

DESCRIPTION

Title of the Invention: Electrolytic cell

5 Technical Field:

[0001]

The present invention relates to an electrolytic cell. More specifically, the present invention relates, but is not limited, to an electrolytic cell that can be suitably used to
10 produce an aqueous solution of quaternary ammonium hydroxide from an aqueous solution of quaternary ammonium salt.

Background Art:

[0002]

15 Patent Documents 1 to 4 below disclose a method for producing an aqueous solution of quaternary ammonium hydroxide from an aqueous solution of quaternary ammonium salt. Such a production method involves the use of an electrolytic cell including a cathode frame, a cathode plate fixed to the inner
20 surface of the cathode frame, an anode frame, and an anode plate fixed to the inner surface of the anode frame. At least one cation exchange membrane is provided between the cathode plate and the anode plate. A solution supply flow path is connected to each compartment separated by the ion exchange membrane. A
25 solution is supplied/discharged through supply/discharge openings provided at any place on the outer surface of the electrolytic cell and openings provided in contact with the compartment. For example, the cathode frame includes a plurality of upper flow paths extending respectively from a
30 plurality of upper openings arranged at intervals in the width direction and a plurality of lower flow paths extending respectively from a plurality of lower openings arranged at intervals in the width direction. Similarly, the anode frame includes a plurality of upper flow paths extending respectively
35 from a plurality of upper openings arranged at intervals in the

width direction and a plurality of lower flow paths extending respectively from a plurality of lower openings arranged at intervals in the width direction. The cathode and anode plates have a rectangular shape and are arranged in a region between
5 the upper openings and the lower openings. The upper edges of the cathode and anode plates are located below the upper openings, and the lower edges thereof are located above the lower openings. An aqueous solution of quaternary ammonium hydroxide is circulated through the lower and upper flow paths
10 provided in the cathode frame. (More specifically, an aqueous solution of quaternary ammonium hydroxide flows in through either of the upper or lower flow paths and flows out through the other flow paths in the cathode frame.) On the other hand, a raw material solution, such as an aqueous solution of
15 quaternary ammonium salt, is circulated through the upper and lower flow paths provided in the anode frame. (More specifically, a raw material solution, such as an aqueous solution of quaternary ammonium salt, flows in through either of the upper or lower flow paths and flows out through the other
20 flow paths in the anode frame.)

Prior Art Documents:

Patent Documents:

[0003]

25 Patent Document 1: JP-A-62-142792
Patent Document 2: JP-B-8-16274
Patent Document 3: JP-B-8-19539
Patent Document 4: JP-A-2009-13477

30 Summary of the Invention:

Problems to be solved by the Invention:

[0004]

In the conventional electrolytic cell as described above, the cathode and anode plates are arranged between the upper and
35 lower openings in the cathode and anode frames, respectively.

With this structure, the each size of the cathode and the anode plates is limited for the each size of the cathode and the anode frames, and accordingly the current-carrying area of the cathode and anode plates is relatively limited for the size of the electrolytic cell. Thus, the electrolysis efficiency of the conventional electrolytic cell is not always sufficient. [0005]

The present invention has been made in view of the aforementioned fact, and a primary technical object of the invention is to provide a novel and improved electrolytic cell in which a cathode plate and an anode plate are relatively large for the each size of a cathode frame and an anode frame as compared with those in the conventional electrolytic cell, so that the current-carrying area of the cathode and anode plates is relatively large for the size of the electrolytic cell, resulting in increased electrolysis efficiency. [0006]

In addition to the primary technical object, it is another technical object of the present invention to provide a novel and improved electrolytic cell in which a liquid flow is not blocked by gaskets interposed between the cathode frame and the cathode plate and between the anode frame and the anode plate even after continued operation of the electrolytic cell. [0007]

In addition to the primary technical object and another technical object, it is still another technical object of the present invention to provide a novel and improved electrolytic cell in which the cathode plate and the anode plate can be effectively prevented from being corroded galvanically or metallica-ly. [0008]

Means for solving the Problems:

[0008]

As a result of an intensive study, the present inventors have found that the above-described primary technical object

can be achieved by: allowing a cathode frame to have an upper opening and a lower opening in an upper end part and a lower end part, respectively, of its inner surface to which a cathode plate is fixed, as well as allowing an anode frame to have an upper opening and a lower opening in an upper end part and a lower end part, respectively, of its inner surface to which an anode plate is fixed; allowing the cathode plate and the anode plate to extend continuously from above the upper openings to below the lower openings; and allowing the cathode plate and the anode plate to have an upper through opening and a lower through opening formed in alignment with the upper opening and the lower opening, respectively.

[0009]

More specifically, in order to achieve the primary technical object, the present invention provides an electrolytic cell including: a cathode frame, a cathode plate fixed to an inner surface of the cathode frame, an anode frame, and an anode plate fixed to an inner surface of the anode frame, wherein

the cathode frame includes at least one upper flow path extending from an upper opening located in an upper end part of the inner surface and at least one lower flow path extending from a lower opening located in a lower end part of the inner surface,

the anode frame includes at least one upper flow path extending from an upper opening located in an upper end part of the inner surface and at least one lower flow path extending from a lower opening located in a lower end part of the inner surface,

the cathode plate extends continuously from above the upper opening of the cathode frame to below the lower opening of the cathode frame,

the cathode plate includes at least one upper through opening in its upper end part that is formed in alignment with the upper opening in the cathode frame, and at least one lower

through opening in its lower end part that is formed in alignment with the lower opening in the cathode frame,

the anode plate extends continuously from above the upper opening of the anode frame to below the lower opening of the anode frame, and

the anode plate includes at least one upper through opening in its upper end part that is formed in alignment with the upper opening in the anode frame, and at least one lower through opening in its lower end part that is formed in alignment with the lower opening in the anode frame.

