

DESCRIPTION

Title of Invention

IMPRESSED CURRENT PROTECT SYSTEM

5

Technical Field

[0001]

The present invention relates to an impressed current protect system of a metal pipe that passes water

10 therethrough. More specifically, the present invention relates to an external power source type impressed current protect system preferable for anticorrosion for a metal pipe that conveys seawater. Here, the "water" includes the "seawater".

15

Background Art

[0002]

A seawater pump is used for pumping up seawater from a sea area to cool a plant, and is also used as an
20 injection system that injects seawater in an oil field into an oil stratum to extract oil components. In addition, a technique for desalinating seawater by using a seawater desalination apparatus to utilize the desalinated seawater as industrial water, agricultural water, and daily life
25 water, such as drinking water, is being developed. In

particular, the large seawater desalination apparatus with reverse osmosis (RO) membranes requires a large number of metal pipes. This emphasizes the reliability of the metal pipe material with respect to corrosion affecting the life of the RO membranes (corrosion resistance).

[0003]

As the metal pipe material for conveying seawater pumped up by the pump to the RO equipment, stainless steel is typically used. The widely used seawater resistant material for the pipe of the pump and the seawater desalination apparatus is not typical SUS304 steel, but SUS316 steel that enhances corrosion resistance in seawater by adding Mo, although it is austenitic steel as with SUS304. For the bellmouth casing of the seawater pump, two-phase stainless steel can be used. In addition, for the pipe at higher pressure due to reverse osmosis by the RO membrane, a high corrosion resistance material, e.g., two-phase stainless steel, such as S32750, is used.

Further, for the downstream pipe for salt-concentrated waste liquid, called a brine pipe, a high-strength high-corrosion resistance material, such as S32750, is used. However, due to corrosion thinning and pitting leak, high-grade engineering plastic can be used in some portions of such pumps.

[0004]

To improve the corrosion resistance of the metal pipe material for the seawater pump and the seawater desalination apparatus, high corrosion resistance metal is used therefor. For instance, for the metal pipe and the brine pipe at higher pressure due to reverse osmosis by the RO membrane, super two-phase stainless steel, such as S32750, can be used. However, the use of such an expensive metal is not preferable in view of the cost.

[0005]

When the general-purpose two-phase stainless steel or austenitic stainless steel is used as the metal pipe material for cost reduction, the possibility of causing pipe corrosion thinning and pitting leak is high, thus requiring an anticorrosion means.

[0006]

To reduce corrosion of the metal pipe material, an impressed current protect method with a sacrificial anode or a cathode electrode, other than the high corrosion resistance metal, can be considered. In particular, in salt manufacturing equipment, impressed current protect is proposed which uses an insoluble cathode electrode of platinum (Pt). These methods are described in Japanese Patent Application Laid-Open Nos. 11-092981 and 61-067782.

Citations List

Patent Literature

[0007]

PTL 1: Japanese Patent Application Laid-Open No. 11-092981

5 PTL 2: Japanese Patent Application Laid-Open No. 61-067782

Summary of Invention

Technical Problem

[0008]

10 To reduce the cost of the seawater pump and the seawater desalination apparatus, it is necessary to reduce the cost, not only of the metal pipe material, but also of the electrode material used for impressed current protect. The impressed current protect systems described in Patent
15 Literature 1 and 2 use the expensive insoluble Pt electrode, which is not preferable for cost reduction.

[0009]

In view of the above circumstances, embodiments of the present invention seek to provide an impressed current
20 protect system that may improve the corrosion resistance of the metal pipe material for a seawater pump and a seawater desalination apparatus at low cost and with high efficiency. Embodiments of the present invention also seek to provide a seawater pump and a seawater

25

desalination apparatus at low cost by using such an impressed current protect system.

Solutions to Problem

[0010]

5 According to a first aspect of the present invention, there is provided an impressed current protect system for preventing corrosion of a metal pipe that passes water therethrough, the system including an anode electrode for impressed current protect sandwiched, so as to be covered
10 except for part thereof, between two insulating gaskets interposed between flanges connecting the coupler sections of the pipe, the part thereof being exposed from the gaskets and configuring a water contact surface that comes in contact with water inside the pipe, an anode electrode
15 terminal having at least part thereof sandwiched between the gaskets, a DC power source connected to the anode electrode and the pipe via the terminal and electric wiring and flowing an anticorrosion current to the water passing section of the pipe, a first seal member that seals the
20 flanges with respect to the gaskets, and a second seal member that seals the gaskets with respect to the terminal or that seals the anode electrode with respect to the terminal, wherein the first seal member and the second seal member are O-rings, and wherein the anode electrode is
25 annular, the two gaskets are joined to form an annular groove on the inner periphery thereof, the annular groove covering the outer periphery and the side surfaces of the anode electrode, and the inner periphery of the anode electrode configures the water contact surface.

