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(73) Patenthaver: **Corron AS, Grandfjæra 20, 6415 Molde, Norge**

(72) Opfinder: **OSHAUG AASEN, Rune, Birkelandvegen 82, 6523 Molde, Norge**
BERG OSHAUG, Stein, Museumsvegen 1, 6413 Molde, Norge

(74) Fuldmægtig i Danmark: **Zacco Denmark A/S, Arne Jacobsens Allé 15, 2300 København S, Danmark**

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(56) Fremdragne publikationer:
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DESCRIPTION

[0001] The present invention relates to a sacrificial anode, for example for use to protect metallic structures from corrosion.

BACKGROUND

[0002] Cathodic protection is commonly used to protect metallic structures from corrosion, often by means of a sacrificial anode. Such anodes will corrode over time in place of the metallic structure to be protected, and thus at some point lose its protective properties when it is dissolved in the galvanic solution.

[0003] Hence, it is of interest to be able to monitor the condition of the sacrificial anodes during operation with respect to damage/lost mass. This is, however, made difficult by the fact that such anodes typically are located in zones that are out of reach of an operator, e.g. submerged in seawater. US 2004/222084, GB 2458141, DE 2919057, EP 18899500, JP H09 125268, US 2014/069804 and WO 92/12277 disclose a sacrificial anode comprising an anode body having at least one cavity within the anode body and a sensor arranged in the cavity.

[0004] The present invention has the objective to provide improved technology and methods relating to sacrificial anodes.

SUMMARY

[0005] In an embodiment, there is provided a sacrificial anode according to claim 1 comprising an anode body having at least one cavity within the anode body and a sensor arranged in the cavity. The appended dependent claims and the detailed description below outline further embodiments.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] These and other characteristics will become clear from the following description of illustrative embodiments, given as non-restrictive examples, with reference to the attached drawings, in which

Figures 1a and 1b are principle drawings of a sacrificial anode according to an embodiment, as seen from different angles,

Figure 1c is a cross-sectional view of the sacrificial anode along line A-A in Figure 1b,

Figure 2 is a block diagram of components of a sacrificial anode according to an embodiment,

Figures 3a and 3b are principle drawings of a sacrificial anode provided with wireless communication means, and

Figures 4a and 4b are principle drawings of a worn sacrificial anode according to an embodiment.

DETAILED DESCRIPTION

[0007] An embodiment according to the present invention relates to a sacrificial anode arranged for condition monitoring and lifetime prediction by means of continuity measurements inside one or more cavities in the anode body. The sacrificial anode may, for example, comprise an anode body provided with several cavities distributed in the anode body for arrangement of sensors. The cavities may be shaped with different heights in the anode body.

[0008] Sensors, such as sea water sensors, may be arranged in the respective cavities. In one embodiment, the sensor is formed by one electrode or by two electrodes spaced apart, e.g. a pair of electrodes or several pairs of electrodes. The sensor or sensors can, however, be any sensor capable of indicating an ingress of water into the cavity or the opening of a previously closed cavity. For example, the sensor may be a pressure sensor which registers a pressure change when the cavity opens to the outside of the anode.

[0009] By providing a signal indicative of water ingress into a cavity in the anode, and/or destruction of the cavity, an indication of the level of wear of the anode can be obtained, and/or information relating to its remaining service life. For example, the sensor and the cavity can be designed such that the sensor signal is triggered when the anode has consumed e.g. approx. 75% of its service life.

[0010] The cavities are filled with a gas or a non-conducting material soluble in sea water or permeable, which gas or non-conducting material initially electrically insulating the electrode or electrodes of the sensor.

[0011] In other embodiments, the sacrificial anode comprises a microcontroller. The sensor may be operatively connected to the microcontroller. For example, the electrodes of a respective sensor in a respective cavity can be connected to the microcontroller, such that a voltage potential is established between the electrodes of the sensor.

[0012] The microcontroller may be positioned within the anode body, for example in one of the sensor cavities or in a dedicated cavity for the microcontroller. Alternatively, the microcontroller may be fixed on the outside of the anode, e.g. on the anode or near the anode.

[0013] According to a further embodiment, the sacrificial anode is provided with a communication device. In one embodiment, the communication device is a wireless communication device integrated in the sacrificial anode for direct wireless transmission. The communications device may be arranged in one of the sensor cavities, or in a dedicated cavity for the communications device. According to a further embodiment, the communication device is a wireless communication device arranged externally of the sacrificial anode and connected to the sensor and/or microcontroller in the sacrificial anode via a wire. In yet a further embodiment, the communication device is connected to a wire which at its other end is connected to a receiver, for example a receiver located subsea or topside.

