CONSTRUCTION OF ELECTROLYTIC CELL

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The present invention relates to an improvement in the construction of electrolytic cells; more particularly, the present invention relates to a new construction of an electrolytic cell, including the anode section, such cell being of a horizontal type useful in the electrolysis of fused salts.

The present invention is particularly applicable to the construction of cells which provide for the electrolysis of molten inorganic compounds at high temperatures wherein a molten metal is employed as the cathode. Cells of this type operating with an electrolyte of fused salt have been known for some time; thus, for example, such cells include the Acker cell, e.g., as described in U.S. Pat. 674,691, the Ashcroft cell, e.g., as disclosed in U.S. Pat. 1,159,154, the Hamprecht cell used in Germany during World War II and described in FIA Report No. 830, as well as the early Szechman cells represented by U.S. Patents 3,104,213, 3,167,492, 3,235,479, 3,244,609, and 3,274,082.

Each of the above-mentioned cells has in common the feature of utilizing a liquid cathode together with at least one fixed anode, generally a graphite anode supported from the top or cover of the cell and in electrical contact therewith.

In the most satisfactory commercial cells of the horizontal type to date, each graphite anode is in the form of a block having a substantially planar lower surface which is disposed at a predetermined distance from the surface of the flowing cathode. This distance is referred to as the anode-cathode "gap," and the voltage in the cell varies, of course, with the size of gap. During normal operation of the cell, each graphite anode is gradually worn away, and this wear is generally localized at the lower surface of the anode. Since the flow of the cathode remains substantially constant, wearing away of the lower surface of the anodes gradually increases the anode-cathode gap, and this increase in the size of the gap causes a gradual increase in the voltage. A certain amount of voltage increase can be tolerated but after it has reached a minimum practical value, which depends upon the particular cell, further increase in voltage must be prevented if economical operation of the cell is to be achieved. Accordingly, it has been customary to lower the anodes from time to time to reduce the anode-cathode gap to the optimum distance, e.g., the distance at which each anode was originally set when new. While such operation does, of course, compensate for the wear of the anodes and keeps the voltage within practicable operating limits, this method has certain practical disadvantages. The graphite anodes usually have a stem or support extending upwardly through the cover plate of the cell and to permit the lowering of the anodes to compensate for wear, as just described, it is necessary to provide for sliding movement of the anode stem in the cover plate. This makes necessary the provision of special means which will permit the sliding movement and yet which will retain the fluid-tightness of the cell. From a practical standpoint this presents many problems and is not wholly satisfactory. Various other proposals have been made to solve the problem of compensating for anode wear, but all suffer from one or more practical disadvantages and generally involve a complicated and expensive construction.

One such proposal to eliminate the problem associated with the use of such anodes is illustrated in U.S. Patent 3,244,609 to Szechman. Such patent discloses a horizontal electrolytic cell wherein a means is provided for adjusting the anode-cathode gap in the electrolysis chamber, the means comprising a vertically adjustable means for varying the level of the liquid cathode in relation to the anode. Such means includes a perforated overflow sleeve member slidably mounted in the electrolysis chamber in sealing engagement with the bottom of the chamber, the sleeve having an internal passageway communicating with the exterior of the chamber, with additional means threadably secured in the electrolysis chamber for vertically adjusting the sleeve member. Such a system is fairly successful in adjusting the gap of the electrolytic cell wherein the anodes are suspended by stems from the top or cover of the electrolytic cell. Since such a system of regulation is quite complicated and expensive, however, there has still been considerable desire to provide an even more efficient and effective means for eliminating the problem associated with anode wear etc.

