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KH MA MD TN(71) Applicant: **Delta-Sistems B.V.****4465 BC Goes (NL)**(72) Inventor: **De Wit, Michiel Jeroen****4465BC Goes (NL)**(74) Representative: **Griebling, Onno****Octrooibureau Griebling BV****Sportweg 10****5037 AC Tilburg (NL)**(30) Priority: **04.01.2023 NL 1044515****(54) ULTRASONIC TRANSDUCER ELEMENT**

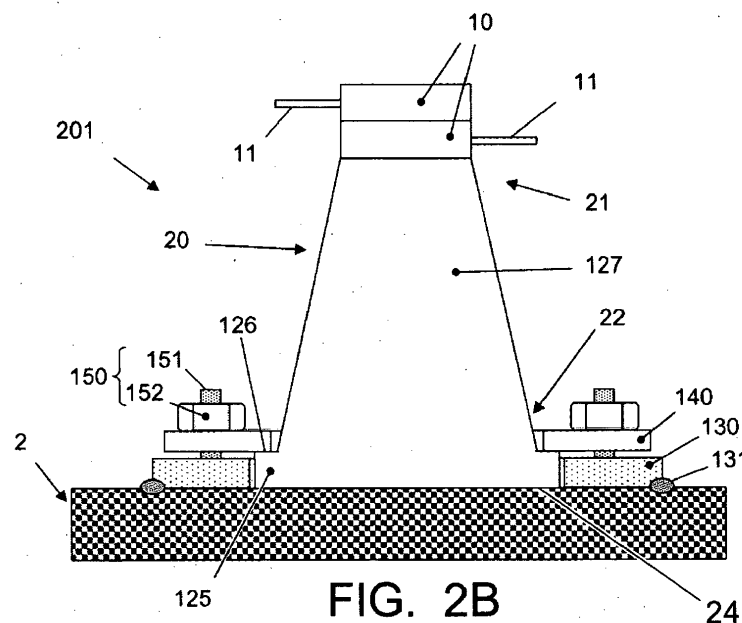
(57) The invention involves an ultrasonic transducer element (101; 201) comprising an ultrasonic vibrator (10) and a transducer body (20) having an input end (21) associated with the ultrasonic vibrator (10) and having an output end (22) adapted for attachment to an object (2) to be treated with ultrasonic vibrations.

The ultrasonic transducer element further comprises a support ring (130) arranged around the output end of the transducer body, and pressing means (140; 150) cooperating with the support ring and engaging the trans-

ducer body for exerting on the transducer body pressing force towards the object (2).

A method for protecting the object against bio-fouling involves firmly pressing onto the object an ultrasonic transducer element comprising at least one ultrasonic vibrator and a transducer body, and energizing the ultrasonic transducer element to generate ultrasonic vibrations into the object;

wherein the pressing force engages the transducer body.

**FIG. 2B****EP 4 397 587 A1**

Description

FIELD OF THE INVENTION

[0001] The present invention relates in general to fouling. Fouling in general can be defined as accumulation of undesired material on the surface of an object. In case the undesired material consists of living organisms, the phrase "bio-fouling" is used. Bio-fouling particularly occurs on objects that, during a substantial time of their life, are at least partly submerged in open water, such as rivers, seas, oceans. A particular problem relates to ships, and components of ships, of which at least portions of the hull and portions of the drive system and other components are located below water, and are susceptible to organisms settling thereon and growing thereon. This is undesirable, and the present invention relates to measures for avoiding such bio-fouling.

BACKGROUND OF THE INVENTION

[0002] Measures against bio-fouling can be of different type. One specific class of measures involves the use of UV-light: irradiating a surface with UV-light will tend to kill the bio-organisms present on that surface.

[0003] Another class of anti-bio-fouling measures involves the use of high-frequency vibrations. The present invention relates particularly to the field of anti-bio-fouling based on high-frequency vibrations.

[0004] It appears that, if a surface is subjected to vibrations, larvae of bio-organisms such as shellfish will not settle on that surface. An important factor in this respect is the frequency of the vibrations, and also the intensity of those vibrations.

