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(54) **WATER HEATER AND CORROSION PREVENTION DESIGN METHOD THEREFOR**

(57) A water heater (100) and a corrosion prevention design method therefor. The water heater (100) comprises: an inner tank (1), which comprises a metal tank body (11) and a first insulating layer covering the inner wall of the metal tank body (11); a metal component (3), which is disposed in the inner tank (1) and is electrically connected to the metal tank body (11); and a corrosion prevention assembly (2), comprising: an electronic anode (21), which extends into the inner tank (1), and a direct-current power source module (22), which comprises a positive electrode electrically connected to the electronic anode (21) and a negative electrode electrically connected to the metal tank body (11), and is configured to apply a weak-current voltage between the metal tank body (11) and the electronic

anode (21), wherein the total area of an exposed metal surface of the metal component (3) that is in direct contact with water in the inner tank (1) is less than or equal to 0.5 m². Since the direct-current power source module (22) applies a weak-current voltage between the metal tank body (11) and the electronic anode (21) and between the metal component (3) and the electronic anode (21), corrosion prevention requirements of the inner tank (1) and the metal component (3) can be met, thereby reducing the risk of hydrogen evolution explosion, reducing the potential safety hazard of electric leakage of the corrosion prevention assembly, and reducing the difficulty of an electronic control design of the water heater (100).

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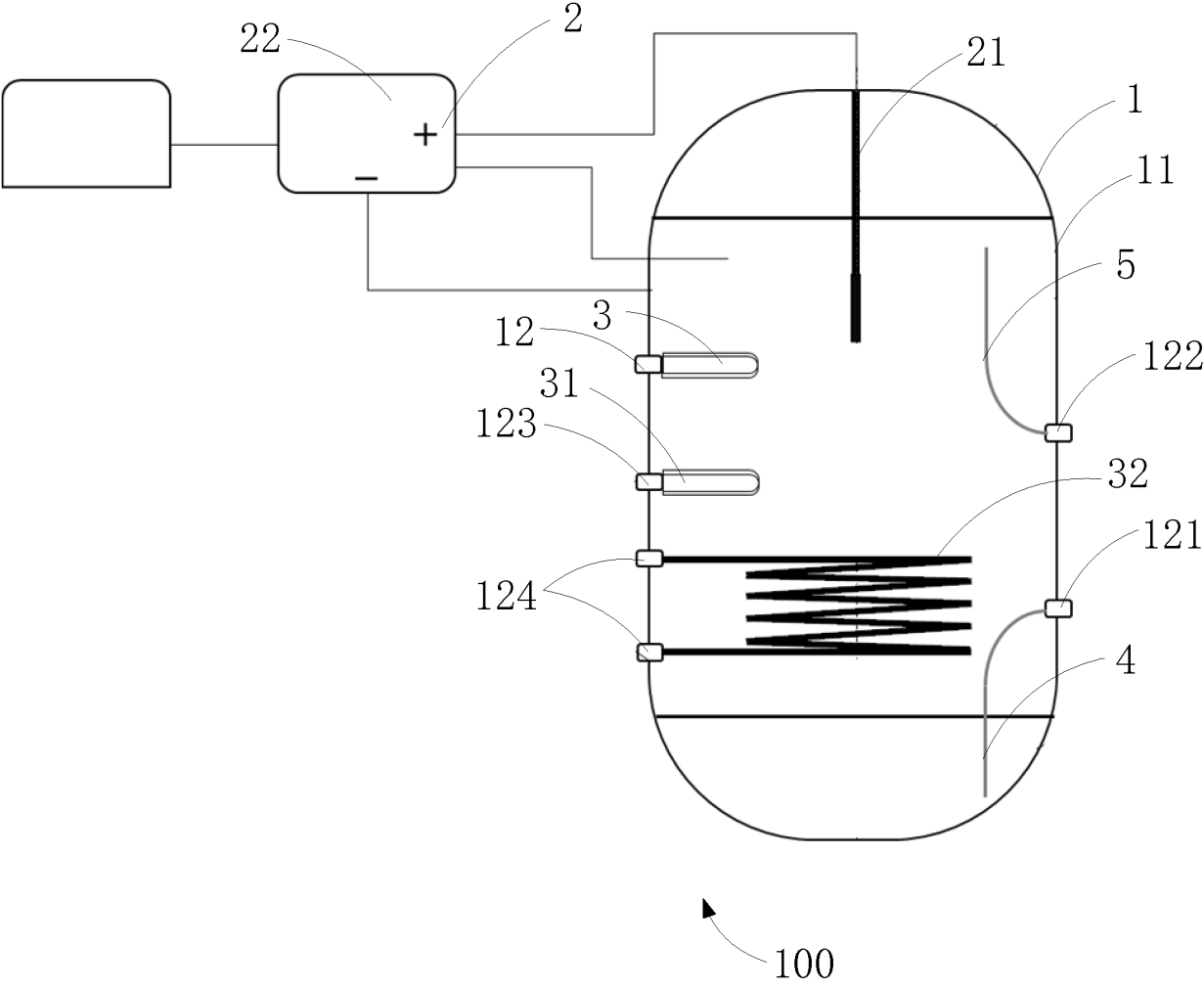


FIG. 1

Description

[0001] The present application claims priority of Chinese Patent Application No. 202410060201.4, filed on January 15, 2024, and entitled "Water Heater and Corrosion Prevention Design Method Therefor", the content of which should be regarded as being incorporated herein by reference.

Technical Field

[0002] The present disclosure relates to corrosion prevention technology for an inner tank, and in particular to a water heater and corrosion prevention design method therefor.

Background

[0003] A water heater is a common household appliance used for hot water supply. However, as the inner tank of the water heater is exposed to a high temperature and humid environment for long time, it is prone to corrosion, thereby affecting the service life of the water heater. To prevent corrosion of the inner tank, traditional water heaters typically employ electronic anode protection technology.

[0004] The electronic anode is a technology that inhibits corrosion of the inner tank by applying an external current to maintain the anode at an anodic protection potential. Conventional electronic anode typically uses a titanium rod as a carrier, with a metal oxide coated thereon as the anode material.

[0005] The traditional electronic anode protects a surface of the enamel inner tank, where the exposed area requiring corrosion inhibition is relatively small. Consequently, the required protection current and voltage are relatively low, thereby the demand for protection current and voltage is relatively low, and the protection current generally only requires 22.5 mA/m² and the protection voltage generally only requires 2-3.8 V. Thus, the electronic anode can achieve control and protection effects using weak-current electricity.

[0006] However, in order to improve heating efficiency and expand application scenarios, water heaters employ components such as metal electric heaters and metal coils. These metal components have a large exposed area, which increases the protection current and voltage required for the electronic anode, and consequently, leads to problems comprising a risk of hydrogen evolution, inability of weak-current electricity to meet protection requirements, safety hazards of electric leakage of strong-current electricity, and increased difficulty in electronic control design.

Summary

[0007] The following is a summary of the subject matter described in detail herein. This summary is not intended to limit the protection scope of the claims.

[0008] An embodiment of the present application provides a water heater, which comprises:

an inner tank comprising a metal tank body, and a first insulating layer covering an inner wall of the metal tank body;

a metal component disposed within the inner tank and electrically connected to the metal tank body; and

a corrosion prevention assembly comprising:

an electronic anode extending into the inner tank; and

a direct-current power source module, wherein the direct-current power source module comprises a positive electrode electrically connected to the electronic anode and a negative electrode electrically connected to the metal tank body, and is configured to apply a weak-current voltage between the metal tank body and the electronic anode;

wherein a total area of an exposed metal surface of the metal component in direct contact with water in the inner tank is less than or equal to 0.5 m².

[0009] In an exemplary embodiment, the metal component comprises a first metal component and/or a second metal component; the first metal component has the exposed metal surface; and a metal surface of the second metal component is subjected to an insulation treatment to form a second insulating layer, wherein the second insulating layer is capable of isolating the metal surface of the second metal component from the water in the inner tank.

[0010] In an exemplary embodiment, a way for the insulation treatment of the metal surface of the second metal component comprises: coating insulating varnish on the metal surface, coating rubber on the metal surface, coating plastic on the metal surface, coating corrosion prevention paint on the metal surface, performing oxidation treatment on the metal surface, performing passivation treatment on the metal surface or attaching an insulating material on the metal surface.

[0011] In an exemplary embodiment, an output current of the direct-current power source module is less than or equal to an output current upper limit value, and the output current upper limit value is calculated using a following formula:

$$I = I_0 \times A_0 + \sum_{i=1}^n I_i \times A_i + \sum_{i=1}^N J_i \times a_i$$

wherein:

I is the output current upper limit value;

I_0 is a protective current density of the inner tank;

A_0 is an area of the inner wall of the metal tank body covered by the first insulating layer;

I_i is a protective current density of an exposed metal surface of an i -th first metal component;

A_i is an area of an exposed metal surface of the i -th first metal component in direct contact with the water in the inner tank;

n is a number of first metal components;

J_i is a protective current density of a metal surface of an i -th second metal component covered by the second insulating layer;

a_i is an area of the metal surface of the i -th second metal component covered by the second insulating layer; and

N is a number of second metal components.

