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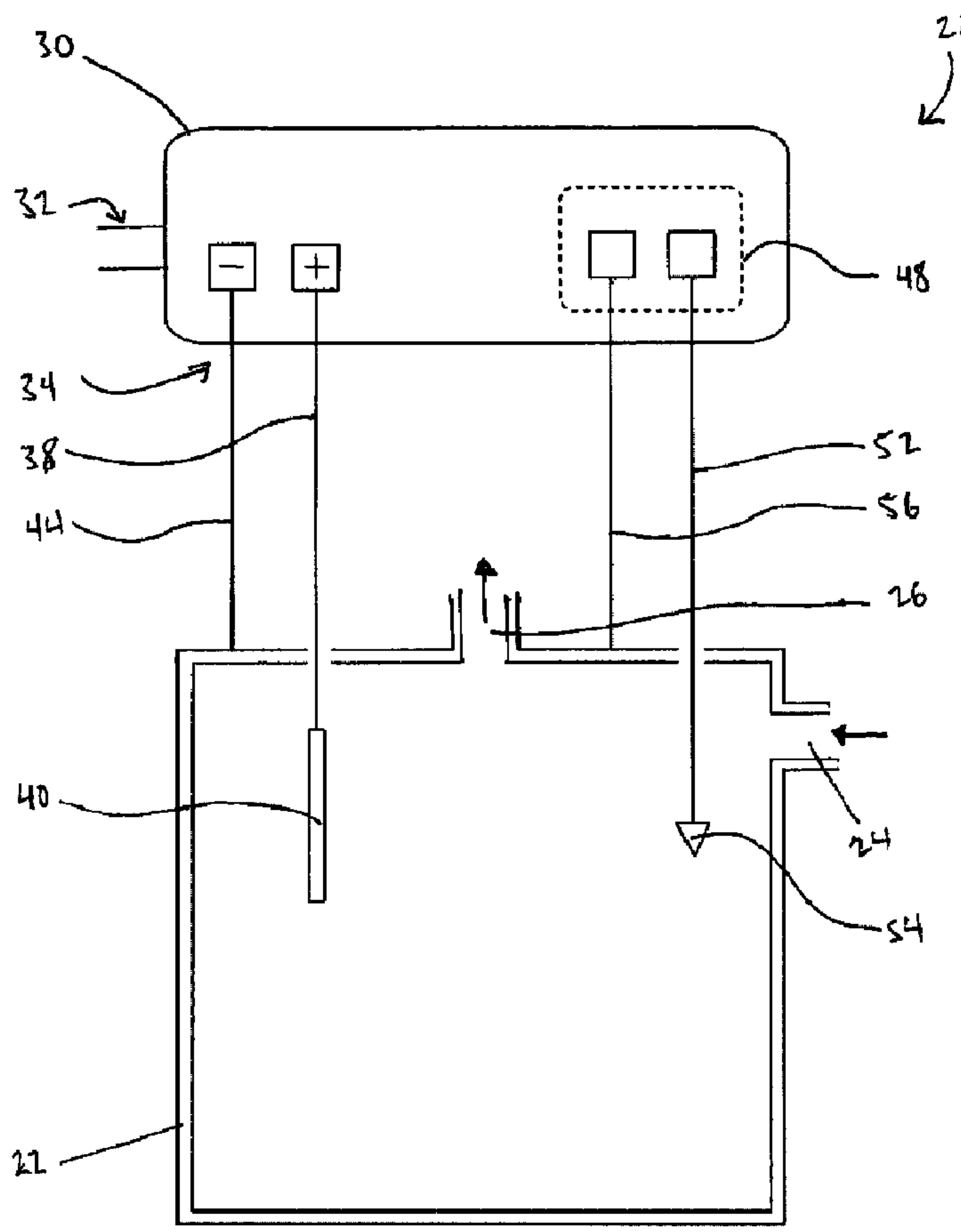
(72) **Inventeur/Inventor:**
SHIM, WINSTON W., CA
(73) **Propriétaire/Owner:**
CORROSION SERVICE COMPANY LIMITED, CA
(74) **Agent:** SIM & MCBURNEY

(54) **Titre : PROCEDE ET APPAREIL SERVANT A APPLIQUER UNE PROTECTION ELECTROCHIMIQUE CONTRE LA CORROSION**
(54) **Title: METHOD AND APPARATUS FOR PROVIDING ELECTROCHEMICAL CORROSION PROTECTION**



(57) **Abrégé/Abstract:**
An apparatus for providing electrochemical corrosion protection to a stainless steel process vessel comprises at least one anode in communication with the process vessel, a DC current supply having an electrical connection to the process vessel and an electrical

(57) **Abrégé(suite)/Abstract(continued):**
connection to the at least one anode, and a potential control unit in communication with the DC current supply. The potential control unit has an electrical connection to the process vessel and an electrical connection to a reference electrode in communication with the process vessel, and is configured for adjusting current supplied by the DC current supply for passivating the process vessel. The apparatus is for use with a process vessel comprising at least one of duplex stainless steel and superaustenitic stainless steel.

ABSTRACT

An apparatus for providing electrochemical corrosion protection to a stainless steel process vessel comprises at least one anode in communication with the process vessel, a DC current supply having an electrical connection to the process vessel and an electrical connection to the at least one anode, and a potential control unit in communication with the DC current supply. The potential control unit has an electrical connection to the process vessel and an electrical connection to a reference electrode in communication with the process vessel, and is configured for adjusting current supplied by the DC current supply for passivating the process vessel. The apparatus is for use with a process vessel comprising at least one of duplex stainless steel and superaustenitic stainless steel.

METHOD AND APPARATUS FOR PROVIDING ELECTROCHEMICAL CORROSION PROTECTION

Field of the Invention

[0001] The present invention relates generally to corrosion protection and in particular, to an apparatus for providing electrochemical corrosion protection to a stainless steel process vessel and a method for same.