[0010]

Preferably, the cathode frame includes a plurality of the upper flow paths extending respectively from a plurality of the upper openings arranged at intervals in a width direction in the upper end part of the inner surface, and a plurality of the lower flow paths extending respectively from a plurality of the lower openings arranged at intervals in the width direction in the lower end part of the inner surface,

the anode frame includes a plurality of the upper flow paths extending respectively from a plurality of the upper openings arranged at intervals in the width direction in the upper end part of the inner surface, and a plurality of the lower flow paths extending respectively from a plurality of the lower openings arranged at intervals in the width direction in the lower end part of the inner surface,

the cathode plate includes a plurality of the upper through openings in its upper end part that are formed in alignment with the plurality of respective upper openings in the cathode frame, and a plurality of the lower through openings in its lower end part that are formed in alignment with the plurality of respective lower openings in the cathode frame, and

the anode plate includes a plurality of the upper through openings in its upper end part that are formed in alignment with the plurality of respective upper openings in the anode frame,

and a plurality of the lower through openings in its lower end part that are formed in alignment with the plurality of respective lower openings in the anode frame.

Suitably, the upper opening and the lower opening in the cathode frame and the upper through opening and the lower through opening in the cathode plate are circular in cross-section, and

the upper opening and the lower opening in the anode frame and the upper through opening and the lower through opening in the anode plate are circular in cross-section.

Suitably, the cathode plate and the anode plate are formed of a rectangular plate.

[0011]

In order to achieve the another technical object of the present invention, the above-described electrolytic cell further includes:

a gasket interposed between the cathode frame and the cathode plate, the gasket including an upper communicating opening through which the upper opening in the cathode frame and the upper through opening in the cathode plate communicate with each other, and a lower communicating opening through which the lower opening in the cathode frame and the lower through opening in the cathode plate communicate with each other; and

a gasket interposed between the anode frame and the anode plate, the gasket including an upper communicating opening through which the upper opening in the anode frame and the upper through opening in the anode plate communicate with each other, and a lower communicating opening through which the lower opening in the anode frame and the lower through opening in the anode plate communicate with each other.

The upper communicating opening is larger than the upper opening and the upper through opening, and the lower communicating opening is larger than the lower opening and the lower through opening.

[0012]

Suitably, the upper opening, the upper through opening, the upper communicating opening, the lower opening, the lower through opening, and the lower communicating opening are circular in cross-section.

5 [0013]

In order to achieve the still another technical object of the present invention, the above-described electrolytic cell further includes a covering member attached to the upper through opening and the lower through opening in each of the cathode plate and the anode plate, the covering member covering an inner peripheral surface of each of the upper through opening and the lower through opening and a region that is adjacent to each of the upper through opening and the lower through opening and is not covered with the gasket on a reverse side of each of the cathode plate and the anode plate.

15 [0014]

Preferably, the covering member includes a tube portion to be inserted in each of the upper through opening and the lower through opening and a flange portion that protrudes from a back end of the tube portion.

Suitably, the tube portion of the covering member is cylindrical in shape, and the upper opening, the upper through opening, the upper communicating opening, the lower opening, the lower through opening, and the lower communicating opening are circular in cross-section,

the upper through opening and the lower through opening have an inner diameter larger than an inner diameter of the upper opening and the lower opening by twice a thickness of the tube portion of the covering member, and the tube portion of the covering member has an inner diameter the same as the inner diameter of the upper opening and the lower opening,

the tube portion has a length the same as a thickness of the cathode plate,

the flange portion of the covering member is annular in shape and has an outer diameter the same as an inner diameter

of the upper communicating opening and the lower communicating opening, and

the flange portion has a thickness the same as a thickness of the gasket.

5 Suitably, the covering member is made of a synthetic resin.

[0015]

The above-described electrolytic cell is suitably used to produce an aqueous solution of quaternary ammonium hydroxide from an aqueous solution of quaternary ammonium salt as a raw material by including at least one cation exchange membrane between the cathode plate and the anode plate.

Effects of the Invention:

15 [0016]

In the electrolytic cell constructed in accordance with the present invention to achieve the above-described primary technical object, each of the cathode plate and the anode plate extends continuously from above the upper opening to below the lower opening formed in each of the cathode frame and the anode frame, and each of the cathode plate and the anode plate has an upper through opening and a lower through opening formed in alignment with the upper opening and the lower opening, respectively. As such, each of the cathode plate and the anode plate extends over approximately the entire inner surface of each of the cathode frame and the anode frame. Therefore, the current-carrying area of the cathode plate and the anode plate is relatively large for the size of the electrolytic cell, resulting in increased electrolysis efficiency.

30 [0017]

In the electrolytic cell constructed in accordance with the present invention to achieve the above-described another technical object, the upper communicating opening is larger than the upper opening and the upper through opening, and the lower communicating opening is larger than the lower opening

and the lower through opening. Therefore, even when the gasket is swollen after continued operation of the electrolytic cell, the communication between the upper opening and the upper through opening and the communication between the lower opening and the lower through opening will never be impaired.

[0018]

The electrolytic cell constructed in accordance with the present invention to achieve the above-described still another technical object includes a covering member attached to the upper through opening and the lower through opening in each of the cathode plate and the anode plate. The covering member covers an inner peripheral surface of each of the upper through opening and the lower through opening and a region that is adjacent to each of the upper through opening and the lower through opening and is not covered with the gasket on a reverse side of each of the cathode plate and the anode plate. Therefore, the cathode plate and the anode plate can be effectively prevented from being corroded galvanically or metallicity.