[0012] In an exemplary embodiment, the protective current density I_0 of the inner tank is a maximum value of self-corrosion current densities of the inner tank in an aqueous solution;

the protective current density I_i of the i -th first metal component is a maximum value of self-corrosion current densities of the exposed metal surface of the i -th first metal component in the aqueous solution;

the protective current density J_i of the i -th second metal component is a maximum value of self-corrosion current densities of the metal surface of the i -th second metal component covered by the second insulating layer in the aqueous solution;

wherein, a temperature of the aqueous solution is within a temperature range which is designed for use of the inner tank, and a conductivity of the aqueous solution is 400-2000 $\mu\text{S}/\text{cm}$.

[0013] In an exemplary embodiment, an output voltage of the direct-current power source module is less than or equal to an output voltage upper limit value, and the output voltage upper limit value is calculated using the following formula:

$$E = I \times \left(R_0 + R_{shui} + \sum_{i=1}^n R_i + \sum_{i=1}^N r_i \right)$$

wherein:

E is the output voltage upper limit value;

I is the output current upper limit value;

R_0 is a polarization resistance of the electronic anode;

R_{shui} is a resistance of the water in the inner tank;

R_i is a cathode polarization resistance of the i -th first metal component;

n is the number of the first metal components;

r_i is a cathode polarization resistance of the i -th second metal component;

N is the number of the second metal components.

[0014] In an exemplary embodiment, the polarization resistance R_0 of the electronic anode is a slope of a polarization curve of the electronic anode in an aqueous solution at a corrosion potential; the cathode polarization resistance R_i of the i -th first metal component is a slope of a polarization curve of the i -th first metal component in the aqueous solution at a corrosion potential; the cathode polarization resistance r_i of the i -th second metal component is a slope of a polarization curve of the i -th second metal component in the aqueous solution at a corrosion potential; wherein, a temperature of the aqueous solution is within a temperature range which is designed for use of the inner tank, and a conductivity of the aqueous solution is 400-2000 $\mu\text{S}/\text{cm}$.

[0015] In an exemplary embodiment, the inner tank is constructed as a cylindrical tank-shaped structure, and the resistance R_{shui} of the water in the inner tank is calculated using the following formula:

$$R_{shui} = \frac{4\rho H}{\pi D^2}$$

wherein:

R_{shui} is the resistance of the water of the inner tank;

ρ is a density of the water of the inner tank;

H is a height of the inner tank; and

D is a diameter of the inner tank.

[0016] In an exemplary embodiment, the output current of the direct-current power source module is less than or equal to 200 mA and the output voltage of the direct-current power source module is less than or equal to 4 V.

[0017] In an exemplary embodiment, the output current upper limit value is greater than 200 mA, and a plurality of corrosion prevention assemblies are provided.

[0018] An embodiment of the present application also proposes a corrosion prevention design method for a water heater. The water heater comprises an inner tank and a metal component disposed in the inner tank, the inner tank comprises a metal tank body electrically connected to the metal component and a first insulating layer covering an inner wall of the metal tank body. The corrosion prevention design method comprises: performing insulation treatment on at least a portion of an exposed metal surface of the metal component based on a total area of the exposed metal surface of the metal component in direct contact with water in the inner tank greater than 0.5 m^2 , so that the total area of the exposed metal surface of the metal component in direct contact with the water in the inner tank is less than or equal to 0.5 m^2 .

[0019] In an exemplary embodiment, the corrosion prevention design method further comprises: performing insulation treatment on at least a portion of the exposed metal surface of the metal component to form a second insulating layer covering the at least a portion of the exposed metal surface of the metal component based on the total area of the exposed metal surface of the metal component in direct contact with water in the inner tank greater than 0.5 m^2 , so that the total area of the exposed metal surface of the metal component in direct contact with the water in the inner tank is less than or equal to 0.5 m^2 .

[0020] In an exemplary embodiment, determining an output current upper limit value according to a protective current density of the inner tank, an area of an inner wall of the metal tank body covered by the first insulating layer, a protective current density of an exposed metal surface of each first metal component, and an area of an exposed metal surface of each first metal component in direct contact with the water in the inner tank, based on the total area of the exposed metal surface of the metal component in direct contact with the water in the inner tank less than or equal to 0.5 m^2 , and the metal component only comprising first metal components having exposed metal surfaces; and setting an output current of a direct-current power source module to be less than or equal to the output current upper limit value.

[0021] In an exemplary embodiment, the corrosion prevention design method further comprises: determining an output voltage upper limit value according to the output current upper limit value, a polarization resistance of an electronic anode, a resistance of the water in the inner tank, and a cathode polarization resistance of each first metal component, based on the total area of the exposed metal surface of the metal component in direct contact with the water in the inner tank less than or equal to 0.5 m^2 , and the metal component only comprising first metal components having exposed metal surfaces; and setting an output voltage of the direct-current power source module to be less than or equal to the output voltage upper limit value.

[0022] In an exemplary embodiment, the corrosion prevention design method further comprises: after performing the insulation treatment on the at least a portion of the exposed metal surface of the metal component, the metal component comprises a first metal component having an exposed metal surface and a second metal component, wherein a metal surface of the second metal component has undergone the insulation treatment;

determining an output current upper limit value according to a protective current density of the inner tank, an area of an inner wall of the metal tank body covered by the first insulating layer, a protective current density of an exposed metal surface of each first metal component, an area of an exposed metal surface of each first metal component in direct contact with the water in the inner tank, a protective current density of a metal surface of each second metal component covered by the second insulating layer, and an area of the metal surface of each second metal component covered by the second insulating layer; and setting an output current of a direct-current power source module to be less than or equal to the output current upper limit value; and

determining an output voltage upper limit value according to the output current upper limit value, a polarization resistance of an electronic anode, a resistance of the water in the inner tank, a cathode polarization resistance of each first metal component, and a cathode polarization resistance of each second metal component, and setting an output voltage of the direct-current power source module to be less than or equal to the output voltage upper limit value.

[0023] In the technical solution of the present application, when water is contained in the inner tank, the water is conductive due to impurities dissolved in the water, and the inner tank, the electronic anode, and the metal component are all in contact with the water. The direct-current power source module applies a positive voltage on the electronic anode, and applies a negative voltage on the metal tank body and the metal component, thereby forming a circuit between the electronic anode, the metal component, the metal tank body, the water and the direct-current power source module. The current output by the positive electrode of the direct-current power source module flows through the electronic anode and the water to reach the metal component and the metal tank body, and finally returns to the negative electrode of the direct-current power source module. In this process, the direct-current power source module outputs electrons to the metal tank body and the metal component, which serve as the cathode. These electrons are provided to substances in the water that can undergo chemical reactions with the metal tank body and the metal component to perform electrochemical reactions, thereby preventing the corrosion of the metal tank body and the metal component.

[0024] Furthermore, since the first insulating layer covers the inner wall of the metal tank body, and the total area of the exposed metal surface of the metal component that is in direct contact with the water in the inner tank is less than or equal to 0.5 m^2 , the total area of the exposed metal surface in direct contact with the water in the inner tank is relatively small. Therefore, applying a weak-current voltage between the metal tank body and the electronic anode, as well as between the metal component and the electronic anode, by the direct-current power source module can meet the corrosion prevention requirements of the inner tank and the metal component, which reduces the risk of hydrogen evolution and explosion, mitigates the safety hazard of electrical leakage in the corrosion prevention assembly, and also lowers the difficulty of electronic control design for the water heater.

[0025] Other features and advantages of the present application will be set forth in the description which follows, and in part will become apparent from the description, or may be learned by practice of the present application. Other advantages of the present application may be achieved and obtained through solutions described in the description and drawings.

[0026] Other aspects will become apparent after reading and understanding the drawings and detailed description.

Brief Description of Drawings

[0027] Accompanying drawings are used to provide understanding of technical solutions of the present application, and constitute a portion of the description. They are used together with embodiments of the present application to explain the technical solutions of the present application, and do not constitute a restriction on the technical solutions of the present application.

FIG. 1 is a schematic diagram of a structure of a water heater in an embodiment of the present application.

FIG. 2 is a schematic diagram of measurement points of an inner tank in an embodiment of the present application.