30

[0011]

According to a second aspect of the present invention, there is provided a seawater pump including a metal pipe, a rotating shaft provided inside the metal pipe, an impeller provided at the end of the rotating shaft, and a motor that
5 rotatively drives the rotating shaft and the impeller, the flow of water from the impeller being pumped up to be guided inside the metal pipe, in which the metal pipe includes the impressed current protect system.

[0012]

10 According to a third aspect of the present invention, there is provided a seawater desalination apparatus including a seawater intake well that stores seawater taken thereinto, a filtered seawater tank that stores the seawater that flows from the seawater intake well to a
15 filter device where the seawater is filtered, a reverse osmosis membrane module that separates, into desalinated water and salt-concentrated water, the filtered seawater from the filtered seawater tank led by a high pressure pump via a protective filter, a produced water tank that stores
20 the desalinated water separated by the reverse osmosis membrane module, and a power recovery turbine disposed coaxially with the high pressure pump and recovering the salt-concentrated water separated by the reverse osmosis membrane module to discharge the recovered salt-
25 concentrated water into a concentrated water pipe, the

seawater intake well, the filter device, the filtered seawater tank, the protective filter, the reverse osmosis membrane module, the produced water tank, the high pressure pump, and the power recovery turbine being connected by metal pipes, in which the metal pipes include the impressed current protect system.

Advantageous Effects of Invention

[0013]

According to embodiments of the present invention, it is possible to provide the impressed current protect system capable of improving the corrosion resistance of the metal pipe material for the seawater pump and the seawater desalination apparatus at low cost and with high efficiency.

It is also possible to provide the seawater pump and the seawater desalination apparatus at low cost by using the impressed current protect system according to embodiments of the present invention.

Brief Description of Drawings

[0014]

Fig. 1 is a schematic sectional view of a first embodiment of an impressed current protect system according to the present invention.

Fig. 2 is a principle view of the impressed current

protect system according to the present invention
illustrated in Fig. 1.

Fig. 3 is a schematic sectional view of an example of
gaskets deformed when an anode electrode is thinned.

5 Fig. 4 is a schematic sectional view of a second
embodiment of the impressed current protect system
according to the present invention.

Fig. 5 is a schematic sectional view of a third
embodiment of the impressed current protect system
10 according to the present invention.

Fig. 6 is a schematic sectional view of a fourth
embodiment of the impressed current protect system
according to the present invention.

Fig. 7 is a schematic sectional view of a seawater
15 pump according to an embodiment of the present invention to
which the impressed current protect system according to the
present invention is applied.

Fig. 8 is a schematic sectional view of a seawater
desalination apparatus according to an embodiment of the
20 present invention to which the impressed current protect
system according to the present invention is applied.

Fig. 9 is a graph of changes in the amount of
corrosion of Example 2 and Comparative Example 2 with time.

Fig. 10 is a graph of changes in the amount of
25 corrosion of Example 3 and Comparative Example 3 with time.

Fig. 11 is a graph of changes in the amount of corrosion of Example 4 and Comparative Example 4 with time.

Description of Embodiments

5 [0015]

The impressed current protect system according to the present invention can optionally include the following aspects.

(i) The first seal member and the second seal member
10 are O-rings.

(ii) The anode electrode is annular, the two gaskets are joined to form an annular groove on the inner periphery thereof, the annular groove covering the outer periphery and the side surface of the anode electrode, and the inner
15 periphery of the anode electrode configures the water contact surface.

(iii) The anode electrode is made of at least one of carbon, graphite, and ferrite.

(iv) The first seal member includes a first O-ring
20 in the pipe periphery direction disposed between one of the flanges of the pipe and the gasket corresponding to the one flange, and a second O-ring in the pipe periphery direction disposed between the other flange of the pipe and the gasket corresponding to the other flange, and the second
25 seal member includes an O-ring in the terminal periphery

direction mounted on the outer periphery of the terminal.

(v) The elastic modulus is increased in the order of the seal members, the gaskets, the anode electrode, and the terminal.

5 (vi) The anode electrode is a carbon sheet.

(vii) The anode electrode is of triangular cross section.

(viii) An organic adhesive is provided between the anode electrode and the gaskets.

10 (ix) The gaskets include a spiral wound insulating gasket that serves as the seal member.

(x) The DC power source is any one of a primary battery, a secondary battery, and a solar battery, and has an applied voltage of 1 V or more and less than 2 V, and a
15 plus side to which the anode electrode is connected.

(xi) An amperemeter is provided between the anode electrode and the DC power source or between the metal pipe and the DC power source.

(xii) The anode electrode has a water permeability
20 of 10% or less.

(xiii) The DC power source is provided outside of the metal pipe.

[0016]

Embodiments according to the present invention will
25 be described below. The present invention is not limited

to the embodiments described here, and any combination and modification can be made within the scope not changing its purport.