[0014] The communication device may, for example, be powered by a galvanic or voltaic cell, such as a battery, or by external power. In one embodiment, the communication device is powered by a battery located within the anode body. The battery may, in a further embodiment, be provided with an isolator, such as a non-conductive material which is soluble in water or which may be washed away by water, and which prevents the communications device from operating until the isolator is removed. By placing the isolator within the anode body, for example within a cavity in the body, this will only be removed when the anode has been subjected to corrosion or wear and water comes into contact with the isolator. The isolator may, for example, be a non-conductive material electrically separating an electrical conductor between the battery and the communication device, or e.g. a water-soluble material holding a pre-tensioned switch in the "open" position until the material has been dissolved away. Alternatively, the non-conductive material may be one permeable by sea water. Alternatively, there may simply be a galvanic cell comprising two materials spaced apart, which can be electrically connected by sea water and thus produce a current.

[0015] According to a further embodiment, a support member or structure for the anode body is provided. The support member may, for example, extend out of the anode, and may be longer in the longitudinal direction than the body. Alternatively, the support member may be an internal support member in the anode body, for example if space requirements require connection bolts to extend through the anode body. The anode body may be casted at least partially around the support member or structure, and/or the support member may be casted partially inside the anode body and extending out of it for fixing the anode to a subsea structure for use. The support member or structure may be of a different material than the anode body.

[0016] In one embodiment, the height of the respective cavities in the anode body is designed to represent general state of the anode body with respect to mass and structural integrity. By the cavities having different heights in the anode body, as the anode body corrodes, surrounding galvanic solution will penetrate the otherwise closed cavities, triggering sensors in the individual cavities through increased electrical conductivity, at different levels of wear. Accordingly, the sealing of the individual cavities will fail depending on the amount of wear of the anode body and their height in the anode body, providing a predictable pattern and automatic detection of the level of wear of the anode body. By arranging the height of the individual cavities according to an expected wear pattern of the anode body, the wear of the sacrificial anode can be more accurately detected and monitored. For example, one may arrange the cavities such that a first sensor signal indicates a wear equivalent to approx. 25% of the anode's service life, a second sensor signal at approx. 50%, and a third at approx. 75%.

[0017] According to embodiments of the invention, there is accordingly provided a sacrificial anode enabling condition monitoring and lifetime prediction by means of continuity measurements made by sensors arranged in the individual cavity in the anode body. By providing the sacrificial anode with a communication device, the state/wear of the sacrificial anode can be transmitted wirelessly or by wire to a receiver more easily accessed by an operator, such as a computer, smartphone or other tablet solution, or forwarded via wire or wirelessly to an operational control system or the like.

[0018] Reference is now made to Figures 1a and 1b, showing principle drawings of a first embodiment of a sacrificial anode 10 according to an embodiment, and Figure 1c which is a cross-sectional view of the sacrificial anode 10 along line A-A in Figure 1b.

[0019] The sacrificial anode 10 comprises an anode body 11, e.g. formed by zinc, but can also be formed by aluminium, magnesium, iron or other suitable metal alloys, casted around a support member or structure 20, extending longer in longitudinal direction than the anode body 11 providing fixation points 21a-b at ends thereof outside the anode body 11, via which fixation points the sacrificial anode 10 can be arranged to a structure to be monitored by suitable fastening means, such as welding, screws, bolts or similar. The sacrificial anode 10 can also of course be fixed to the structure by other appropriate fastening means well known for a skilled person.

[0020] The anode body 11 is provided with a number of cavities 12 of known geometry, distributed in the anode body 11, in this embodiment distributed in the longitudinal direction.

[0021] The sacrificial anode 10 further comprises sensors 30 arranged in the respective cavities 12, the sensors 30 consisting of two electrodes 31a-b, spaced apart, preferably a pair of electrodes 31a-b or several pairs of electrodes 31a-b. Alternatively, there may be a single electrode, and the second electric lead being provided by the anode body. The sensors 30 are fixed to the support member or structure 20 and have an extension in longitudinal direction of the respective cavities 12. The electrodes 31a-b are fixed to the support member or structure 20 via non-conducting means such that there is no electrical connection between the support member or structure 20 and the electrodes 31a-b.

[0022] The cavities 12 can, for example, be filled with gas (such as air), a non-conducting material soluble in sea water (such as grease), or a material permeable to sea water (such as a perforated or porous, non-conducting material). Suitable materials for this purpose may, for example, be a refractory fiber material or a porous ceramic material. These materials can assist in defining the cavity 12 and keeping molten material out of the cavity when manufacturing the anode, while allowing water to enter the cavity when the anode has corroded sufficiently or is otherwise damaged.

[0023] The cavities 12 are thus enclosed and sealed from the seawater surrounding the sacrificial anode 10, but as the anode body 11 of the sacrificial anode 10 corrodes, the seals of the cavities 12 are compromised, allowing the galvanic solution (sea water) to flow into the cavities 12. In this embodiment, the sensors 30 comprise two electrodes arranged in each cavity 12, and further initially electrically insulated from each other by the mentioned gas, or a non-conducting material inside. However other sensor types may be equally suitable for use in the cavities, such as a pressure sensor configured to detect a pressure change when the structure around the cavity is compromised and sea water enters.