Detailed Description

[0028] A plurality of embodiments are described in the present application, but the description is exemplary and not restrictive, and it will be apparent to those skilled in the art, there may be more embodiments and implementations within the scope of the embodiments described in the present application. Although many possible combinations of features are shown in the drawings and discussed in the detailed implementations, many other combinations of the

disclosed features are also possible. Unless specifically limited, any feature or element of any embodiment may be used in combination with, or may be substituted for, any other feature or element of any other embodiment.

[0029] The present application comprises and contemplates combinations with features and elements known to those of ordinary skills in the art. The embodiments, features and elements already disclosed herein may also be combined with any conventional features or elements to form unique inventive schemes. Any feature or element of any embodiment may also be combined with features or elements from other inventive schemes to form another unique inventive scheme. Accordingly, it should be understood that any of the features shown and/or discussed in the present application may be implemented alone or in any suitable combination. Therefore, the embodiments are not limited other than limitations in accordance with the appended claims and their equivalents. Furthermore, various modifications and changes may be made within the scope of the appended claims.

[0030] Further, when representative embodiments are described, a method and/or process may have been presented as steps in a particular sequence in the specification. However, to an extent that the method or process does not depend on the particular sequence of the steps herein, the method or process should not be limited to the steps in the particular sequence. Those of ordinary skills in the art will understand that other sequences of steps may also be possible. Therefore, the particular sequence of the steps illustrated in the specification should not be interpreted as a limitation on claims. In addition, the claims directed to the method and/or process should not be limited to performing the steps according to the written sequence. Those skilled in the art may easily understand that these sequences may be changed, and the method and/or process in the changed sequence are still in the essence and scope of the embodiments of the present application.

[0031] As shown in FIG. 1, FIG. 1 shows a structure of a water heater 100 in an embodiment of the present application. The water heater 100 comprises an inner tank 1, a water inlet pipe 4, a water outlet pipe 5, a metal component 3 and a corrosion prevention assembly 2.

[0032] The inner tank 1 is used to hold water, which may be tap water. The inner tank 1 comprises a metal tank body 11, a first insulating layer and a joint 12. The metal tank body 11 serves as a skeleton structure of the inner tank 1. The metal tank body 11 is made of metal, which can be iron, iron alloy, copper or copper alloy. The metal tank body 11 is formed, for example, by welding steel plates, which may be carbon steel plates or stainless steel plates. The metal tank body 11 may be constructed to be cylindrical, capsule-shaped, box-shaped, or spherical. The inner wall of the metal tank body 11 is provided with the first insulating layer. The first insulating layer covers the entire inner wall of the metal tank body 11. The first insulating layer is made of an insulating material, which may be ceramics, glass, plastic, rubber, silicone, etc. In the present embodiment, the first insulating layer is an enamel layer, which is an insulating layer formed by fusing and solidifying an inorganic glass material onto the inner wall of the metal tank body 11. The first insulating layer can separate the water in the inner tank 1 from the metal tank body 11, so that the water in the inner tank 1 is difficult to corrode the metal tank body 11. The metal tank body 11 is provided with a through hole, and the joint 12 is inserted through the through hole of the metal tank body 11 and connected to the metal tank body 11. The joint 12 may be made of metal and is electrically conductive with the metal tank body 11. The joint 12 may be welded to the metal tank body 11. The joint 12 may be constructed as a tubular structure, with one end located inside the metal tank body 11 and the other end located outside the metal tank body 11. The end of the joint 12 facing towards the interior of the metal tank body 11 may be provided with threads, which may be internal threads or external threads. Multiple through holes may be provided on the metal tank body 11, and a joint 12 is provided at each through hole. The joints 12 may be provided on the side wall of the metal tank body 11. The multiple joints 12 may comprise a water inlet joint 121 and a water outlet joint 122. The height of the water inlet joint 121 may be lower than that of the water outlet joint 122.

[0033] The water inlet pipe 4 and the water outlet pipe 5 are both arranged in the inner tank 1. The water inlet pipe 4 may be arranged below the water outlet pipe 5. One end of the water inlet pipe 4 is connected to the water inlet joint 121, and the other end of the water inlet pipe 4 extends toward the top of the inner tank 1. One end of the water outlet pipe 5 is connected to the water outlet joint 122, and the other end of the water outlet pipe 5 extends toward the bottom of the inner tank 1. The water inlet pipe 4 is configured to inject water into the inner tank 1, and the water outlet pipe 5 is configured to drain away the water from the inner tank 1. The end of the water inlet joint 121 facing outward from the inner tank 1 is configured to be connected to an external tap water supply pipeline, and the end of the water outlet joint 122 facing outward from the inner tank 1 is configured to be connected to an external hot water usage pipeline.

[0034] The metal component 3 is made of metal material, which may be iron, iron alloy, copper or copper alloy. The metal component 3 is disposed in the inner tank 1 and connected to the joint 12 of the inner tank 1. The metal component 3 is fixed onto the metal tank body 11 via the joint 12. The joint 12 electrically connects the metal component 3 and the metal tank body 11. The connection between the metal component 3 and the joint 12 may be a threaded connection or a welded connection. The number of metal components 3 may be one or multiple. The metal component 3 comprises a heat exchanger and an electric heater. The heat exchanger comprises a heat exchange tube. The heat exchange tube may be a copper tube or a steel tube. The heat exchange tube may be constructed as a coiled tube, which may be a tubular structure constructed in a spiral shape. The joint 12 may also comprise a heat

exchange joint 124 and an electric heating joint 123. Two heat exchange joints 124 may be provided, and the two heat exchange joints 124 are respectively connected to opposite ends of the coiled tube. A high-temperature refrigerant is input into one end of the heat exchange tube, and the refrigerant exchanges heat with the water in the inner tank 1 when flowing through the heat exchange tube, thereby heating the water in the inner tank 1. The electric heater is installed on the electric heating joint 123. The electric heater is configured to convert electric energy into thermal energy, thereby heating the water inside the inner tank 1. The electric heater may comprise a metal outer cover and an electric heating wire, the metal outer cover may be a tubular outer cover, the metal outer cover may be a stainless steel outer cover, the electric heating wire is insulated from the metal outer cover and disposed in the metal outer cover, wherein the metal outer cover is electrically conductive with the metal tank body 11, and the electric heating wire is configured to be connected to an external power source to generate heat. A plurality of electric heaters may be provided, and the plurality of electric heaters are connected to a plurality of electric heating joints 123 respectively. A total area of exposed metal surface of the metal component 3 in direct contact with the water in the inner tank 1 is less than or equal to 0.5 m².

[0035] The corrosion prevention assembly 2 comprises an electronic anode 21 and a direct-current power source module 22. The electronic anode 21 is a conductor. The shape of the electronic anode 21 is not limited and may be rod-shaped, ring-shaped, spherical or annular. In the present embodiment, the electronic anode 21 is constructed in a shape of a straight strip. One end of the electronic anode 21 is fixed on the top of the inner tank 1 and is not in direct contact with the metal tank body 11 of the inner tank 1. The metal tank body 11 of the inner tank 1 and the electronic anode 21 may be separated by an insulating member, which may be constructed as a sleeve structure, and the insulating member is sleeved on the end of the electronic anode 21 close to the top of the inner tank 1. The electronic anode 21 may be disposed on a central axis of the inner tank 1. The electronic anode 21 may be made of corrosion-resistant metal.

[0036] The direct-current power source module 22 comprises a positive electrode and a negative electrode. The direct-current power source module 22 may be disposed outside the inner tank 1. The positive electrode of the direct-current power source module 22 is electrically connected to the electronic anode 21 through a wire. The negative electrode of the direct-current power source module 22 is electrically connected to the metal tank body 11 of the inner tank 1 through a wire. The positive electrode of the direct-current power source module 22 outputs a positive voltage, and the negative electrode of the direct-current power source module 22 outputs a negative voltage. The voltage output by the direct-current power source module 22 is a weak-current voltage. The weak-current voltage is a direct-current voltage less than or equal to 36 V.

[0037] When water is contained in the inner tank 1, the water is conductive due to impurities dissolved in the water, and the inner tank 1, the electronic anode 21, and the metal component 3 are all in contact with the water. The direct-current power source module 22 applies a positive voltage on the electronic anode 21 and a negative voltage on the metal tank body 11 and the metal component 3, thereby forming a circuit between the electronic anode 21, the metal component 3, the metal tank body 11, water and the direct-current power source module 22. The current output from the positive electrode of the direct-current power source module 22 flows through the electronic anode 21 and the water to reach the metal component 3, the joint 12 and the metal tank body 11, and finally returns to the negative electrode of the direct-current power source module 22. In this process, the direct-current power source module 22 outputs electrons to the metal tank body 11, the joint 12 and the metal component 3, which serve as the cathode. These electrons are provided to substances in the water that can undergo chemical reactions with the metal tank body 11, the joint 12 and the metal component 3 to perform electrochemical reactions, thereby preventing the corrosion of the metal tank body 11, the joint 12 and the metal component 3.