Brief Description of the Drawings:

[0019]

[FIG. 1]: a schematic cross-sectional view showing a preferred embodiment of an electrolytic cell constructed in accordance with the present invention;

[FIG. 2]: a schematic cross-sectional view showing a cathode frame and a cathode plate in the electrolytic cell shown in Figure 1, taken along the line II-II in Figure 1;

[FIG. 3]: a partially enlarged cross-sectional view showing an upper opening in the cathode frame, an upper through opening formed in the cathode plate, and an upper communicating opening formed in a gasket, in the electrolytic cell shown in Figure 1;

[FIG. 4]: a partially enlarged cross-sectional view showing a modification in which a covering member is attached to the upper through opening in the cathode plate (and an anode plate); and

[FIG. 5]: a perspective view of the covering member shown in Figure 4.

Mode for Carrying out the Invention:

5 [0020]

Hereinafter, a preferred embodiment of an electrolytic cell constructed in accordance with the present invention will be described in further detail with reference to the accompanying drawings.

10 [0021]

Referring to Figures 1 and 2, the illustrated electrolytic cell constructed in accordance with the present invention includes a hollow rectangular housing 2 constructed from a cathode frame 4 (Figure 1), an anode frame 6 (Figure 1),
15 a cathode side upper wall member 8, an anode side upper wall member 10, a cathode side lower wall member 12, an anode side lower wall member 14, a cathode side front wall member 16 (Figure 2), an anode side front wall member (not shown), a cathode side back wall member 18 (Figure 2), and an anode side back wall member
20 (not shown). The cathode frame 4, the anode frame 6, the cathode side front wall member 16, the anode side front wall member, the cathode side back wall member 18, and the anode side back wall member extend substantially vertically, while the cathode side upper wall member 8, the anode side upper wall member 10,
25 the cathode side lower wall member 12, and the anode side lower wall member 14 extend substantially horizontally. The base end surface (i.e., the right end surface in Figure 1) of the cathode side upper wall member 8 is connected to an upper end edge part of the inner surface of the cathode frame 4 by appropriate
30 connecting means such as a fastening screw or an adhesive, and the base end surface (i.e., the right end surface in Figure 1) of the cathode side lower wall member 12 is connected to a lower end edge part of the inner surface of the cathode frame 4 by appropriate connecting means. Similarly, the base end surface
35 (i.e., the left end surface in Figure 1) of the anode side upper

wall member 10 is connected to an upper end edge part of the inner surface of the anode frame 6 by appropriate connecting means, and the base end surface (i.e., the left end surface in Figure 1) of the anode side lower wall member 14 is connected to a lower end edge part of the inner surface of the anode frame 6 by appropriate connecting means. The cathode side front wall member 16 and the anode side front wall member are connected to the front surface of the cathode frame 4 and the front surface of the anode frame 6, respectively, by appropriate connecting means, while the cathode side back wall member 18 and the anode side back wall member are connected to the back surface of the cathode frame 4 and the back surface of the anode frame 6, respectively, by appropriate connecting means. The upper wall member 8, 10 and the lower wall member 12, 14 on the cathode or anode side, as well as the front wall member 16 and the back wall member 18 are connected to the cathode frame 4 or the anode frame 6 in the above-described manner. Alternatively, these wall members may be integrally formed in advance before being connected to the cathode frame 4 or the anode frame 6.

Alternatively, the wall members may be integrally formed with the cathode frame 4 or the anode frame 6. When the upper wall member 8, 10 and the lower wall member 12, 14 as well as the front wall member 16 and the back wall member 18 are integrally formed, they may be fixed to the cathode frame 4 or the anode frame 6 via a seal member. In such a case, a gasket 38, 62 (described later), which corresponds in size to the cathode plate 32 or an anode plate 56, may be extended to correspond to the cathode frame 4 or the anode frame 6 so that the extended portion can serve as the seal member. Each of the cathode frame 4, the anode frame 6, the cathode side upper wall member 8, the anode side upper wall member 10, the cathode side lower wall member 12, the anode side lower wall member 14, the cathode side front wall member 16, the anode side front wall member, the cathode side back wall member 18, and the anode side back wall member may be in the form of a solid block or plate except for

openings and flow paths (described later), and can be made of an appropriate synthetic resin, such as an olefin-based resin (e.g., polypropylene or polyethylene), a vinyl chloride-based resin, or a fluorine-based resin. An appropriate sealing member (not shown), such as a gasket, can be placed in each interconnection region between the cathode frame 4, the anode frame 6, the cathode side upper wall member 8, the anode side upper wall member 10, the cathode side lower wall member 12, the anode side lower wall member 14, the cathode side front wall member 16, the anode side front wall member, the cathode side back wall member 18, and the anode side back wall member.