[0024] Reference is now made to Figure 2 which is a block diagram of components of the sacrificial anode 10 showing power and data flows in the sacrificial anode 10. The sensors 30 with the at least two electrodes 31a-b in the individual cavities 12 are connected to a microcontroller 40 such that a voltage potential is established between the two electrodes 31a-b of the sensor 30, and the microcontroller 40 is further arranged to measure continuity between the electrodes 31a-b of the sensors 30, i.e. electrical conductivity. The microcontroller 40 will measure no continuity across the at least two electrodes 31a-b (electrode pairs) as long the cavity 12 seal is intact, but as soon as the seal is broken, the galvanic solution, now enclosing the electrodes 31a-b, will exhibit measurable conductivity, and a current will flow across the electrodes 31a-b of the sensors 30, which can be registered by the microcontroller 40.

[0025] Alternatively, a different type of sensor 30 may be used, such as one where a water-soluble isolator mechanically holds a pre-tensioned conductor pin in the "open" state until it is dissolved in the water. Any other type of sensor which is triggered by water ingress into the cavity can also be used.

[0026] The sacrificial anode 10 is further provided with a communication device 50. Figure 3a shows an embodiment where the communication device 50 is a wireless communication device integrated/arranged in the sacrificial anode 10 for direct wireless transmission. The communication device may be arranged in one of the sensor cavities, or in a separate cavity for this purpose. Figure 3b shows an embodiment where the communication device 50 is a wireless communication device and arranged externally of the sacrificial anode 10 and connected to the microcontroller 40 in the sacrificial anode 10 via a wire 51. In an alternative embodiment, the wire 51 can extend to a receiver located subsea or topside. For example, the wire may extend to a junction box in a subsea installation, whereby the sensor signals may be forwarded to a topside location via an existing communications link, such as an umbilical. Alternatively, the cable 51 may itself be a dedicated communications line to topside, or part of an umbilical for this purpose, and lead to a receiver located topside or onshore.

[0027] According to an alternative embodiment the microcontroller 40 is integrated with the external wireless communication device 50, and the sensors 30 are connected to the microcontroller 40 via a wire 51.

[0028] For wireless transfer directly from the sacrificial anode 10 or via an external wireless communication device, as shown in Figures 3a and 3b, the signal medium is water and wireless transmission can, for example, be achieved by means of acoustic transfer, i.e. by means of an underwater acoustic communication (UAC), where an acoustic signal is sent directly from the sacrificial anode 10 or via the external wireless communication device, and received by a receiving unit outside the anode, e.g. at the water surface. As the signal transfer rate required is very low, UAC may provide satisfactory performance for this purpose. Alternatively, other wireless communication standards can be used for this purpose. For example, in some embodiments it may be possible to provide a reader device, temporarily or permanently, in close proximity to the anode, in which case communication via e.g. Bluetooth may be possible.

[0029] Figures 1a and 1b show a further embodiment where the communication device 50 is arranged in a wire 51 for wire transmission to a receiver above the water surface.

[0030] Readings or measurements made by the sensors 30 and provided to the microcontroller 40 can be transmitted wirelessly or by wire 51 to a receiver outside the anode, e.g. on the water surface, in turn alerting an operator of the corrosion progression and condition of the sacrificial anode 10.

[0031] Reference is now again made to Figure 1c, as well as Figures 4a and 4b. According to this embodiment, the cavities 12 of the sacrificial anode 10 are shaped with different heights in the anode body 11. By this design, the time needed for the corrosion process to breach the seals to the individual cavities 12 are different between cavities. Hence, the individual cavities 12 can be designed such that the seals will fail one after the other in a predictable pattern, depending on the wear of the anode body 11. Thereby, the general state of the anode body 11 with respect to mass and structural integrity may be inferred from the information about broken and remaining intact cavities 12.

[0032] As the anode body 11 corrodes, as shown in Figure 4a, the surrounding galvanic solution (sea water) will penetrate the otherwise closed cavities 12, as shown in Figure 4b, triggering sensors 30 in the individual cavities 12, e.g. through increased electrical conductivity, as described above.

[0033] By means of the sacrificial anode 10 according to the above described embodiments, the wear, i.e. status of the sacrificial anode 10 can be monitored, where the condition status of the sacrificial anode 10 is either sent wireless directly to a receiving unit or the condition status is sent via a wire 51 to the water surface, where the signal can be easily accessed by an operator or forwarded to an operator.

[0034] The invention is only limited by the scope of the appended claims.

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- US2004222084A [0003]
- GB2458141A [0003]
- DE2919057 [0003]
- EP18899500A [0003]
- JPH09125268B [0003]
- US2014069804A [0003]
- WO9212277A [0003]

Patentkrav

1. Offeranode (10), der omfatter et anodelegeme (11) med mindst et hulrum (12) i anodelegemet (11) og en sensor (30), der er anbragt i hulrummet (12); hvor sensoren (30) er:
en sensor, der kan betjenes til at måle tilstedeværelsen af havvand i hulrummet (12), eller
en sensor, der kan betjenes til at måle fluidkommunikation mellem hulrummet (12) og ydersiden af anoden (10),
hvor sensoren (30) omfatter mindst en elektrode (31a,b), eller hvor sensoren er dannet af mindst to elektroder (31a,b), der er anbragt med indbyrdes afstand, og
hvor det mindst ene hulrum (12) er fyldt med et ikke-ledende materiale, der kan opløses i havvand eller er gennemtrængeligt for havvand.