[0017]

5 (First embodiment of an impressed current protect system)

Fig. 1 is a schematic sectional view of a first embodiment of an impressed current protect system according to the present invention. As illustrated in Fig. 1, an impressed current protect system 100 of the present invention has an anode electrode 7 for impressed current protect sandwiched, so as to be covered except for part thereof, between two insulating gaskets 2a, 2b interposed between flanges connecting the coupler sections of a metal pipe 6 that conveys seawater (not illustrated), the part thereof being exposed from the gaskets 2a, 2b and configuring a water contact surface that comes in contact with water inside the metal pipe 6, an anode electrode terminal 1 having at least part thereof sandwiched between the gaskets 2a, 2b, a DC power source 9 connected to the anode electrode 7 and the metal pipe 6 via the terminal 1 and electric wiring 10 and flowing an anticorrosion current to the water passing section of the metal pipe 6, a first seal member 4 (4a, 4b) that seals the flanges of the metal pipe 6 with respect to the gaskets 2a, 2b, and a second seal member 5 that seals the gaskets 2a, 2b with respect to

the terminal 1. The second seal member that seals the gaskets 2a, 2b with respect to the terminal 1 as illustrated in Fig. 1 may seal the anode electrode 7 with respect to the terminal 1, which will be described later in detail.

[0018]

The two gaskets 2a, 2b and the anode electrode 7 are annular, the gaskets 2a, 2b are joined to form an annular groove on the inner periphery thereof, the annular groove covering the outer periphery and the side surfaces of the anode electrode 7, and the inner periphery of the anode electrode 7 configures the water contact surface.

[0019]

The first seal member 4 and the second seal member 5 can be of any shape and material, but are preferably rubber O-rings.

[0020]

The first seal member 4 includes the first O-ring 4a in the pipe periphery direction disposed between one of the flanges of the pipe and the gasket corresponding to the one flange, and the second O-ring 4b in the pipe periphery direction disposed between the other flange of the pipe and the gasket corresponding to the other flange, and the second seal member includes an O-ring in the terminal periphery direction mounted on the outer periphery of the

terminal 1.

[0021]

Like the anode electrode 7, a terminal 1' is provided on the metal pipe, and is connected to the DC power source 9 via the electric wiring 10.

[0022]

Fig. 2 is a principle view of the impressed current protect system according to the present invention illustrated in Fig. 1. The metal pipe 6 is connected to the minus side of the DC power source 9. The anode electrode 7 is connected to the plus side of the DC power source 9 from which the electric current is supplied to the anode electrode 7. This configuration supplies electrons onto the surface of the metal pipe 6 that comes in contact with seawater to attract cations (positive ions) in the seawater. Thus, the metal pipe 6 is inhibited from emitting its metal cations in the corrosion reaction. The use of such impressed current protect means can prevent the metal pipe of the seawater pump and the seawater desalination apparatus from being corroded.

[0023]

To obtain the impressed current protect function, the anode electrode 7 is held by the gaskets 2a, 2b so that part thereof comes in contact with seawater flowing inside the metal pipe 6. In addition, the anode electrode 7

applies a minus potential to the metal pipe 6 that then has a potential lower than the natural immersion potential of its own pipe material.

[0024]

5 The material for the anode electrode 7 is required to be electrically conductive. The material for the anode electrode 7 is preferably any one of carbon, graphite, and ferrite in view of the cost. In the seawater desalination apparatus, the material for the anode electrode 7 is
10 preferably a metal, which is eluted by electrochemical melting from electric coupling with the metal pipe 6, but does not lower the RO membrane function of the seawater desalination apparatus. More specifically, in the seawater desalination apparatus, a water treatment agent used for
15 the RO membrane is combined with the metal eluted from the anode electrode to form metal compounds (e.g., an oxide, hydroxide, sulfate, and chloride) that are then accumulated on the surface of the RO membrane to cause clogging of the RO membrane, resulting in the desalination ability being
20 lowered. From this, the material for the anode electrode 7 that is applied to the seawater desalination apparatus is carbon more preferably. On the contrary, the seawater pump does not have the above problem about elution of the anode electrode 7. The anode electrode 7 can thus be made of any
25 material.

[0025]

When carbon is used for the anode electrode 7, a carbon sheet is more preferable.

[0026]

5 Pt, an insoluble material, is often used for the anode electrode in impressed current protect. However, Pt is expensive, and is not preferable for the anticorrosion device of the seawater desalination apparatus because it lowers the salt concentration effect when adhering onto the
10 surface of the RO membrane. Zinc and aluminum, which are metals less noble than the pipe material, are effective for a sacrificial anode, but are not preferable because they lower the salt concentration effect when adhering onto the surface of the RO membrane.