Background of the Invention

[0002] Corrosion of metal structures is a well-understood phenomenon, and occurs when the metal gives up electrons by electrochemical reactions with its surrounding environment. Such corrosion may be prevented by forcing electrons into the metal from an external power source at a rate which is at least just as great as the rate of electrons leaving the metal to participate in the corrosion-causing electrochemical reaction occurring between the metal and its environment.

[0003] One commonly used approach to achieve this is impressed current cathodic protection, whereby an electromotive force (EMF) is used to provide electrons directly to the metal structure in its operating environment. This prevents the metal structure from serving as a source of the electrons that would otherwise be required for the corrosion reaction to proceed.

[0004] Several approaches for providing impressed current cathodic protection to metal structures fabricated of stainless steel have been described. For example, U.S. Patent No. 4,152,236 to Beese et al. is directed to a cathodic current from a DC current source applied through a platinum electrode, which provides protection to stainless steel from pitting corrosion particularly in the interior of long narrow stainless steel tubes exposed to hot concentrated chloride brine.

[0005] U.S. Patent No. 4,285,787 to Garner et al. is directed to a method for electrochemical corrosion protection of a partly submersed, rotating, stainless steel drum in a vat containing a corrosive, oxidizing, chloride-containing bleach liquor.

[0006] In general, corrosion protection is required in industrial applications. There is, therefore, a need to provide an apparatus and method for providing electrochemical corrosion protection in such applications.

Summary of the Invention

[0007] Accordingly, in one aspect there is provided an apparatus for providing electrochemical corrosion protection to a stainless steel process vessel, the apparatus comprising: at least one anode in communication with the process vessel; a DC current supply having an electrical connection with the process vessel and an electrical connection with the at least one anode; and a potential control unit in communication with the DC current supply, the potential control unit having an electrical connection to the process vessel and an electrical connection to a reference electrode in communication with the process vessel, the potential control unit adjusting current supplied by the DC current supply for passivating the process vessel; wherein the process vessel comprises at least one of duplex stainless steel and superaustenitic stainless steel.

[0008] In another aspect, there is provided a method of providing electrochemical corrosion protection to a stainless steel process vessel, the method comprising: supplying a current from a DC current supply to at least one anode in communication with the process vessel, the DC current supply having an electrical connection to the process vessel, the current supplied by the DC current supply being adjusted by a potential control unit so as to passivate the process vessel, the potential control unit having an electrical connection to the process vessel and an electrical connection to a reference electrode in communication with the process vessel, wherein the process vessel comprises at least one of duplex stainless steel and superaustenitic stainless steel, and wherein the process vessel forms part of a scrubber system.

[0009] In still another aspect, there is provided a system comprising: a stainless steel process vessel; and an electrochemical corrosion protection apparatus providing a passivating current to the stainless steel process vessel, wherein the process vessel comprises at least one of duplex stainless steel and superaustenitic stainless steel, and wherein the system is a scrubber system.

Brief Description of the Drawings

[00010] Embodiments will now be described more fully with reference to the accompanying drawings in which:

[00011] Figure 1 is a schematic side view of an electrochemical corrosion protection apparatus;

[00012] Figure 2 is a side view of an embodiment of an anode arrangement for use with the apparatus of Figure 1;

[00013] Figure 3 is a bottom plan view of the anode arrangement of Figure 2; and

[00014] Figures 4a and 4b are side elevation and front cross-sectional views, respectively, of a first end of an anode in the arrangement of Figure 2.

Detailed Description of the Embodiments

[00015] The following is directed to an apparatus and method for providing electrochemical corrosion protection to a stainless steel process vessel, wherein the stainless steel process vessel comprises at least one of superaustenitic stainless steel and duplex stainless steel.

[00016] Turning now to Figure 1, an apparatus for providing electrochemical corrosion protection is shown, and is generally indicated using reference numeral 20. Apparatus 20 is configured to provide electrochemical corrosion protection to a stainless steel process vessel 22 which, in this embodiment, is a scrubber vessel. However, it will be understood that apparatus 20 is not limited to use with scrubber vessels, and alternatively may be used to provide electrochemical corrosion protection to any stainless steel process vessel, such as, and without being limited thereto, a fluid tank, a reactor, a reaction tank, a pipe, a pipeline, and the like.

[00017] Process vessel 22 is generally hollow, and has an interior in which process fluids are enclosed. Process vessel 22 has an input 24 through which the process fluids enter the process vessel 22, and an output 26 through which the process fluids exit the process vessel 22. As will be understood, the positions of input 24 and output 26 are not limited to those illustrated, and may alternatively be positioned differently. In this embodiment, the process vessel 22 is a scrubber vessel forming part of a flue gas desulphurization scrubber system, and the process fluids are flue gases that are produced during combustion of fossil fuel in an industrial facility, such as a coal burning power plant. Here, the flue gases are flowed continuously through the process vessel 22 via input 24 and output 26 for removal of sulphur dioxide (SO_2) gas by a scrubbing process. Under normal operating conditions of the scrubber, the SO_2 gas reacts to form sulfuric acid and thereby contributes to a corrosive environment in the interior of the scrubber vessel.

[00018] In this embodiment, the stainless steel process vessel 22 is a scrubber vessel fabricated of a duplex stainless steel. As is known in the art, duplex stainless steels have a generally mixed microstructure consisting of both austenite and ferrite. This microstructure gives rise to both higher strength and generally improved resistance to localized corrosion, particularly pitting, crevice corrosion and stress corrosion cracking, as compared to austenitic stainless steels. One commonly used duplex stainless steel is alloyed with 22% chromium, and has Unified Numbering System (UNS) designation of S31803/S32205 and is commonly known as 2205 stainless steel. However, other grades of duplex stainless steels are available.