2. Offeranode (10) ifølge det foregående krav, hvor det mindst ene hulrum (12) er en flerhed af hulrum (12), der er fordelt i anodelegemet (11), og hvor hver af flerheden af hulrum (12) omfatter en sensor (30).

3. Offeranode (10) ifølge det foregående krav, hvor flerheden af hulrum (12) er anbragt således, at en vægtykkelse mellem hulrummet (12) og en yderside af anoden (10) er forskellig for mindst to af flerheden af hulrum (12).

4. Offeranode (10) ifølge et af de to foregående krav, hvor flerheden af hulrum er fordelt i en langsgående retning af anodelegemet (11).

5. Offeranode (10) ifølge et af de tre foregående krav, hvor flerheden af hulrum (12) er formet med forskellige højder i anodelegemet (11).

6. Offeranode (10) ifølge et af de foregående krav, omfattende en mikrocontroller (40), der er funktionsforbundet med sensoren (30).

7. Offeranode (10) ifølge det foregående krav, hvor de mindst to elektroder (31a-b) er forbundet med mikrocontrolleren (40), således at et spændingspotentiale etableres mellem elektroderne (31a-b).

8. Offeranode (10) ifølge krav 1 i kombination med krav 7, hvor det ikke-ledende materiale er indrettet til elektrisk at isolere sensorens (30) mindst to elektroder (31a-b).

9. Offeranode (10) ifølge et af de foregående krav, omfattende en kommunikationsindretning (50), der er funktionsforbundet med sensoren (30).

10. Offeranode (10) ifølge det foregående krav, hvor kommunikationsindretningen (50) er
anbragt i det mindst ene hulrum (12),
anbragt i anodelegemet (11),
fastgjort til anodelegemet (11) eller
anbragt uden for anodelegemet (11) og funktionsforbundet med sensoren (30) via en transmissionsledning (51).

11. Offeranode (10) ifølge et af de to foregående krav, hvor kommunikationsindretningen (50) er en trådløs kommunikationsindretning (50).

12. Offeranode (10) et af de tre foregående krav, endvidere omfattende en galvanisk celle og/eller et batteri, der er funktionsforbundet med kommunikationsindretningen (50).

13. Offeranode (10) ifølge det foregående krav, endvidere omfattende en isolator mellem den galvaniske celle og/eller batteriet og kommunikationsindretningen (50), hvor isolatoren er anbragt i anodelegemet (11) og indrettet til at muliggøre elektrisk kommunikation mellem den galvaniske celle og/eller batteriet og kommunikationsindretningen (50), når isolatoren kommer i kontakt med vand.

14. Offeranode (10) ifølge det foregående krav, hvor isolatoren omfatter et materiale, der kan opløses i vand eller er gennemtrængeligt for vand.

15. Offeranode (10) ifølge et af kravene 9-14, hvor kommunikationsindretningen (50) omfatter en akustisk sender.

16. Offeranode (10) ifølge et af de foregående krav, omfattende et støtteelement (20), hvor anodelegemet (11) er støbt i det mindste delvist omkring støtteelementet (20).