[0005] The typical vibrations used in practice are in the range of 20.000 Hz and higher, i.e. the ultrasonic frequencies. Vibration anti-fouling is therefore also indicated as ultrasonic anti-fouling. For applying ultrasonic vibrations to an object, an ultrasonic transducer is attached to the object to be protected. The transducer comprises a vibration transfer body having an input and an opposite output end. The input end is attached to an ultrasonic generator, typically comprising a piezo element with a resonator. The output end is adapted for attachment to the surface to be protected. Typically, the transducer output end is attached to the surface by means of an adhesive. For being able to transfer the ultrasonic vibrations from the transducer body to the object body, the adhesive has to be of a type that hardens to become a solid.

[0006] The effectiveness of the vibrations at the object surface may depend on circumstances. With increasing distance to the transducer, the energy of the vibrations decreases. Further, the object may be a plate of a certain thickness, and opposite the surface where the transducer is attached the plate may be provided with or without transverse plates for strengthening. Also, the object may be a complex object such as a box cooler. For an effective vibration, over the whole surface area of the object to be

protected, it may be necessary to apply multiple transducers. However, not all locations are suitable for applying an ultrasonic transducer, and having a multitude of transducers would increase the costs. Therefore, it is desirable to have transducers of higher power, which will have a capability of protecting a larger portion of the object.

[0007] The ultrasonic generators, i.e. piezo elements, are driven by a control unit that applies drive current and drive voltage at the correct frequency. For increasing the ultrasonic power, i.e. the sound pressure level, it would in any case be necessary to increase the ultrasonic amplitude, which can be achieved by increasing the drive current and/or voltage.

SUMMARY OF THE INVENTION

[0008] However, merely increasing the drive power of an ultrasonic transducer is not sufficient for generating ultrasonic vibrations with sufficient sound pressure level and in a reliable manner in the object to be protected. The inventor has found that the interface between the transducer and the object surface is of vital importance. More particularly, the inventor has found that the adhesive has disadvantageous properties. In one aspect, the adhesive layer causes transition losses and reflection losses. Further, experiments have shown that, with increasing ultrasonic power, the solid adhesive between transducer and object surface may crack, and may become loose, within a relatively short period of time. Further, it was found that merely being attached to the object is not sufficient for an efficient transfer of vibrational power: more efficient transfer is achieved if the transducer is strongly pressed onto the object's surface.

[0009] It is therefore an objective of the present invention to provide an alternative method of attaching the transducer to the object surface, i.e. to provide an alternative for the adhesive connection with more favourable properties.

[0010] According to an important aspect of the present invention, this objective is attained by providing pressure means that press the transducer onto the object surface.

[0011] GB-703158 discloses a vibration system that comprises a vibrator body of magnetostriction type. The vibrator body has its lower end soldered directly on the object to be treated with ultrasonic vibrations. Pressing force is exerted on the opposite upper end of the vibrator body. In practice, however, it is very difficult to obtain good contact between such body and the object, whether by gluing or by welding, because the attachment has to be executed in situ in difficult circumstances, and further it is difficult to inspect such contact after attachment. Furthermore, it has been found that exerting compressive forces on the vibrator body will reduce its energy output towards the object.

[0012] US-5532980 discloses a vibration system that comprises an electromagnetic vibrator body screwed on to a foot part 54 that is welded directly on the object to

be treated with vibrations. Vibrations are generated by the vibrator body vibrating as a whole, and it is difficult or even impossible to achieve ultrasonic frequencies in this way. Since the vibration energy has to be transferred from the vibrator body to the foot part 54 via a screw connection 48/58, the screw thread is in the vibration transfer path and liable to failure. The welded joint between foot part 54 and object 56 constitutes a relatively small contact surface, while further it is difficult to achieve good welding quality.