[0038] Since the first insulating layer covers the inner wall of the metal tank body 11, and the total area of the exposed metal surface of the metal component 3 that is in direct contact with the water in the inner tank 1 is less than or equal to 0.5 m², the total area of the exposed metal surface in direct contact with the water in the inner tank 1 is relatively small, applying a weak-current voltage between the metal tank body 11 and the electronic anode 21, as well as between the metal component 3 and the electronic anode, by the direct-current power source module 22 can meet corrosion prevention requirements of the inner tank 1 and the metal component 3, which reduces the risk of hydrogen evolution and explosion, mitigates the safety hazard of electrical leakage in the corrosion prevention assembly 2, and also lowers the difficulty of electronic control design for the water heater 100.

[0039] In an exemplary embodiment, the metal component 3 only comprises the first metal component 31. The first metal component 31 has an exposed metal surface, which is in direct contact with the water in the inner tank 1. There may be one or a plurality of first metal components 31. The total area of exposed metal surfaces of all first metal components 31 is less than or equal to 0.5 m².

[0040] Since the metal tank body 11 is electrically connected to the first metal component 31, the metal tank body 11 is electrically connected to the negative electrode of the direct-current power source module 22, and the electronic anode 21 is electrically connected to the positive electrode of the direct-current power source module 22, the direct-current power source module 22 can apply a negative voltage to the metal tank body 11 and the first metal component

31, and a positive voltage to the electronic anode 21, thereby preventing the metal tank body 11 and the first metal tank body 11 from being corroded by water.

[0041] The direct-current power source module 22 is configured with an output current upper limit value. An output current of the direct-current power source module 22 is less than or equal to the output current upper limit value. The output current upper limit value is calculated using the following formula:

$$I = I_0 \times A_0 + \sum_{i=1}^n I_i \times A_i \quad (1)$$

Herein:

I is the output current upper limit value, in units of A;

I_0 is a protective current density of the inner tank 1, in units of A/m²;

A_0 is an area of the inner wall of the metal tank body 11 covered by the first insulating layer, in units of m²;

I_i is a protective current density of the i -th first metal component 31, in units of A/m²;

A_i is an area of the exposed metal surface of the i -th first metal component 31 in direct contact with the water in the inner tank 1, in units of m²;

n is a number of first metal components 31.

[0042] An output voltage of the direct-current power source module 22 is less than or equal to an output voltage upper limit value, and the output voltage upper limit value is calculated according to the following formula:

$$E = I \times \left(R_0 + R_{shui} + \sum_{i=1}^n R_i \right) \quad (2)$$

Herein:

I is the output current upper limit value, in units of A;

R_0 is a polarization resistance of the electronic anode 21, in units of Ω ;

R_{shui} is a resistance of the water in the inner tank 1, in units of Ω ;

R_i is a cathode polarization resistance of the i -th first metal component 31, in units of Ω ;

n is the number of first metal components 31.

[0043] In this way, when a current output by the direct-current power source module 22 is less than or equal to the output current upper limit value, and a voltage output by the direct-current power source module 22 is less than or equal to the output voltage upper limit value, the current output by the direct-current power source module 22 mainly provides a protection current for the metal tank body 11, the joint 12 and the first metal component 31, so that the metal tank body 11, the joint 12 and the first metal component 31 are not corroded, and water is not electrolyzed to generate hydrogen, which can prevent occurrence of explosion due to hydrogen evolution.

[0044] This example also presents a validation test as follows.

[0045] The protection current density of the inner tank 1 is 12 mA/m². The area of the inner wall of the metal tank body 11 covered by the first insulating layer is 1.85 m². The first metal component 31 is an electric heater, and the protective current density of the first metal component 31 is 70 mA/m². The area of the exposed metal surface of the first metal component 31 in direct contact with the water in the inner tank 1 is 0.025 m². At 20 °C, when the resistivity of the water in the inner tank 1 is 0.055 $\Omega \cdot m$, it may be calculated to obtain the output current upper limit value of 23.95 mA and the output voltage upper limit value of 2.8 V.

[0046] When the direct-current power source module 22 outputs the current according to the output current upper limit value and the output voltage upper limit value, the protection potentials at five positions on the outer wall of the inner tank 1 are measured. The test points are shown in FIG. 2, which meet the protection potential requirement, that is, a protection potential range of -850 to -1100 mV.

Table 1 Protection potential (vs. SCE) test results of the inner tank 1

Position	1#	2#	3#	4#	5#
Voltage	-905 mV	-925 mV	-957 mV	-923 mV	-964 mV

[0047] In an exemplary embodiment, the metal component 3 comprises the first metal component 31 and a second metal component. The first metal component 31 has an exposed metal surface that is in direct contact with the water in the inner tank 1. There may be one or a plurality of first metal components 31. The total area of exposed metal surfaces of all first metal components 31 is less than or equal to 0.5 m².

[0048] The metal surface of the second metal component 32 is subjected to insulation treatment to form a second insulating layer. The way for the insulation treatment of the metal surface of the second metal component 32 comprises coating insulating varnish on the metal surface, coating rubber on the metal surface, coating plastic on the metal surface, coating corrosion prevention paint on the metal surface, performing oxidation treatment on the metal surface, performing passivation treatment on the metal surface or attaching an insulating material on the metal surface. The second insulating layer may be an insulating varnish layer, a plastic layer or a corrosion prevention paint layer coated on the metal surface of the second metal component 32. The second insulating layer may also be an insulating material layer attached to the metal surface of the second metal component 32, such as a glass layer, a rubber layer or a silicone layer. The second insulating layer may also be a metal oxide layer covering the second metal component 32. The second insulating layer may separate the metal surface of the second metal component 32 from the water in the inner tank 1. The second insulating layer can greatly slow down the corrosion rate of the second metal component 32. When the second metal component 32 is immersed in the water in the inner tank 1, a certain leakage current may be generated between the metal part of the second metal component 32 and the water, leading to the slow corrosion of the second metal component 32.

[0049] Since the metal tank body 11 is electrically connected to the first metal component 31 and the second metal component 32, the metal tank body 11 is electrically connected to the negative electrode of the direct-current power source module 22, and the electronic anode 21 is electrically connected to the positive electrode of the direct-current power source module 22, the direct-current power source module 22 may apply a negative voltage to the metal tank body 11, the first metal component 31 and the second metal component 32, and apply a positive voltage to the electronic anode 21, which can prevent the metal tank body 11, the first metal tank body 11 and the second metal component from being corroded by water.

[0050] The output current of the direct-current power source module 22 is less than or equal to the output current upper limit value, and the output current upper limit value is calculated using the following formula:

$$I = I_0 \times A_0 + \sum_{i=1}^n I_i \times A_i + \sum_{i=1}^N J_i \times a_i \quad (3)$$

Herein:

I is the output current upper limit value, in units of A;

I_0 is the protective current density of the inner tank 1, in units of A/m²;

A_0 is the area of the inner wall of the metal tank body 11 covered by the first insulating layer, in units of m²;

I_i is the protective current density of the i -th first metal component 31, in units of A/m²;

A_i is the area of the exposed metal surface of the i -th first metal component 31 in direct contact with the water in the inner tank 1, in units of m²;

n is a number of first metal components 31;

J_i is a protective current density of the i -th second metal component 32, in units of A/m²;

a_i is an area of a metal surface of the i -th second metal component 32 covered by the second insulating layer, in units of m²;

N is a number of second metal components 32.

[0051] The output voltage of the direct-current power source module 22 is less than or equal to the output voltage upper limit value, and the output voltage upper limit value is calculated using the following formula:

$$E = I \times \left(R_0 + R_{shui} + \sum_1^n R_i + \sum_1^N r_i \right) \quad (4)$$

Herein:

E is the output voltage upper limit, in units of V;

I is the output current upper limit value, in units of A;

R_0 is the polarization resistance of the electronic anode 21, in units of Ω ;

R_{shui} is the resistance of the water in the inner tank 1, in units of Ω ;

R_i is the cathode polarization resistance of the i-th first metal component 31, in units of Ω ;

n is the number of first metal components 31;

r_i is a cathode polarization resistance of the i-th second metal component 32, in units of Ω ;

N is the number of second metal components 32.

[0052] In this way, when the current output by the direct-current power source module 22 is less than or equal to the output current upper limit value, and the voltage output by the direct-current power source module 22 is less than or equal to the output voltage upper limit value, the current output by the direct-current power source module 22 is mainly used to protect the metal tank body 11, the joint 12, various first metal components 31 and various second metal components 32 from corrosion, and water is not electrolyzed to generate hydrogen, which can prevent occurrence of explosion due to hydrogen evolution.

