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(54) ## SYSTEM FOR ENHANCING CORROSION PROTECTION OF A MARINE STRUCTURE

(57) A system enhances corrosion protection of a protected surface (30) of a marine structure (110) in contact with a liquid containing biofouling organisms. The protected surface is electrically conductive and is protected against corrosion by impressed current cathodic protection (ICCP). The system has a light emitting arrangement (100) comprising a light source (20) for emitting anti-fouling light (22). The light emitting arrangement is arranged to emit the anti-fouling light from the light source towards a zone of the protected surface (30). Effectively biofouling is prevented and the operation of the ICCP is enhanced when the marine structure is partly immersed in the fouling liquid.

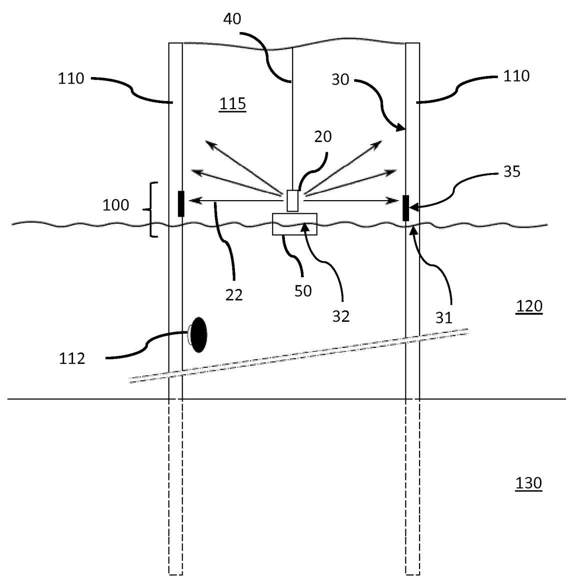

FIG. 1

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Description

FIELD OF THE INVENTION

[0001] The invention relates to methods, systems and devices for enhancing corrosion protection of a protected surface of a marine structure in a liquid containing biofouling organisms. Marine structures are metallic structures in various wet environments such as pipelines, wind turbines, steel pier piles, offshore oil platforms, offshore wind farm foundations, monopiles for wind turbines, non-monopile supports for wind turbines, oil rigs, structures for harvesting tidal energy and/or wave energy, etc. The liquid containing biofouling organisms may be any aqueous or oily environment, in particular sea water. In general, corrosion causes such constructions to weaken. Corrosion may be accelerated by biofouling, which may cause so-called pit corrosion. The invention may be applied for reducing or preventing corrosion of such marine structures in contact with the liquid.

BACKGROUND OF THE INVENTION

[0002] Cathodic protection makes an electrically conductive surface act as a cathode, which is a technique used to reduce corrosion of a metal surface by making it the cathode of an electrochemical cell. A passive method of protection connects the metal to be protected to a more easily corroded sacrificial metal to act as the anode. The sacrificial metal then corrodes instead of the protected metal. For various reasons, passive galvanic cathodic protection may not be adequate.

[0003] An external DC electrical power source may be used to provide sufficient current to cause a potential of the protected surface with respect to the liquid required to prevent corrosion. Using this method is usually called impressed current cathodic protection (ICCP). Impressed current cathodic protection systems may protect a wide range of marine structures. ICCP is aiming at stopping corrosion by creating a potential on the metal to be protected; the potential required being 0.8-0.9 V.

SUMMARY OF THE INVENTION

[0004] It follows from the foregoing that impressed current cathodic protection measures are known to effectively reduce corrosion of immersed and even buried protected surfaces. However, at some protected surfaces of a partly immersed marine structure protected by ICCP, corrosion still poses a problem.

[0005] The invention has as an object to enhance protection against corrosion of surfaces of a marine structure in contact with a liquid containing biofouling organisms.

[0006] According to the invention, a system is provided for enhancing corrosion protection of a protected surface of a marine structure in contact with a liquid containing biofouling organisms, the protected surface being electrically conductive and being protected against corrosion by impressed current cathodic protection. The system comprises a light emitting arrangement comprising a light source for emitting anti-fouling light, the light emitting arrangement being arranged to emit the anti-fouling light from the light source towards a zone of the protected surface.

[0007] According to another aspect of the invention, there is provided a marine structure, especially a support structure for a sea-based wind turbine, having a protected surface being electrically conductive to be protected against corrosion by impressed current cathodic protection when in contact with a liquid containing biofouling organisms, the marine structure comprising the above system, wherein the light emitting arrangement is arranged to emit anti-fouling light towards the zone of the protected surface

[0008] According to another aspect of the invention, there is provided a marine structure, especially a support structure for a sea-based wind turbine, having a protected surface arranged to be electrically conductive to be protected against corrosion by impressed current cathodic protection (ICCP) when in contact with a liquid containing biofouling organisms, the marine structure being arranged to receive the aforementioned system. The marine structure may, for instance, comprise one or more coupling elements for coupling the marine structure and the aforementioned system to each other. The marine structure may comprise a first guidance element arranged to cooperate with a second guidance element on a distance keeper to keep the light source comprised in the system at a predefined distance from a zone of the marine structure for providing at least a predefined intensity of the anti-fouling light at the zone.

[0009] According to another aspect of the invention, there is provided a method of enhancing corrosion protection of a protected surface of a marine structure in contact with a liquid containing biofouling organisms, the protected surface being electrically conductive, the method comprising providing impressed current cathodic protection of the protected surface, and powering a light source to emit anti-fouling light towards a zone of the protected surface.

[0010] The above features have the effect that, when the invention is put to practice, the anti-fouling light reaches the zone of the protected surface. The marine structure is protected against corrosion by impressed current cathodic protection (ICCP), requiring the protected surfaces to be electrically conductive and in contact with the liquid. However, the inventors have found that corrosion still occurs, and that a reason for this might be biofouling. The ICCP reduces corrosion but may be rendered less effective by biofouling. Biofouling has been found to locally reduce effectiveness of ICCP working at the normal operational voltage range of 0.8 to 0.9 V. So, accelerated corrosion may occur due to the influence of microbes at a surface protected by ICCP. Killing or keeping at a distance such bacteria has been found to be necessary to maintain the effects of ICCP. This has been achieved by combining ICCP and the light source emitting the anti-fouling light towards the zone of the protected surface. The anti-fouling light, e.g. UV(C), will reduce biofouling so that ICCP can continue protecting the protected surface against corrosion.

[0011] The zone may comprise a part, usually called tidal part or a splash part, located at the level of the liquid when the marine structure is partly immersed in the liquid, usually called the liquid line. The tidal part is the part covering varying liquid levels due to tides. The splash part, just above the waterline at the outside of marine structures, may be exposed intermittently to both water and air, for example due to waves.

[0012] In the system, the light emitting arrangement may be constructed or positioned to emit the anti-fouling light from the light source towards the zone at or around the liquid line, e.g. the zone having said tidal part and/or splash part. The ICCP system relies on the electric conductivity of water, but is not effective above the waterline. Any dry metal part above the surface of the liquid is not protected as no current can flow. In addition, the inventors have found that the impressed current cathodic protection is less effective on protected surfaces that are wetted intermittently, for example, protected surfaces of partly immersed marine structures may be wetted regularly but not constantly due to a varying water line of sea water due to tides, waves or currents. Bacteria may be abundant in thin films of water which are drying up. By applying anti-fouling light like UV light on a zone at the liquid line, such fouling is prevented and accelerated corrosion in the tidal and/or splash parts is reduced. In such zones, which are particularly prone to corrosion due to fouling, accelerated corrosion is effectively prevented by ICCP in combination emitting the anti-fouling light towards such parts.

[0013] Also, surfaces below the waterline may be prone to biofouling which reduces efficiency of ICCP. The zone may comprise a submerged part located below the level of the liquid. Biofouling is prevented by providing the anti-fouling light on the submerged part at sufficient intensity to kill or keep at a distance bacteria to reduce or prevent microbial induced corrosion. Advantageously the submerged parts of the zone remain accessible for ICCP due to the anti-fouling light that keeps the submerged parts free of biofouling.

