swells come in the direction alongside of the ship. The response of the LNG ship 14 to waves in the direction alongside the ship thereby comes in the form of considerably lower rolling and stamping movements and reduced midship dynamics.

[0113] The following numbered clauses correspond to the claims of the parent application number 12803799.1 as filed.

1. Harbour plant for storage, loading and unloading of hydrocarbon products at sea, comprising a number of units (9) being mutually placed on the seabed so that a harbour plant is formed, the units (9) being placed independently at a given distance apart in sideways direction and having a front surface along which a vessel is intended to be moored, the units (9) forming passage(s) for parts of the waves, and being configured to dampen a part of the incoming waves while allowing other parts of the waves and current to pass through the harbour plant, the sideways distances between two neighbouring units (9) being governed by the frequency of the waves to be dampened and the frequencies of the waves allowed to pass in between the units (9),
characterized in that the front surface of one of the units (9) is offset with a distance (R) relative to the front surfaces of two neighbouring in a traverse direction with respect to the longitudinal direction of the plant (10), away from said incoming waves, and that R is in the range of 0 to Z, where Z is the length of offset central unit (9).

2. Harbour plant according to clause 1, wherein Z is the length of the largest vessel to be moored along a longitudinal side of the central, offset unit (9).

3. Harbour plant according to clause 1 or 2, wherein the units (9) are configured in such way that the width (Q) of the passage between two neighbouring units increases or decreases in direction of the wave motion

4. Harbour plant according to one of the clauses 1 to 3, wherein the offset distance of said unit is in the range 2 to 60 metres.

5. Harbour plant according to one of the claims 1 to 4, wherein the foot print of the displaced unit is trapezoidal, where the parallel side surfaces are perpendicular to the predominant direction of the waves.

6. Harbour plant according to one of the clauses 1 to 5, wherein the units are configured in such way that a width of the passage between two neighbouring units decreased in direction of the incoming wave.

7. Harbour plant according to one of the clauses 1 to 6, wherein the minimum width (q) of the passage corresponds to approximately ¼-½ times the wavelength of the wavelength that is desired to damp.

8. Harbour plant according to one of the clauses 1 to 7, wherein the footprint of the two neighbouring units is trapezoidal.

9. Harbour plant according to one of the clauses 1 to 8, wherein an angle (α) between one of the two parallel sides of the unit and at least one of the slanted sides is in the range 0 to 30 degrees.

10. Harbour plant according to clause 9, wherein the angle (α) may be different for one side wall of a unit.

11. Harbour plant according to one of the clauses 1 to 10, wherein the distance between two neighbouring units and/or the laterally offset distance between two units is such that there is no visual opening in the passage (8).

12. Harbour plant according to one of the clauses 1 to 11, wherein the mean sideways distance between the units is about 20 metres when the units are placed at a water depth of 18 metres.

13. Harbour plant according to one of the clauses 1 to12, wherein the units (9) are arranged so that two or more mooring places are formed, and where said mooring places form an angle in relation to each other, such as 90 degrees.

14. Harbour plant according to one of the clauses 1 to 13, wherein the units are provided with means for protecting the units from damages caused by collision, said means comprising elements projecting out from surfaces facing vessels, said means also preferably serving as anchoring points for a vessel intended to be moored along the harbour plant and also preferably contribute to a wave breaking effect..

15. Harbour plant according to clause 14, wherein the means for collision protection is configured to extend down through waterline when in installed position.

16. Method for constructing and placing of a harbour site according to one of the preceding clauses 1-11, **characterized in** that it comprises the following steps:

to place at least three units (9) standing on their own a distance apart so that the harbour site dampens a part of the incoming waves while other waves pass through the harbour site,
to displace one of the at least three units in a lateral direction with respect to the neighbouring unit(s), and
to calculate the distance between the units (9) according to which wave frequencies one wishes to dampen and which frequencies one wishes to pass between the units (9).

17. Method according to clause 16, wherein the distance between the units is determined with the help of the following steps:

to measure the wave height in a desired area over a period of time,
to create a wave spectrum of measured wave heights,
to calculate a statistical distribution of the wave spectrum
to determine the average wave height according to the normal distribution of the wave spectrum, and
to determine the distance between the units according to the value of the average wave height.