In addition to the aforementioned problems with respect to electrolytic cell construction, particularly electrolytic cells of the horizontal type, efforts have been made in the past to provide a cell construction wherein air will be kept out of the electrolysis environment. For this purpose, a cover is usually provided which will be as air tight as possible. However, even with the best prior art covers employed for electrolytic cells, some air tends to infiltrate around the edges of the cover and also through the apertures which are provided for reception of the anode stems, which extend upwardly above the cover so that they can be suitably connected to a source of positive electrolytic current. While efforts have been made to reduce the quantity of air which tends to infiltrate into such electrolytic cells and horizontal electrolytic cells in particular, particularly around the stems of the anodes, none of the prior proposals has been entirely satisfactory and this problem, which is a major problem in the case of the electrolysis of molten salts, has remained generally unsolved.

It has now been discovered in accordance with the present invention that each of the above disadvantages of previous electrolytic cell construction, particularly, electrolytic cells of a horizontal type, can be eliminated through the construction of the present invention. In this regard, the present invention relates to an improvement in electrolytic cell construction wherein the anode of the electrolytic cell consists of an upper horizontal portion of graphite supported directly by the refractory wall of the bottom half of the cell, such anode being stronger and less susceptible to deviation than if the same were hanging from the top of the cell by stems or necks as in conventional electrolytic cell construction. Accordingly, such use of horizontal slabs of graphite as the anode portion of the horizontal electrolytic cell provides an improvement in that the anode is more rigidly positioned with respect
to the molten cathode surface, thereby lessening deviation in the cathode-anode gap during usage. In addition, the anodes are submerged slightly in the electrolyte employed, e.g., fused salt, and such fused salt wets the crack or gasket between the graphite and the refractory cell lining above and below the same and through the phenomenon of "freezing" provides a seal which prevents the entrance of air into the electrolytic cell and prevents the evolved gas from escaping where specifically designed. Accordingly, such a feature provides a vast improvement over a conventional horizontal electrolytic cell specifically adapted for the electrolysis of fused salts at high elevated temperatures.

Accordingly, it is a principal object of the present invention to provide an electrolytic cell construction, particularly of the horizontal type, which electrolytic cell construction eliminates disadvantages and deficiencies of previous constructions utilized for the electrolysis of fused salts.

It is a further object of the present invention to provide such an improved construction for electrolytic cells, particularly horizontal electrolytic cells wherein the anode consists of one or more horizontal slabs of graphite supported by the refractory wall of the bottom half of the cell.

It is yet a further object of the present invention to provide such an improved construction wherein such horizontal slabs of graphite are submerged slightly in the electrolyte so that the electrolyte, i.e., fused salt wets the crack or gasket between the graphite and the refractory cell lining above and below the same so as to produce air tight seals through a "freeze-seal" phenomenon.

It is still a further object of the present invention to provide such an improved construction for an electrolytic cell, particularly of the horizontal type wherein the refractory linings of the cell possess a substantially hollow cylindrical or spherical shape with approximately equal thicknesses throughout.

Yet further objects and advantages of the novel cell construction of the present invention will become more apparent from the following detailed description thereof in association with the drawings, wherein:

FIG. 1 is a longitudinal cross-sectional view of an electrolytic cell in accordance with the present invention, illustrating the relationship of the anode to the top and bottom halves of the electrolytic cell;

FIG. 2 is a cross-sectional view showing in enlarged section the juncture of anode and top and bottom halves of the refractory lining, also including a further modification of the cell construction;

FIG. 3 is a further enlarged view of the juncture of anode and top and bottom halves of the refractory lining at those portions where electrical contact is not made;

FIG. 4 is a further cross-sectional view of the juncture of anode and top and bottom halves of the refractory lining indicating an alternative modification of the structure of FIG. 2;

FIG. 5 is a top elevation view of an exemplary horizontal anode in accordance with the present invention; and

FIG. 6 is a further top view of a suitable anode showing a modification of openings.

The apparatus of the present invention constitutes an improvement in the basic electrolytic cell construction generally adapted for the electrolysis of fused salts, and sodium chloride, in particular. In this regard, such apparatus constitutes an improvement in horizontal electrolytic cells which allow for the electrolysis of sodium chloride or other similar salt by maintaining the same only slightly above the melting point of the electrolyte and having an electrolytical current through the molten salt by a graphite anode on the top and the molten metal cathode, e.g., lead cathode, on the bottom. Chlorine produced in such a process is given off through grooves and holes in the anode slabs and sodium is electrodeposited into the molten cathode. In this way, the sodium and chlorine are effectively kept apart so that they cannot readily recombine, thus, allowing for a high current efficiency in the electrolytic cell.