[0053] Meanwhile, when the total area of the exposed metal surface of the metal component 3 is greater than 0.5 m², the total area of the exposed metal surface of the metal component 3 may be reduced by performing insulation treatment on part or all of the exposed metal surface of the metal component 3, so that the total area of the exposed metal surface of the metal component 3 is less than or equal to 0.5 m², thereby achieving the protection of the inner tank 1 and the metal component 3 by applying a weak-current voltage.

[0054] This example also provides a validation test as follows.

[0055] The protective current density of the inner tank 1 is 12 mA/m², the area of the inner wall of the metal tank body 11 covered by the first insulating layer is 1.85 m². The first metal component 31 is an electric heater, and the protective current density of the first metal component 31 is 70 mA/m². The area of the exposed metal surface of the first metal component 31 in direct contact with the water in the inner tank 1 is 0.025 m². The second metal component 32 is a heat exchanger, and the protective current density of the second metal component 32 is 12 mA/m². The area of the metal surface of the second metal component 32 covered by the second insulating layer is 0.32 m². At 20 °C, when the resistivity of the water in the inner tank 1 is 0.055 $\Omega \cdot m$, it may be calculated to obtain the output current upper limit value of 27.79 mA and the output voltage upper limit value of 3.2 V.

[0056] When the direct-current power source module 22 outputs the current according to the output current upper limit value and the output voltage upper limit value, the protection potentials at five positions on the outer wall of the inner tank 1 are measured. The test points are shown in FIG. 2, which meet the protection potential requirement, that is, a protection potential range of -850 to -1100 mV.

Table 2 Protection potential (vs. SCE) test results of the inner tank 1

Position	1#	2#	3#	4#	5#
Voltage	-1002 mV	-975 mV	-997 mV	-982 mV	-989 mV

[0057] In one exemplary embodiment, the protective current density I_0 of the inner tank 1 is the maximum value of self-corrosion current densities of the inner tank 1 in an aqueous solution within a temperature range which is designed for use of the inner tank 1 and having a conductivity of 400-2000 $\mu S/cm$. A portion of the inner tank 1 as a sample may be cut from the inner tank 1, and the side of the sample of the inner tank 1 provided with the first insulating layer is immersed in an aqueous solution within a temperature range which is designed for use of the inner tank 1 and having a conductivity of 400-2000 $\mu S/cm$. Then, an electrochemical workstation is used to measure the maximum value of the self-corrosion current densities of the sample of the inner tank 1. The temperature range which is designed for use of the inner tank 1 may be -10 °C to 85 °C.

[0058] The protective current density I_i of the i-th first metal component 31 is the maximum value of the self-corrosion current densities of the exposed metal surface of the i-th first metal component 31 in an aqueous solution within the temperature range which is designed for use of the inner tank 1 and having a conductivity of 400-2000

$\mu\text{S/cm}$. A portion of the i -th first metal component 31 as a sample may be cut from the i -th first metal component 31, and the exposed metal surface of the sample of the i -th first metal component 31 is immersed in an aqueous solution within the temperature range which is designed for use of the inner tank 1 and having a conductivity of 400-2000 $\mu\text{S/cm}$. Then, an electrochemical workstation is used to measure the maximum value of the self-corrosion current density of the exposed metal surface of the sample of the i -th first metal component 31.

[0059] The protective current density J_i of the i -th second metal component 32 is the maximum value of the self-corrosion current densities of the metal surface of the i -th second metal component 32 covered by the second insulating layer, in an aqueous solution within the temperature range which is designed for use of the inner tank 1 and having a conductivity of 400-2000 $\mu\text{S/cm}$. A portion of the i -th second metal component 32 as a sample may be cut from the i -th second metal component 32, and the second insulating layer and the metal surface covered by the second insulating layer of the sample of the i -th second metal component 32 are immersed in an aqueous solution within the temperature range which is designed for use of the inner tank 1 and having a conductivity of 400-2000 $\mu\text{S/cm}$. Then, an electrochemical workstation is used to measure the maximum value of the self-corrosion current densities of the metal surface of the sample of the i -th second metal component 32 covered by the second insulating layer.

[0060] Due to variations in the water quality of household water across different regions, such as differences in the composition and content of dissolved substances in the household water, resulting in different conductivities, the conductivity of household water generally ranges from 400 to 2000 $\mu\text{S/cm}$. The aforementioned output current upper limit value is the maximum of the protective current required for the inner tank 1, which prevents the household water from corroding the inner tank 1, the first metal component 31, and the second metal component 32 during the operation of the water heater 100, a sum of the protective current required for the first metal component 31, and the protective current required for the second metal component 32. Therefore, when the output current of the direct-current power source module 22 is less than or equal to the above-mentioned output current upper limit value, the output current of the direct-current power source module 22 is used to form protective current for the inner tank 1, the first metal component 31, and the second metal component 32, without electrolyzing water to generate hydrogen, thereby further preventing electrolysis of the household water in the inner tank 1 that could lead to a hydrogen explosion.

[0061] In one exemplary embodiment, the polarization resistance R_0 of the electronic anode 21 is the slope of a polarization curve of the electronic anode 21 at the corrosion potential in an aqueous solution within a temperature range which is designed for use of the inner tank 1 and having a conductivity of 400-2000 $\mu\text{S/cm}$. The temperature range which is designed for use of the inner tank 1 may be from -10°C to 85°C . The polarization curve of the electronic anode 21 is a curve representing the relationship between the electrode potential and the polarization current, where the horizontal axis of the polarization curve is the electrode potential and the vertical axis is the polarization current. The polarization curve of the electronic anode 21 may be directly measured by immersing the electronic anode 21 in an aqueous solution within the temperature range which is designed for use of the inner tank 1 and having a conductivity of 400-2000 $\mu\text{S/cm}$. The corrosion potential of the electronic anode 21 is a potential measured when the electronic anode 21 reaches a stable corrosion state in an aqueous solution within the temperature range which is designed for use of the inner tank 1 and having a conductivity of 400-2000 $\mu\text{S/cm}$, without any applied external current. The slope of the tangent to the polarization curve of the electronic anode 21 at the corrosion potential of the electronic anode 21 is the polarization resistance of the electronic anode 21. In this embodiment, the electronic anode 21 comprises an anode body and an MMO coating (mixed metal oxide coating). The anode body may be constructed in a strip shape. The anode body is made of titanium or a titanium alloy. The anode body may be made of TA1 material or TA2 material. Titanium or a titanium alloy has good electrical conductivity and corrosion resistance, is not easily corroded after long-term immersion in tap water, and does not affect water quality. The MMO coating is applied to the outer surface of the anode body. The MMO coating has excellent corrosion resistance and can extend the service life of the electronic anode 21. Since the MMO coating separates the anode body from the water, the polarization resistance of the electronic anode 21 is the polarization resistance of the MMO coating.

[0062] The cathode polarization resistance R_i of the i -th first metal component 31 is the slope of the polarization curve of the i -th first metal component 31 at the corrosion potential in an aqueous solution within the temperature range which is designed for use of the inner tank 1 and having a conductivity of 400-2000 $\mu\text{S/cm}$. The polarization curve of the i -th first metal component 31 may be directly measured by immersing the i -th first metal component 31 in an aqueous solution within the temperature range which is designed for use of the inner tank 1 and having a conductivity of 400-2000 $\mu\text{S/cm}$. The corrosion potential of the i -th first metal component 31 is a potential measured when the i -th first metal component 31 reaches a stable corrosion state in an aqueous solution within the temperature range which is designed for use of the inner tank 1 and having a conductivity of 400-2000 $\mu\text{S/cm}$, without any applied external current. The slope of the tangent to the polarization curve of the i -th first metal component 31 at the corrosion potential of the i -th first metal component 31 is the polarization resistance of the i -th first metal component 31.

[0063] The cathode polarization resistance r_i of the i -th second metal component 32 is the slope of the polarization

curve of the i-th second metal component 32 at the corrosion potential in an aqueous solution within the temperature range which is designed for use of the inner tank 1 and having a conductivity of 400-2000 $\mu\text{S}/\text{cm}$. The polarization curve of the i-th second metal component 32 may be directly measured by immersing the i-th second metal component 32 in an aqueous solution within the temperature range which is designed for use of the inner tank 1 and having a conductivity of 400-2000 $\mu\text{S}/\text{cm}$. The corrosion potential of the i-th second metal component 32 is the potential measured when the i-th second metal component 32 reaches a stable corrosion state in an aqueous solution within the temperature range which is designed for use of the inner tank 1 and having a conductivity of 400-2000 $\mu\text{S}/\text{cm}$, without any applied external current. The slope of the tangent to the polarization curve of the i-th second metal component 32 at the corrosion potential of the i-th second metal component 32 is the polarization resistance of the i-th second metal component 32.