Claims

1. A harbour plant for storage, loading and unloading of hydrocarbon products at sea, comprising a number of units (9) being mutually placed apart on the seabed with at least three units forming a harbour site having a front surface along which a vessel is intended to be moored, the units (9) being placed independently at a given distance apart in sideways direction, the units (9) forming a passage or passages for parts of the waves, and being configured to dampen a part of the incoming waves, while allowing other parts of the waves and current to pass through the passage or passages between neighbouring units (9), the sideways distances between two neighbouring units (9) being governed by the frequency of the waves to be dampened and the frequencies of the waves allowed to pass in between the units (9), **characterized in that** the front surface of middle unit of said three units (9) is offset with a distance (R) relative to the front surfaces of two neighbouring units (9) in a traverse direction with respect to the longitudinal direction of the plant (10), away from said incoming waves, and that R is in the range of 2 to 60 meters.

2. A harbour plant according to claim 1, wherein the units (9) are configured in such way that the width (Q) of the width of the passage between two neighbouring units increases or decreases in direction of the wave motion

3. A harbour plant according to any of claims 1 and 2, wherein the footprint of the displaced unit is trapezoidal, where the parallel side surfaces are perpendicular to the predominant direction of the waves.

4. A harbour plant according to any of claims 1 to 3, wherein the minimum width (q) of the passage corresponds to approximately ¼-½ times the wavelength of the wavelength that is desired to damp.

5. A harbour plant according to any of claims 1 to 4, wherein an angle (α) between one of the two parallel sides of the unit and at least one of the slanted sides is in the range 0 to 30 degrees.

6. A harbour plant according to any of claims 1 to 5, wherein the distance between two neighbouring units and/or the laterally offset distance between two units is such that there is no visual opening in the passage (8).

7. A harbour plant according to any of claims 1 to 6, wherein mean sideways distance between the units is about 20 metres when the units are placed at a water depth of 18 metres.

8. A harbour plant according to any of claims 1 to 7, wherein the units (9) are arranged so that two or more mooring places are formed, and where said mooring places form an angle in relation to each other, such as 90 degrees.

9. A harbour plant according to any of claims 1 to 8, wherein the minimum width Q of the passage between two neighbouring units corresponds to approximately 1/4 - 1/2 times the wavelength of the wavelength to be dampened.

10. A harbour plant according to any of claims 1 to 9, wherein the units are provided with means for protecting the units from damages caused by collision, said means comprising elements projecting out from surfaces facing vessels, said means also preferably serving as anchoring points for a vessel intended to be moored along the harbour plant and also preferably contribute to a wave breaking effect..