[0014] Optionally, the light emitting arrangement comprises a float for positioning the light emitting arrangement at the zone. By floating such a device, the zone of the protected surface at the liquid line, e.g. the water line of sea water, is protected by anti-fouling light. As the device floats the light emitting arrangement automatically takes a position at the required level, e.g. during installation, and may follow vertical variations of the liquid level, e.g. due to tides, so the device is positioned at a required vertical position of the zone.

[0015] Surfaces of inner spaces marine structures like monopiles may be prone to biofouling around the waterline. Optionally, the device is shaped to movably fit within an inner space of the marine structure, the protected surface being formed by the inner surface of walls of the inner space. The device may also comprise the above float. Advantageously, in use, the inner surface of the marine structure receives the anti-fouling light near the liquid line, where the ICCP is less effective. By being shaped to movably fit, and optionally float, within the inner space the device may follow vertical variations of the water level, e.g. due to tides, while the horizontal position is maintained by appropriate shape. For example, in a monopile there may be a round inner space. The device may have an outer boundary of a substantially circular shape for movably fitting inside the inner space. Advantageously, the distance between the light source and the zone remains within predetermined boundaries.

[0016] Optionally, the system comprises a distance keeper to keep the light source at a predefined distance from the zone for providing at least a predefined intensity of the anti-fouling light at the zone. During operation, the device is kept within a distance from the protected surface by the distance keeper. For example, the distance keeper may be formed by a few bumpers, buffers or fenders at the outer boundary of the device at the liquid line.

[0017] Optionally, the distance keeper comprises a guidance element to be coupled to the marine structure, the guidance element being arranged to keep the light emitting arrangement at a predefined distance from the zone while the level of the liquid varies in height. The distance keeper may comprise a guidance element that positions the device at some distance from the protected surface. The level of the liquid may vary in height, while the marine structure and part of the distance keeper remain at a fixed position. A part of the distance keeper attached to the light emitting arrangement, or being part of the light emitting arrangement, may cooperate with the fixed part. So, a first guidance element attached to the marine structure may cooperate with a second guidance element on the distance keeper.

[0018] Optionally, the distance keeper is arranged for being coupled to a fixed point. For example, the fixed point may be a fixed point of the marine structure or some anchoring pin drilled into the seabed providing guidance. The distance keeper may be an anchoring chain or a suspension arrangement coupled to a fixed point of the marine structure so as to maintain a predefined position of the floating device with respect to the marine structure, e.g. a cable to a central suspension point in an inner space of the marine structure where the device is kept floating, or one or more ropes or cables to one or more fixed points above or below the device.

[0019] Optionally, the light emitting arrangement is arranged to move the light source with respect to the zone in a direction parallel to the surface of the liquid and/or perpendicular to the surface of the liquid. The light emitting from light source may be arranged to, in use, horizontally move along the protected surface. For example, the light source itself, or a mirror may be arranged to move along a rail. Also, the device or the light emitting arrangement may be arranged to, in use, rotate for said moving of the light source.

[0020] In practice the light source may be adapted to emit ultraviolet light. A general advantage of using ultraviolet light for realizing anti-biofouling is that the microorganisms are prevented from adhering and rooting on the surface to be kept clean, without any harmful side effects or side effects which cannot be easily counteracted.

[0021] Optionally, the above system as comprises an impressed current unit for providing the impressed current cathodic protection (ICCP) of the protected surface. Advantageously, controlling and/or powering the ICCP and the light source may be combined.

[0022] The invention is applicable in various contexts in marine structures, which then comprise the above system. For example, the system according to the invention may be applied to a monopile carrying a wind turbine, or a marine vessel. The marine structure has a surface to be protected against corrosion when in contact with a liquid containing biofouling organisms. The protected surface is electrically conductive and is to be protected by impressed current cathodic protection, while the marine structure comprises the above described system to enhance the efficiency of ICCP by the anti-fouling light. The light emitting arrangement may float at the surface of the liquid, and may be positioned within a predefined distance range from the zone by a distance keeper.

[0023] Also, use of the above system is foreseen for enhancing corrosion protection of a protected surface of a marine structure when partly immersed in a liquid containing biofouling organisms. The use comprises providing impressed current cathodic protection via the protected surface which is electrically conductive, and powering the light source to emit the anti-fouling light towards the zone.

[0024] The above-described and other aspects of the invention will be apparent from, and elucidated with reference to, the following detailed description of embodiments.

BRIEF DESCRIPTION OF THE DRAWINGS

[0025] These and other aspects of the invention will be apparent from and elucidated further with reference to the embodiments described by way of example in the following description and with reference to the accompanying drawings, in which

Fig. 1 shows an example of a system for enhancing corrosion protection of a protected surface,
Fig. 2 shows a further example of a system for enhancing corrosion protection of a protected surface,
Fig. 3 shows an example of a light emitting arrangement having a raised light unit,
Fig. 4 shows a further example of a light emitting arrangement having submerged light units, and
Fig. 5 shows a further example of a light emitting arrangement having an LED foil.

[0026] The figures are purely diagrammatic and not drawn to scale. In the Figures, elements which correspond to elements already described may have the same reference numerals.

DETAILED DESCRIPTION OF EMBODIMENTS

[0027] To counter natural corrosion of a steel marine structures, surfaces may be coated or painted and are in addition often equipped with passive or active cathodic protecting systems such that the structure remains protected against natural corrosion even when the protective coating fails locally. Passive systems use sacrificial Zinc, Aluminum or Iron anodes that dissolve electro-chemically over time, whereas active systems impress a DC current in using anodes made of MMO-Ti (mixed metal oxides) coated Titanium or Pt/Ti (Platinum coated Titanium). Active systems like impressed current cathodic protection (ICCP) impress a DC current into the sea water, while careful monitoring is required as too large currents may dissolve the hull locally at enhanced rates. The current document focuses on improving active impressed current cathodic protection, working at the normal operational relative electrochemical potential of 0.8 to 0.9 V versus Ag/AgCl/seawater or as applicable.

[0028] The impressed current cathodic protection (ICCP) may reduce corrosion. However, ICCP may only work under water and if the metal is not insulated from the current. It has been found that accelerated corrosion may be caused by microbial organisms in marine structures, even if they are protected by ICCP. As ICCP may not sufficiently protect some areas against corrosion, it is proposed to provide anti-fouling light like UVC to complement the ICCP. Anti-fouling light is effective above the water and may prevent biofilms causing insulation of electrical currents under water. Combination of ICCP with UVC radiation enhances the protection, for example by reaching areas where ICCP doesn't work and keeping areas free of biofilms, which otherwise would block the ICCP system.

[0029] Biofouling of surfaces which are exposed to water, during at least a part of their lifetime, is a phenomenon known as such, which causes substantial problems in many fields. For example, in the field of shipping, biofouling on the hull of ships is known to cause a severe increase in drag of the ships, and thus increased fuel consumption of the ships. Users of ICCP on stationary marine structures are, as such, not interested in antifouling measures as fouling per se does not pose a problem to them. For instance, support structures for sea-based wind turbines do not suffer from increased drag due to macro-fouling as ships do.

[0030] In general, biofouling is the accumulation of microorganisms, plants, algae, small animals and the like on surfaces. According to some estimates, over 1,800 species comprising over 4,000 organisms are responsible for biofouling. Hence, biofouling is caused by a wide variety of organisms, and involves much more than an attachment of barnacles and seaweeds to surfaces. Biofouling is divided into micro fouling which includes biofilm formation and bacterial adhesion, and macro fouling which includes the attachment of larger organisms. Due to the distinct chemistry and biology that determine what prevents them from settling, organisms are also classified as being hard or soft. Hard fouling organisms include calcareous organisms such as barnacles, encrusting bryozoans, mollusks, polychaetes and other tube worms, and zebra mussels. Soft fouling organisms include non-calcareous organisms such as seaweed, hydroids, algae and biofilm "slime". Together, these organisms form a fouling community. Waste products from bacteria may include substances like sulfuric acid, which may corrode steel. In marine structures, corrosion may at least partly be attributed to biofouling, usually called microbial induced corrosion (MIC).