[00019] Turning now to the electrochemical corrosion protection apparatus, apparatus 20 comprises a DC power supply 30 that has an AC input 32 and a DC output 34. DC output 34 is electrically connected via an anode line 38 to an anode 40, which is positioned in the interior of stainless steel process vessel 22, and is electrically isolated from the stainless steel process vessel 22. DC output 34 is also electrically connected via a current return line 44 to the stainless steel process vessel 22. DC power supply 30 is in communication with a potential control unit 48. Potential control unit 48 is electrically connected via a reference electrode line 52 to a reference electrode 54 positioned within an interior of the stainless steel process vessel 22, and is electrically isolated from the stainless steel process vessel 22. In this embodiment, reference electrode 54 is a Ag/AgCl reference electrode, however other electrode types may alternatively be used. Potential control unit 48 is also electrically connected to the stainless steel process vessel 22 via a reference line 56. In this embodiment, potential control unit 48 has a user input that allows a user to enter a target value of potential that is to be assumed by the electrochemical system formed by the reference electrode 54, the process fluids, and the stainless steel process vessel 22. As will be understood by those skilled in the art, potential control unit 48 is configured to measure the electrochemical potential of this electrochemical system, and to adjust the current supplied by the DC power supply 30 based on this measurement and in accordance with the target value of potential.

[00020] In use, DC power supply 30 applies a DC current so as to bring the stainless steel process vessel 22 to a passivation potential. The passivation potential lies within a passivation zone of the polarization curve of a metal or metal alloy, where the passivation zone is a range of potential in which corrosion of the metal or metal alloy occurs at a generally insignificant or tolerable rate. In this embodiment, the passivation zone of the duplex stainless steel used to fabricate stainless steel process vessel 22 ranges from about -850mV to about +500mV, with respect to the Ag/AgCl reference electrode 54. Accordingly, by using a target value of potential that lies within this passivation zone, the DC power supply 30 of apparatus 20 supplies a passivating current to the stainless steel process vessel 22, and thereby passivates the stainless steel process vessel 22.

[00021] As will be understood, the specific passivation potential used may depend on a number of factors, such as the composition of the stainless steel process vessel, the geometry and the position of the anode relative to the stainless steel process vessel, and the conditions to which the stainless steel process vessel is exposed so as to reduce corrosion. Typically, for a stainless steel process vessel used in a scrubbing process, the value of passivation potential applied may range from about -350mV to about +400mV.

[00022] In absence of such an application of passivating current from DC power supply 30, the electrochemical system formed by reference electrode 54, the process fluids, and the stainless steel process vessel 22 will otherwise assume a potential that occurs during normal scrubbing operations, and which lies above the passivation zone and within a zone of pitting corrosion. As is known in the art, pitting corrosion results in general mechanical deterioration of the duplex stainless steel over time, and will eventually cause mechanical failure of stainless steel process vessel 22. Such mechanical failure eventually requires the repair or replacement of stainless steel process vessel 22, which may in turn result in costly downtime. In contrast, application of a passivating current by apparatus 20 to stainless steel process vessel 22 advantageously reduces pitting corrosion to an insignificant or tolerable level, and thereby prolongs the lifetime of the stainless steel process vessel 22.

[00023] The electrochemical corrosion protection apparatus is not limited to the configuration of the embodiment described above. For example, Figures 2 to 4 illustrate an embodiment of an alternative anode arrangement for use with the electrochemical corrosion protection apparatus 20, generally indicated using reference numeral 140. Anode arrangement 140 consists of a set of six (6) anodes 140a to 140f that are arranged in a radial pattern within in a horizontal plane inside stainless steel process vessel 22, and which are positioned at a predetermined height above floor 22a of the stainless steel process vessel 22. In this embodiment, each of the anodes 140a to 140f consists of a platinum-clad niobium rod having a copper core, however it will be understood that other suitable materials and shapes may be used. As may be more clearly seen in Figures 4a and 4b, each of the anodes 140a to 140f is mounted to a set of insulators 164, which are suspended from a respective support 162 by angle iron 168. In this embodiment, supports 162 are air spargers for introducing air into the stainless steel process vessel 22 for the scrubbing process carried out therein, however it will be understood that other structures may be used for supporting the anodes. Each of the anodes 140a to 140f has a first end 170 positioned inside of the stainless steel process vessel 22 that terminates in a loop. Each of the anodes 140a to 140f also has a second end 172 mounted within the wall of process vessel 22 using an electrically insulated seal 176, and this second end 172 is connected via an anode line (not shown) to a DC output (not shown) of a DC power supply (not shown). Each of the anodes 140a to 140f is therefore electrically insulated from the stainless steel process vessel 22 by insulators 164 and by insulated seal 176.

[00024] The anode arrangement is not limited to that described above. For example, in other embodiments, the anode arrangement may alternatively comprise any number of anodes. Additionally, in other embodiments, the anode arrangement may comprise one or more anodes arranged in any way, such as for example in a different pattern within a horizontal plane, in a vertical plane, or in a plane of any orientation, and in any number of planes. Additionally, each of the anodes may be oriented in any direction within the process vessel, such as in a horizontal direction, in a vertical direction, in a diagonal direction, or in any direction.

[00025] The electrochemical corrosion protection apparatus of the embodiments described above is not limited to use with stainless steel process vessels fabricated of duplex stainless steels, and in other embodiments may alternatively be used with stainless steel process vessels fabricated of other stainless steels, such as superaustenitic stainless steel. As is known in the art, superaustenitic stainless steels have higher molybdenum, nitrogen, and nickel contents, which together increase the resistance to pitting, crevice corrosion, and stress-corrosion cracking, as compared to standard "300 series" austenitic stainless steels. Two examples of superaustenitic stainless steels are AL-6XN™, which has UNS designation N08367, and 254SMO stainless steel. However, other grades of superaustenitic stainless steels are available. In still other embodiments, the apparatus may be used with a process vessel fabricated of more than one kind of stainless steel, and which may include both a duplex stainless steel and a superaustenitic stainless steel.