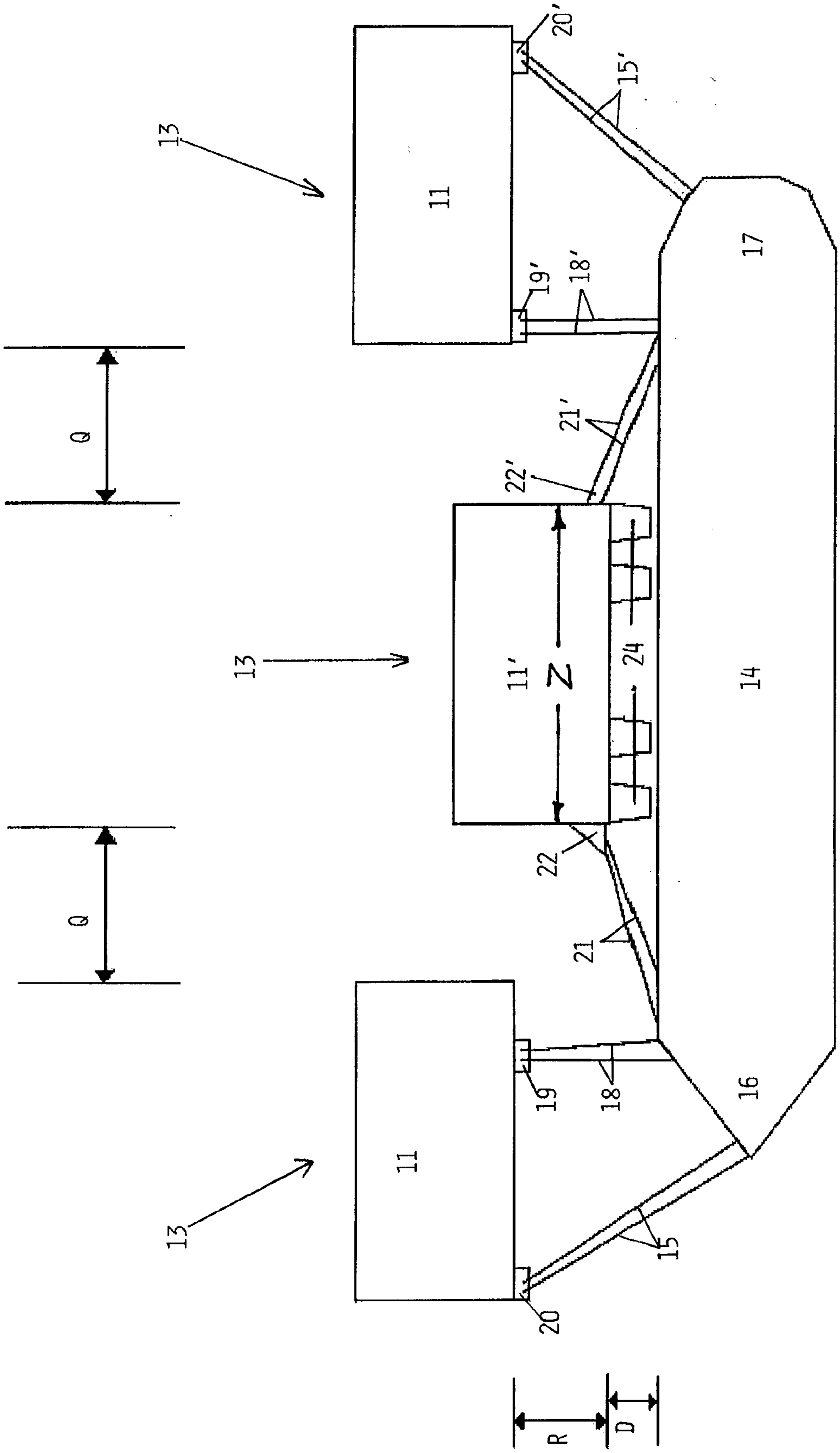
11. A harbour plant according to claim 10, wherein the means for collision protection is configured to extend down through waterline when in installed position.

12. A method for constructing and placing of a harbour site according to any of claims 1 to 12, **characterized in that** it comprises the following steps:

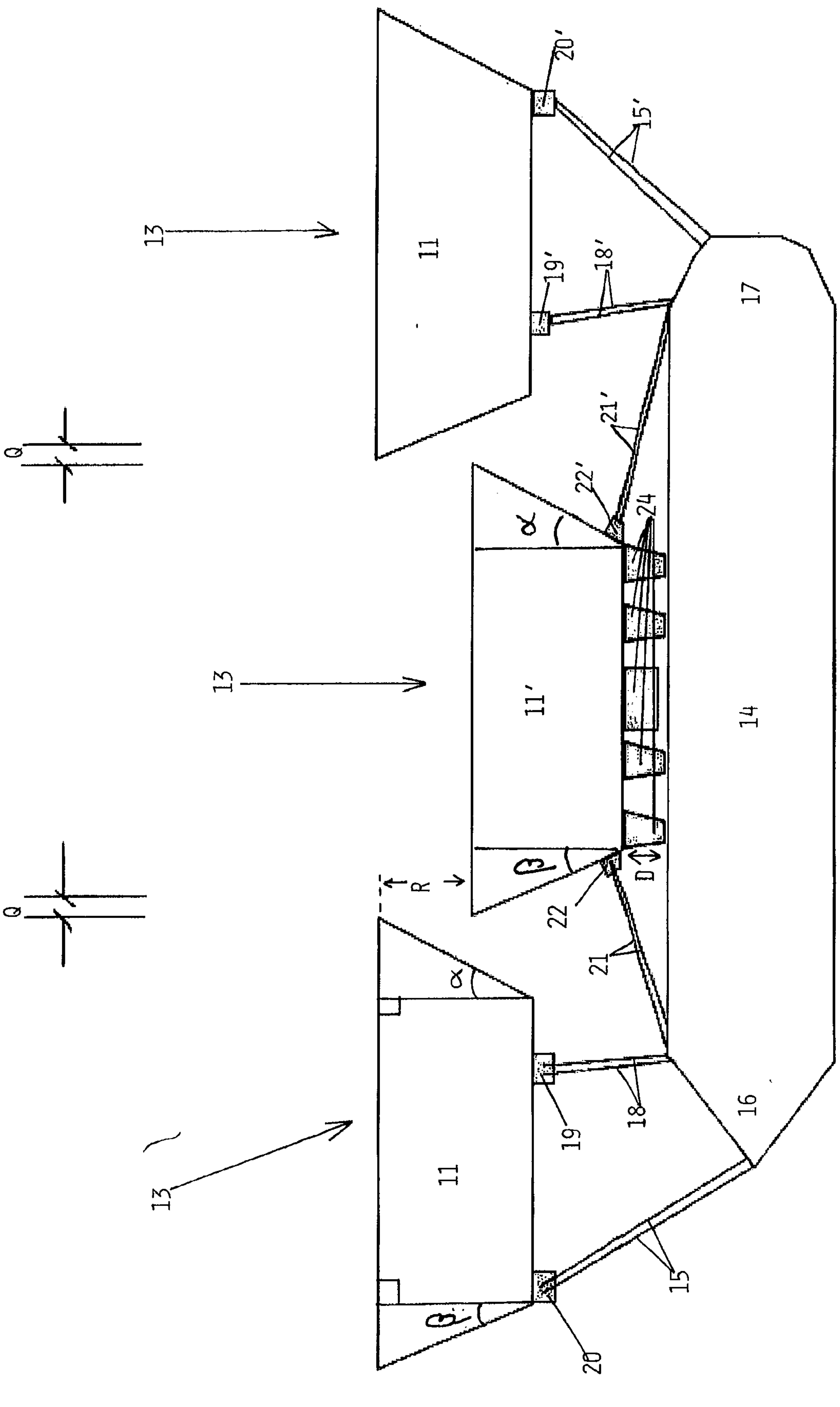
- based on wave frequencies to be dampened and allowable frequencies to pass between the units (9), calculating the distances between the units (9),
- placing at least three units (9) such that they stand on their own weight on a seabed and are spaced a distance apart sideways aligned across the direction of the predominating direction of the incoming waves, forming openings between two neighbouring units in the direction of the incoming waves, so that the harbour site dampens a part of the incoming waves while other waves pass through the harbour site, and
- laterally displacing one of the at least three units in a direction of the incoming wave with respect to the neighbouring unit(s).

13. A method according to claim 12, wherein the distance between the units is determined with the help of the following steps:

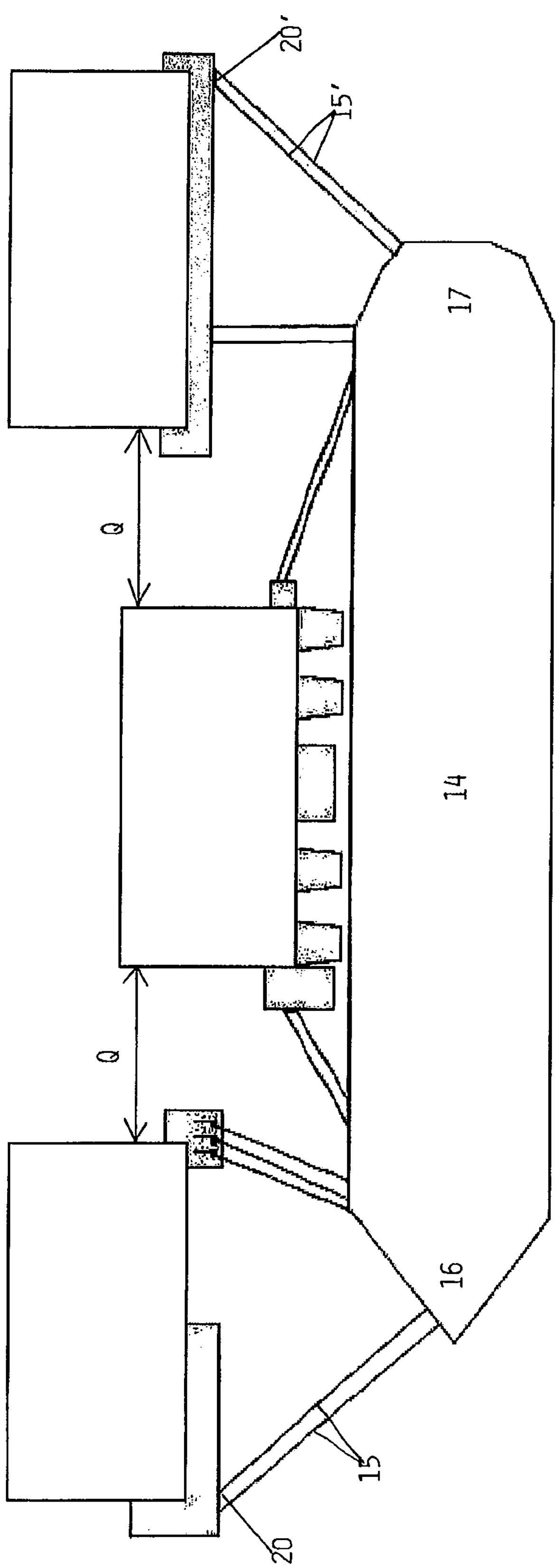
measuring the wave height in a desired area over a period of time,
creating a wave spectrum of measured wave heights,
calculating a statistical distribution of the wave spectrum
determining the average wave height according to the normal distribution of the wave spectrum, and
determining the distance between the units according to the value of the average wave height.