[0022]

Still referring to Figures 1 and 2 as well as Figure 3, in an upper end part of the inner surface (i.e., the left surface in Figure 1) of the cathode frame 4, a plurality of (e.g., three in the drawing) upper openings 20 (one of which is shown by a dashed line and a solid line in Figures 1 and 3, respectively) are formed at regular intervals in the width direction (i.e., the direction perpendicular to the paper plane in Figure 1; the horizontal direction in Figure 2). The cathode frame 4 includes a plurality of (e.g., three in the drawing) upper flow paths 22 (one of which is shown by a dashed line and a solid line in Figures 1 and 3, respectively), each extending substantially horizontally from each of the upper openings 20 to penetrate through the cathode frame 4. Similarly, in a lower end part of the inner surface (i.e., the left surface in Figure 1) of the cathode frame 4, a plurality of (e.g., three in the drawing) lower openings 24 (one of which is shown by a dashed line in Figure 1) are formed at regular intervals in the width direction (i.e., the direction perpendicular to the paper plane in Figure 1; the horizontal direction in Figure 2). The cathode frame 4 includes a plurality of (e.g., three in the drawing) lower flow paths 26 (one of which is shown by a dashed line in Figure 1), each extending substantially horizontally from each of the lower openings 24 to penetrate through the cathode frame 4. The

upper openings 20 and the lower openings 24 may be circular, and the upper flow paths 22 and the lower flow paths 26 may be circular in cross-section to match the circular shape of the upper openings 20 and the lower openings 24. The upper flow paths 22 and the lower flow paths 26 are connected to each other by an outside flow path 31 (partially shown in Figure 2) provided on the outside of the housing 2. The outside flow path 31 is provided with a circulating pump, a product storage tank, a plurality of valve members for flow control, and the like. (A detailed description of the outside flow path and the aforementioned components provided therein will be omitted herein as they are well known to those skilled in the art.) [0023]

The cathode plate 32 is fixed to the inner surface of the cathode frame 4. It is important for the cathode plate 32 to extend continuously from above the upper openings 20 formed in the cathode frame 4 to below the lower openings 24 formed in the cathode frame 4. In the illustrated embodiment, the cathode plate 32, which is constructed from a rectangular plate formed of appropriate conductive metal such as nickel, is located such that: its upper end surface abuts or is close to the inner surface (i.e., the lower surface) of the cathode side upper wall member 8; its lower end surface abuts or is close to the inner surface (i.e., the upper surface) of the cathode side lower wall member 12; its front side surface abuts or is close to the inner surface (i.e., the back surface) of the front wall member 16; and its back side surface abuts or is close to the inner surface (i.e., the front surface) of the back wall member 18. The cathode plate 32 can be fixed to the cathode frame 4 suitably by, for example, inserting a fastening screw (not shown) in each corner of the cathode plate 32 so that the cathode plate 32 is screwed to the cathode frame 4. In an upper end part of the cathode plate 32, a plurality of (e.g., three in the drawing) upper through openings 34 are formed at regular intervals in the width direction (i.e., the direction perpendicular to the paper plane

in Figure 1; the horizontal direction in Figure 2). In a lower end part of the cathode plate 32, a plurality of (e.g., three in the drawing) lower through openings 36 are formed at regular intervals in the width direction (i.e., the direction perpendicular to the paper plane in Figure 1; the horizontal direction in Figure 2). It is important for the upper through openings 34 formed in the cathode plate 32 to be located in alignment with the respective upper openings 20 formed in the upper end part of the cathode frame 4. In the illustrated embodiment, the upper through openings 34 have the same shape (i.e., a circular shape) and dimensions as the upper openings 20. Similarly, it is important for the lower through openings 36 formed in the cathode plate 32 to be located in alignment with the respective lower openings 24 formed in the lower end part of the cathode frame 4. In the illustrated embodiment, the lower through openings 36 have the same shape (i.e., a circular shape) and dimensions as the lower openings 24. It is preferable that the upper through openings 34 (and the upper openings 20) are located close to the upper end of the cathode plate 32 and that the lower through openings 36 (and the lower openings 24) are located close to the lower end of the cathode plate 32.

[0024]

In the illustrated embodiment, the cathode frame 4 includes the plurality of upper openings 20 and lower openings 24 formed at regular intervals in the width direction, and the cathode plate 32 includes the plurality of upper through openings 34 and lower through openings 36 formed at regular intervals in the width direction. Alternatively, if desired, the cathode frame 4 can include a single upper opening and a single lower opening that are elongated in the width direction, and the cathode plate 32 can include a single upper through opening and a single lower through opening that are elongated in the width direction.

[0025]

Still referring to Figures 1 and 3, in the illustrated embodiment, the gasket 38 is suitably interposed between the cathode frame 4 and the cathode plate 32. The gasket 38 helps to stably fix the cathode plate 32 to the cathode frame 4 and to prevent, for example, corrosion resulting from liquid infiltration at the interface between the cathode frame 4 and the cathode plate 32. The gasket 38 may be formed of a rectangular plate with substantially the same dimensions as the cathode plate 32 (or alternatively, the gasket 38 can also be sized to correspond to the cathode frame 4 as mentioned above). The gasket 38 can be made of an appropriate elastomer, such as silicone rubber, ethylene propylene rubber, chloroprene rubber, non-rigid PVC, butyl rubber, butadiene rubber, or fluoro rubber. When the gasket 38 is interposed between the cathode frame 4 and the cathode plate 32, a fastening screw (not shown) may be inserted in each corner of the cathode plate 32 so that the cathode plate 32 together with the gasket 38 can be screwed to the cathode frame 4. In an upper end part of the gasket 38, a plurality of (e.g., three in the drawing) upper communicating openings 40 are formed, through which the upper through openings 34 formed in the cathode plate 32 and the upper openings 20 formed in the cathode frame 4 communicate respectively with each other. In a lower end part of the gasket 38, a plurality of (e.g., three in the drawing) lower communicating openings 42 are formed, through which the lower through openings 36 formed in the cathode plate 32 and the lower openings 24 formed in the cathode frame 4 communicate respectively with each other. As is clearly understood from Figure 3, the upper communicating opening 40 and the lower communicating opening 42 formed in the gasket 38 are desired to be larger than the upper through opening 34 and the upper opening 20, as well as the lower through opening 36 and the lower opening 24. As will be understood from Examples below, when the upper communicating opening 40 and the lower communicating opening 42 formed in the gasket 38 have substantially the same dimensions as the upper through opening