[0031] Biofilm formation may be reduced by using a higher potential in an ICCP like system, for example 0.95 V-1.1V. This may be called impressed current anti fouling (ICAF). When bacteria come into contact with a metallic surface that has been negatively charged at said higher potential, repulsion forces thus produced may reduce attachment of the bacteria onto the surface. Similar systems may aim at stopping fouling by dissolving Cu ions in the water. Various other systems are known to reduce biofouling. The book "Microbiologically Influenced Corrosion", by Javaherdashti, in particular chapter 9, pp 133-158, provides an overview of the various known systems to reduce MIC. Chapter 9.2.2 discusses ultraviolet radiation, in particular various shortcomings of UV treatment.

[0032] The following is noted in respect of anti-biofouling by using ultraviolet light as proposed. The light source may be chosen to specifically emit ultraviolet light of the c type, which is also known as UVC light, and even more specifically, light with a wavelength roughly between 220 nm and 300 nm. In practice the peak efficiency is achieved around 265 nm, with a fall-off towards higher and lower wavelengths. At 220 nm and at 300 nm, is has dropped to ~10% efficiency.

[0033] In the following, the present invention will be explained with reference to an application scenario in a monopile of a wind turbine, which is an example of a marine structure usually protected by ICCP. Wind turbines are often placed on monopiles. Corrosion due to microorganisms is usually called microbial corrosion or bacterial corrosion, bio-corrosion, microbiologically influenced corrosion, or microbial induced corrosion (MIC), which corrosion is caused or promoted by microorganisms, usually chemoautotrophs. The inside of the monopiles was assumed to be less vulnerable for such corrosion as the space is usually air-tight. It has been found that accelerated corrosion of surfaces protected by ICCP may be due to such microorganisms. The monopiles are an example of offshore marine constructions which may be affected. However, any steel or metal structure may be protected by the proposed system.

[0034] Fig. 1 shows an example of a system for enhancing corrosion protection of a protected surface. The Figure shows, in vertical intersection, the system having a light emitting arrangement 100 in combination with a marine structure 110 which is partly immersed in a liquid 120 containing biofouling organisms, for example sea water. In the example the marine structure 110 is partly embedded in soil 130, for example schematically indicating a monopile for carrying a wind turbine or a leg of an oil platform. The marine structure has a protected surface 30 which is electrically conductive and is protected against corrosion by impressed current cathodic protection, as described above. For providing the impressed current cathodic protection the marine structure may be provided with an anode 112, while the steel parts of the structure constitute the cathode.

[0035] The light emitting arrangement 100 has a light source 20 for emitting anti-fouling light 22. The light emitting arrangement is constructed to emit the anti-fouling light from the light source towards a zone of the protected surface 30. In the Figure, the zone is located at a height of the liquid level, which level is commonly called the liquid line 31. The zone may have parts below, at and/or above the liquid line.

[0036] The light emitting arrangement 100 may have a float 50 for floating the device at the surface of the fouling liquid. Also, the system may have a distance keeper 40, to keep the device near the protected surface 30 at a required distance.

[0037] The distance keeper may be arranged for being coupled to a fixed point of the marine structure. In the example the Figure shows the distance keeper to be a cable that is suspended from a fixed point (not shown) of the marine structure. The cable may be flexible, or be guided via pulley using a counterweight, to adapt to a varying level of the liquid and allow the device to keep floating on the liquid while being positioned at a required distance from the protected surface.

[0038] Optionally, the distance keeper has a guidance element to be coupled to the marine structure. The guidance element may be arranged to keep the light emitting arrangement at a predefined distance from the zone while the level of the liquid varies in height. The marine structure may have a further guidance element to cooperate with the guidance element on the distance keeper. For example, the distance keeper may have one or more vertical rods that are to be coupled to the marine structure, e.g. pointing downward from a platform welded inside a monopile above the waterline, while the device has cooperating holes or eyes to keep a predefined horizontal position. Also, a central vertical cable cooperating with a central eye in the device may constitute a guidance element. The cable may be fixed below the water line or may have a weight pending for keeping the cable straight.

[0039] In the light emitting arrangement, the light source may have at least one light unit near the liquid line, which unit is arranged to emit at least part of the anti-fouling light parallel to the surface of the fouling liquid while floating.

[0040] The light emitting arrangement may be constructed or positioned to emit the anti-fouling light directed to the zone having a tidal part 35 just above the liquid line. Also, or additionally, some of the anti-fouling light may be directed to some higher parts of the zone such as a splash zone. The optical power of the light source is chosen to be at least sufficient to lighten said tidal part 35 at an intensity sufficient for anti-fouling. Using an appropriate light guiding and/or focusing arrangement to direct the light towards said zone may reduce the required optical power of the light source. As such, light armatures providing a concentration of emitted light at an area to be illuminated are well-known.

[0041] The light source may be selected based on the following. It has been found that most fouling organisms are killed, rendered inactive, or rendered unable to reproduce by exposing them to a certain dose of the ultraviolet light. A typical intensity which appears to be suitable for realizing anti-biofouling is about 30 mW per square meter. The light may be applied continuously or at a suitable frequency while maintaining 30 mW / m2 as average, whatever is appropriate in a given situation, especially at a given light intensity. Various types of UV light sources may be used. One or more LEDs may constitute an UVC light source which may be applied as the light source of the light emitting arrangement. It is a fact that LEDs can generally be included in relatively small packages and may consume less power than other types of light sources. Furthermore, LEDs can be manufactured to emit (ultraviolet) light of various desired wavelengths, and their operating parameters, most notably the output power, can be controlled to a high degree.

[0042] The marine structure may have an inner space 115, e.g. having a circular shape near the liquid line. The device is shown floating in the inner space. In the example as shown in Fig. 1, the light unit is positioned at a fixed, central position in the inner space 115. So, the anti-fouling light may be emitted in a 360-degree range. Optionally, the device or the light emitting arrangement is arranged to, in use while floating, move the light source with respect to the protected surface in a direction parallel to the surface of the fouling liquid. A less powerful light unit may be used, while such unit, or the light emitted by such unit, may be made to move along the protected surface and to light only part of the surface at any given time, while covering the full surface during said movement.

[0043] In practice, for prevention of fouling a protected surface should receive optical power of around 30 mW / m2. In air the absorption of UVC light is neglectable, but in clean seawater it is about 4%/cm. This leads to different solutions for above and below the waterline, as discussed below.

[0044] Assuming that a monopile has an inner space having a diameter of 7 m, above the waterline a low power lamp of a few watt / m could keep the surface free of bio films and the bacteria responsible for MIC. If only the area in the neighborhood of the waterline would need protection a 5 Watt TL lamp on a floater may be sufficient.

[0045] In the examples of the Fig. 1 and 2, in the light emitting arrangement, the light source comprises at least one light unit near the liquid line, which unit is arranged to emit at least part of the anti-fouling light parallel to the surface of the fouling liquid while floating. The light parallel to the surface lights the area 35 of the protected surface just above the liquid line 31.

[0046] Fig. 2 shows a further example of a system for enhancing corrosion protection of a protected surface. The Figure shows a light emitting arrangement 102, similarly to Fig. 1, in combination with a marine structure 110, and differing with respect to the distance keeper. Like the device of Fig. 1, and further examples, the light emitting arrangement has a light source 20 for emitting anti-fouling light 22.