[0013] GB-1044879 discloses a vibration system for transferring vibration energy to a cleaning liquid in a tank. The known system is for operating at frequencies in a range around 13 kHz, i.e. much lower than ultrasonic frequencies. The known system comprises transducers 2 that are attached to plugs, which in turn are screwed into an end face of a probe 1. The probe 1 extends through a hole in the tank bottom 7. The probe is attached to the tank bottom in a watertight manner, near a nodal plane of the probe so that little or no vibration energy is transferred to the tank bottom. The probe has a circumferential flange 4 that is clamped against the tank bottom 7, with a resilient sealing ring 8 in between, which effects watertightness, reduces transfer of vibration energy towards the bottom and does not hamper the probe's freedom to vibrate and transfer energy to the liquid in the tank. Effectively, the basic problem underlying the present invention, i.e. how to ensure a proper and long-lasting vibration transfer contact between transducer and object, is not present in this known system at the interface between probe and tank bottom. The only physical transitions in the vibration path are from transducer 2 to plug 3 (but the document does not disclose how the transducers are attached to the plugs), from plug 3 to probe 1 (which is a screw joint), and from probe 1 to liquid.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] These and other aspects, features and advantages of the present invention will be further explained by the following description of one or more preferred embodiments with reference to the drawings, in which same reference numerals indicate same or similar parts, and in which:

Figure 1 is a schematic cross section of an ultrasonic transducer element attached to an object by adhesive in accordance with prior art;

Figures 2A and 2B are schematic cross sections of exemplary ultrasonic transducer elements attached to an object in accordance with the present invention; Figures 3A and 3B illustrate variations of the pressing means.

DETAILED DESCRIPTION OF THE INVENTION

[0015] Figure 1 schematically illustrates an ultrasonic transducer element 1, mounted on an object 2. The trans-

ducer element 1 comprises a transducer body 20, having an output end 22 attached to the object 2, and an opposite input end 21. The output end 22 includes an object contact surface 24. The output end 22 is attached to the object 2 by an adhesive layer 23. The transducer element 1 further comprises an arrangement of one or more piezo elements 10 arranged above each other and on the input end 21 of the transducer body 20. Each piezo element 10 has one or more electrical contact terminals 11 for receiving electrical drive current from a control source which is not shown for sake of simplicity. Opposite the transducer body 20, a resonator mass 9 is attached to the arrangement of piezo elements 10.

[0016] The transducer element 1 as shown in figure 1 is only capable of introducing ultrasonic energy into the object 2 up to a relatively low level of ultrasonic power: at higher power, the adhesive layer 23 will fail.

[0017] Figures 2A and 2B schematically illustrate two examples of an ultrasonic transducer element 101, 201 in accordance with the present invention. These transducer elements 101, 201 also comprise a resonator mass, but for sake of simplicity the resonator mass is omitted in these figures.

[0018] The transducer element 101, 201 comprises a support ring 130, having an inner diameter corresponding to, yet slightly larger than, the outer diameter of the output end 22 of the transducer body 20. The support ring 130 is attached firmly to the object 2, i.e. the surface of the object 2, preferably and as shown by brazing or welding 131. The welding 131 may involve a series of weld spots or weld beads around the perimeter of the support ring 130, but a contiguous weld of 360° around the perimeter of the support ring 130 is preferred, since this would prevent water from creeping under the support ring 130. The support ring 130 is preferably made from a weldable material such as aluminium, steel or stainless steel, depending on the material of the object to be protected.

[0019] The support ring 130 performs at least two functions. One function is to provide a boundary around the transducer element 101, 201: even if the transducer element 101, 201 would move due to the vibrations, it can not escape from the ring 130. A second important function is in the context of pressing the transducer element 101, 201 onto the object to be protected, i.e. pressing the object contact surface 24 onto the object's surface, as will be described in more detail in the following, in which the direction perpendicular to the object contact surface 24 will be indicated as axial direction.

[0020] The transducer body 20 has its output end 22 arranged inside the support ring 130. Near the output end 22, the transducer body 20 has a foot portion or mounting flange 125 projecting radially outward with respect to the transducer body's remaining portion 127 above the flange 125. The mounting flange 125 has an upper surface 126 that will also be indicated as a step. Above the flange 125, the transducer body portion 127 can have a cylindrical contour of constant diameter, as illustrated in figure 2A, or can for instance have a conical

contour in which the diameter reduces in the direction from output end 22 to input end 21, as illustrated in figure 2B. Variations or combinations on this contour are also possible.

[0021] The transducer element 101, 201 further comprises a pressing ring 140 arranged around the transducer body 20 and engaging the step 126 of the mounting flange 125. The mounting flange 125 has a height slightly larger than the height of the support ring 130, so that it is ensured that, when the pressing ring 140 is arranged around the transducer body 20, it will engage on the mounting flange 125 leaving a small gap between the support ring 130 and the pressing ring 140. In practice, a suitable size for the height difference is between 0.1 and 2 mm.