34 and the upper opening 20, as well as the lower through opening 36 and the lower opening 24, the communication between the upper through opening 34 and the upper opening 20 and the communication between the lower through opening 36 and the lower opening 24 tend to be insufficient or impaired after continued operation of the electrolytic cell, because the gasket 38 is somewhat swollen and causes the upper communicating opening 40 and the lower communicating opening 42 to be reduced in size and displaced. The upper communicating opening 40 and the lower communicating opening 42 may be in the shape of a circle with a diameter larger by a predetermined amount than that of the upper through opening 34 and the upper opening 20, as well as the lower through opening 36 and the lower opening 24. The upper communicating opening 40 and the lower communicating opening 42 do not always have to be concentric but can be eccentric with respect to the upper through opening 34 and the upper opening 20, and the lower through opening 36 and the lower opening 24, respectively. The diameter of the upper communicating opening 40 and the lower communicating opening 42 and the degree of their eccentricity with respect to the upper through opening 34 and the upper opening 20, and the lower through opening 36 and the lower opening 24, respectively, can be set on an experimental basis based on the swelling and displacement of the gasket 38 caused by continued operation of the electrolytic cell. When the upper communicating opening 40 and the lower communicating opening 42 formed in the gasket 38 are larger, the communication between the respective openings is less likely to be insufficient or impaired. However, the larger upper communicating opening 40 and lower communicating opening 42 increase the area of contact with a liquid on the rear surface of the cathode plate 32, which results in galvanic or metallic corrosion, so that an increased amount of electrode metal is contained in the liquid, as described later. Accordingly, each preferred size of the upper communicating opening 40 and the lower communicating opening 42 formed in the gasket 38 is

provided as follows:

The size of the upper communicating opening 40 is larger than each size of the upper through opening 34 and of the upper opening 20, respectively, by 30 mm or less, preferably 20 mm or less, and more preferably 10 mm or less. The size of the lower communicating opening 42 is larger than each size of the lower through opening 36 and of the lower opening 24, respectively, by 30 mm or less, preferably 20 mm or less, and more preferably 10 mm or less. Meanwhile, when the gasket 38 is made of a material that hardly swells, the communication between the respective openings is less likely to be insufficient or impaired even when the upper communicating opening 40 and the lower communicating opening 42 are close in size to the upper through opening 34 and the upper opening 20, as well as the lower through opening 36 and the lower opening 24. As such, the material for the gasket 38 preferably has a coefficient of linear expansion of 3×10^{-4} ($1/^{\circ}\text{C}$) or less, more preferably 1.5×10^{-4} ($1/^{\circ}\text{C}$) or less, and most preferably 1×10^{-4} ($1/^{\circ}\text{C}$) or less.

[0026]

In the illustrated embodiment, the anode frame 6 is substantially the same as the above-described cathode frame 4. More specifically, the cathode frame 4 and the anode frame 6 are symmetric with respect to a virtual plane extending therebetween perpendicularly to the paper plane in Figure 1. As such, the anode frame 6 includes upper openings 44, upper flow paths 46, lower openings 48, and lower flow paths 50. To avoid duplication of description, the upper openings 44, the upper flow paths 46, the lower openings 48, and the lower flow paths 50 will not be described in detail. The upper flow paths 46 and the lower flow paths 50 are connected to each other by an outside flow path (not shown) provided on the outside of the housing 2. The outside flow path is provided with a circulating pump, a product storage tank, a plurality of valve members for flow control, and the like. (A detailed description of the

outside flow path and the aforementioned components provided therein will be omitted herein as they are well known to those skilled in the art.)

[0027]

5 The anode plate 56 is fixed to the inner surface of the anode frame 6. In the illustrated embodiment, the anode plate 56 is substantially the same as the above-described cathode plate 32, except that it is made of an appropriate conductive metal suitable for an anode, such as titanium with an indium
10 oxide plated surface. More specifically, the cathode plate 32 and the anode plate 56 are symmetric with respect to a virtual plane extending therebetween perpendicularly to the paper plane in Figure 1. As such, the anode plate 56 has a rectangular shape that extends continuously from above the upper openings 44
15 formed in the anode frame 6 to below the lower openings 48 formed in the anode frame 6. The anode plate 56 includes upper through openings 58 and lower through openings 60 located in alignment with the upper openings 44 and the lower openings 48, respectively, formed in the anode frame 6. To avoid duplication
20 of description, the anode plate 56 will not be described in detail.

[0028]

 In the illustrated embodiment, the gasket 62 is interposed also between the anode frame 6 and the anode plate
25 56. The gasket 62 is also substantially the same as the gasket 38 interposed between the cathode frame 4 and the cathode plate 32. More specifically, the gasket 38 and the gasket 62 are symmetric with respect to a virtual plane extending therebetween perpendicularly to the paper plane in Figure 1.
30 As such, the gasket 62 includes upper communicating openings 64 through which the upper openings 44 formed in the anode frame 6 and the upper through openings 58 formed in the anode plate 56 communicate respectively with each other, and lower communicating openings 66 through which the lower openings 48
35 formed in the anode frame 6 and the lower through openings 60

formed in the anode plate 56 communicate respectively with each other. To avoid duplication of description, the gasket 62, the upper communicating opening 64, and the lower communicating opening 66 will not be described in detail.