[00026] Although embodiments described above are directed to a stainless steel process vessel that is a scrubber vessel, in other embodiments, the stainless steel process vessel may be any process vessel that forms part of a scrubber system. For example, in a related embodiment, the stainless steel process vessel may be a reaction tank of a scrubber system. Similarly, the apparatuses and methods described above are not limited to use with the scrubber systems described above, and may alternatively be used with scrubber systems having other configurations and/or other kinds of stainless steel process vessel not mentioned above. It will also be understood that the apparatuses and methods described above are not limited to use with scrubber vessels, and alternatively may be used to provide electrochemical corrosion protection to any stainless steel process vessel, such as, and without being limited thereto, a fluid tank, a reactor, a reaction tank, a pipe, a pipeline, and the like.

[00027] Although in embodiments described above the anode or anodes are described as being positioned in the interior of the stainless steel process vessel, in other embodiments, the anode or anodes may alternatively be positioned anywhere with respect to the stainless steel process vessel provided that the anode or anodes, the process fluids, and the process vessel are able to function as an electrochemical cell, and therefore provided that the anode or anodes are in communication with the stainless steel process vessel. For example, the anode or anodes may alternatively be positioned within any of an input or an output of the stainless steel process vessel.

[00028] Similarly, although in embodiments described above the reference electrode is described as being positioned in the interior of the stainless steel process vessel, in other embodiments, the reference electrode may alternatively be positioned anywhere with respect to the stainless steel process vessel provided the reference electrode, the process fluids, and the process vessel are able to function as an electrochemical cell, and therefore provided that the reference electrode is in communication with the stainless steel process vessel. For example, the reference electrode may alternatively be positioned within any of an input or an output of the stainless steel process vessel.

[00029] Although in embodiments described above the potential control unit is in communication with the DC power supply, this communication is not limited to any specific configuration and may include, for example, any of a wired and a wireless connection between the potential control unit and the DC power supply. Additionally, the DC power supply and the potential control unit may be structurally integrated with each other, or they may be structurally separate from each other.

[00030] Although in embodiments described above the potential control unit has a user input that allows a user to enter the target value of potential, in other embodiments, the target value of potential may alternatively be predefined and/or fixed. Additionally, those of skill in the art will understand that still other configurations are possible with respect to the target value of potential.

[00031] Although embodiments have been described above with reference to the accompanying drawings, those of skill in the art will appreciate that variations and modifications may be made without departing from the scope thereof.

What is claimed is:

1. A method of providing electrochemical corrosion protection to a stainless steel process vessel, the method comprising:

supplying a current from a DC current supply to at least one anode in communication with the process vessel, the DC current supply having an electrical connection to the process vessel, the current supplied by the DC current supply being adjusted by a potential control unit so as to passivate the process vessel, the potential control unit having an electrical connection to the process vessel and an electrical connection to a reference electrode in communication with the process vessel;

wherein the process vessel comprises at least one of duplex stainless steel and superaustenitic stainless steel, and

wherein the process vessel forms part of a scrubber system.

2. The method of claim 1, wherein the process vessel consists essentially of at least one of duplex stainless steel and superaustenitic stainless steel.

3. The method of claim 1 or 2, wherein at least one of the reference electrode and the at least one anode is positioned in an interior of the process vessel.

4. The method of any one of claims 1 to 3, wherein the scrubber system is a flue gas desulphurization scrubber system.

5. The method of any one of claims 1 to 4, wherein the process vessel is a scrubber vessel.

6. The method of any one of claims 1 to 4, wherein the process vessel is a reaction tank.

7. The method of any one of claims 1 to 6, wherein each said at least one anode is suspended from a respective air sparger.

8. The method of any one of claims 1 to 7, wherein the current adjusts potential of the process vessel from about -850mV to about +500mV relative to the reference electrode.

9. The method of any one of claims 1 to 8, wherein the current adjusts potential of the process vessel from about -350mV to about +400mV relative to the reference electrode.

10. A system comprising:

a stainless steel process vessel; and

an electrochemical corrosion protection apparatus providing a passivating current to the stainless steel process vessel;

wherein the process vessel comprises at least one of duplex stainless steel and superaustenitic stainless steel, and

wherein the system is a scrubber system.

11. The system of claim 10, wherein the process vessel consists essentially of at least one of duplex stainless steel and superaustenitic stainless steel.

12. The system of claim 10 or 11, wherein the electrochemical corrosion protection apparatus comprises:

at least one anode in communication with the process vessel;

a DC current supply having an electrical connection with the process vessel and an electrical connection with the at least one anode; and

a potential control unit in communication with the DC current supply, the potential control unit having an electrical connection to the process vessel and an electrical connection to a reference electrode in communication with the process vessel, the potential control unit adjusting current supplied by the DC current supply for passivating the process vessel.

13. The system of claim 12, wherein at least one of the reference electrode and the at least one anode is positioned in an interior of the process vessel.

14. The system of any one of claims 10 to 13, wherein the scrubber system is a flue gas desulphurization scrubber system.

15. The system of any one of claims 10 to 14, wherein the process vessel is a scrubber vessel.

16. The system of any one of claims 10 to 14, wherein the process vessel is a reaction tank.

17. The system of any one of claims 10 to 16, wherein the apparatus adjusts potential of the process vessel from about -850mV to about +500mV relative to the reference electrode in communication with the process vessel.

18. The system of any one of claims 10 to 17, wherein the apparatus adjusts potential of the process vessel from about -350mV to about +400mV relative to the reference electrode in communication with the process vessel.