15 [0027]

In the present invention, the potential of the metal pipe material 6 becomes low to be easily absorb cations. It is thus possible to expect the effect of capturing ions or ionic cluster substances with plus charge lowering the
20 RO function of the metal pipe 6. In addition, the present inventors have confirmed the effect of reducing bacteria adhesion that causes microbial-influenced corrosion.

[0028]

The anode electrode 7 preferably has a water
25 permeability of 10% or less.

[0029]

The anode electrode 7 made of inexpensive carbon, graphite, or ferrite for cost reduction has a larger amount of thinning than the anode electrode 7 made of expensive Pt.

5 When the anode electrode 7 is thinned, the gaskets 2a, 2b are deformed, resulting in a gap between the gaskets 2a, 2b to be likely to flow seawater to the outside of the metal pipe 6. In the present invention, the first seal member 4 and the second seal member 5 can prevent deformation of the
10 gaskets 2a, 2b due to thinning of the anode electrode 7, thereby preventing seawater leak. The effect of the first seal member 4 and the second seal member 5 will be described below.

[0030]

15 Fig. 3 is a schematic sectional view of an example of the gaskets deformed when the anode electrode is thinned. The terminal is not illustrated. In Fig. 3, each dotted line portion indicates the anode electrode 7 and the gasket 2 before thinning, and each solid line portion indicates an
20 anode electrode 7' and a gasket 2' after thinning. As illustrated in Fig. 3, the anode electrode 7 to which the electric current is supplied is gradually thinned to be triangular. The thus thinned anode electrode 7 deforms the gasket 2, as indicated by the gasket 2'. Seawater flowing
25 inside the metal pipe 6 has 10 atm or more, and leaks to

the outside when the gasket 2 is deformed as illustrated in Fig. 3. In the present invention, the first seal member 4 and the second seal member 5 can prevent the gasket 2 from being deformed even when the anode electrode 7 is thinned, and the seawater flowing inside the metal pipe 6 can be prevented from leaking to the outside. The impressed current protect efficiency can thus be improved.

[0031]

More specifically, although thinning of the anode electrode 7 can cause a gap between the gasket 2 and the side surface of the anode electrode 7 to narrow the width of a flange 8 on the seawater side, the first seal member 4 intercepts a seawater flow passage that is likely to be created between the flange 8 and the gasket 2, thus preventing leak. In addition, the second seal member 5 can prevent leak until the anode electrode 7 disappears to further corrode the lead of the terminal 1.

[0032]

As described above, the first seal member 4 and the second seal member 5 prevent deformation of the gasket 2 due to thinning of the anode electrode 7. Thus, the effect of the present invention can be higher when the inexpensive material that is likely to be thinned is applied to the anode electrode 7.

[0033]

In the impressed current protect system according to the present invention, the Young's modulus with respect to the mechanical action in the compression direction is preferably increased in the order of the first seal member 4 and the second seal member 5, the gaskets 2a, 2b, the anode electrode 7, and the terminals 1, 1'. This can significantly prevent reduction in the gasket seal effect due to thinning of the anode electrode 7 with time. The components of the impressed current protect system and the preferable Young's modulus are shown in Table 1.

[0034]

[Table 1]

Components of impressed current protect system	Young's modulus (GPa)	Compressive strength (MPa)
Terminals 1, 1'	150-220	10
Anode electrode 7	5-85	10
Gasket 2	1-9.5	10
First seal member 4	0.12-0.5	10
Second seal member 5	0.12-0.5	10
Metal pipe 6	150-220	10

[0035]

In the present invention, the anode electrode 7 is provided between the gaskets 2a, 2b that are then fixed by bolts that fix the flanges of the metal pipe 6 (not illustrated). This can subject the metal pipe 6 to impressed current protect without inhibiting the flow of

seawater inside the metal pipe 6. In addition, the metal pipe 6 through which seawater is passed is corroded with time depending on the salt concentration. In particular, the metal pipe 6 is corroded at higher rate at the flanges as the pipe coupling sections and at the welding sections whose surface texture and surface roughness are not uniform. In the present invention, the gaskets 2a, 2b that hold the anode electrode 7 are disposed in the connection sections of the flanges of the metal pipe 6, thereby significantly preventing corrosion of the connection sections of the flanges (so-called crevice corrosion).

[0036]

The DC power source 9, which generates a potential difference between the metal pipe 6 and the anode electrode 7, may be any one of a primary battery such as a dry battery, a second battery such as a lead acid battery or a lithium battery, a DC power source, and a solar battery. For the potential difference, the applied voltage is preferably 1 V or more and less than 2 V. The anode electrode 7 (carbon, graphite, or ferrite) has a natural electrode potential of +0.5 V, while the metal pipe 6 (stainless steel) has a natural electrode potential of -0.5 V, so that the minimum applied potential applied to the metal pipe 6 for anode reaction occurrence is 1 V. In addition, the applied voltage is preferably less than 2 V

because when the applied voltage exceeds 2 V, hypochlorous acid is likely to be generated by seawater electrolysis.