5 [0029]

As is clearly understood from Figure 1, a cation exchange membrane 68 is provided between the cathode plate 32 and the anode plate 56 in the illustrated embodiment. The cation exchange membrane 68, which may be in a form known per se, is in the shape of a rectangular plate, and is located such that: its upper end edge part is held between the cathode side upper wall member 8 and the anode side upper wall member 10; its lower end edge part is held between the cathode side lower wall member 12 and the anode side lower wall member 14; its edge part on the front surface side of the cathode frame 4 and the anode frame 6 is held between the cathode side front wall member 16 and the anode side front wall member; and its edge part on the back surface side of the cathode frame 4 and the anode frame 6 is held between the cathode side back wall member 18 and the anode side back wall member. An appropriate seal member (not shown) can be placed between the cation exchange membrane 68 and each of the cathode side upper wall member 8, the anode side upper wall member 10, the cathode side lower wall member 12, the anode side lower wall member 14, the cathode side front wall member 16, the anode side front wall member, the cathode side back wall member 18, and the anode side back wall member.

[0030]

In the electrolytic cell as described above, a cathode or product compartment 70 is defined between the cathode plate 32 and the cation exchange membrane 68, and an anode, that is, material compartment 72 is defined between the anode plate 56 and the cation exchange membrane 68. At an early stage, a dilute aqueous solution of quaternary ammonium hydroxide (or pure water) is circulated through the product compartment 70. More specifically, the solution flows into the product compartment

70 through either of the lower flow paths 26 or the upper flow paths 22 formed in the cathode frame 4 and flows out of the product compartment 70 through the other flow paths. At the same time, an aqueous solution of quaternary ammonium salt is circulated through the material compartment 72. More specifically, the solution flows into the material compartment 72 through either of the lower flow paths 50 or the upper flow paths 46 formed in the anode frame 6 and flows out through the other flow paths. An electrolytic voltage is applied between the cathode plate 32 and the anode plate 56. Thus, the aqueous solution of quaternary ammonium hydroxide circulated through the product compartment 70 gradually increases in concentration. A detailed description of such an electrolytic action will be omitted herein as it is well known to those skilled in the art. According to the electrolytic cell constructed in accordance with the present invention, the cathode plate 32 and the anode plate 56 extend continuously from above the upper openings 20 and 44 to below the lower openings 24 and 48 formed in the cathode frame 4 and the anode frame 6, respectively. The cathode plate 32 and the anode plate 56 include the upper through openings 34 and 58 and the lower through openings 36 and 60 formed in alignment with the upper openings 20 and 44 and the lower openings 24 and 48, respectively. As such, the cathode plate 32 and the anode plate 56 extend over approximately the entire inner surfaces of the cathode frame 4 and the anode frame 6, respectively. Thus, the current-carrying area of the cathode plate 32 and the anode plate 56 is relatively large for the size of the electrolytic cell, with result that electrolysis is conducted by increased electrolysis efficiency.

[0031]

Figure 4 shows a modification of the above-described preferred embodiment of the electrolytic cell constructed in accordance with the present invention. In the modification shown in Figure 4, a covering member 74 is attached with the cathode plate 32 to cover the inner peripheral surface of each

of the upper through openings 34 (and the lower through openings 36) in the cathode plate 32 and a region that is adjacent to each of the upper through openings 34 (and the lower through openings 36) and is not covered with the gasket 38 on the reverse side (i.e., the right side in Figure 4) of the cathode plate 32. Figure 4 shows one of the upper through openings 34 in the cathode plate 32 and one of the covering members 74 attached thereto. As is clearly understood from Figures 4 and 5, the covering member 74 shown in the drawings includes a cylindrical tube portion 76 to be inserted in the upper through opening 34, and an annular flange portion 78 protruding from the back end (i.e., the right end in Figure 4) of the tube portion 76. The covering member 74 is preferably made of a synthetic resin that has a small coefficient of thermal expansion and is excellent in electrical insulation, heat resistance, and resistance to an aqueous solution of quaternary ammonium hydroxide to be circulated. Examples of such a synthetic resin include an olefin-based resin such as polypropylene or polyethylene, and a fluorine-based resin such as perfluoroalkoxy alkane (PFA) or polytetrafluoroethylene (PTFE).

[0032]

In the modification shown in Figure 4, the inner diameter of the upper through opening 34 formed in the cathode plate 32 is set to be larger than the inner diameter of the upper opening 20 formed in the cathode frame 4 by twice the thickness of the tube portion 76 of the covering member 74. The outer diameter of the tube portion 76 of the covering member 74 is the same as the inner diameter of the upper through opening 34, and the inner diameter of the tube portion 76 of the covering member 74 is the same as the inner diameter of the upper flow path 22. The length of the tube portion 76 of the covering member 74 is the same as the thickness of the cathode plate 32. The outer diameter of the flange portion 78 of the covering member 74 is the same as the inner diameter of the upper communicating opening 40 formed in the gasket 38, and the thickness of the

flange portion 78 of the covering member 74 is the same as the thickness of the gasket 38. In a case where the gasket 38 is so flexible that it is squashed thin when the cathode plate 32 is fixed to the cathode frame 4, the thickness of the flange portion 78 of the covering member 74 is suitably adjusted to match the thickness of the thinned gasket 38. Prior to fixing the cathode plate 32 and the gasket 38 to the cathode frame 4, the tube portion 76 of the covering member 74 is inserted in the upper through opening 34 from the reverse side (i.e., the right side in Figure 4) of the cathode plate 32 until the front surface (i.e., the left surface in Figure 4) of the flange portion 78 abuts the rear surface of the cathode plate 32, whereby the inner peripheral surface of the upper through opening 34 formed in the cathode plate 32 is covered with the tube portion 76 of the covering member 74, while the portion that is not covered with the gasket 38 on the reverse side of the cathode plate 32 is covered with the flange portion 78 of the covering member 74, as shown in Figure 4.