[0022] The pressing ring 140 has an inner diameter smaller than the outer diameter of the mounting flange 125, and corresponding to, yet slightly larger than, the inner diameter of the mounting flange 125, which is equal to the outer diameter of the transducer body portion 127 at the transition to the mounting flange 125.

[0023] The transducer element 101, 201 further has tightening means 150 for tightening the pressing ring 140 towards the support ring 130 in axial direction. In the embodiments shown, the tightening means 150 comprise screw studs 151 attached to, for instance screwed into, the support ring 130 and projecting upwards from the support ring 130, while the pressing ring 140 has corresponding passage holes through which the screw studs extend. The tightening means 150 in this example further comprise nuts 152 to be screwed onto the studs 151. The tightening means 150 may comprise a series of three or more, for instance six or eight or more, screw studs arranged equidistantly along the support ring 130.

[0024] In an embodiment where the support ring 130 is welded by a series of welding points or welding beads, those welding points or welding beads are preferably aligned with the positions of the screw studs.

[0025] In the following, the combination of the support ring 130 and the pressing ring 140 will be indicated as mounting means, to reflect the fact that they serve to mount the transducer body 20 on the object 1. Further, the combination of the pressing ring 140 and the tightening means 150 will be indicated as pressing means.

[0026] The arrangement of a pressing ring 140 engaging mechanically on the lower end of the transducer body 20, by engaging on the projecting mounting flange 125, allows for the object contact surface 24 of the transducer body 20 to be pressed onto the object 2 with high force. The mounting means 130, 140 are capable of exerting high pressure force in axial direction, higher than an adhesive, and this force is part of a closed force loop that passes through the weld between the support ring 130 and the object 2, so that it will not easily break away from the object 2.

[0027] In the embodiment illustrated and described, the pressing means engage on the transducer body 20 at a low position, near the output end 22. I.e. the distance

between step 126 and the transducer's object contact surface is relatively small, in the order of a few mm. It is possible that the step 126 is closer to the input end 21, so that the pressing means engage on the transducer body 20 at a higher position, even near the input end 21. It is however not allowed to engage higher than the input end 21; particularly, it is not allowed to engage on the resonator mass 9, as this would impede its functioning as resonator mass.

[0028] In any case, the pressing means should engage on the transducer body 20 at a position lower than the input end 21, i.e. between the input end and the output end 22. Preferably, the pressing means engage on the transducer body 20 at a position closer to the output end 22 than to the input end 21. More preferably, the pressing means engage on the transducer body 20 at a position less than 2 cm from the output end 22, measured axially.

[0029] In summary, the invention involves an ultrasonic transducer element 101; 201 comprising at least one ultrasonic vibrator 10 and a transducer body 20 having an input end 21 associated with the at least one ultrasonic vibrator 10 to receive ultrasonic vibrations from the ultrasonic vibrator, and having an output end 22 including an object contact surface 24 adapted for contacting a surface of an object 2 to be treated with ultrasonic vibrations such as to transfer ultrasonic vibrations to such object. The ultrasonic transducer element 101; 201 further comprises a support ring 130 arranged around the output end 22 of the transducer body 20, and pressing means 140; 150 cooperating with the support ring 130 and engaging the transducer body 20 for exerting on the transducer body 20 axial pressing force towards the object 2. In use, the support ring 130 will be attached to said surface of the object 2, and the cooperation of the pressing means 140; 150 with the support ring 130 involves the pressing means 140; 150 exerting on the support ring 130 a reaction force directed away from said surface of the object 2.