DRAWINGS

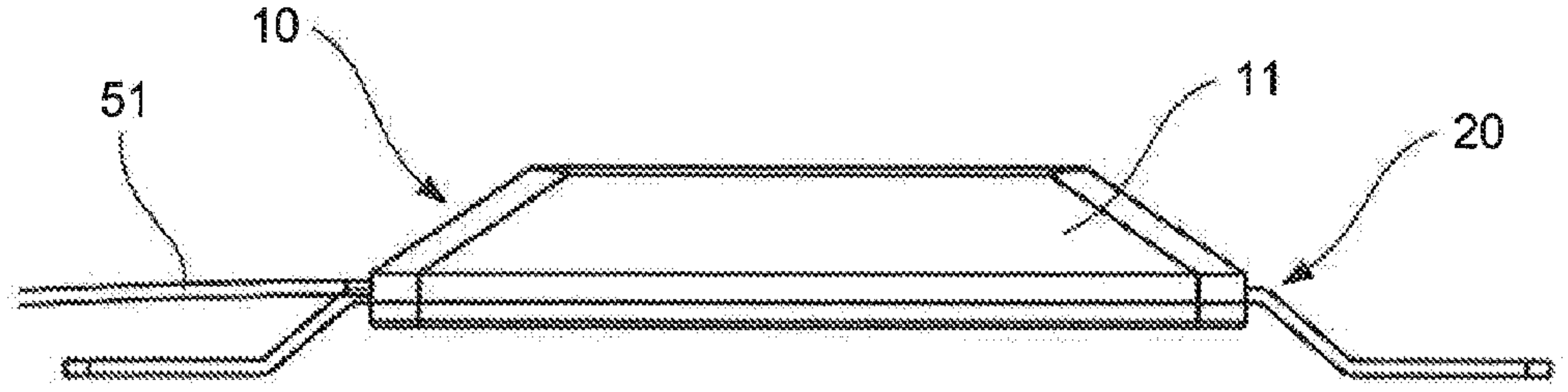

Fig. 1a

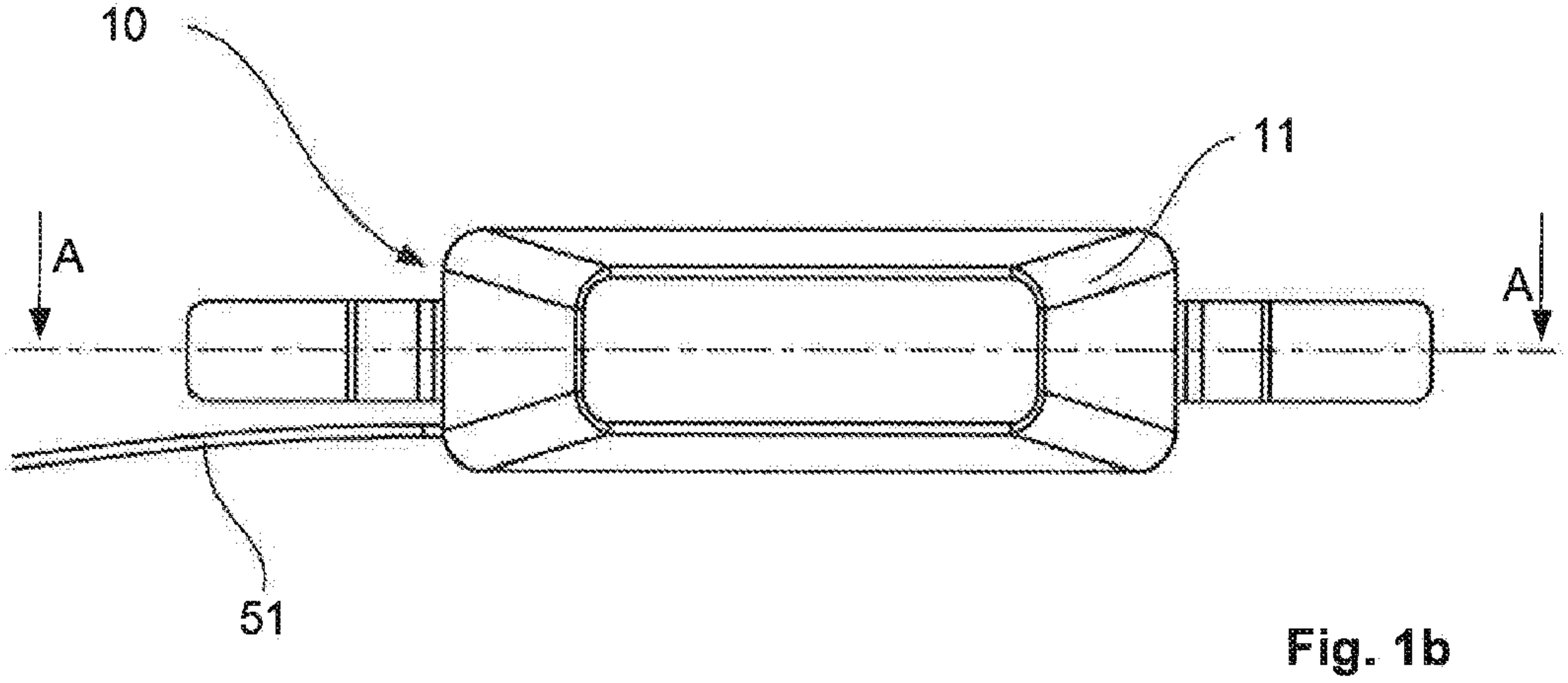

Fig. 1b