[0047] The light emitting arrangement 102 has a distance keeper 41 on a float 50 for floating the device at the surface of the fouling liquid at a required distance of the protected surface 30. In the example the Figure shows the distance keeper as a dish mounted on the float, the dish having rounded edges that may temporarily contact marine structure walls the to allow the device to float on the liquid while being positioned within the required distance from the protected surface by loosely fitting the inner space 115. For example, the device has an outer boundary of a circular shape near the liquid line for movably fitting inside the inner space having a similar shape. For other shapes of the inner space, or other parts, of the marine structure to be protected, complementary shaped distance keeper elements may be part of the device, e.g. integrally formed with the float. The distance keeper may, additionally or alternatively, have distance keeping arms, bumpers, buffers or fenders at the outer boundary of the device at the liquid line so as to control the distance and to avoid damage.

[0048] Fig. 3 shows an example of a light emitting arrangement for anti-fouling of a protected surface having a raised light unit. The Figure shows the light emitting arrangement 103, similarly to Fig. 1, in combination with a marine structure 110, and differing with respect to the light source. The light emitting arrangement 103 has, as the light source, a light unit 25 arranged to be at a distance above the liquid line. The unit 25 is arranged to emit at least a part of the anti-fouling light at an angle towards the surface of the fouling liquid so that the part of the anti-fouling light reaches a submerged part of the protected surface below the liquid line, as indicated by arrow 23 which angles down at the surface of the liquid. The angled anti-fouling light lights the area just below the liquid line.

[0049] Due to the absorption below the water the optical power of the light unit must be determined taking into account the distance the light has to travel though the fouling liquid, and the absorption as indicated earlier. The absorption may be known in advance, but may also be measured periodically and the optical power of the light units may be adjusted based on the measured absorption.

[0050] For protection under the waterline the light source may be positioned close to the protected surface, as the anti-fouling light is absorbed by the seawater. For example, in a circular inner space, this can be done by a carousel with lamps mounted on it, which optionally slowly turns along the protected surface.

[0051] Fig. 4 shows a further example of a light emitting arrangement for anti-fouling of a protected surface having submerged light units. The Figure shows the light emitting arrangement 104, similarly to Fig. 1, in combination with a marine structure 110, and differing with respect to the light source and the distance keeper. The light emitting arrangement may have a float to float at the surface of the liquid. The device 104 may be arranged for sub-surface use and may have, as the light source in the light emitting arrangement, at least one light unit 27 mounted under the liquid line, e.g. pending below the waterline. To mount the light unit the device may have a rigid element such as a pole going down or a flexible element such as a cable.

[0052] The light unit 27 is arranged to emit the anti-fouling light from a very short distance towards the protected surface taking into account the absorption of the fouling liquid, so that a substantial part of the anti-fouling light reaches a submerged part of the protected surface 36 extending below the liquid line.

[0053] Due to the absorption of the fouling liquid the light units need to be closer to the wall to prevent the forming of biofilms or other bio fouling. So, the distance keeper is arranged to keep the submerged light unit within a predetermined distance of the submerged part, the predetermined distance and optical power of the light unit being determined in view of absorption of the anti-fouling light by the fouling liquid. It can be calculated that a following configuration would be sufficient to prevent bio fouling using UV lamps, e.g. mercury gas lamps that are kept within a predetermined distance. The estimated power is given for a zone 36 having a height of 1 meter (i.e. amount of power per altimeter). For a monopile of diameter D = 8 m, the surface for one altimeter is π * D * 1 meter = 25 m2. At a required intensity of 30 mW/m2 UV at the surface, the total UV light power = 25 * 30 mW/m2 UV = 750 mW UV. The corresponding electrical power is (assuming about 30% efficiency) 750 mW / 30% = about 2.5 W. At a predefined distance of 17 cm and a transparency of 85% / cm the remaining intensity is 6%, so about 2,5/6% = 35 W total required average power. The light energy emitted by a configuration of about 10 static lamps may effectively arrive only partly at the protected surface due to losses of distribution and the lamps being static, so in practice more power will be needed, e.g. 165 W.

[0054] During manufacture and/or installation of the device the predetermined distance, the optical power of the light unit and the absorption of the anti-fouling light by the fouling liquid may be determined, e.g. according to the above example. Optionally, the device comprises a control unit 61 arranged to determine one or more of the following parameters: the predetermined distance, the optical power of the light unit, the electrical power of the light unit, the absorption of the anti-fouling light by the fouling liquid, the amount of biofouling actually occurring, etc. The parameters may be pre-set and/or may be adapted dynamically. The control unit may include various sensors for measuring respective parameters, and/or may be connected via a network to receive one or more parameters. For example, the actual optical power emitting from the light source reaching the protected surface may be measured via an UV sensor. Such parameters may be updated regularly, e.g. according to a programmed schedule, by an operator or automatically via a remote connection to the control unit. Based on the parameters the optical or electrical power of the light source may be controlled, and/or movement of the light source may be adapted by the control unit. Also, the control unit may generate warnings and/or error messages, e.g. when a light source fails.

[0055] Like the device of Fig. 1, and further examples, the device shown in Fig. 4 has a distance keeper to keep the device near the protected surface 30. The distance keeper has a number of diagonal cables 43 suspended from a central cable 42 or fixed point coupled to the marine structure. The diagonal cables are linked to a platform 44 mounted on the float 51. The platform is part of the light emitting arrangement that carries the light source. The distance keeper may also be used in the other embodiments.

[0056] Alternatively, or additionally, the device and/or the light emitting arrangement may be arranged to rotate as indicated by an arrow. For example, the device may rotate by rotating a central cable 42 on which the device is suspended by an electric motor (not shown). Also at least part of the light arrangement may rotate, for example by rotating a part of the light emitting arrangement carrying the submerged light unit 27. While rotating, the submerged light unit 27 will also light other submerged parts 36'of the protected surface. When rotating, less power is needed for the lighting, e.g. one lamp of 50 Watt / altimeter at about the same distance used for the calculation above while making turns along the wall around the marine structure's axis. The turns don't need to be fast; once in a few hours would do. The mechanism to rotate may also be used in the other embodiments of the device.

[0057] Optionally, the device or the light emitting arrangement is arranged to, in use, move the light source with respect to the protected surface in a direction perpendicular to the surface of the fouling liquid. In an embodiment, the light emitting arrangement has a mechanism to move the light unit up and down, which covers more height of the surface to be protected. For example, the light emitting arrangement 20 shown in Fig. 2, or the light emitting arrangement 25 shown in Fig. 3 may be further provided with a mechanism to slowly vary the height of the light source with respect to the liquid line. Also, the light emitting arrangement shown in Fig. 4 may have a mechanism to vary the height of the submerged light unit 27.

[0058] Optionally, the light source may be embedded in, or coupled to, an optical medium to guide the light towards the protected surface. When the light source is adapted to emit ultraviolet light, it is advantageous for the optical medium to comprise an ultraviolet transparent material such as ultraviolet transparent silicone. In a general sense, the fact that the optical medium comprises material that is configured to allow at least part of the anti-fouling light to distribute through the optical medium may be understood such as to imply that the optical medium comprises material that is substantially transparent to the anti-fouling light.

[0059] It is a practical possibility for the light emitting arrangement according to the invention to comprise an optical medium, a plurality of light sources, and possibly also one or more mirrors. The optical medium of the light emitting arrangement may be of any suitable shape and size, while light sources such as LEDs may be distributed throughout the optical medium. The light emitted by each of the light sources is guided by the optical medium and/or mirrors towards the protected surface.

[0060] Fig. 5 shows a further example of a light emitting arrangement for anti-fouling of a protected surface having a LED foil. The Figure shows a light emitting arrangement 105, similarly to Fig. 1, in combination with a marine structure 110, and differing with respect to the light source and the distance keeper. The light emitting arrangement 105 has, as the light source, a LED foil 28 covering at least part of a side wall of a float 52. The LED foil comprises a multitude of LED light units 29 shown as dots distributed across the foil. In the example the light emitting arrangement has the LED foil arranged at the outer boundary of the device near the liquid line.