[0033]

The present inventors have learned through experience that after continued operation of the electrolytic cell, the cathode plate 32 without the covering member 74 attached to each of the upper through openings 34 and the lower through openings 36 tends to suffer from galvanic or metallic corrosion, as shown by a phantom line 80 in Figure 4, on the inner peripheral surface of each of the upper through openings 34 and the lower through openings 36 in the cathode plate 32 and in the region that is not covered with the gasket 38 on the reverse side of the cathode plate 32. To the contrary, the cathode plate 32 with the covering member 74 attached to each of the upper through openings 34 and the lower through openings 36 can be effectively prevented from being corroded galvanically or metallicity.

[0034]

The description has been given of the covering member 74 for the upper through opening 34 in the cathode plate 32.

However, the covering member 74 can also be attached to each of the lower through openings 36 in the cathode plate 32 and the upper through openings 58 and lower through openings 60 in the anode plate 56.

5 [0035]

Examples 1 to 6

The electrolytic cells according to the embodiment shown in Figures 1 to 3 were prepared, one of which included the covering member shown in Figures 4 and 5, and then operated.
10 The electrolytic cells were examined for the state of the upper and lower communicating openings formed in the gasket interposed between the cathode plate and the cathode frame, and for the concentration of metal (nickel) contained in a product. The results are shown in Table 1.

15 [0036]

In Table 1, the state of the communicating openings was evaluated as follows: "Gasket not protruding" indicates that the communicating openings were less than 10% blocked; "Gasket protruding" indicates that the communicating openings were 10%
20 or more blocked but were not completely blocked; and "Blocked" indicates that the communicating openings were blocked such that no product could flow.

Component details and operating conditions of the electrolytic cells were as follows.

25 Operating time: 30 days

Cathode: Nickel plate (thickness: 2 mm; surface area: 1 m × 1 m)

Anode: Titanium plate with an indium oxide plated surface (thickness: 2 mm; surface area: 1 m × 1 m)

30 Number of through openings in cathode plate: 10 upper through openings (outlets) and 10 lower through openings (inlets)

Number of through openings in anode plate: 10 upper through openings (outlets) and 10 lower through openings
35 (inlets)

Cation exchange membrane: Exchange membrane (thickness: 1 mm) marketed by The Chemours Company under the product name of "N324"

5 Raw material: Aqueous solution of tetramethylammonium chloride

Product: Aqueous solution of tetramethylammonium hydroxide

10 Cross-sectional shape of flow path: Circle with a diameter of 10 mm, which applies to all of the upper and lower openings and upper and lower flow paths in the cathode and anode frames, as well as the upper and lower through openings in the cathode and anode plates.

15 Covering member: Member of polypropylene, with a tube portion outer diameter of 10 mm, a tube portion inner diameter of 8 mm, a tube portion length of 2 mm, a flange portion outer diameter of 16 mm, and a flange portion thickness of 1 mm

Current: 1000 A (10 A/dm²)

Operating temperature: 70°C

20 Temperature during assembly of electrolytic cell: 20°C

[0037]

[Table 1]

	State of communicating openings			Concentration of metal contained (ppt)	Gasket			Covering member
	Gasket not protruding	Gasket protruding	Blocked		Material	Diameter of communicating openings (mm)	Coefficient of linear expansion ($10^{-4}/^{\circ}\text{C}$)	
Example 1	0	16	4	254	EPDM	10	1.8	Absent
Example 2	15	5	0	260	EPDM	16	1.8	Absent
Example 3	20	0	0	34	EPDM	16	1.8	Present
Example 4	19	1	0	189	Fluoro rubber	16	1	Absent
Example 5	0	14	6	270	Silicone rubber	16	3.2	Absent
Example 6	20	0	0	1147	EPDM	30	1.8	Absent

[0038]

The preferred embodiment of the present invention has been described in detail with reference to the accompanying drawings. However, the present invention is not limited to this embodiment, and various modifications and alterations can be made without departing from the technical scope of the present invention. For example, in the illustrated embodiment, the single cation exchange membrane 68 is provided between the cathode plate 32 and the anode plate 56. However, the present invention is also applicable to an electrolytic cell including a plurality of exchange membranes (i.e., a cation exchange membrane and an anion exchange membrane) between the cathode plate 32 and the anode plate 56.

15 Explanations of Letters or Numerals:

[0039]

- 2: Housing of electrolytic cell
- 4: Cathode frame
- 6: Anode frame
- 20 8: Cathode side upper wall member
- 10: Anode side upper wall member
- 12: Cathode side lower wall member
- 14: Anode side lower wall member
- 16: Cathode side front wall member
- 25 18: Cathode side back wall member
- 20: Upper opening
- 22: Upper flow path
- 24: Lower opening
- 26: Lower flow path
- 30 31: Outside flow path
- 32: Cathode plate
- 34: Upper through opening
- 36: Lower through opening
- 38: Gasket
- 35 40: Upper communicating opening

- 42: Lower communicating opening
- 44: Upper opening
- 46: Upper flow path
- 48: Lower opening
- 5 50: Lower flow path
- 56: Anode plate
- 58: Upper through opening
- 60: Lower through opening
- 62: Gasket
- 10 64: Upper communicating opening
- 66: Lower communicating opening
- 68: Cation exchange membrane
- 70: Product compartment (cathode compartment)
- 72: Material compartment (anode compartment)
- 15 74: Covering membrane
- 76: Tube portion
- 78: Flange portion
- 80: Galvanic or metallic corrosion

Claims

[Claim 1]