[0064] The inner tank 1 is constructed as a cylindrical tank-shaped structure, and the resistance R_{shui} of the water in the inner tank 1 is calculated using the following formula:

$$R_{shui} = \frac{4\rho H}{\pi D^2}$$

Herein:

R_{shui} is the resistance of the water in the inner tank 1, in units of Ω ;
 ρ is the density of the water in the inner tank 1, in units of kg/m^3 ;
 H is the height of the inner tank 1, in units of m;
 D is the diameter of the inner tank 1, in units of m.

[0065] In this way, the output voltage upper limit value of the direct-current power source module 22 is matched with the output current upper limit value of the direct-current power source module 22, that is, when the output voltage of the direct-current power source module 22 reaches the output voltage upper limit value, the output current of the direct-current power source module 22 reaches the output current upper limit value. Furthermore, since the output current upper limit value is the maximum of the protective current required for the inner tank 1, which prevents the household water from corroding the inner tank 1, the first metal component 31, and the second metal component 32 during the operation of the water heater 100, a sum of the protective current required for the first metal component 31, and the protective current required for the second metal component 32, when the output voltage of the direct-current power source module 22 is less than or equal to the aforementioned output voltage upper limit value, the output current of the direct-current power source module 22 is used to form protective currents for the inner tank 1, the first metal component 31, and the second metal component 32, without electrolyzing water to generate hydrogen, thereby further preventing electrolysis of the household water in the inner tank 1 that could lead to a hydrogen explosion.

[0066] In one exemplary embodiment, the output current of the direct-current power source module 22 is less than or equal to 200 mA, and the output current of the direct-current power source module 22 is less than or equal to the output current upper limit value. The output voltage of the direct-current power source module 22 is less than or equal to 4 V, and the output voltage of the direct-current power source module 22 is less than or equal to the output voltage upper limit value.

[0067] The output current of the direct-current power source module 22 is less than or equal to 200 mA, and the output voltage of the direct-current power source module 22 is less than or equal to 4 V, so that no hydrogen evolution reaction occurs at the metal tank body 11 and the metal components 3 serving as the cathode, further reducing the possibility of hydrogen evolution explosion.

[0068] In one exemplary embodiment, when the output current upper limit value of the direct-current power source module 22 is greater than 200 mA, that is, when the maximum value of the protective current required by the inner tank 1 and the sum of the protective current of the metal component 3 is greater than 200 mA, multiple corrosion prevention components 2 are provided.

[0069] Since the maximum value of the sum of the protective currents required for the inner tank 1 and the metal components 3 is relatively large, multiple corrosion prevention assemblies 2 may be arranged to simultaneously apply protective currents to the metal tank body 11 and the metal components 3, which not only avoids a case in which a single corrosion prevention assembly 2 cannot provide a sufficiently large protective current, but also avoids hydrogen evolution explosion caused by an excessively high output voltage of the direct-current power source module 22 of a single corrosion prevention assembly 2.

[0070] The present embodiment also proposes a corrosion prevention design method for the water heater 100. The water heater 100 comprises an inner tank 1 and a metal component 3. The metal component 3 is arranged in the inner tank 1. The inner tank 1 comprises a metal tank body 11 and a first insulating layer, and the first insulating layer covers

the inner wall of the metal tank body 11. The metal component 3 is electrically connected to the metal tank body 11.

[0071] The corrosion prevention design method comprises the following steps.

[0072] In step S1, it is determined whether the total area of the exposed metal surface of the metal component 3 in direct contact with the water in the inner tank 1 is greater than 0.5 m^2 , if so, proceeding to step S2.

[0073] In step S2, an insulation treatment is performed on at least a portion of the exposed metal surface of the metal component 3 to cover it with a second insulating layer, so that the total area of the exposed metal surface of the metal component 3 in direct contact with the water in the inner tank 1 is less than or equal to 0.5 m^2 .

[0074] The way for the insulation treatment of the metal surface of the second metal component 32 comprises coating insulating varnish on the metal surface, coating rubber on the metal surface, coating plastic on the metal surface, coating corrosion prevention paint on the metal surface, performing oxidation treatment on the metal surface, performing passivation treatment on the metal surface or attaching insulating material on the metal surface. The insulating material may be rubber, silicone, etc.

[0075] Since the first insulating layer covers the inner wall of the metal tank body 11, and the total area of the exposed metal surface of the metal component 3 that is in direct contact with the water in the inner tank 1 is less than or equal to 0.5 m^2 , the total area of the exposed metal surface in direct contact with the water in the inner tank 1 is relatively small. Therefore, applying a weak-current voltage between the metal tank body 11 and the electronic anode 21, as well as between the metal component 3 and the electronic anode, by the direct-current power source module 22 can meet the corrosion prevention requirements of the inner tank 1 and the metal component 3, which reduces the risk of hydrogen evolution and explosion, mitigates the safety hazard of electrical leakage in the corrosion prevention assembly 2, and also lowers the difficulty of electronic control design for the water heater 100.

[0076] In an exemplary embodiment, the corrosion prevention design method further comprises step S3.

[0077] Step S1 further comprises: when the total area of the exposed metal surface of the metal component 3 in direct contact with the water in the inner tank 1 is not greater than 0.5 m^2 , and the metal component 3 only comprises a first metal component 31 having an exposed metal surface, proceeding to Step S3.

[0078] In step S3, an output current upper limit value is determined according to the protective current density of the inner tank 1, the area of the inner wall of the metal tank body 11 covered by the first insulating layer, the protective current density of the exposed metal surface of each first metal component 31, and the area of the exposed metal surface of each first metal component 31 in direct contact with the water in the inner tank 1, and the output current of the direct-current power source module 22 is set to be less than or equal to the output current upper limit value.

[0079] An output voltage upper limit value is determined according to the output current upper limit value, the polarization resistance of the electronic anode 21, the resistance of the water in the inner tank 1, and the cathode polarization resistance of each first metal component 31, and the output voltage of the direct-current power source module 22 is set to be less than or equal to the output voltage upper limit value.

[0080] The output current upper limit value of the direct-current power source module 22 may be calculated using the above formula (1). The output voltage upper limit value of the direct-current power source module 22 may be calculated using the above formula (2).

[0081] In this way, when the current output by the direct-current power source module 22 is less than or equal to the output current upper limit value, and the voltage output by the direct-current power source module 22 is less than or equal to the output voltage upper limit value, the current output by the direct-current power source module 22 mainly provides protective current for the metal tank body 11, the joint 12, and the first metal component 31, so that the metal tank body 11 and the first metal component 31 are not corroded, without electrolyzing water to generate hydrogen, thereby preventing occurrence of explosion due to hydrogen evolution.

[0082] In one exemplary embodiment, the corrosion prevention design method further comprises step S4 following the step S2.

[0083] In step S4, the metal component 3 comprises a first metal component 31 with an exposed metal surface and a second metal component 32 of which the metal surface has undergone insulation treatment.

[0084] The output current upper limit value is determined according to the protective current density of the inner tank 1, the area of the inner wall of the metal tank body 11 covered by the first insulating layer, the protective current density of the exposed metal surface of each first metal component 31, the area of the exposed metal surface of each first metal component 31 in direct contact with the water in the inner tank 1, the protective current density of the metal surface of each second metal component 32 covered by the second insulating layer, and the area of the metal surface of each second metal component 32 covered by the second insulating layer, and the output current of the direct-current power source module 22 is set to be less than or equal to the output current upper limit value.

[0085] The output voltage upper limit value is determined based on the output current upper limit value, the polarization resistance of the electronic anode 21, the resistance of water in the inner tank 1, the cathode polarization resistance of each first metal component 31, and the cathode polarization resistance of each second metal component 32, and the output voltage of the direct-current power source module 22 is set to be less than or equal to the output voltage upper limit value.

[0086] The output current upper limit value of the direct-current power source module 22 may be calculated using the above formula (3). The output voltage upper limit value of the direct-current power source module 22 may be calculated using the above formula (4).

[0087] In this way, when the current output by the direct-current power source module 22 is less than or equal to the output current upper limit value, and the voltage output by the direct-current power source module 22 is less than or equal to the output voltage upper limit value, the current output by the direct-current power source module 22 mainly provides protective current for the metal tank body 11, the first metal component 31, and the second metal component 32, so that the metal tank body 11, the first metal component 31, and the second metal component 32 are not corroded, without electrolyzing water to generate hydrogen, thereby preventing occurrence of explosion due to hydrogen evolution.