[0061] The LED foil has an optical medium and at least one LED light unit embedded in the optical medium for emitting the anti-fouling light. The optical medium allows at least part of the anti-fouling light to distribute through the optical medium. WO 2014/188347 A1 describes further examples of such a foil. Optionally, the foil 28 further comprises at least one mirror for reflecting anti-fouling light from the LED light unit 29 towards the emission surface of the optical medium.

[0062] A back surface of the foil is facing the device and an emission surface is emitting the anti-fouling light in a direction towards the protected surface 30 while the device is floating near the near the protected surface. The LED foil may be mounted both below and above the liquid line, so as to light both a part 37 of the protected surface submerged below the liquid line and a part 37' of the protected surface just above the liquid line.

[0063] Like the device of Fig. 1, and further examples, the light emitting arrangement 105 shown in Fig. 5 may have a distance keeper and/or a float to keep the device near the protected surface 30. The distance keeper may be formed by the float itself which thereto is designed to tightly fit within the inner space of the marine structure. Thereto the float may have a multitude of segments that are joint during installation. In a different embodiment, to adapt the diameter of the float to the available inner space, the float may be constructed using a flexible material, and is made inflatable or fillable. The foil may also be flexible, or may be arranged pending around the float while not being fixed to the outer wall of the float. During installation, the float is inflated at a required height. After inflating, the float may still be movable to keep floating and follow variations of the liquid line. Alternatively, the float may be inflated to fit into a fixed position.

[0064] It will be clear to a person skilled in the art that the scope of the invention is not limited to the examples discussed in the foregoing, but that several amendments and modifications thereof are possible. While the invention has been illustrated and described in detail in the figures and the description, the figures and description are to be considered illustrative or exemplary only, and not restrictive. The invention is not limited to the disclosed embodiments. The drawings are schematic, wherein details that are not required for understanding the invention may have been omitted, and not necessarily to scale.

[0065] Variations to the disclosed embodiments can be understood and effected by a person skilled in the art in practicing the claimed invention, from a study of the figures, the description and the attached claims. For example, the various embodiments of the light emitting arrangement may be combined to constitute a device that has multiple light sources,

[0066] In the claims, the word "comprising" does not exclude other steps or elements, and the indefinite article "a" or "an" does not exclude a plurality. The term "comprise" as used in this text will be understood by a person skilled in the art as covering the term "consist of'. Hence, the term "comprise" may in respect of an embodiment mean "consist of', but may in another embodiment mean "contain/include at least the defined species and optionally one or more other species". Any reference signs in the claims should not be construed as limiting the scope of the invention.

[0067] Elements and aspects discussed for or in relation with a particular embodiment may be suitably combined with elements and aspects of other embodiments, unless explicitly stated otherwise. Thus, the mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measures cannot be used to advantage.

[0068] In a general sense, it is a basic function of the device and light emitting arrangement according to the invention to keep a protected surface free from biofouling. Hence, the invention is applicable in all situations involving a fouling risk, which are situations in which the protected surface is intended to be immersed, at least during a part of the lifetime thereof, in a liquid containing biofouling organisms. Seawater is a well-known example of such a fouling liquid. So, a marine structure may have a surface protected by the above described light emitting arrangement. The light emitting arrangement is then attached to said outer surface for anti-fouling of the outer surface when immersed in a fouling liquid containing biofouling organisms. Similarly, a method for installing the above light emitting arrangement includes the step of attaching the light emitting arrangement to an outer surface of a marine structure for enhancing corrosion protection of the outer surface when immersed in a fouling liquid containing biofouling organisms. Also, a method is provided to enhancing corrosion protection of a protected surface of a marine structure when immersed in a fouling liquid containing biofouling organisms using a device as described above. The method involves providing impressed current cathodic protection, for example by inducing current from a DC power source via the protected surface being electrically conductive. The method may further involve having the light emitting arrangement float near the protected surface and powering the light source to emit the anti-fouling light.

[0069] According to an aspect of the invention, use of the above light emitting arrangement is foreseen, in particular use of the light emitting arrangement installed on a float near a protected surface of a marine structure for enhancing corrosion protection of the surface when partly immersed in a liquid containing biofouling organisms. The use requires the light emitting arrangement to be powered by an electrical power source. Other examples of the protected surface include surfaces of subsea offshore equipment, interior walls of water reservoirs like ballast tanks of vessels, and surfaces of filter systems in desalination plants.

[0070] Also, according to an aspect of the invention, the marine structures are stationary. In stationary marine structures biofouling as such may not pose a problem, but as explained above corrosion has been found to occur in spite of ICCP. However, the system may also be applied to non-stationary marine structures like ships.

[0071] Also, according to an aspect of the invention, a support for a sea-based wind turbine may comprise a guidance element arranged to cooperate with a corresponding element on a float that carries the light emitting arrangement. Also, a float may be used to only move, via a mechanical coupling, one or more light sources or mirrors in accordance with the liquid level to direct the anti-fouling light towards the liquid line or a tidal or splash zone.

[0072] Summarizing, a system protects, against corrosion, a protected surface of a marine structure in contact with a liquid containing biofouling organisms. The protected surface is electrically conductive and is protected against corrosion by impressed current cathodic protection (ICCP). The system has a light emitting arrangement comprising a light source for emitting anti-fouling light. The light emitting arrangement is arranged to emit the anti-fouling light from the light source towards a zone of the protected surface. Effectively, biofouling is prevented and the operation of the ICCP is enhanced when the marine structure is partly immersed in the fouling liquid.

[0073] Aspects of the invention include:

1. A system for enhancing corrosion protection, of a protected surface (30) of a marine structure (110) in contact with a liquid containing biofouling organisms, the protected surface being electrically conductive and being protected against corrosion by impressed current cathodic protection (ICCP),
the system comprising
a light emitting arrangement (100) comprising a light source (20) for emitting anti-fouling light (22), the light emitting arrangement being arranged to emit the anti-fouling light from the light source towards a zone of the protected surface (30).

2. System as claimed in aspect 1, wherein the zone comprises a tidal part or a splash part located at the level of the liquid when the marine structure is partly immersed in the liquid.

3. System as claimed in aspect 1 or 2, wherein the zone comprises a submerged part located below the level of the liquid when the marine structure is partly immersed in the liquid

4. System as claimed in any of the aspects 1-3, wherein the light emitting arrangement comprises a float (50) for positioning the light emitting arrangement at the zone.

5. System as claimed in any of the preceding aspects, wherein the light emitting arrangement (100) is shaped to movably fit within an inner space (115) of the marine structure, the protected surface being formed by at least a part of the inner surface of walls of the inner space.

6. System as claimed in any of the preceding aspects, wherein the system comprises a distance keeper (40) to keep the light source at a predefined distance from the zone for providing at least a predefined intensity of the anti-fouling light at the zone.

7. System as claimed in aspect 6, wherein distance keeper (40) comprises a guidance element to be coupled to the marine structure, the guidance element being arranged to keep the light emitting arrangement at a predefined distance from the zone while the level of the liquid varies in height.

8. System as claimed in any of the preceding aspects, wherein the light source comprises at least one first light unit (25) arranged to be at a distance above the liquid to emit at least a part (23) of the anti-fouling light at an angle towards the surface of

the liquid so that the part of the anti-fouling light reaches a submerged part of the zone.

9. System as claimed in any of the preceding aspects, wherein the light source comprises a LED foil arranged at an outer boundary of the light emitting arrangement, the LED foil (28) comprising an optical medium and at least one LED light unit (29) embedded in the optical medium for emitting the anti-fouling light towards the zone, the optical medium allowing at least part of the anti-fouling light to distribute through the optical medium.

10. System as claimed in any of the preceding aspects, wherein the light source comprises at least one second light unit (27) arranged to be submerged below the level of the liquid when the marine structure is partly immersed in the liquid, which light unit is arranged to emit at least part of the anti-fouling light towards a submerged part (36) of the zone.