A high energy efficiency for the electrolytic cell is obtained by minimizing the voltage across the cell and specifically the IR drop across the electrolyte layer.

In such a process utilizing an electrolytic cell, including the improved electrolytic cell of the present invention, the sodium or similar metal is removed by causing the sodium-cathode, e.g., lead alloy, to flow from one end of the cell to the other, from where the sodium is partially removed by distillation, and the depleted sodium-lead alloy returned to the other end of the cell. The flow of the sodium-lead alloy in the above manner requires a small hydraulic gradient, or slope of the surface of the alloy lying underneath the molten sodium chloride layer, but otherwise the cathode-electrolyte interface is flat and essentially horizontal. Accordingly, with respect to such electrolytic cells, in order to maintain the thickness of the molten electrolyte uniform and at a controllable minimum, it is necessary that the anode face the anode be entirely parallel to the upper surface of the cathode. This can best be achieved in accordance with the present invention whereby the anode comprises one or more horizontal slabs positioned with respect to and held directly by the refractory lining of the bottom half of the cell. Thus, such an arrangement in accordance with the present invention, as will be discussed in more detail hereinafter is more advantageous than previous arrangements whereby the anodes were suspended from the cover of the electrolytic cell through anode stems. Thus, in such previous arrangements more thermal expansion and relative deflections tend to occur thereby eliminating the necessary parallelism between the lower surface of the anodes and the upper surface of the electrolyte.

In this regard, except for such arrangement of the anode and upper and lower halves of the refractory lining and other associated features to be hereinafter described, the remaining characteristics of the horizontal electrolytic cell of the present invention are conventional in the art and are as shown in the Szechman patents described above.

Turning to the drawings, like numerals indicate like elements throughout the several views. As seen in FIG. 1, the horizontal electrolytic cell 1 is such that the upper refractory lining 7 and lower refractory lining 9 form a substantially hollow cylindrical or spherical shape. In this regard, it is preferred in accordance with the present invention that where possible, the upper refractory lining 7 and lower refractory lining 9 are of the same thickness throughout, this feature increasing the strength of the lining against temperature gradients and against unwanted floating forces. It is, of course, obvious that the refractory material of the upper refractory lining 7 and lower refractory lining 9 are suitably prepared from the same refractory material which can be any conventional material generally employed in the formation of electrolytic cells and horizontal electrolytic cells in particular.

As seen in FIG. 1, the upper and lower halves of the refractory lining are surrounded by the cell body itself comprising the upper metallic shell 3 and lower metallic shell 5, generally corresponding to the shape of the upper refractory lining 7 and lower refractory lining 9 of the horizontal electrolytic cell. The upper and lower sections 3 and 5 of the metal shell constituting the body of the horizontal electrolytic cell of the present invention can be prepared from any conventional material generally utilized in the fabrication of electrolytic cells. Such materials are those which have the requisite characteristics of ability to conduct electricity and to be resistant to the temperatures to which the metal shell is heated during the electrolysis process. Preferably, the lower metallic shell is prepared from a nickel-clad mild steel with the nickel-clad surface facing downward, to resist atmospheric oxidation. Doubly nickel-clad mild steel, or pure nickel sheet,
is preferred for the upper shell, since nickel also effectively resists the action of dry chlorine gas up to a temperature of about 1,000°F, whereas straight steel resists such action only up to a temperature of about 300°F. Accordingly, while various metals can be effectively employed for the metal shell of the horizontal electrolytic cell, the use of the nickel-clad mild steel is preferred and has become conventional in the art.