[0030] It should be clear to a person skilled in the art that the present invention is not limited to the exemplary embodiments discussed above, but that several variations and modifications are possible within the protective scope of the invention as defined in the appending claims. For instance, in stead of screw studs plus nuts, it is also possible to have other mechanical tightening means. For instance, it is possible that the tightening means 150 include mutually cooperating threading of the support ring 130 and the pressing ring 140, and that pressing force is exerted on the mounting flange 125 by screwing the pressing ring 140 with respect to the support ring 130. Figure 3A illustrates an embodiment where the support ring 130 has an upward cylindrical wall 153 with internal threading, cooperating with an external threading 154 at the outer perimeter of the pressing ring 140. Figure 3B illustrates an embodiment where the pressing ring 140 has a downward cylindrical wall 155 with external threading, cooperating with an internal threading 156 at the inner perimeter of the support ring 130. It is also possible that the support ring 130 has an upward cylindrical

wall and that the pressing ring 140 has an downward cylindrical wall with mutually cooperating threadings, in which case the cylindrical wall with smallest diameter and external threading may be associated with either the support ring 130 or the pressing ring 140.

[0031] Further, for exerting the required down-force on the transducer body 20, it is also possible to use for instance pneumatic or hydraulic means.

[0032] Even if certain features are recited in different dependent claims, the present invention also relates to an embodiment comprising these features in common.

[0033] Even if certain features have been described in combination with each other, this does not mean that these features must always be applied in combination with each other, and the present invention also relates to an embodiment in which one or more of these features are omitted.

[0034] Features which have not been explicitly described as being essential may also be omitted.

[0035] Any reference signs in a claim should not be construed as limiting the scope of that claim.

Claims

1. Ultrasonic transducer element (101; 201) comprising at least one ultrasonic vibrator (10) and a transducer body (20) having an input end (21) associated with the at least one ultrasonic vibrator (10) and having an output end (22) adapted for attachment to an object (2) to be treated with ultrasonic vibrations; wherein the ultrasonic transducer element (101; 201) further comprises a support ring (130) arranged around the output end (22) of the transducer body (20), and pressing means (140; 150) cooperating with the support ring (130) and engaging the transducer body (20) for exerting on the transducer body (20) pressing force to press the output end (22) towards the object (2).
2. Ultrasonic transducer element (101; 201) according to claim 1, wherein the support ring (130) is adapted for being welded onto the object to be treated.
3. Ultrasonic transducer element (101; 201) according to claim 1 or 2, wherein the transducer body (20) at its output end (22) is provided with a mounting flange (125) having a step (126).
4. Ultrasonic transducer element (101; 201) according to claim 3, wherein the pressing means (140; 150) comprise a pressing ring (140) arranged around the transducer body (20) engaging the step (126) of the mounting flange (125), and tightening means (150) for tightening the pressing ring (140) towards the support ring (130).
5. Ultrasonic transducer element (101; 201) according to claim 4, wherein the tightening means (150) are adapted for exerting pressing force on the pressing ring (140), for pressing the pressing ring (140) towards the support ring (130).
6. Ultrasonic transducer element (101; 201) according to claim 5, wherein the tightening means (150) comprise screw studs (151) attached to the support ring (130), and matching nuts (152).
7. Ultrasonic transducer element (101; 201) according to claim 5, wherein the tightening means (150) comprise mutually cooperating threading of the support ring (130) and the pressing ring (140).
8. Method for protecting an object (2) against bio-fouling, wherein the method comprises the steps of attaching onto the object (2) to be protected an ultrasonic transducer element comprising at least one ultrasonic vibrator (10) and a transducer body (20), exerting pressing force to firmly press the ultrasonic transducer element onto the object (2) to be protected, and energizing the ultrasonic transducer element (101; 201) to generate ultrasonic vibrations into the object (2); wherein the pressing force engages the transducer body (20).
9. Method according to claim 8, wherein the ultrasonic transducer element is the ultrasonic transducer element (101; 201) according to any of claims 1-7.
10. Method according to claim 9, wherein the step of attaching comprises the step of welding the support ring (130) onto the object (2).
11. Method for protecting an object (2) against bio-fouling, wherein the method comprises the step of attaching onto the object (2) to be protected an ultrasonic transducer element (101; 201) according to any of claims 1-7.
12. Method according to claim 11, wherein the step of attaching comprises the steps of
 - firmly attaching the support ring (130) onto the object (2), preferably by brazing or welding;
 - arranging the output end (22) of the transducer body (20) inside the support ring (130), in contact with the object (2);
 - applying the pressing means (140; 150) in cooperation with the support ring (130) to engage the transducer body (20) such as effectively exerting on the transducer body (20) pressing force towards the object (2).
13. Method according to claim 12, wherein the transducer body (20) at its output end (22) is provided with a

mounting flange (125) having a step (126). wherein the pressing means (140; 150) comprise a pressing ring (140) arranged around the transducer body (20) engaging the step (126) of the mounting flange (125), and wherein the method comprises the step of applying the tightening means (150) for tightening the pressing ring (140) towards the support ring (130). 5