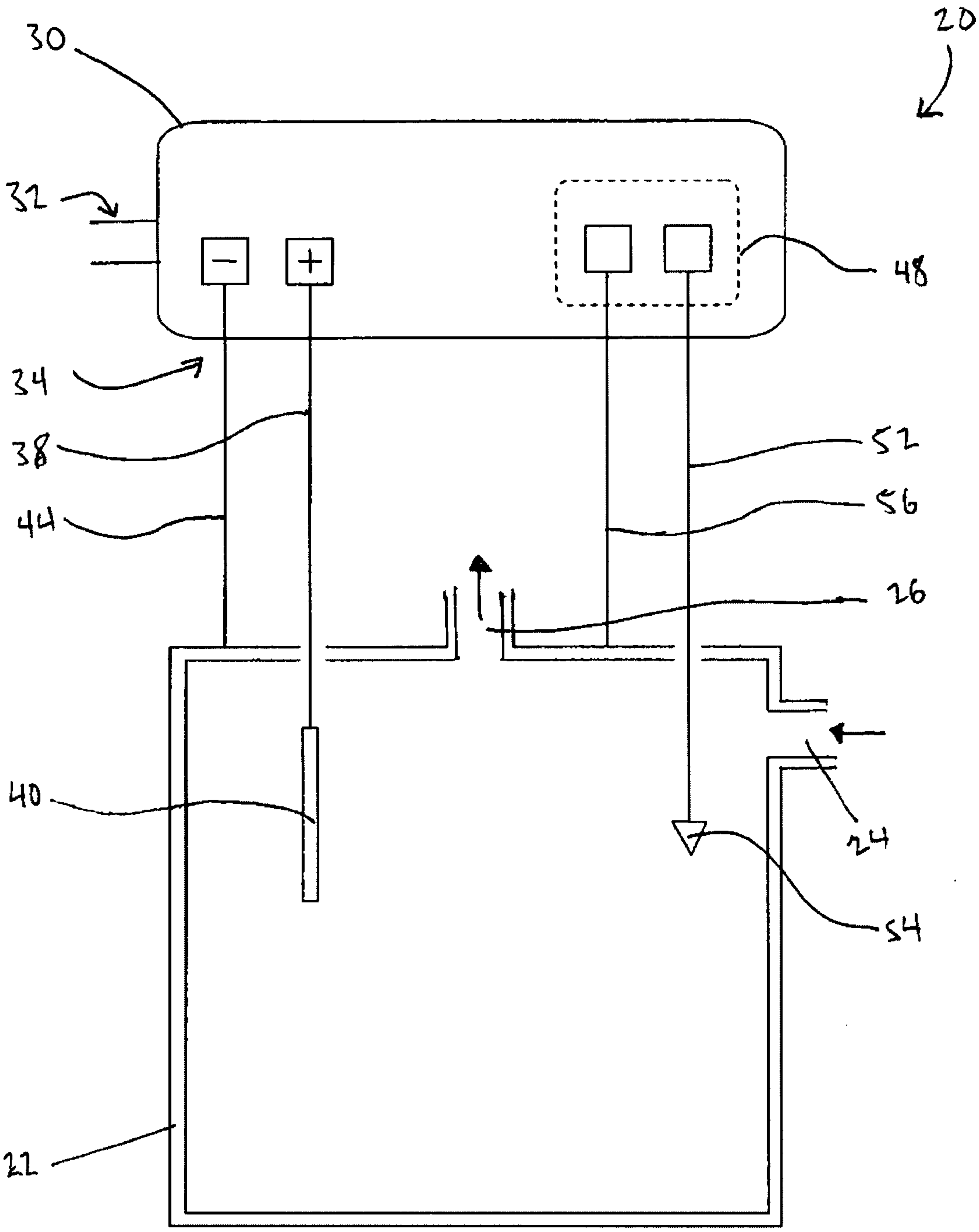


Figure 1

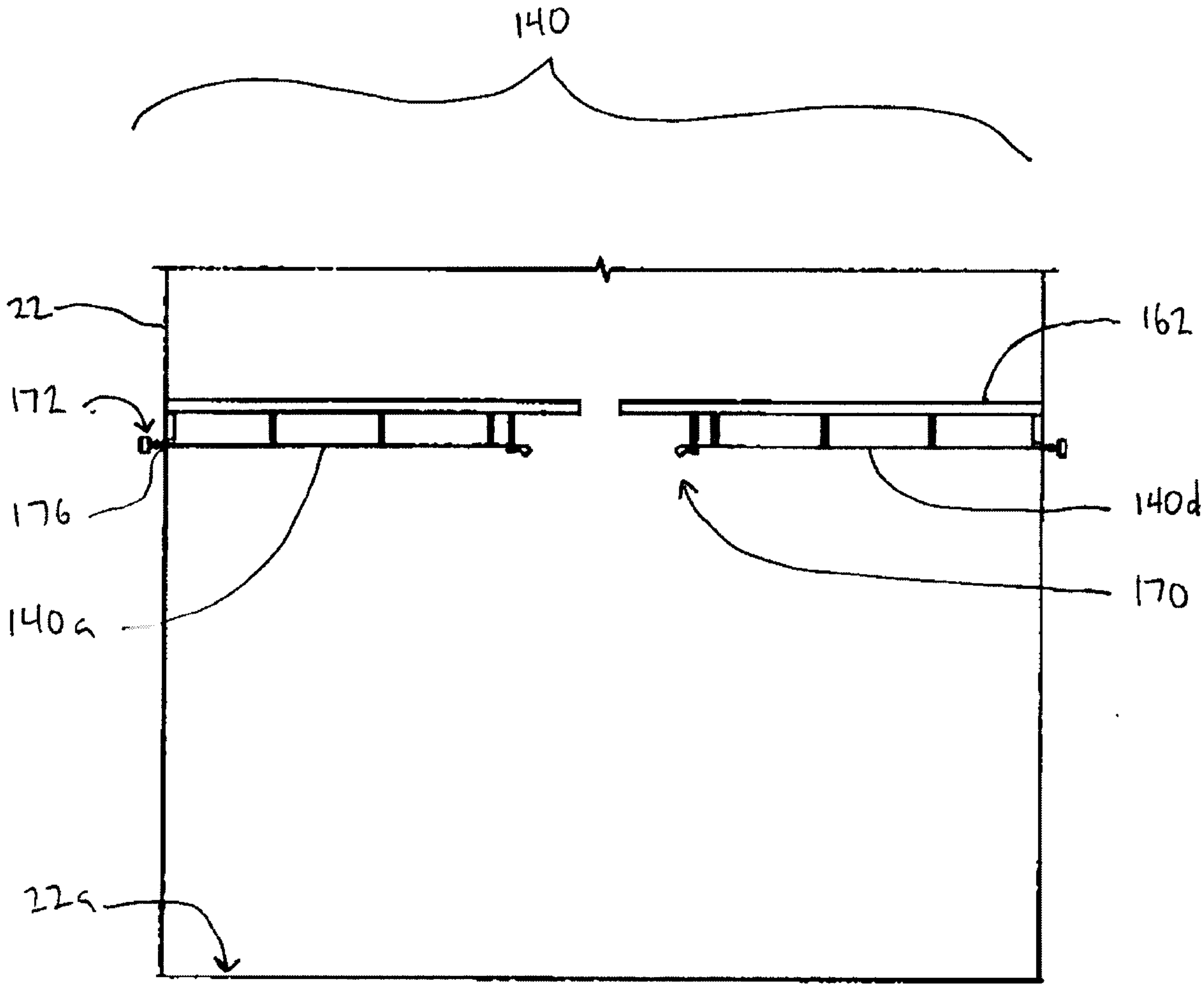