[0088] Those of ordinary skills in the art can appreciate that all or some of the acts in the above disclosed methods, functional modules/units in apparatuses or systems may be implemented as software, firmware, hardware, and appropriate combinations thereof. In a hardware implementation, a division of the function modules/units mentioned in the above description does not always correspond to a division of physical components. For example, a physical component may have multiple functions, or a function or an act may be executed by several physical components in cooperation. Some or all of the components may be implemented as software executed by a processor, such as a digital signal processor or a microprocessor, or as hardware, or as an integrated circuit, such as an application specific integrated circuit. Such software may be distributed on computer-readable media, which may comprise computer storage media (or non-transitory media) and communication media (or transitory media). As is well-known to those of ordinary skills in the art, the term "computer storage media" comprises volatile and non-volatile, removable and non-removable media implemented in any method or technique for storing information (such as computer-readable instructions, data structures, program modules, or other data). Computer storage media comprise, but are not limited to, RAM, ROM, EEPROM, a flash memory or another memory technology, CD-ROM, a digital versatile disk (DVD) or another optical disk storage, a magnetic cartridge, a magnetic tape, a magnetic disk storage, or another magnetic storage apparatus, or any other media that may be configured to store desired information and may be accessed by a computer. In addition, it is well-known to those of ordinary skills in the art that the communication media usually comprises computer-readable instructions, data structures, program modules, or other data in a modulated data signal of, such as, a carrier or another transmission mechanism, and may comprise any information delivery medium.

Claims

1. A water heater, comprising:

an inner tank comprising a metal tank body, and a first insulating layer covering an inner wall of the metal tank body;
a metal component disposed within the inner tank and electrically connected to the metal tank body; and
a corrosion prevention assembly comprising:

an electronic anode extending into the inner tank; and
a direct-current power source module, wherein the direct-current power source module comprises a positive electrode electrically connected to the electronic anode and a negative electrode electrically connected to the metal tank body, and is configured to apply a weak-current voltage between the metal tank body and the electronic anode;

wherein a total area of an exposed metal surface of the metal component in direct contact with water in the inner tank is less than or equal to 0.5 m².

2. The water heater according to claim 1, wherein the metal component comprises a first metal component and/or a second metal component;

the first metal component has the exposed metal surface;
a metal surface of the second metal component is subjected to an insulation treatment to form a second insulating layer, wherein the second insulating layer is capable of isolating the metal surface of the second metal component from the water in the inner tank.

3. The water heater according to claim 2, wherein a way for the insulation treatment of the metal surface of the second metal component comprises:

coating insulating varnish on the metal surface, coating rubber on the metal surface, coating plastic on the metal surface, coating corrosion prevention paint on the metal surface, performing oxidation treatment on the metal surface, performing passivation treatment on the metal surface, or attaching an insulating material on the metal surface.

4. The water heater according to claim 2, wherein an output current of the direct-current power source module is less than or equal to an output current upper limit value, and the output current upper limit value is calculated using the following formula:

$$I = I_0 \times A_0 + \sum_{1}^n I_i \times A_i + \sum_{1}^N J_i \times a_i$$

wherein:

I is the output current upper limit value;

I_0 is a protective current density of the inner tank;

A_0 is an area of the inner wall of the metal tank body covered by the first insulating layer;

I_i is a protective current density of an exposed metal surface of an i -th first metal component;

A_i is an area of an exposed metal surface of the i -th first metal component in direct contact with the water in the inner tank;

n is a number of first metal components;

J_i is a protective current density of a metal surface of an i -th second metal component covered by the second insulating layer;

a_i is an area of the metal surface of the i -th second metal component covered by the second insulating layer;

and

N is a number of second metal components.

5. The water heater according to claim 4, wherein the protective current density I_0 of the inner tank is a maximum value of self-corrosion current densities of the inner tank in an aqueous solution;

the protective current density I_i of the i -th first metal component is a maximum value of self-corrosion current densities of the exposed metal surface of the i -th first metal component in the aqueous solution;

the protective current density J_i of the i -th second metal component is a maximum value of self-corrosion current densities of the metal surface of the i -th second metal component covered by the second insulating layer in the aqueous solution;

wherein, a temperature of the aqueous solution is within a temperature range which is designed for use of the inner tank, and a conductivity of the aqueous solution is 400-2000 $\mu\text{S/cm}$.

6. The water heater according to claim 4 or 5, wherein an output voltage of the direct-current power source module is less than or equal to an output voltage upper limit value, and the output voltage upper limit value is calculated using the following formula:

$$E = I \times \left(R_0 + R_{shui} + \sum_{1}^n R_i + \sum_{1}^N r_i \right)$$

wherein:

E is the output voltage upper limit value;

I is the output current upper limit value;

R_0 is a polarization resistance of the electronic anode;

R_{shui} is a resistance of the water in the inner tank;

R_i is a cathode polarization resistance of the i -th first metal component;

n is the number of the first metal components;

r_i is a cathode polarization resistance of the i -th second metal component;

N is the number of the second metal components.

7. The water heater according to claim 6, wherein

the polarization resistance R_o of the electronic anode is a slope of a polarization curve of the electronic anode in an aqueous solution at a corrosion potential;
the cathode polarization resistance R_i of the i-th first metal component is a slope of a polarization curve of the i-th first metal component in the aqueous solution at a corrosion potential;
the cathode polarization resistance r_i of the i-th second metal component is a slope of a polarization curve of the i-th second metal component in the aqueous solution at a corrosion potential;
wherein, a temperature of the aqueous solution is within a temperature range which is designed for use of the inner tank, and a conductivity of the aqueous solution is 400-2000 $\mu\text{S/cm}$.

8. The water heater according to claim 6, wherein the inner tank is constructed as a cylindrical tank-shaped structure, and the resistance R_{shui} of the water in the inner tank is calculated using the following formula:

$$R_{shui} = \frac{4\rho H}{\pi D^2}$$

wherein:

ρ is a density of the water of the inner tank;
 H is a height of the inner tank; and
 D is a diameter of the inner tank.

9. The water heater according to claim 6, wherein the output current of the direct-current power source module is less than or equal to 200mA and the output voltage of the direct-current power source module is less than or equal to 4V.

10. The water heater according to claim 9, wherein the output current upper limit value is greater than 200mA, and a plurality of corrosion prevention assemblies are provided.

11. A corrosion prevention design method for a water heater, wherein the water heater comprises an inner tank and a metal component disposed in the inner tank, the inner tank comprises a metal tank body electrically connected to the metal component and a first insulating layer covering an inner wall of the metal tank body; the corrosion prevention design method comprises:
performing insulation treatment on at least a portion of an exposed metal surface of the metal component based on a total area of the exposed metal surface of the metal component in direct contact with water in the inner tank greater than 0.5 m^2 , so that the total area of the exposed metal surface of the metal component in direct contact with the water in the inner tank is less than or equal to 0.5 m^2 .

12. The corrosion prevention design method according to claim 11, wherein the corrosion prevention design method further comprises:

performing insulation treatment on at least a portion of the exposed metal surface of the metal component to form a second insulating layer covering the at least a portion of the exposed metal surface of the metal component based on the total area of the exposed metal surface of the metal component in direct contact with water in the inner tank greater than 0.5 m^2 , so that the total area of the exposed metal surface of the metal component in direct contact with the water in the inner tank is less than or equal to 0.5 m^2 .

13. The corrosion prevention design method according to claim 12, wherein the corrosion prevention design method further comprises:

determining an output current upper limit value according to a protective current density of the inner tank, an area of an inner wall of the metal tank body covered by the first insulating layer, a protective current density of an exposed metal surface of each first metal component, and an area of an exposed metal surface of each first metal component in direct contact with the water in the inner tank, based on the total area of the exposed metal surface of the metal component in direct contact with the water in the inner tank less than or equal to 0.5 m^2 , and the metal component only comprising first metal components having exposed metal surfaces; and setting an output current

of a direct-current power source module to be less than or equal to the output current upper limit value.

14. The corrosion prevention design method according to claim 13, wherein the corrosion prevention design method further comprises:

determining an output voltage upper limit value according to the output current upper limit value, a polarization resistance of an electronic anode, a resistance of the water in the inner tank, and a cathode polarization resistance of each first metal component, based on the total area of the exposed metal surface of the metal component in direct contact with the water in the inner tank less than or equal to 0.5 m^2 , and the metal component only comprising first metal components having exposed metal surfaces; and setting an output voltage of the direct-current power source module to be less than or equal to the output voltage upper limit value.

15. The corrosion prevention design method according to claim 12, wherein the corrosion prevention design method further comprises:

after performing the insulation treatment on the at least a portion of the exposed metal surface of the metal component, the metal component comprises a first metal component having an exposed metal surface and a second metal component wherein a metal surface of the second metal component has undergone the insulation treatment;

determining an output current upper limit value according to a protective current density of the inner tank, an area of an inner wall of the metal tank body covered by the first insulating layer, a protective current density of an exposed metal surface of each first metal component, an area of an exposed metal surface of each first metal component in direct contact with the water in the inner tank, a protective current density of a metal surface of each second metal component covered by the second insulating layer, and an area of the metal surface of each second metal component covered by the second insulating layer; and setting an output current of a direct-current power source module to be less than or equal to the output current upper limit value; and

determining an output voltage upper limit value according to the output current upper limit value, a polarization resistance of an electronic anode, a resistance of the water in the inner tank, a cathode polarization resistance of each first metal component, and a cathode polarization resistance of each second metal component, and setting an output voltage of the direct-current power source module to be less than or equal to the output voltage upper limit value.