As seen in FIG. 1, one or more horizontal anode slabs \( n \) are directly supported by the lower refractory lining \( 9 \) and extend across the whole depth of the electrolytic cell. Because of such arrangement of the horizontal anode slab in accordance with the present invention, electrical contact cannot be made through the top or cover of the electrolytic cell as in accordance with conventional horizontal cell constructions. As in conventional horizontal electrolytic cells, electrical contact through the cathode is obtained through an electrical lead \( 19 \) connected to the lower metal shell \( 5 \). This is suitably accomplished by having apertures \( 12 \) in the refractory lining so that over a minor portion of the surface area of the bottom of the electrolytic cell the cathode metal is directly in contact with the technique for obtaining a reactive cell. According to the electrical contact through the cathode, metallic shell \( 5 \) and electrical lead \( 19 \).

In accordance with the embodiments of the present invention as illustrated in FIG. 1, the other electrical connection is made directly with the horizontal anode utilizing no other conductor but the graphite of the anode in contact with the electrolyte and chlorine. This is accomplished in accordance with the embodiment of FIG. 1 by having the horizontal anode \( 11 \) extend outwardly to the edge of the upper refractory lining \( 7 \) and lower refractory lining \( 9 \). The necessary electrical contact is made from the anode \( 11 \) through a bushar or contact \( 21 \) which extends in contact with the anode between the anode surface and the refractory lining \( 7 \), over a portion of the surface of the anode \( 11 \) in juxtaposition with the refractory linings \( 7 \) and \( 9 \). The electrical current is applied to the bushar through a flexible electrical lead \( 23 \) attached thereto.

It is noted in FIG. 1 that the edges of the upper metal shell \( 13 \) and lower metal shell \( 8 \) have flanges \( 17 \) which allow for the clamping of the halves of the cell body together so as to obtain a good seal between the upper and lower halves of the cell so as to prevent the introduction of air and to prevent the exit of electrolyte and evolved chlorine. The elimination of the top and lower halves of the electrolytic cell is achieved through a bolt \( 25 \) or similar mechanical clamping means extending through flanges \( 17 \). It will be noted by reference to FIG. 1 that at that portion where electrical connection is made through the anode \( 11 \) the upper and lower sections of the refractory linings \( 7 \) and \( 9 \) are separated from another by a distance substantially equivalent to the thickness of the anode \( 11 \) and the bus or lug \( 21 \).

In accordance with the present invention, an effective seal for the exit of electrolyte and evolved chlorine and for the entrance of air is obtained by the "freeze-seal" phenomenon. In this regard, in many environments a valuable technique for obtaining a molten bath is by freezing the same at its outer reaches. This is done in some processes in which salts or oxides are melted by application of heat locally, such as by an arc at the center of the pool. In such processes, the pool is held in a cooled shell so that although the material is molten in the center of the pool the material against the outer shell is frozen and protects the shell from overheating or attack by the molten portion of the pool. A somewhat comparable procedure has been employed with molten metal, and particularly, sodium, in sodium handling equipment and nuclear reactors. In such embodiment cooling is applied to shafts, bearings, valve stems, etc. emerging from a body of molten metal. The sodium thus freezes in that location, sealing off the possible entrance of air and exit of sodium. In such environment the "freeze-seal" has the advantage that it is sufficiently ductile that the shaft can be turned or slid without breaking the seal. A substantial equivalent phenomenon occurs in accordance with the present invention wherein a freeze-seal prevents the exit of electrolyte and evolved chlorine vapors and prevents the entrance of air into the electrolytic cell.