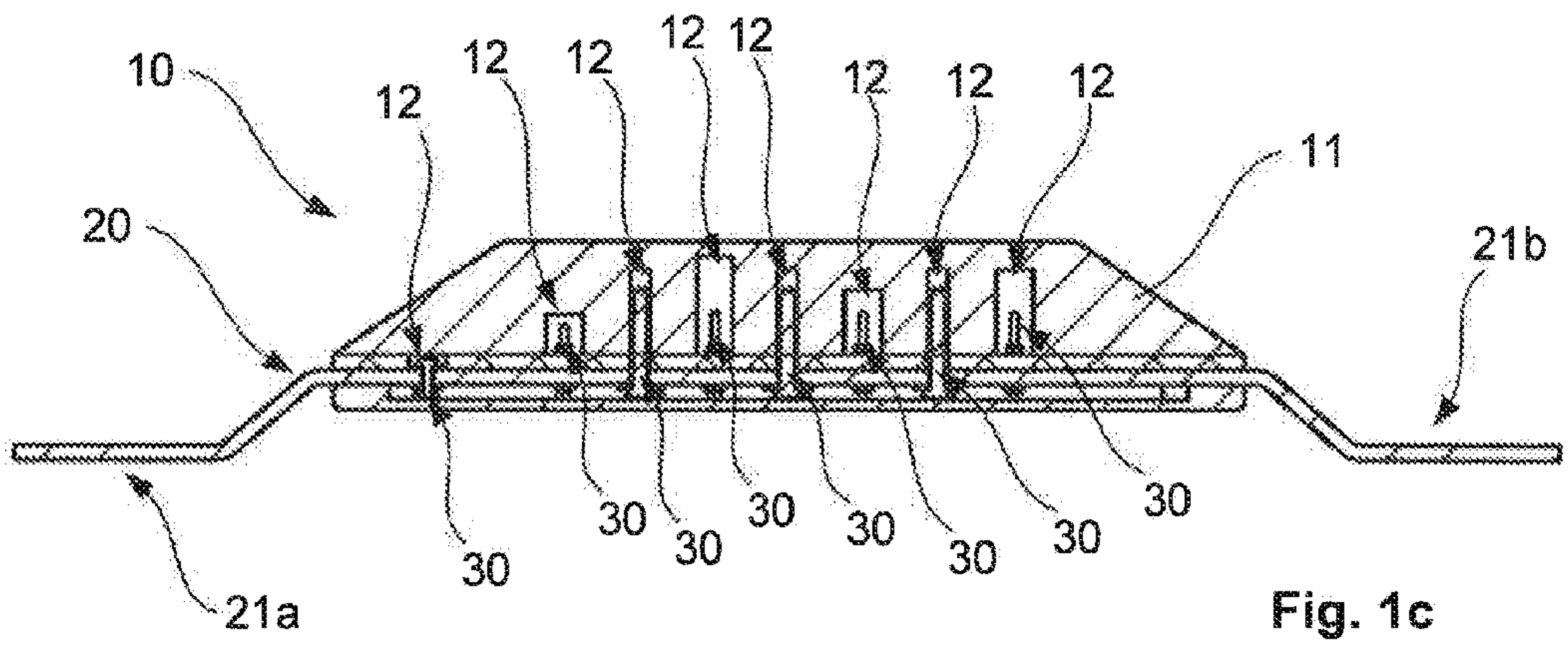

Fig. 1c

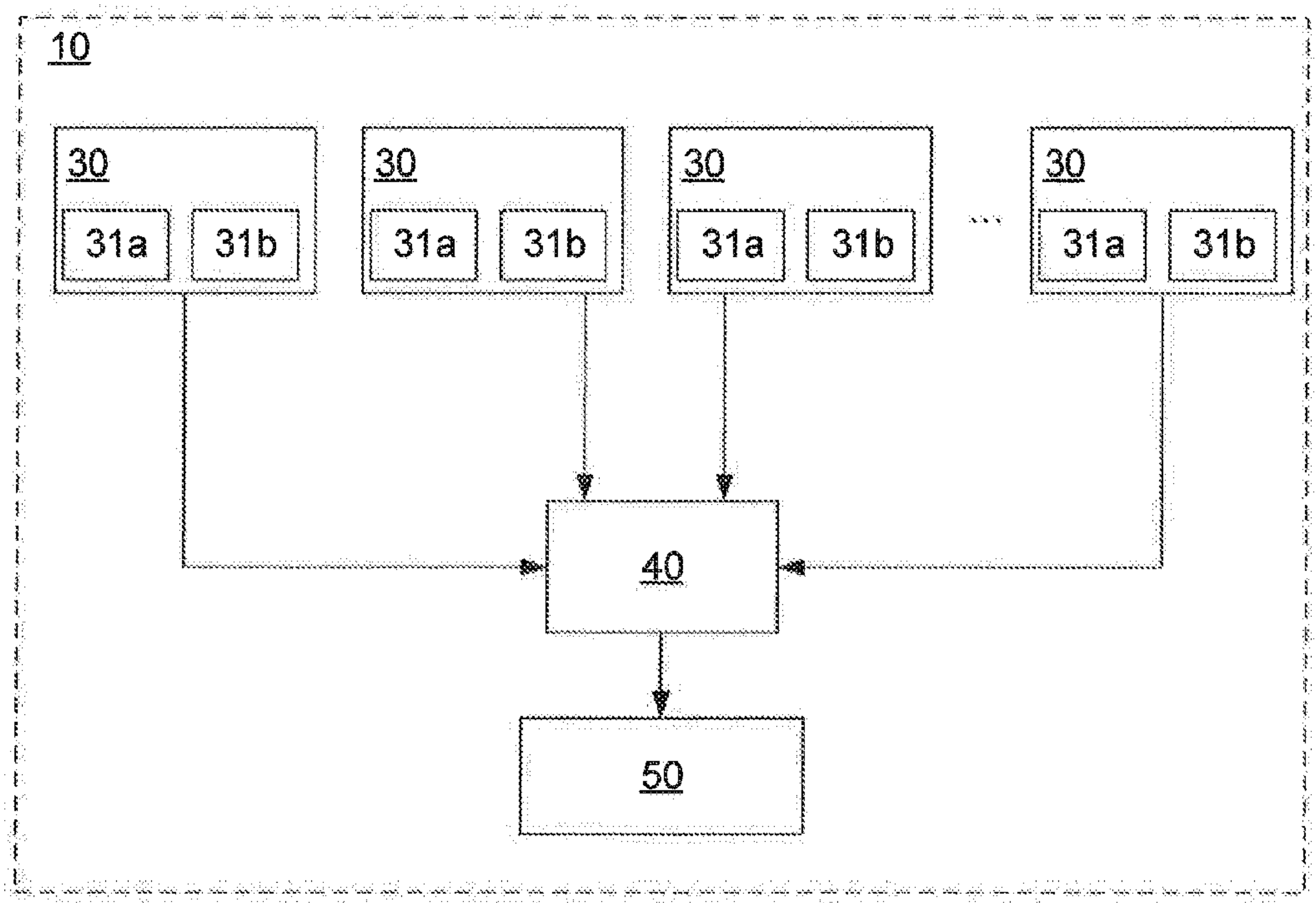

Fig. 2

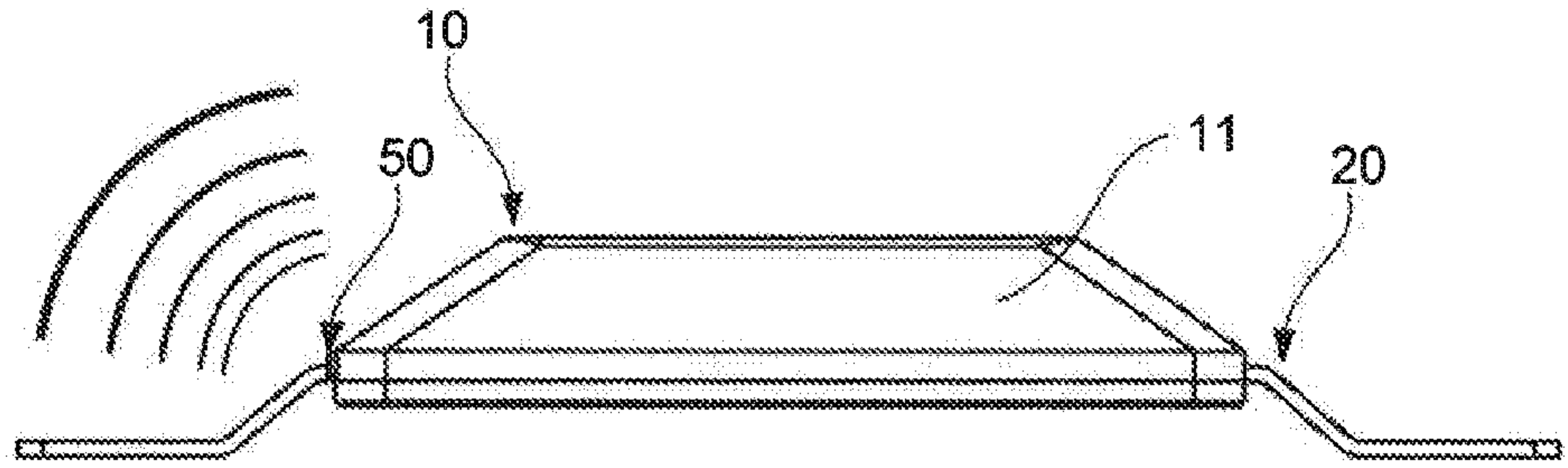