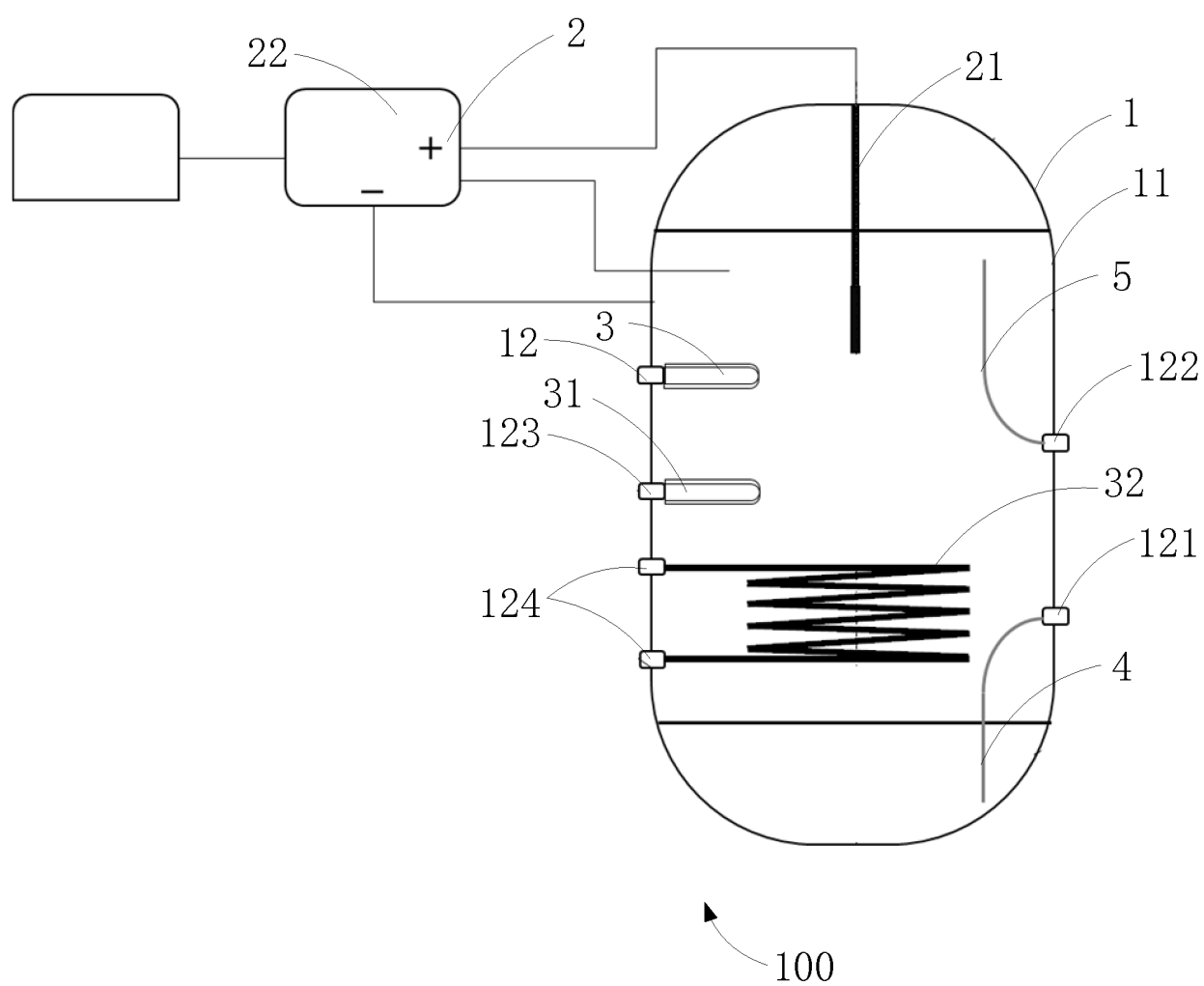


FIG. 1

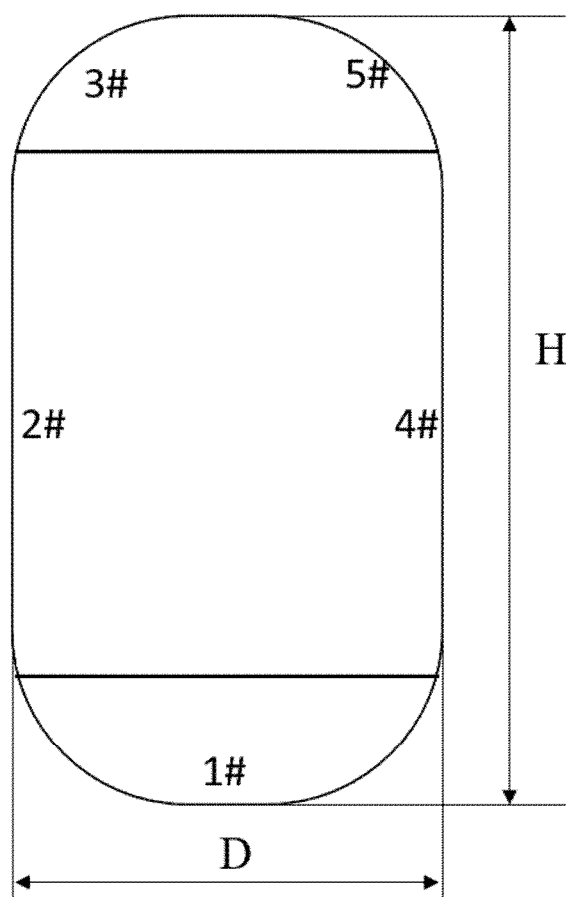


FIG. 2

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2024/126201

A. CLASSIFICATION OF SUBJECT MATTER

F24H9/45(2022.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC: F24H, C23F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

CNTXT, CNABS, CNKI, VEN, ENTXT: 绝缘层, 面积, 防腐, insulating layer, area, anticorrosion

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	CN 110701784 A (WUHU MIDEA KITCHEN & BATH APPLIANCES MANUFACTURING CO., LTD. et al.) 17 January 2020 (2020-01-17) description, paragraphs 26-39, and figures 1-4	1-3, 11-12
Y	CN 206986283 U (QINGDAO RENSHENG TECHNOLOGY INDUSTRIAL CO., LTD.) 09 February 2018 (2018-02-09) description, paragraphs 14-29, and figures 1-2	1-3, 11-12
Y	CN 109827322 A (WUHU MIDEA KITCHEN & BATH APPLIANCES MANUFACTURING CO., LTD.) 31 May 2019 (2019-05-31) description, paragraphs 49-92, and figures 1-16	1-3, 11-12
A	CN 105222363 A (GUANGDONG MIDEA HVAC EQUIPMENT CO., LTD. et al.) 06 January 2016 (2016-01-06) entire document	1-15
A	CN 109869910 A (QINGDAO ECONOMY AND TECHNOLOGY DEVELOPMENT ZONE HAIER WATER HEATER CO., LTD.) 11 June 2019 (2019-06-11) entire document	1-15

☒ Further documents are listed in the continuation of Box C.☒ See patent family annex.

* Special categories of cited documents:	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A" document defining the general state of the art which is not considered to be of particular relevance	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"D" document cited by the applicant in the international application	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"E" earlier application or patent but published on or after the international filing date	"&" document member of the same patent family
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	
"O" document referring to an oral disclosure, use, exhibition or other means	
"P" document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search 08 January 2025	Date of mailing of the international search report 11 January 2025
Name and mailing address of the ISA/CN China National Intellectual Property Administration (ISA/CN) China No. 6, Xitucheng Road, Jimenqiao, Haidian District, Beijing 100088	Authorized officer Telephone No.

Form PCT/ISA/210 (second sheet) (July 2022)

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2024/126201

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2021095891 A1 (ADEMCO INC.) 01 April 2021 (2021-04-01) entire document	1-15

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2024/126201

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Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)			Publication date (day/month/year)
CN	110701784	A	17 January 2020	None			
CN	206986283	U	09 February 2018	None			
CN	109827322	A	31 May 2019	None			
CN	105222363	A	06 January 2016	None			
CN	109869910	A	11 June 2019	None			
US	2021095891	A1	01 April 2021	US	11906203	B2	20 February 2024

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- CN 202410060201 [0001]