14. Combination of an object (2) and at least one ultrasonic transducer element (101; 201) according to any of claims 1-7 attached to the object (2). 10

15. Combination according to claim 14, wherein the support ring (130) is welded onto the object (2). 15

16. Combination according to claim 14 or 15, wherein the object (2) is a portion of a ship.

17. Ship provided with at least one ultrasonic transducer element (101; 201) according to any of claims 1-7 attached to a portion of the ship for protection against bio-fouling. 20

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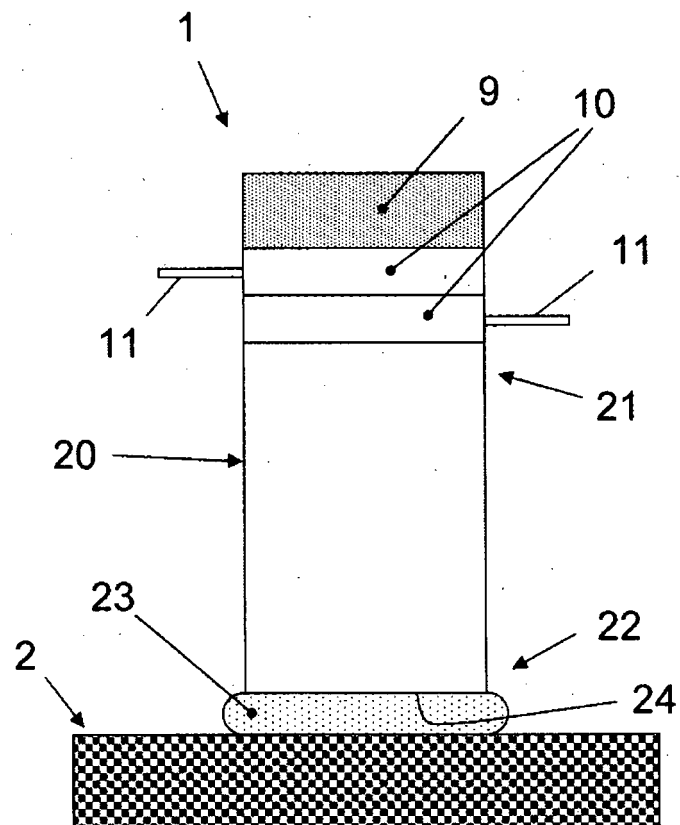
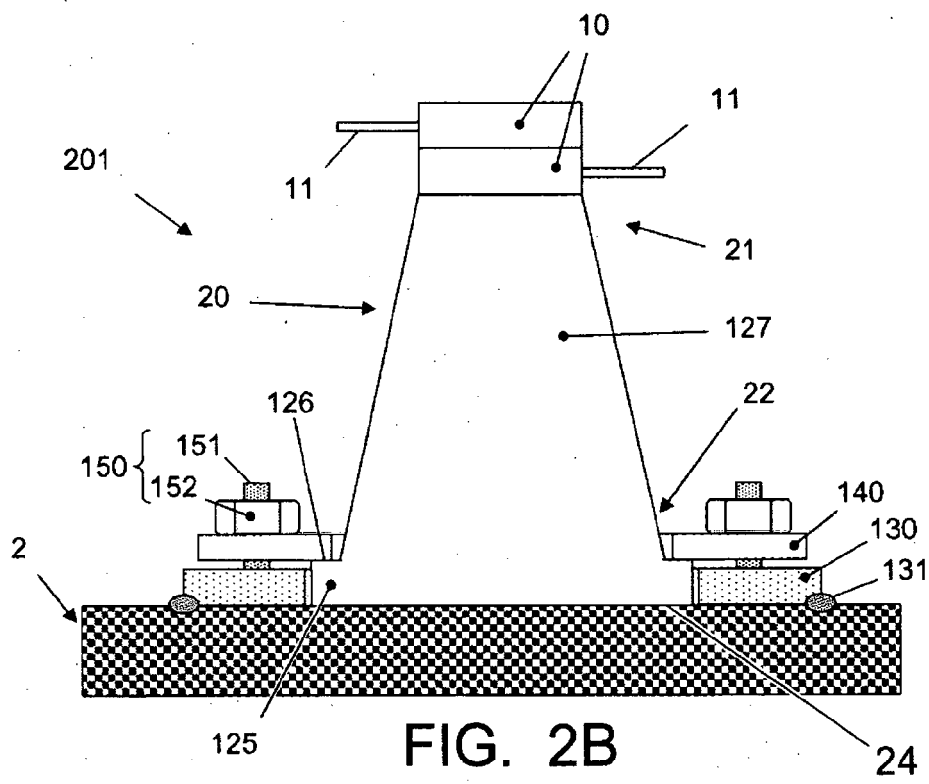
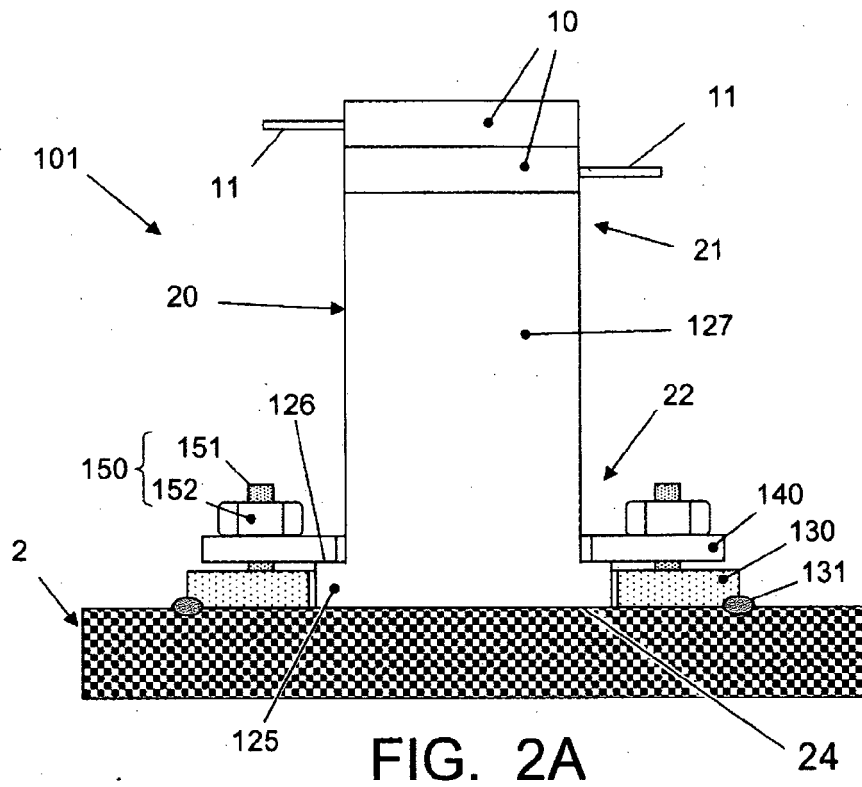
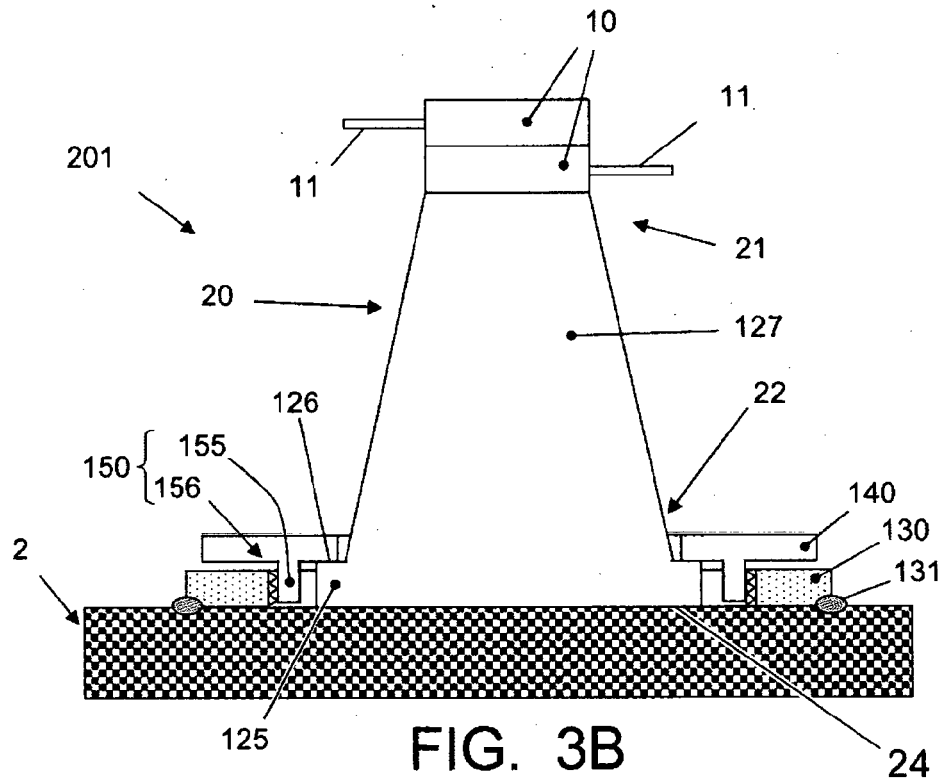
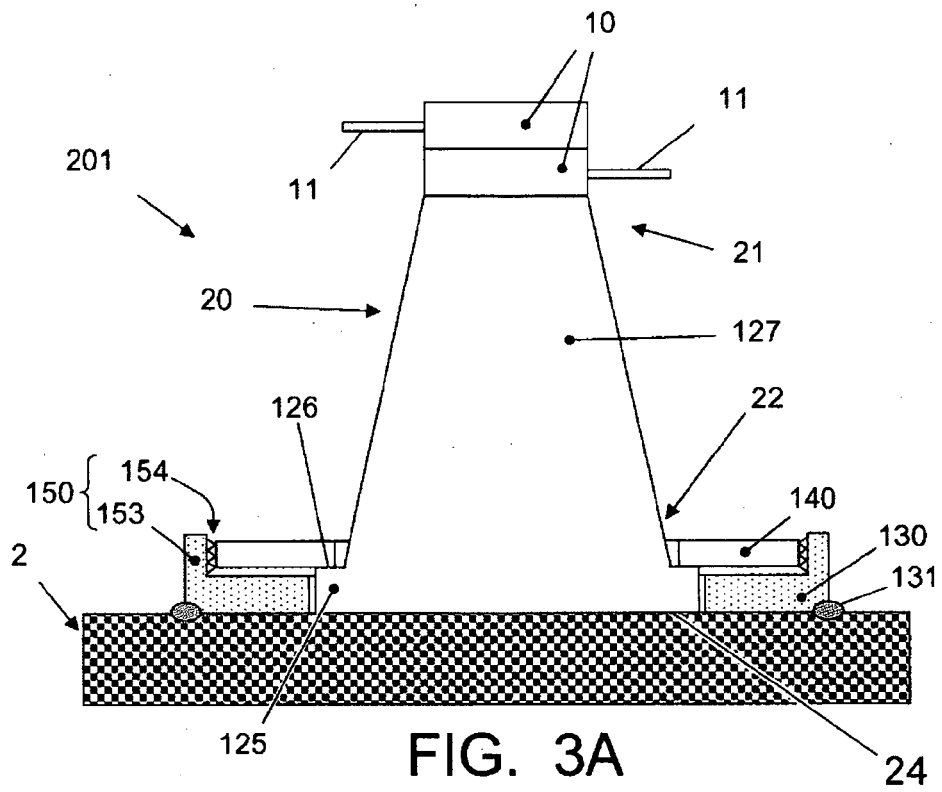


FIG. 1







EUROPEAN SEARCH REPORT

Application Number

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EPO FORM 1503 03:82 (P04C01)

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The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 21 March 2024	Examiner Pañeda Fernández, J
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	

**ANNEX TO THE EUROPEAN SEARCH REPORT
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5 This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
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