Thus, as seen in accordance with the construction of FIG. 1 the horizontal graphite anode extends beyond the electrolytic refractory to provide electrical connection and will make electrical connection with the bus or lug \( 21 \). Accordingly, molten electrolyte and chlorine must be prevented from leaking out past the graphite anode \( 11 \) while air must be prevented from leaking into the cell. In accordance with the process to which the apparatus of the present invention is best adapted the electrolyte is usually maintained at a temperature only slightly above its melting point to maximize the economy and life of the electrolytic cell. Accordingly, it is extremely easy to freeze the sodium chloride or any other salt electrolyte employed in the electrolysis process conducted in the horizontal electrolytic cell of the present invention. In this regard, for example, when sodium chloride is employed as the electrolyte in the electrolytic cell the cell will be operated at approximately 825° C, only some 20° to 25° C above the melting point of the sodium chloride electrolyte. Accordingly, due to the temperature drop at the outer end of the horizontal graphite anode \( 11 \), where the electrical connection is made, freezing of the sodium chloride electrolyte will take place between the anode \( 11 \) and upper and lower refractory linings \( 7 \) and \( 9 \) to provide a "freeze-seal." Such freeze-seal will prevent the exit of any electrolyte and evolved chlorine gas and will prevent the introduction of air into the horizontal electrolytic cell. Thus, due to the fact that the cell is operated just slightly above the melting point of the electrolyte the freeze-seal phenomenon will take place at the outer areas where the cell must be sealed against the exit of reactants and products and the entrance of undesirable air.

If for some reason such "freeze-seal" phenomenon is not sufficient merely due to the lower temperature encountered near the outer regions of the electrolytic cell not being low enough to cause freezing, some other mechanical means can be adapted to cool the outer regions so as to effect a freezing of the electrolyte and to provide the necessary seal against the exit of reactants and products and the entrance of air. Thus, where normal radiant cooling of the outer edges of the horizontal electrolytic cell is insufficient to achieve freezing of the electrolyte at the proper locations in the cracks and gaskets that it penetrates between the anodes \( 11 \) and upper and lower refractory linings \( 7 \) and \( 9 \), an air blower may be utilized aimed against the outer housing or metal shell of the electrolytic cell at the juncture of the top and lower halves thereof. Alternatively, a cooling water tube attached to the flange of the outer housing may be employed to ensure freezing of the electrolyte at the proper location at the interface of the horizontal anode and upper and lower refractory linings. Such use of an additional blower or cooling water tube is not illustrated in the drawings but constitutes an additional auxiliary apparatus which can be advantageously employed in accordance with the electrolytic cell construction of the present invention.

As indicated in the above discussion the areas between the anode \( 11 \) and the upper refractory lining \( 7 \) and lower refractory lining \( 9 \) can contain a suitable fibrous gasket in order to prevent direct contact of the surfaces and in order to provide gaskets for preventing exit of reactants and products and entrance of undesirable air. Such gaskets are shown as \( 26 \) in FIG. 1, it being, of course, obvious that a gasket should not be employed where electrical contact must be made between the surface of anode \( 30 \) and the bus or lug \( 21 \).
to the electrical lead 23. At all other interfaces of the anode 11 and the upper refractory lining 7 and lower refractory lining 9 such suitable gaskets 26 can be optionally utilized. Such gaskets 26 can be of any construction or type allowing penetration and freezing of the electrolyte within the same. In this regard, due to the freeze-seal phenomenon which occurs the electrolyte absorbed by the fibrous gasket will free within the same thereby providing a seal for the electrolyte cell to prevent the leakage of the electrolyte and evolved chlorine and entrance of air.