Fig. 3a

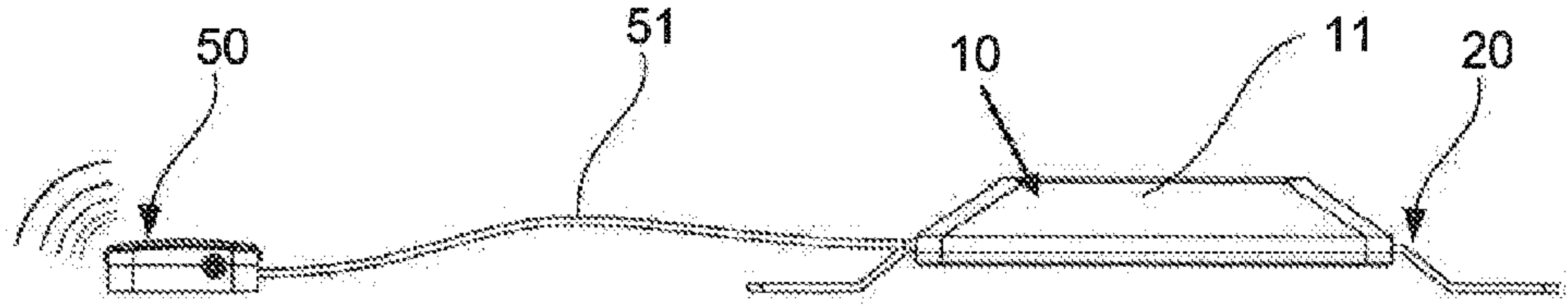

Fig. 3b

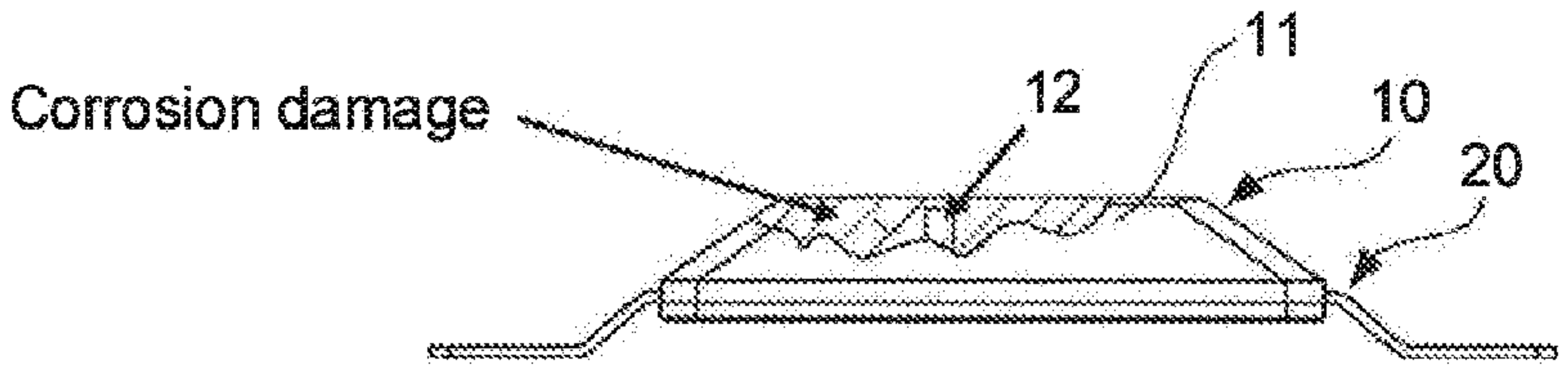