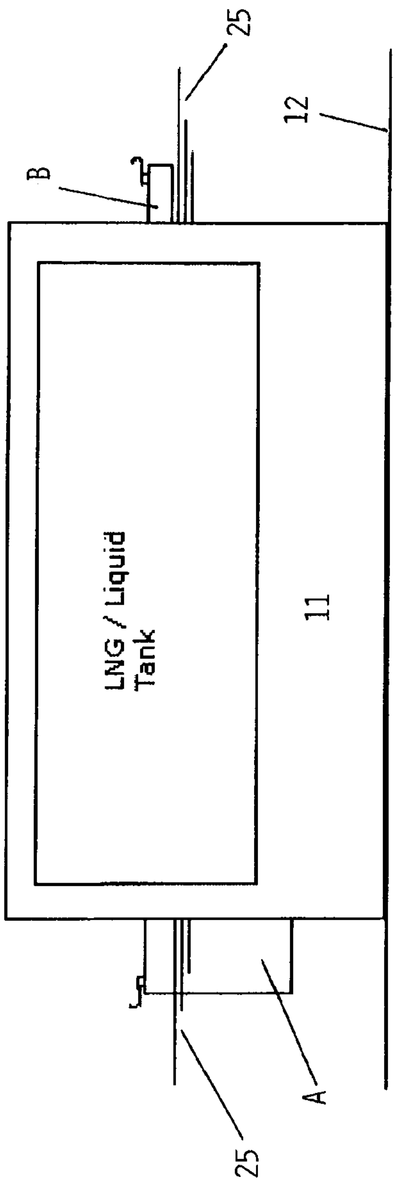
FIGUR 1



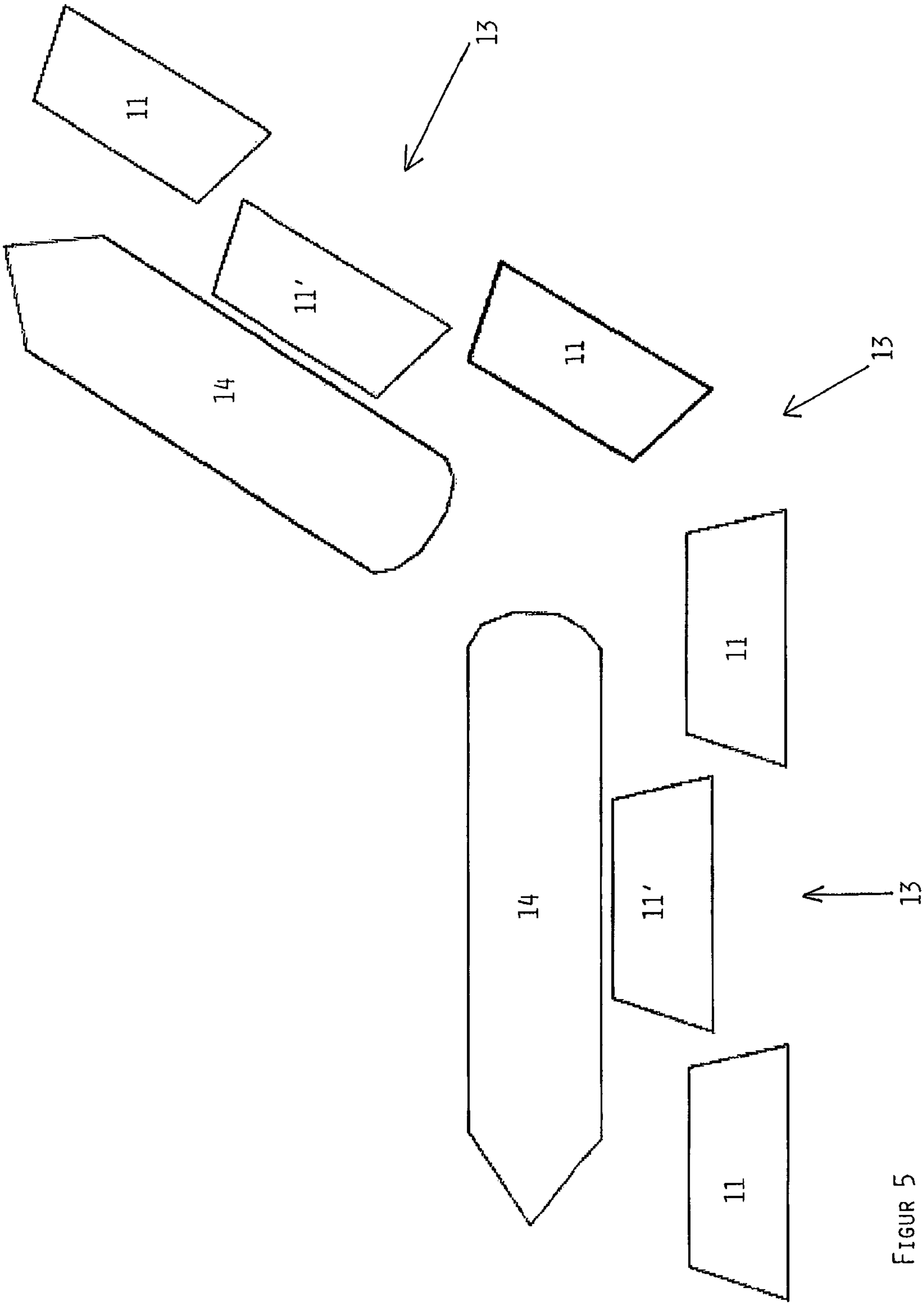
FIGUR 2



FIGUR 3



FIGUR 4



Figur 5

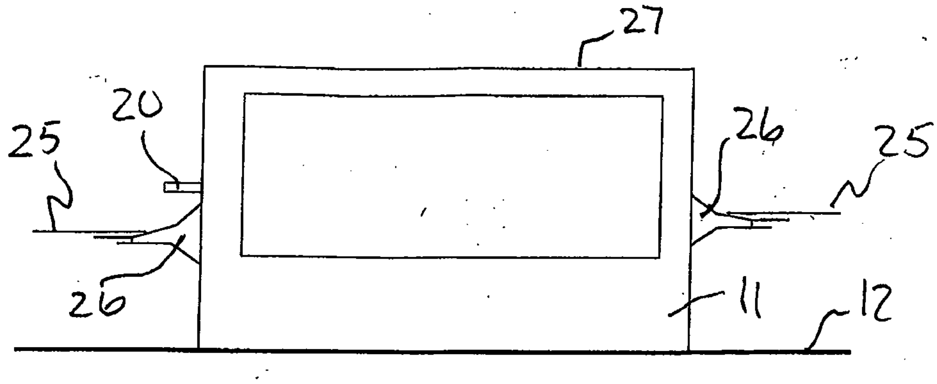


Fig. 6

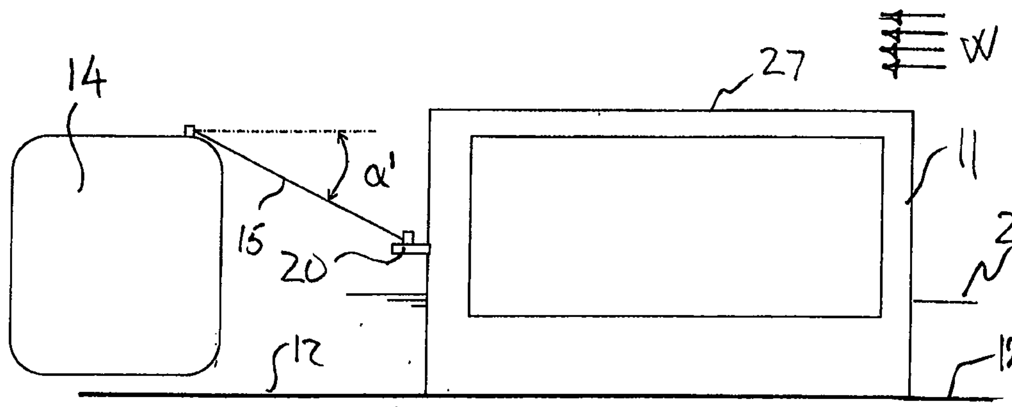


Fig. 7

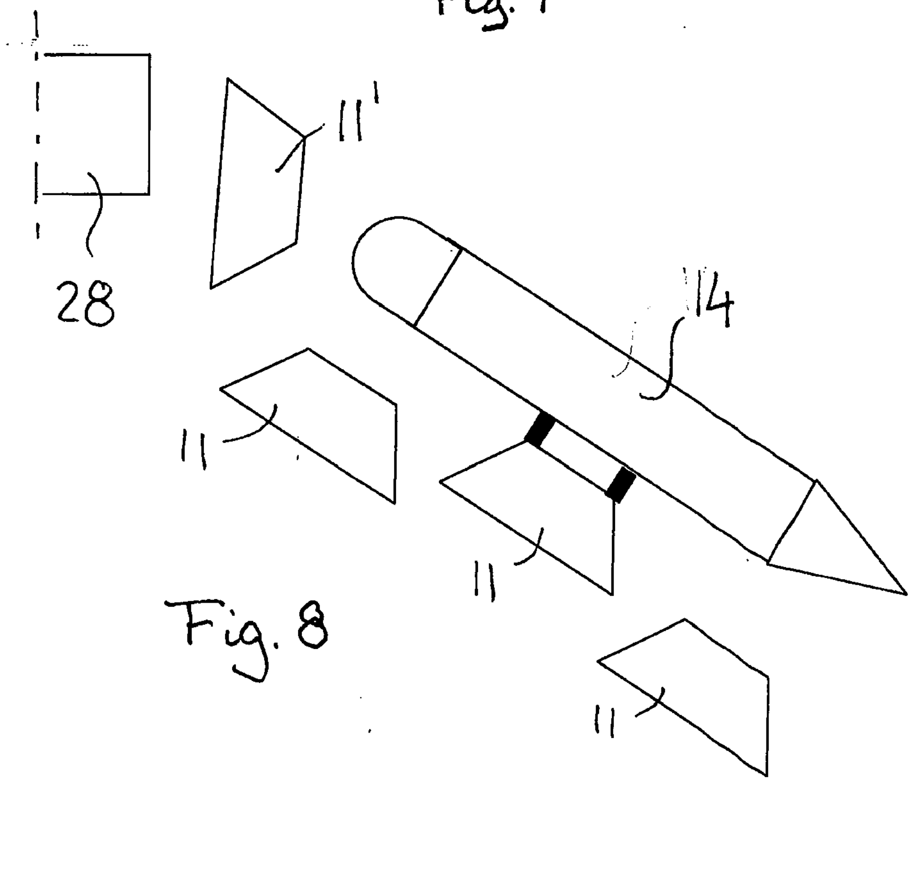


Fig. 8

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EUROPEAN SEARCH REPORT

Application Number
EP 20 16 2728

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E02B

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	12 June 2020	López-García, G

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12-06-2020

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