An electrolytic cell comprising: a cathode frame, a
5 cathode plate fixed to an inner surface of the cathode frame,
an anode frame, and an anode plate fixed to an inner surface
of the anode frame, wherein

the cathode frame includes at least one upper flow path
extending from an upper opening located in an upper end part
10 of the inner surface and at least one lower flow path extending
from a lower opening located in a lower end part of the inner
surface,

the anode frame includes at least one upper flow path
extending from an upper opening located in an upper end part
15 of the inner surface and at least one lower flow path extending
from a lower opening located in a lower end part of the inner
surface,

the cathode plate extends continuously from above the
upper opening of the cathode frame to below the lower opening
20 of the cathode frame,

the cathode plate includes at least one upper through
opening in its upper end part that is formed in alignment with
the upper opening in the cathode frame, and at least one lower
through opening in its lower end part that is formed in alignment
25 with the lower opening in the cathode frame,

the anode plate extends continuously from above the upper
opening of the anode frame to below the lower opening of the
anode frame, and

the anode plate includes at least one upper through
30 opening in its upper end part that is formed in alignment with
the upper opening in the anode frame, and at least one lower
through opening in its lower end part that is formed in alignment
with the lower opening in the anode frame.

35 [Claim 2]

The electrolytic cell according to claim 1, wherein
the cathode frame includes a plurality of the upper flow
paths extending respectively from a plurality of the upper
openings arranged at intervals in a width direction in the upper
end part of the inner surface, and a plurality of the lower flow
5 paths extending respectively from a plurality of the lower
openings arranged at intervals in the width direction in the
lower end part of the inner surface,

the anode frame includes a plurality of the upper flow
10 paths extending respectively from a plurality of the upper
openings arranged at intervals in the width direction in the
upper end part of the inner surface, and a plurality of the lower
flow paths extending respectively from a plurality of the lower
openings arranged at intervals in the width direction in the
15 lower end part of the inner surface,

the cathode plate includes a plurality of the upper
through openings in its upper end part that are formed in
alignment with the plurality of respective upper openings in
the cathode frame, and a plurality of the lower through openings
20 in its lower end part that are formed in alignment with the
plurality of respective lower openings in the cathode frame,
and

the anode plate includes a plurality of the upper through
openings in its upper end part that are formed in alignment with
25 the plurality of respective upper openings in the anode frame,
and a plurality of the lower through openings in its lower end
part that are formed in alignment with the plurality of
respective lower openings in the anode frame.

30 [Claim 3]

The electrolytic cell according to claim 1 or 2, wherein
the upper opening and the lower opening in the cathode
frame and the upper through opening and the lower through
opening in the cathode plate are circular in cross-section, and
35 the upper opening and the lower opening in the anode frame

and the upper through opening and the lower through opening in the anode plate are circular in cross-section.

[Claim 4]

5 The electrolytic cell according to any one of claims 1 to 3, wherein the cathode plate and the anode plate are formed of a rectangular plate.

[Claim 5]

10 The electrolytic cell according to any one of claims 1 to 4, further comprising:

 a gasket interposed between the cathode frame and the cathode plate, the gasket including an upper communicating opening through which the upper opening in the cathode frame and the upper through opening in the cathode plate communicate with each other, and a lower communicating opening through which the lower opening in the cathode frame and the lower through opening in the cathode plate communicate with each other; and

 a gasket interposed between the anode frame and the anode plate, the gasket including an upper communicating opening through which the upper opening in the anode frame and the upper through opening in the anode plate communicate with each other, and a lower communicating opening through which the lower opening in the anode frame and the lower through opening in the anode plate communicate with each other.

[Claim 6]

 The electrolytic cell according to claim 5, wherein the upper communicating opening is larger than the upper opening and the upper through opening, and the lower communicating opening is larger than the lower opening and the lower through opening.

[Claim 7]

35 The electrolytic cell according to claim 6, wherein

the upper opening, the upper through opening, the upper communicating opening, the lower opening, the lower through opening, and the lower communicating opening are circular in cross-section.

5

[Claim 8]

The electrolytic cell according to claim 6 or 7, further comprising a covering member attached to the upper through opening and the lower through opening in each of the cathode plate and the anode plate, the covering member covering an inner peripheral surface of each of the upper through opening and the lower through opening and a region that is adjacent to each of the upper through opening and the lower through opening on a reverse side of each of the cathode plate and the anode plate and is not covered with the gasket.

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[Claim 9]

The electrolytic cell according to claim 8, wherein the covering member includes a tube portion to be inserted in each of the upper through opening and the lower through opening and a flange portion that protrudes from a back end of the tube portion.

20

[Claim 10]

The electrolytic cell according to claim 9, wherein the tube portion of the covering member is cylindrical in shape, and the upper opening, the upper through opening, the upper communicating opening, the lower opening, the lower through opening, and the lower communicating opening are circular in cross-section,

25
30

the upper through opening and the lower through opening have an inner diameter larger than an inner diameter of the upper opening and the lower opening by twice a thickness of the tube portion of the covering member, and the tube portion of the covering member has an inner diameter the same as the inner

35

diameter of the upper opening and the lower opening,

the tube portion has a length the same as a thickness of the cathode plate,

5 the flange portion of the covering member is annular in shape and has an outer diameter the same as an inner diameter of the upper communicating opening and the lower communicating opening, and

the flange portion has a thickness the same as a thickness of the gasket.

10

[Claim 11]

The electrolytic cell according to any one of claims 8 to 10, wherein the covering member is made of a synthetic resin.

15 [Claim 12]

A method for producing an aqueous solution of quaternary ammonium hydroxide from an aqueous solution of quaternary ammonium salt as a raw material using the electrolytic cell according to any one of claims 1 to 10 including at least one
20 cation exchange membrane between the cathode plate and the anode plate.