As illustrated in Fig. 1, an amperemeter 11 may be disposed in series with the DC power source 9. The amperemeter 11 should have an internal circuit with less resistance. The current value in this case is optional, but is desirably 10 μ A or more.

[0037]

The cathode range capable of having the potential difference is typically known to be Wagner length that reaches several meters or more depending on the cathode shape, seawater flow rate, electric conductivity, and temperature. The potential of 1 V or more is suitable, as described above, and the potential application for gaining Wagner length is limited because when the potential exceeds 2 V, hydrogen is generated by water electrolysis.

[0038]

The metal pipe 6 may be made of any material, but is preferably made of stainless steel. For stainless steel, SUS316L and S32101 are preferable in view of the cost.

[0039]

(Second embodiment of the impressed current protect system)

Fig. 4 is a schematic sectional view of a second embodiment of the impressed current protect system according to the present invention. Fig. 4 illustrates, by

half, gaskets 401a, 401b, an anode electrode 402, a terminal 403, first seal members 404a, 404b, and a second seal member 405, and does not illustrate the metal pipe, the terminal connected to the metal pipe, and the DC power source that is connected to the metal pipe and the anode electrode via the electric wiring. This embodiment is different from the first embodiment in that the second seal member 405 seals the anode electrode 402 with respect to the terminal 403, and that the anode electrode 402 has a different shape.

[0040]

As illustrated in Fig. 4, the anode electrode 402 is of triangular cross section. In anticorrosion at low voltage and at constant current density, the anode current is decreased with the progress of thinning with increased anticorrosion time. That is, when the electrode of triangular cross section is used to measure (monitor) the change in the electric current with time, the consumed state of the anode electrode can be recognized. Here, the anode electrode 402 continues its anticorrosion function so as to act as an anode, eluting the electrode material by the anode reaction. With the elution, the anode electrode 402 is gradually thinned from the bottom toward the apex of its triangular cross section, thus gradually reducing its water contact area. Consequently, the anode current

determined by the product of the water contact area by the current density is decreased even when the current density per unit area is the same. This can monitor the consumed state of the anode electrode from the change in the anode current. Other configurations are the same as the first embodiment, and will not be described here.

[0041]

(Third embodiment of the impressed current protect system)

Fig. 5 is a schematic sectional view of a third embodiment of the impressed current protect system according to the present invention. Fig. 5 illustrates, by half, gaskets 501a, 501b, an anode electrode 502, a terminal 503, first seal members 504a, 504b, and a second seal member 505, and does not illustrate the metal pipe, the terminal connected to the metal pipe, and the DC power source that is connected to the metal pipe and the anode electrode via the electric wiring. This embodiment is different from the first embodiment in that the second seal member 505 seals the anode electrode 502 with respect to the terminal 503, and that an organic adhesive 506 is provided between the anode electrode 502 and the gaskets 501a, 501b. Thus, the contactivity between the anode electrode 502 and the gaskets 501a, 501b can be increased, thus preventing progressing of crevice corrosion caused at the interface between the anode electrode 502 and the

gaskets 501a, 501b.

[0042]

The organic adhesive can include an epoxy adhesive.
Other configurations are the same as the first embodiment,
5 and will not be described here.

[0043]

(Fourth embodiment of the impressed current protect system)

Fig. 6 is a schematic sectional view of a fourth
embodiment of the impressed current protect system
10 according to the present invention. Fig. 6 illustrates, by
half, a gasket 601, an anode electrode 602, and a terminal
603, and does not illustrate the metal pipe, the terminal
connected to the metal pipe, and the DC power source that
is connected to the metal pipe and the anode electrode via
15 the electric wiring. This embodiment is different from the
first embodiment in that the gasket 601 is not annular, but
is spiral wound. Thus, the spiral wound insulating gasket
601 covers the center of the anode electrode 602, thereby
maintaining its sealability even when the anode electrode
20 602 is thinned. That is, in this embodiment, the spiral
wound gasket serves as the seal member. The spiral wound
gasket has higher pressure resistance than the annular
gasket. Other configurations are the same as the first
embodiment, and will not be described here.

25 [0044]

(Seawater pump)

Fig. 7 is a schematic sectional view of the seawater pump according to an embodiment of the present invention to which the impressed current protect system according to the present invention is applied. As illustrated in Fig. 7, a seawater pump 200 mainly has, on its outer periphery, a column pipe 201, a casing 202, a casing liner 203, a bellmouth casing 204, and a flange 205 mutually coupling these. The seawater pump also has, on its axis, a rotating shaft 206 disposed inside the column pipe 201, the casing 202, the casing liner 203, and the bellmouth casing 204, the rotating shaft 206 having an end at which an impeller 208 is mounted. Although not illustrated in Fig. 7, the seawater pump further has a motor that rotatively drives the rotating shaft 206 and the impeller 208. The flow of water from the rotating shaft 206 and the impeller 208 driven by the motor moves upward in Fig. 7 to be pumped up.