Figure 2

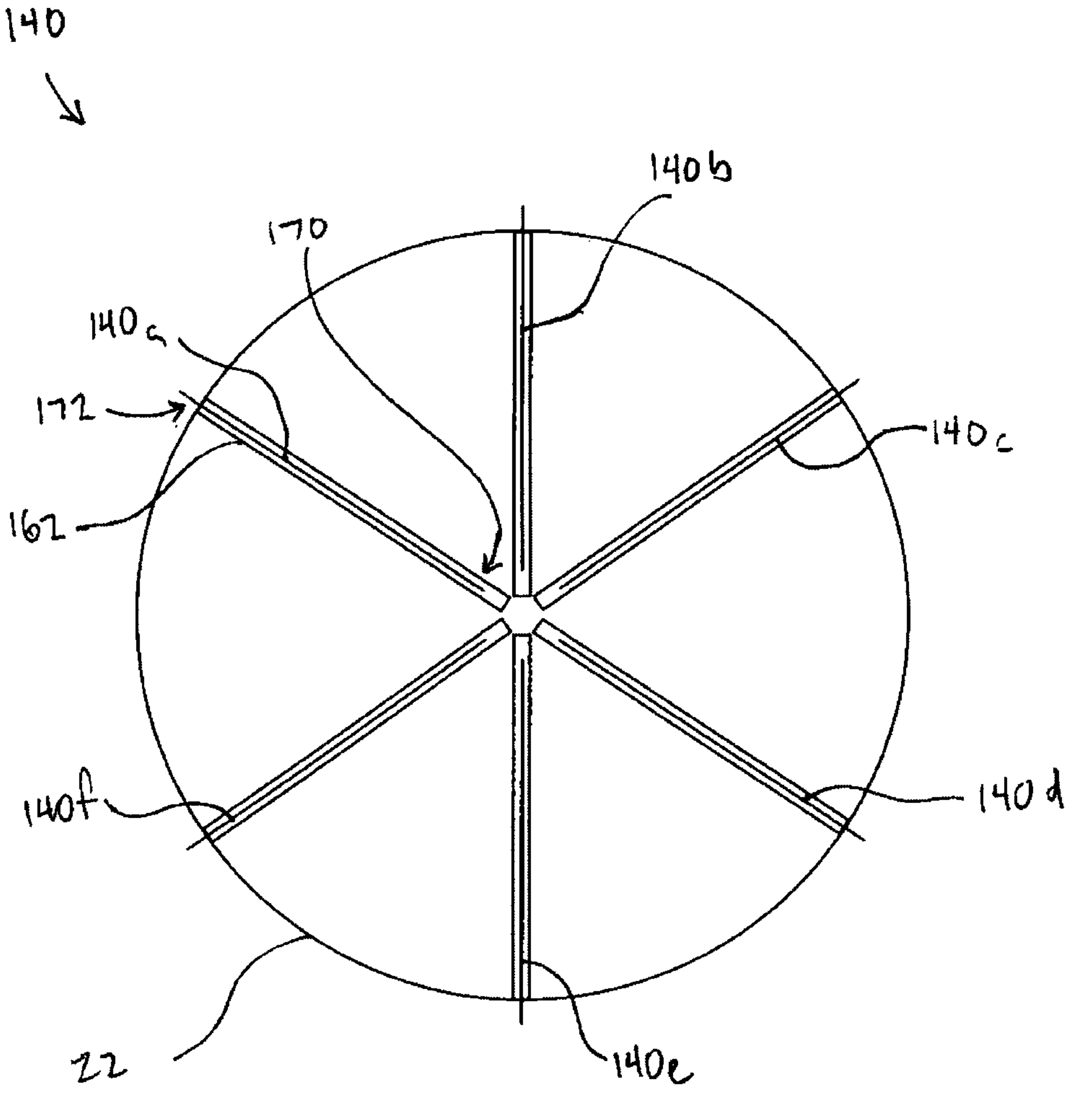


Figure 3

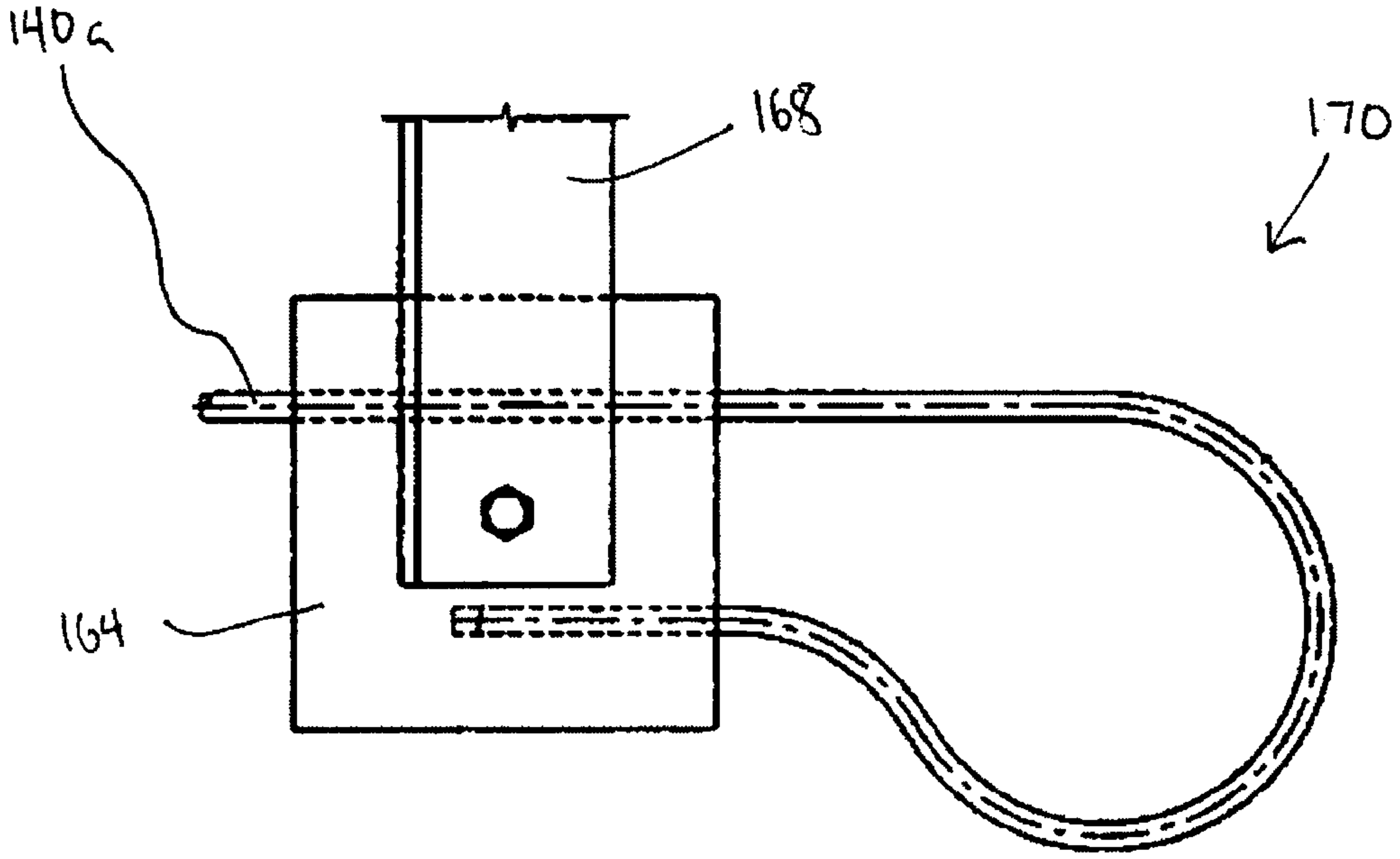