Corrosion damage
12
11
10
20

Fig. 4a

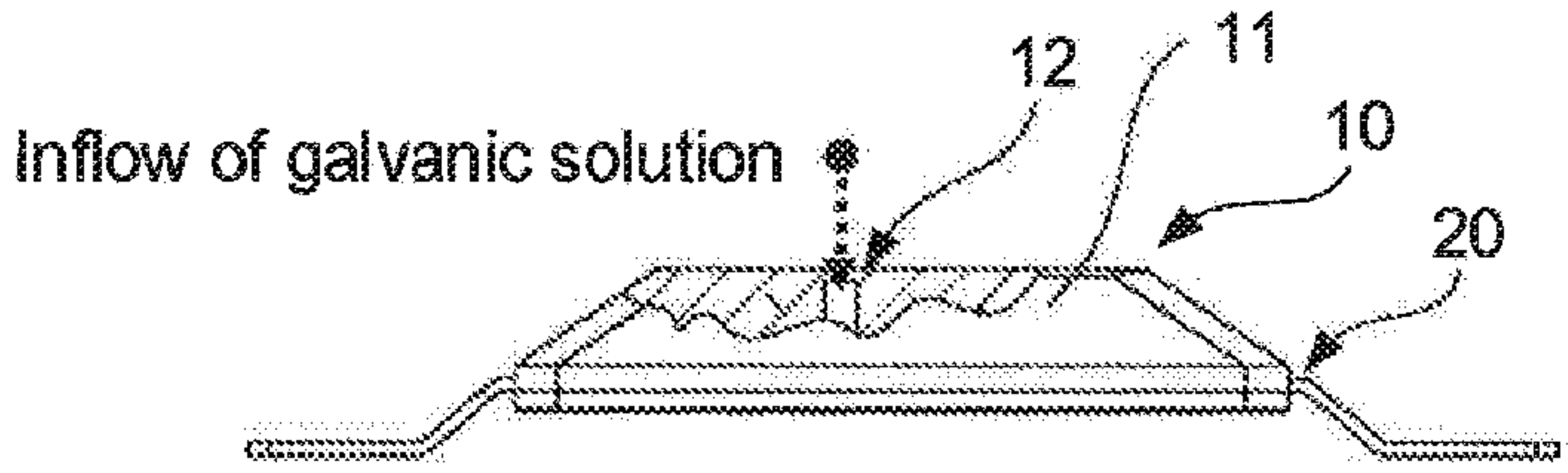
Inflow of galvanic solution
12
11
10
20

Fig. 4b