[0045]

In the seawater pump 200 of this embodiment, an anode electrode 103 is disposed with respect to the outer surface of the column pipe 201, and is fixed via an insulating sheet 111 by means of a conductive fixing member 104 while being electrically conductive to the column pipe 201. On the side surface of the anode electrode 103, an amperemeter 112 is disposed. The amperemeter 112 is connected to a DC

power source 113 by cables 115. The cables 115 transmit and receive signals, and supply electric power. In Fig. 7, the anode electrode 103 and the DC power source 113 are enlarged so as to be easily seen, but, can, of course, have any size.

In addition, the anode electrode 103 is disposed via the flange configuration so as to come in contact with seawater flowing inside the column pipe 201 (not illustrated). In this case, in order not to affect the flow of water inside the pump, and to prevent falling-off of the anode electrode 103, the anode electrode 103 is disposed on the flange surface of the column pipe 201. For this, the anode electrode 103 is insulated from the column pipe 201.

[0046]

(Seawater desalination apparatus)

Fig. 8 is a schematic sectional view of the seawater desalination apparatus according to an embodiment of the present invention to which the impressed current protect system according to the present invention is applied. As illustrated in Fig. 8, the seawater desalination apparatus has a seawater intake pump 300, a seawater intake well 301 that stores seawater, a double layer filter device 302, a filtered seawater tank 303, a protective filter 304, a high pressure pump 305, a reverse osmosis membrane module 306, a

power recovery turbine 307, a produced water tank 308, a concentrated water pipe 309, and pipes 310, 311, and 312. To convey seawater, pumps 313 are provided in respective places of the seawater desalination apparatus.

5 [0047]

The impressed current protect system of the present invention is applied to the seawater intake pump 300 in which the inner and outer surfaces of the column pipe are immersed into seawater. In addition, the impressed current
10 protect system of the present invention is applied to the inner surfaces of the high pressure pump 305 and the pumps 313 that come in contact with seawater.

[0048]

The metal pipes are used for the pipe sections on the
15 downstream from the high pressure pump, and flow seawater therethrough at an internal pressure of 10 atm or more. The metal pipes are corroded depending on the salt concentration with time, and in particular, are likely to be corroded at high reaction rate at the flanges as the
20 pipe coupling sections and at the welding portions whose surface texture and surface roughness are not uniform. To prevent the corrosion action, the impressed current protect system of the present invention is preferable for the metal pipes.

25 [0049]

When, as described above, the impressed current protect system of the present invention is applied to the seawater desalination apparatus, elution and partial separation of metal ions from the anode electrode are likely to accelerate deterioration of the RO membrane (deterioration of the reverse osmosis membrane module). It is thus necessary to use the material that is unlikely to accelerate the deterioration.

Examples

[0050]

The present invention will be described below more specifically by examples and comparative examples. The present invention is not limited to these examples.

[0051]

(Leak test)

A seawater leak test was conducted on the metal pipe to which the impressed current protect system according to the first embodiment of the present invention was applied. Artificial seawater was flowed through the metal pipe at 20 atm for 72 hours, and the applied voltage of the DC power source was 3 V. From the results of the leak test, the impressed current protect system causing no leak was evaluated as "Accepted", and the impressed current protect system causing leak was evaluated as "Rejected". The measurement results are shown in Table 2. The "Yes" and

"No" in Table 2 represent the presence and absence of the respective members.

[0052]

[Table 2]

	Seal members		Leak test evaluation
	First seal member	Second seal member	
Example 1	Yes	Yes	Accepted
Reference Example 1	Yes	No	Rejected
Reference Example 2	No	Yes	Rejected
Comparative Example 1	No	No	Rejected

5

[0053]

From Table 2, the impressed current protect system according to the present invention (Example 1) caused no leak, and was evaluated as "Accepted" in the leak test.

10 The impressed current protect systems with one of the seal members (Reference Examples 1 and 2) caused leak, and were evaluated as "Rejected" in the leak test. The impressed current protect system without both seal members (Comparative Example 1) caused leak, and was evaluated as
 15 "Rejected" in the leak test. From this, it was found that the impressed current protect system according to the present invention can prevent deformation of the gaskets due to thinning of the anode electrode, thereby reliably

preventing seawater from leaking.

[0054]

(Evaluation (1) of the amount of corrosion of SUS316L steel)

5 For the impressed current protect system according to the first embodiment of the present invention, the change in the amount of corrosion of the stainless pipe with time was evaluated.

[0055]

10 SUS316L steel as stainless steel was used for the metal pipe, and artificial graphite (graphite) was used for the anode electrode. Artificial seawater (60°C, air-saturated, 7% salt concentration) assuming brine water (salt-concentrated water) was passed through the metal pipe.