Figure 4a

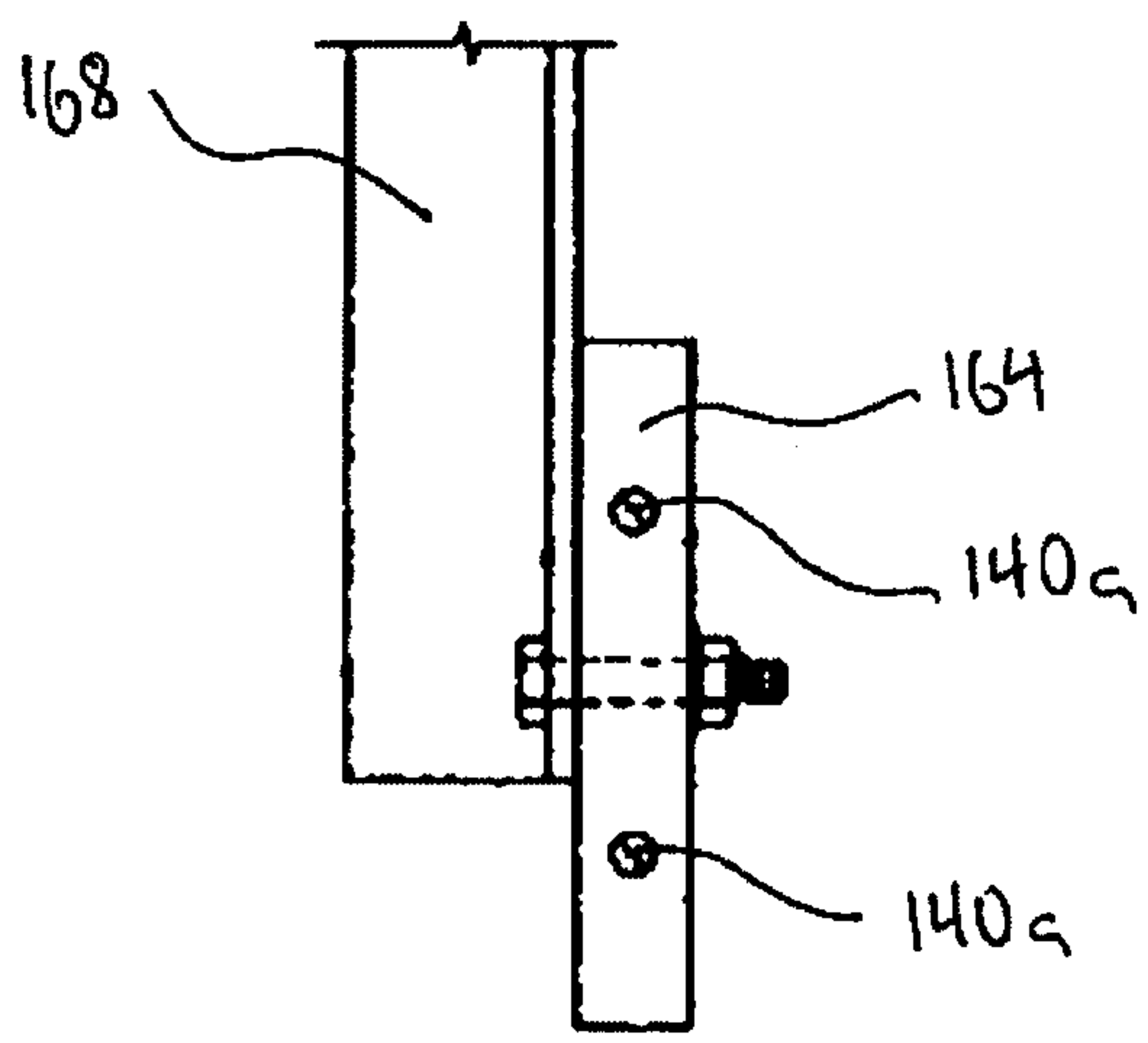