11. System as claimed in any of the preceding aspects, wherein the system comprises a control unit (61) to determine a distance between the light source and the zone, optical power of the light source and/or absorption of the anti-fouling light by the liquid.

12. System as claimed in any of the preceding aspects, wherein the light emitting arrangement is arranged to move the light source with respect to the zone in a direction parallel to the surface of the liquid and/or perpendicular to the surface of the liquid.

13. System as claimed in any of the preceding aspects, wherein the system comprises an impressed current unit for providing the impressed current cathodic protection (ICCP) of the protected surface.

14. A marine structure, especially a support structure for a sea-based wind turbine, having a protected surface (30) arranged to be electrically conductive to be protected against corrosion by impressed current cathodic protection (ICCP) when in contact with a liquid containing biofouling organisms, the marine structure comprising:

- the system (100, 102,103,104,105) as claimed in any of the preceding aspects, wherein the light emitting arrangement is arranged to emit anti-fouling light towards the zone of the protected surface (30).

15. A marine structure, especially a support structure for a sea-based wind turbine, having a protected surface (30) arranged to be electrically conductive to be protected against corrosion by impressed current cathodic protection (ICCP) when in contact with a liquid containing biofouling organisms, the marine structure comprising:

a first guidance element arranged to cooperate with a second guidance element on a distance keeper as described in aspect 7.

15. Method of enhancing corrosion protection of a protected surface (30) of a marine structure (110) in contact with a liquid containing biofouling organisms, the protected surface being electrically conductive, the method comprising

providing impressed current cathodic protection (ICCP) of the protected surface (30), and powering a light source to emit anti-fouling light towards a zone of the protected surface.

Claims

1. A system for enhancing corrosion protection of a protected surface (30) of a marine structure (110) in contact with a liquid containing biofouling organisms, the protected surface being electrically conductive and being protected against corrosion by impressed current cathodic protection (ICCP),
the system comprising

- a light emitting arrangement (100) comprising a light source (20) for emitting anti-fouling light (22), the light emitting arrangement being arranged to emit the anti-fouling light from the light source towards a zone of the protected surface (30).

2. System as claimed in claim 1, wherein the system is arranged to, during use, emit the anti-fouling light towards the zone, wherein the zone comprises at least one of:

- a tidal part or a splash part located at the level of the liquid when the marine structure is partly immersed in the liquid;
- a submerged part located below the level of the liquid when the marine structure is partly immersed in the liquid.

3. System as claimed in any of the claims 1-2, wherein the light emitting arrangement comprises a float (50) for positioning the light emitting arrangement at the zone.

4. System as claimed in any of the preceding claims, wherein the light emitting arrangement (100) is shaped to movably fit within an inner space (115) of the marine structure, the protected surface being formed by at least a part of the inner surface of walls of the inner space.

5. System as claimed in any of the preceding claims, wherein the system comprises a distance keeper (40) to keep the light source at a predefined distance from the zone for providing at least a predefined intensity of the anti-fouling light at the zone.

6. System as claimed in claim 5, wherein distance keeper (40) comprises a guidance element to be coupled to the marine structure, the guidance element being arranged to keep the light emitting arrangement at a predefined distance from the zone while the level of the liquid varies in height.

7. System as claimed in any of the preceding claims, wherein the light source comprises at least one first light unit (25) arranged to be at a distance above the liquid to emit at least a part (23) of the anti-fouling light at an angle towards the surface of the liquid so that the part of the anti-fouling light reaches a submerged part of the zone.

8. System as claimed in any of the preceding claims, wherein the light source comprises a LED foil arranged at an outer boundary of the light emitting arrangement, the LED foil (28) comprising an optical medium and at least one LED light unit (29) embedded in the optical medium for emitting the anti-fouling light towards the zone, the optical medium allowing at least part of the anti-fouling light to distribute through the optical medium.

9. System as claimed in any of the preceding claims, wherein the light source comprises at least one second light unit (27) arranged to be submerged below the level of the liquid when the marine structure is partly immersed in the liquid, which light unit is arranged to emit at least part of the anti-fouling light towards a submerged part (36) of the zone.

10. System as claimed in any of the preceding claims, wherein the system comprises a control unit (61) to determine a distance between the light source and the zone, optical power of the light source and/or absorption of the anti-fouling light by the liquid.

11. System as claimed in any of the preceding claims, wherein the light emitting arrangement is arranged to move the light source with respect to the zone in a direction parallel to the surface of the liquid and/or perpendicular to the surface of the liquid.

12. System as claimed in any of the preceding claims, wherein the system comprises an impressed current unit for providing the impressed current cathodic protection (ICCP) of the protected surface.

13. A marine structure, especially a support structure for a sea-based wind turbine, having a protected surface (30) arranged to be electrically conductive to be protected against corrosion by impressed current cathodic protection (ICCP) when in contact with a liquid containing biofouling organisms, the marine structure comprising

- the system (100, 102,103,104,105) as claimed in any of the preceding claims, wherein the light emitting arrangement is arranged to emit anti-fouling light towards the zone of the protected surface (30).

14. A marine structure, especially a support structure for a sea-based wind turbine, having a protected surface (30) arranged to be electrically conductive to be protected against corrosion by impressed current cathodic protection (ICCP) when in contact with a liquid containing biofouling organisms, the marine structure being arranged to receive a system as claimed in claims 1-12.

15. Method of enhancing corrosion protection of a protected surface (30) of a marine structure (110) in contact with a liquid containing biofouling organisms, the protected surface being electrically conductive, the method comprising

providing impressed current cathodic protection (ICCP) of the protected surface (30), and
powering a light source to emit anti-fouling light towards a zone of the protected surface.