15 Then, the DC stabilization power source was used to control the metal pipe to hold a voltage that was 1 V lower than the voltage of the artificial graphite for measuring the change in the amount of corrosion with time. The amount of corrosion was determined from the difference between the

20 weights of the metal pipe before and after passing of the seawater. Fig. 9 shows the measurement result of Example 2 in which the impressed current protect system of the first embodiment of the present invention was used, and the measurement result of Comparative Example 2 in which the

25 metal pipe was simply immersed without using the impressed

current protect system according to the present invention.

[0056]

From Fig. 9, the amount of corrosion of Comparative Example 2 after the elapse of 1,000 hours was eight times or more the amount of corrosion of Example 2. It was thus found that the impressed current protect system of the present invention can significantly prevent the metal pipe from being corroded.

[0057]

10 (Evaluation (2) of the amount of corrosion of SUS316L steel)

For the impressed current protect system according to the first embodiment of the present invention, the change in the amount of corrosion of the stainless pipe with time was evaluated.

[0058]

SUS316L steel as stainless steel was used for the metal pipe, and artificial graphite (graphite) was used for the anode electrode. Artificial seawater (25°C, air-saturated, 3.5% salt concentration) assuming brine water (salt-concentrated water) was passed through the metal pipe. Then, the DC stabilization power source was used to control the metal pipe to hold a voltage that was 1 V lower than the voltage of the artificial graphite for measuring the change in the amount of corrosion with time. The amount of

corrosion was determined from the difference between the weights of the metal pipe before and after passing of the seawater. Fig. 10 shows the measurement result of Example 3 in which the impressed current protect system of the first embodiment of the present invention was used, and the measurement result of Comparative Example 3 in which the metal pipe was simply immersed without using the impressed current protect system according to the present invention.

[0059]

From Fig. 10, the amount of corrosion of Comparative Example 3 after the elapse of 1,000 hours was five times or more the amount of corrosion of Example 3. It was thus found that the impressed current protect system of the present invention can significantly prevent the metal pipe from being corroded.

[0060]

(Evaluation of the amount of corrosion of S32101)

For the impressed current protect system according to the first embodiment of the present invention, the change in the amount of corrosion of the stainless pipe with time was evaluated.

[0061]

S32101 steel as stainless steel was used for the metal pipe, and artificial graphite (graphite) was used for the anode electrode. Artificial seawater (25°C, air-

saturated, 3.5% salt concentration) assuming brine water (salt-concentrated water) was passed through the metal pipe. Then, the DC stabilization power source was used to control the metal pipe to hold a voltage that was 1 V lower than the voltage of the artificial graphite for measuring the change in the amount of corrosion with time. The amount of corrosion was determined from the difference between the weights of the metal pipe before and after passing of the seawater. Fig. 11 shows the measurement result of Example 4 in which the impressed current protect system of the first embodiment of the present invention was used, and the measurement result of Comparative Example 4 in which the metal pipe was simply immersed without using the impressed current protect system according to the present invention.

[0062]

From Fig. 10, the amount of corrosion of Comparative Example 4 after the elapse of 1,000 hours was five times or more the amount of corrosion of Example 4. It was thus found that the impressed current protect system of the present invention can significantly prevent the metal pipe from being corroded.

[0063]

As described above, according to the present invention, it is possible to provide the impressed current protect system capable of improving the corrosion

resistance of the metal pipe material for the seawater pump and the seawater desalination apparatus at low cost and with high efficiency, and the seawater pump and the seawater desalination apparatus at low cost by using the impressed current protect system according to the present invention.

[0064]

Although the embodiments of the present invention have been described above in detail, the present invention is not limited thereto, and various changes in design can be made within the scope not departing from the spirit of the present invention described in the claims. For instance, the embodiments have been described in detail to easily understand the present invention, and do not necessarily include all the described configurations. In addition, part of the configuration of one of the embodiments can be replaced with the configurations of the other embodiments, and the configuration of the one embodiment can be added with the configurations of the other embodiments. Further, part of the configuration of each embodiment can be added with, deleted from, and replaced with the other configurations.

Reference Signs List

[0065]

1, 1', 403, 503, 603 ... Terminal,
 2a, 2b, 2', 401a, 401b, 501a, 501b, 601 ... Gasket,
 3, 8 ... Flange,
 4, 4a, 4b, 404a, 404b, 504a, 504b ... First seal member,
 5 5, 405, 505 ... Second seal member,
 6 ... Metal pipe,
 7, 7', 103, 402, 502, 602 ... Anode electrode,
 9, 113 ... DC power source,
 10, 115 ... Cable,
 10 11, 112 ... Amperemeter,
 506 ... Organic adhesive,
 100 ... Impressed current protect system,
 104 ... Conductive fixing member,
 200 ... Seawater pump,
 15 201 ... Column pipe,
 202 ... Casing,
 203 ... Casing liner,
 204 ... Bellmouth casing,
 205 ... Flange,
 20 206 ... Rotating shaft,
 208 ... Impeller,
 300 ... Seawater intake pump,
 301 ... Seawater intake well,
 302 ... Double layer filter device,
 25 303 ... Filtered seawater tank,

304 ... Protective filter,
305 ... High pressure pump,
306 ... Reverse osmosis membrane module,
307 ... Power recovery turbine,
5 308 ... Produced water tank,
309 ... Concentrated water pipe,
310, 311, 312 ... Pipe,
313 ... Pump.