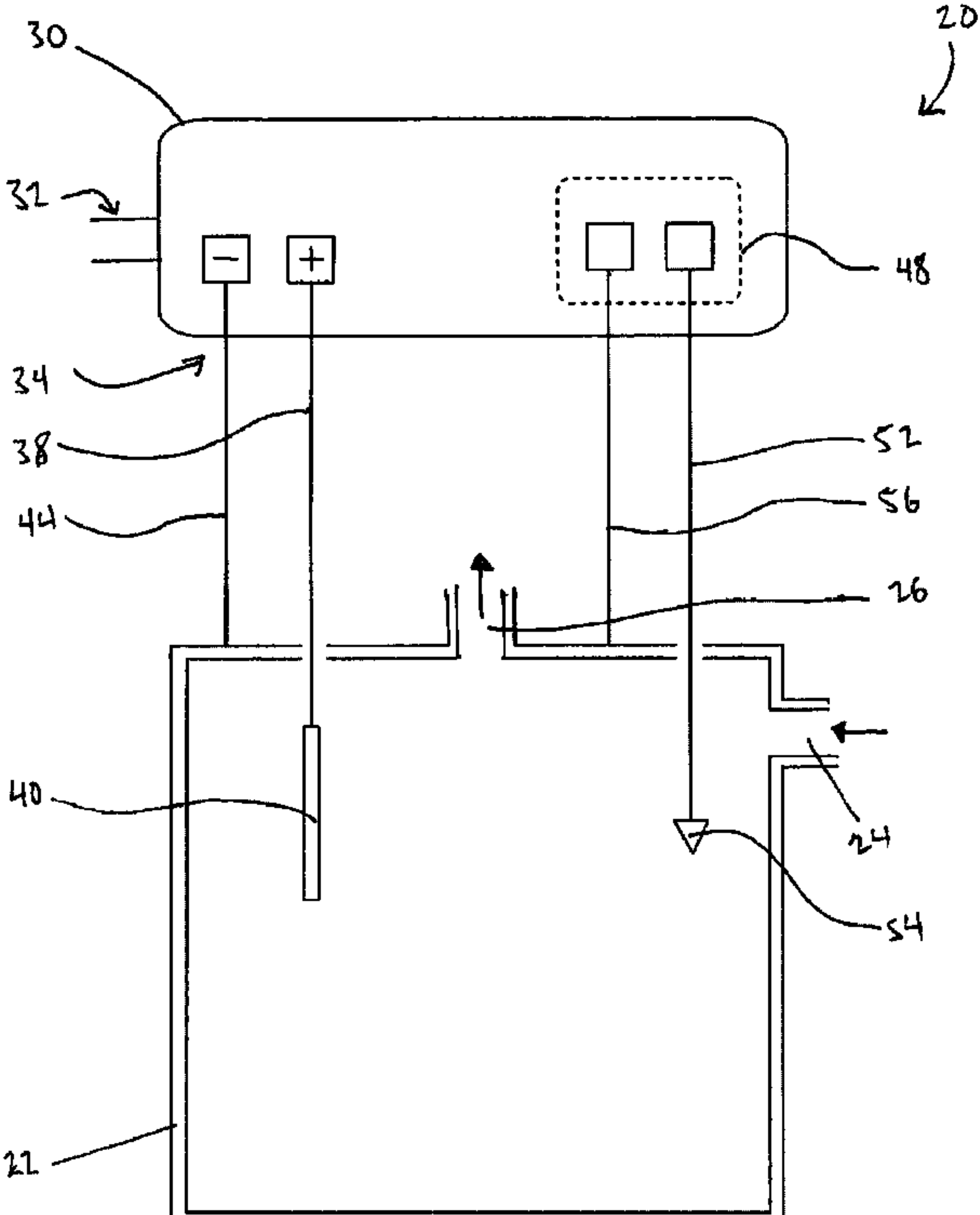


Figure 4b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