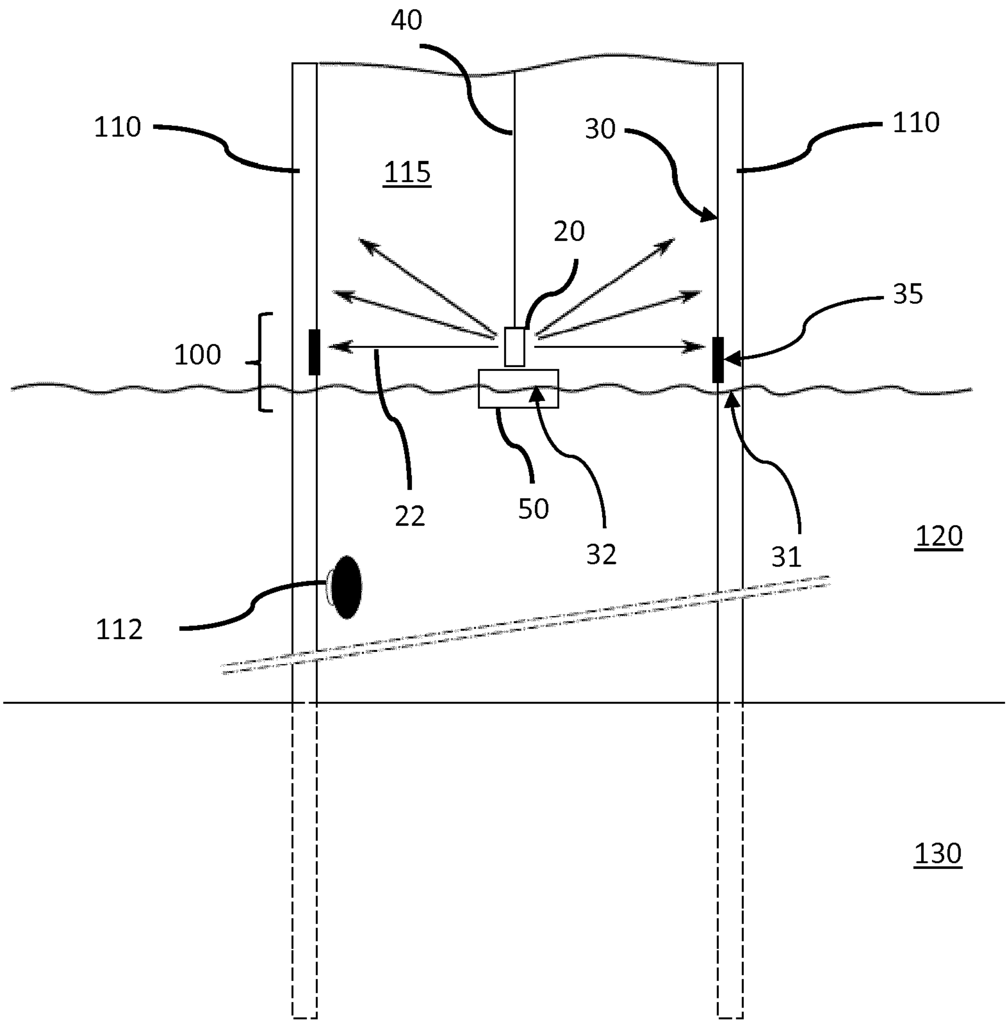

FIG. 1

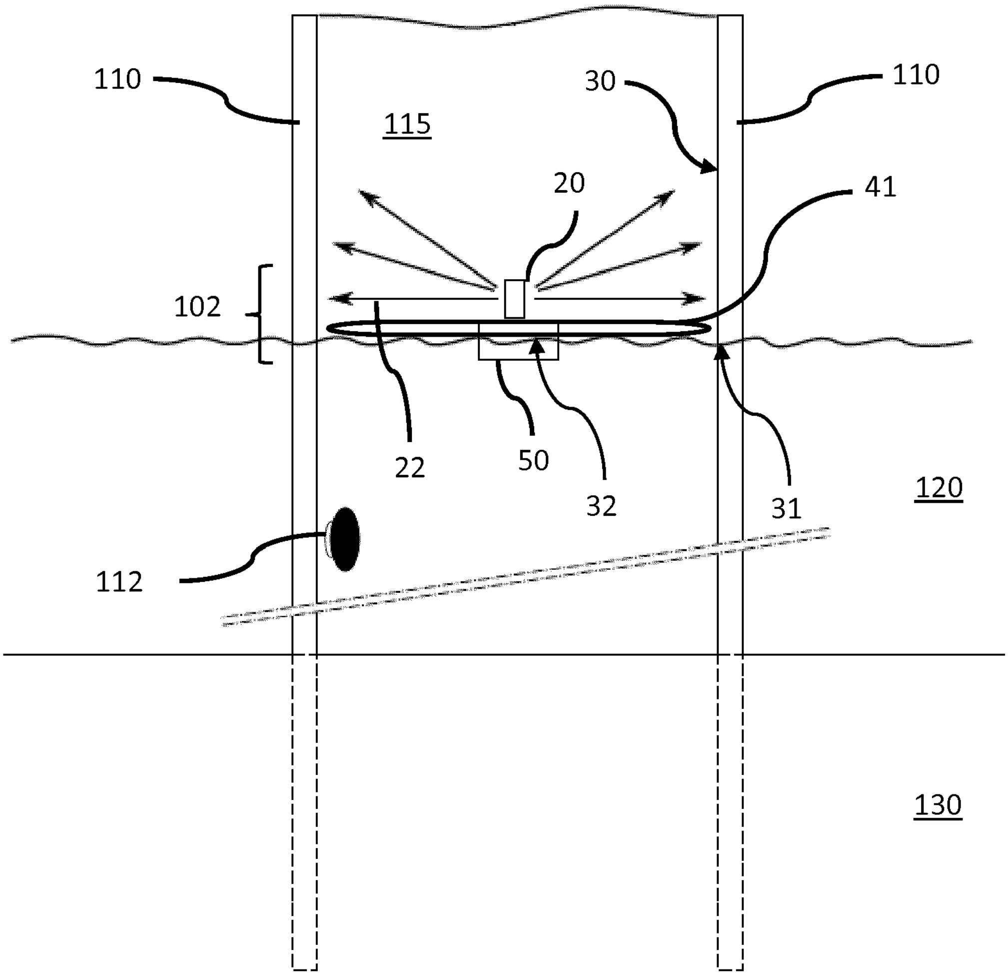

FIG. 2

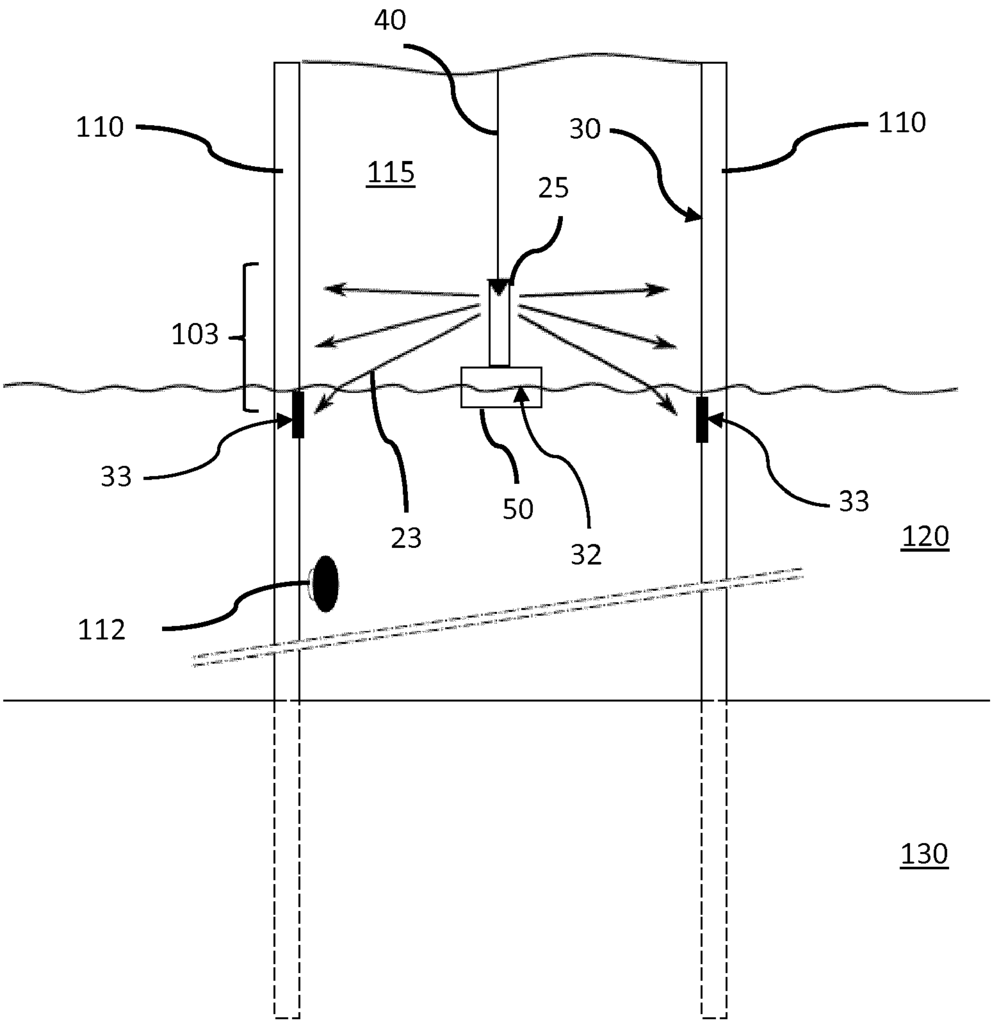

FIG. 3

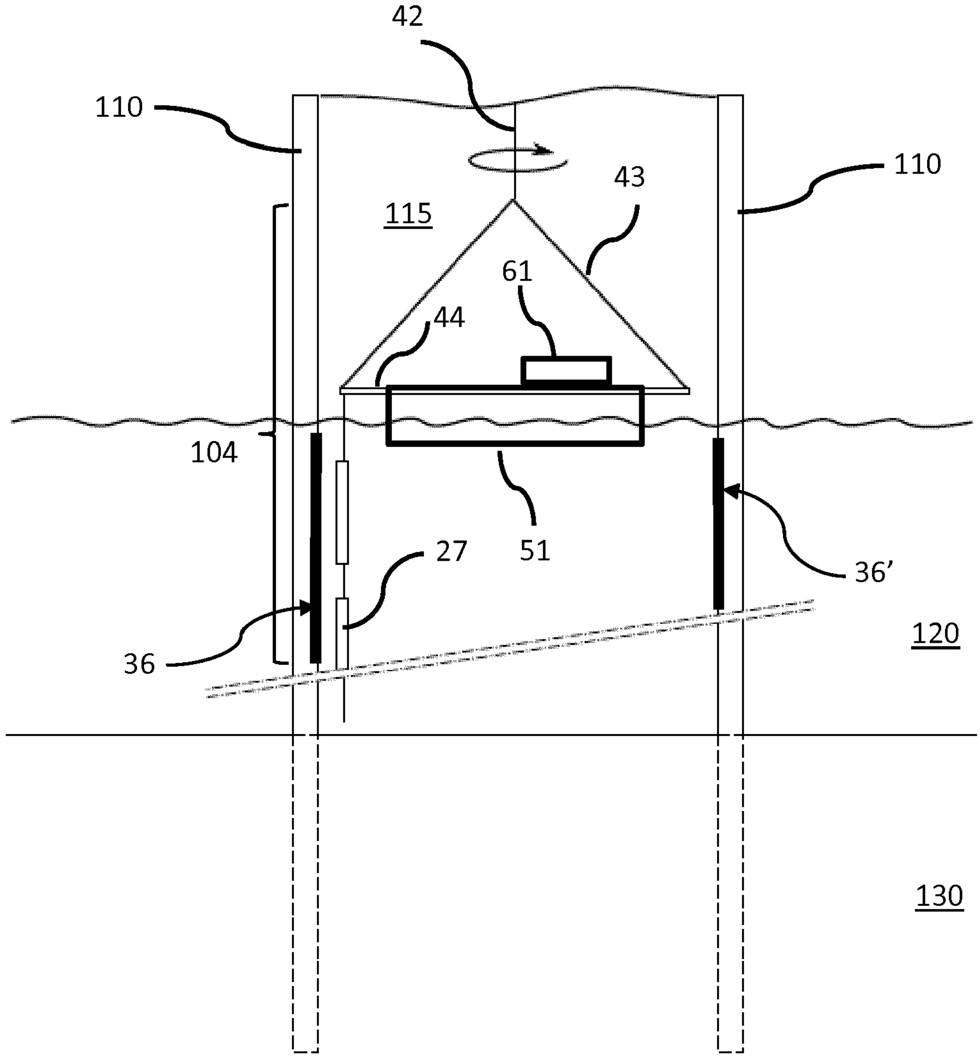

FIG. 4

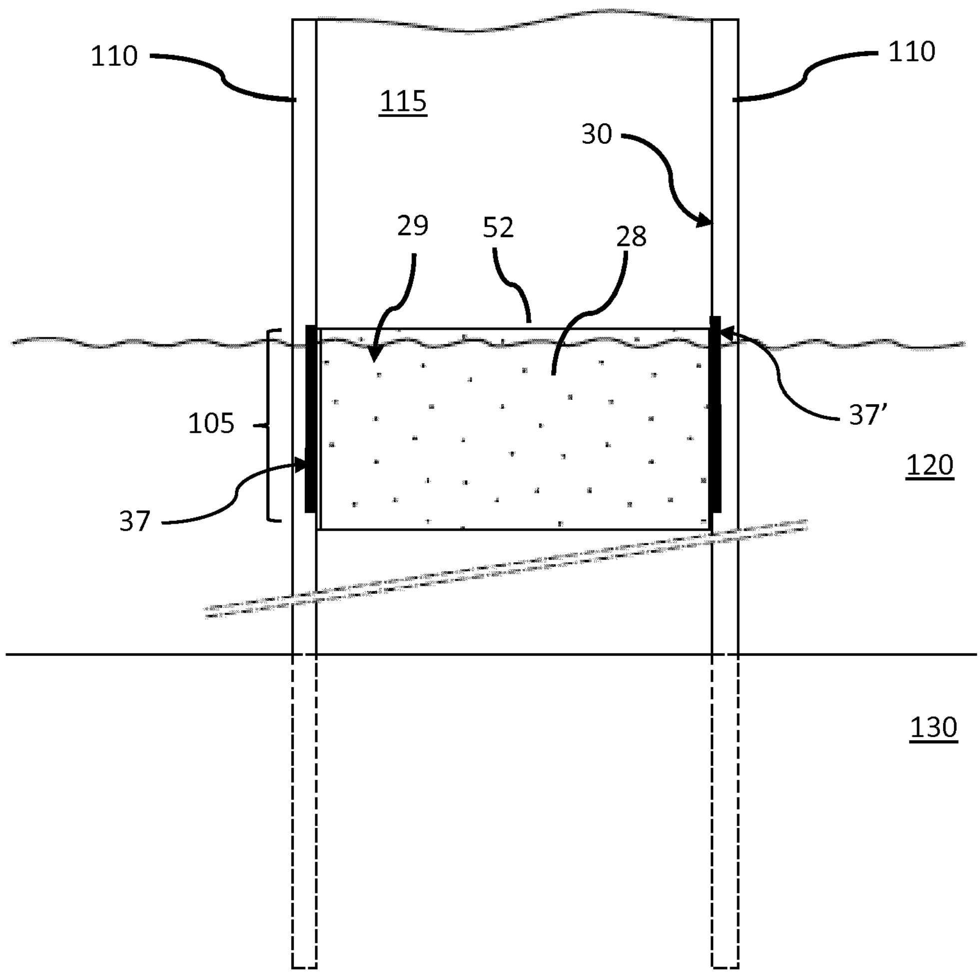

FIG. 5

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EUROPEAN SEARCH REPORT

Application Number
EP 17 19 3091

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	WO 2016/193114 A1 (KONINKLIJKE PHILIPS NV [NL]) 8 December 2016 (2016-12-08) * page 20, line 31 - page 29, line 34; figures 1-5 * * page 18, line 28 - page 19, line 6 * * page 11, line 3 - page 11, line 10 * -----	1-15	INV. H02J50/05 B08B17/02 B63B59/04 C23F13/02 E02B17/00 C23F13/04 C23F13/12
X	WO 2016/000980 A1 (KONINKL PHILIPS NV [NL]) 7 January 2016 (2016-01-07) * page 28, line 32 - page 38, line 15; figures 1-7 * * page 24, line 28 - page 25, line 10 * -----	1-15	
			TECHNICAL FIELDS SEARCHED (IPC)
			H02J B08B B63B C23F 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	26 February 2018	Zuurveld, Gerben

CATEGORY OF CITED DOCUMENTS

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26-02-2018

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2016193114 A1	08-12-2016	AU 2016269629 A1	18-01-2018
		CA 2987873 A1	08-12-2016
		TW 201711913 A	01-04-2017
		WO 2016193114 A1	08-12-2016
WO 2016000980 A1	07-01-2016	CN 106660083 A	10-05-2017
		EP 3160836 A1	03-05-2017
		JP 2017523326 A	17-08-2017
		KR 20170027796 A	10-03-2017
		US 2017190397 A1	06-07-2017
		WO 2016000980 A1	07-01-2016

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Patent documents cited in the description

- WO 2014188347 A1 **[0061]**

Non-patent literature cited in the description

- **JAVAHERDASHTI.** Microbiologically Influenced Corrosion. 133-158 **[0031]**