CLAIMS

1. An impressed current protect system for preventing corrosion of a metal pipe that passes water through the pipe, the system comprising:

an anode electrode for impressed current protect sandwiched, so as to be covered except for part of the anode electrode, between insulating gaskets interposed between flanges connecting the coupler sections of the pipe, the part of the anode electrode being exposed from the gaskets and configuring a water contact surface that comes in contact with water inside the pipe;

an anode electrode terminal having at least part of the anode electrode terminal sandwiched between the gaskets;

a DC power source connected to the anode electrode and the pipe via the terminal and electric wiring and flowing an anticorrosion current to the water passing section of the pipe;

a first seal member that seals the flanges with respect to the gaskets; and

a second seal member that seals the gaskets with respect to the terminal or that seals the anode electrode with respect to the terminal,

wherein the first seal member and the second seal member are O-rings, and

wherein the anode electrode is annular, the two gaskets are joined to form an annular groove on the inner periphery

5 thereof, the annular groove covering the outer periphery and the side surfaces of the anode electrode, and the inner periphery of the anode electrode configures the water contact surface.

10 2. The impressed current protect system according to claim 1, wherein the anode electrode is made of at least one of carbon, graphite, and ferrite.

3. The impressed current protect system according to
15 claim 1 or 2,

wherein the first seal member includes a first O-ring in the pipe periphery direction disposed between one of the flanges of the pipe and the gasket corresponding to the one flange, and a second O-ring in the pipe periphery direction
20 disposed between the other flange of the pipe and the gasket corresponding to the other flange,

wherein the second seal member includes an O-ring in

the terminal periphery direction mounted on the outer periphery of the terminal.

4. The impressed current protect system according to any one of claims 1 to 3, wherein the elastic modulus is increased in the order of the seal members, the gaskets, the anode electrode, and the terminal.

5. The impressed current protect system according to any one of claims 1 to 4, wherein the anode electrode is a carbon sheet.

6. The impressed current protect system according to any one of claims 1 to 5, wherein the anode electrode is of triangular cross section.

7. The impressed current protect system according to any one of claims 1 to 6, wherein an organic adhesive is provided between the anode electrode and the gaskets.

8. The impressed current protect system according to any

one of claims 1 to 7, wherein the DC power source is any one of a primary battery, a secondary battery, and a solar battery, and has an applied voltage of 1V or more and less than 2V, and a plus side to which the anode electrode is
5 connected.

9. The impressed current protect system according to any one of claims 1 to 8, wherein an amperemeter is provided between the anode electrode and the DC power source or
10 between the metal pipe and the DC power source.

10. The impressed current protect system according to any one of claims 1 to 9, wherein the anode electrode has a water permeability of 10% or less.

11. The impressed current protect system according to any one of claims 1 to 10, wherein the DC power source is provided outside of the metal pipe.

20 12. A seawater pump comprising:

a metal pipe;
a rotating shaft provided inside the metal pipe;
an impeller provided at the end of the rotating
shaft; and

25 a motor that rotatively drives the rotating shaft and

the impeller,

the flow of water from the impeller being pumped up
to be guided inside the metal pipe,

wherein the metal pipe includes the impressed current

5 protect system according to any one of claims 1 to 11.

13. A seawater desalination apparatus comprising:

a seawater intake well that stores seawater taken
into the seawater intake well;

10 a filtered seawater tank that stores the seawater
that flows from the seawater intake well to a filter device
where the seawater is filtered;

a reverse osmosis membrane module that separates,
into desalinated water and salt-concentrated water, the
15 filtered seawater from the filtered seawater tank led by a
high pressure pump via a protective filter;

a produced water tank that stores the desalinated
water separated by the reverse osmosis membrane module; and

a power recovery turbine disposed coaxially with the
20 high pressure pump and recovering the salt-concentrated
water separated by the reverse osmosis membrane module to
discharge the recovered salt-concentrated water into a
concentrated water pipe,

the seawater intake well, the filter device, the
25 filtered seawater tank, the protective filter, the reverse

osmosis membrane module, the produced water tank, the high pressure pump, and the power recovery turbine being connected by metal pipes,

wherein the metal pipes include the impressed current
5 protect system according to any one of claims 1 to 11.