With regard to the freeze-seal phenomenon which occurs so as to seal the interfaces of the horizontal anode 11 and upper and lower refractory linings 7 and 9 it is pointed out that as long as the temperature is lower the farther away from the center of electrolytic cell the frozen seal position can move as required without causing expansion stresses. Thus, in maintaining fairly steady state operating conditions utilizing the frozen electrolyte seal concept the seal against ingress to and egress from the cell will be maintained notwithstanding a certain degree of expansion or contraction of the graphite anode 11 and refractory surface which is present during operating conditions. With respect to such freeze-seal phenomenon, it is to be noted that adhesion of the frozen salt to the graphitic anode will be minimal. When relative expansion or contraction of the graphite anode 11 and refractory tends to take place due to temperature fluctuations, such relative expansion and contraction will readily occur by movement in shear between the frozen electrolyte and the graphite anode, the molten salt seal maintaining itself and freezing again when conditions are stable. However, it is quite obvious that it would be undesirable and lead to possible deformation and fracture if the liquid salt could creep around the graphite and freeze behind it, trapped between the graphite and anode 11 and the outer wall or the refractory lining of the cell. In such instance, whenever relative contraction of the graphite occurred, a void would develop behind it that might then fill up with the molten salt. If and when the salt again froze it would deny the graphite the space to expand back into. Accordingly, it is a feature of the apparatus of the present invention that all of the vertical edges of the graphite anode 11 should either permit free circulation of molten salt around themselves such as the two long lateral edges which are freely bathed with electrolyte pool or provide penetration into a liquid salt which molten salts cannot reach, due to its freeze-seal phenomenon. Accordingly, the edges of the graphite anode 11 should either be supported only over a short length and without a tight seal so that any salt immediately behind it does not freeze or else the anode should extend to and form part of the outer surface of the cell. This second embodiment is shown in FIG. 1. Accordingly, as shown in FIG. 1, the edge is completely freeze-sealed and there are no outer voids between the ends of the anode and the outer shell which can trap and freeze salts.

As indicated previously, in accordance with the novel apparatus of the present invention, it is necessary that the graphite anode surfaces in contact, particularly the bottom surface of the graphite anode 11 against the refractory lining 9 of the bottom half of the cell and the top surface of the anode in contact with the refractory lining of the top half of the cell 7 or, alternatively, any fibrous or other gasket that is utilized at those two interfaces, be below the liquid level 15 of the molten electrolyte. Accordingly, in the apparatus of the present invention, the graphite anode 11 would be completely submerged to at least a small extent so that both its top and bottom surfaces where they emerge from the center of the cell for electrical connection would be submerged and their insulation would be wetted with molten electrolyte. Accordingly, as seen in FIG. 1, the whole of the horizontal anode 11 is submerged in the electrolyte whose upper surface 15 is substantially parallel to the upper surface 13 of the flowing cathode metal.

As shown in FIG. 1, an anode 27 is provided for the cathode metal and an exit 29 is provided for the cathode metal rich in electrolyte metal, e.g., the lead-sodium alloy to be passed by the anode 11 and the upper refractory lining 7 and lower refractory lining 9 of the electrolytic cell. In connection with the inlet 27 and outlet 29, there are a number of support apparatus which are not illustrated in the accompanying drawings. These, however, are conventional in the art and are generally utilized in conjunction with horizontal electrolytic cells. Thus, for example, various apparatus is known for removing the lead-sodium alloy from outlet port or exit 29 and taking the same to a distillation zone wherein sodium vapors are distilled out of the lead-sodium alloy. Similarly, apparatus is known and is conventional for therefor returning the lead, less rich in sodium, to the inlet 27 of the horizontal electrolytic cell wherein the same can be reused as the flowing molten metal cathode in accordance with the electrolysis process. Other support apparatus well known in the art include means for heating the electrolyte and flowing molten metal cathode and means for regulating the level of the cathode in the horizontal electrolytic cell. All of such support apparatus are well known in the art and can be employed in conjunction with the improved horizontal electrolytic cell construction of the present invention.

The chlorine evolved in the electrolysis of fused sodium chloride passes out of the electrolytic cell through outlet port or exit 31. The chlorine gas is allowed to pass through the graphite anode 11 through apertures 33 present therein into the space above the level of the electrolyte and out of the exit port. Of course, hence a gas, certain auxiliary and complementary apparatus not shown in FIG. 1 can be suitably employed in conjunction with the improved cell construction of the present invention as is conventional in the art. These systems include, for example, chlorine transportation units including compression and storage facilities. Again, due to the freeze-seal phenomenon which occurs forming a seal between the horizontal anode 11 and the upper and lower refractory linings 7 and 9, all of the chlorine gas evolved in the electrolysis process will exit the apparatus through exit port 31. This, of course, eliminates any possible contamination of the environment due to the escape of chlorine gas. Thus, the complementary apparatus associated with exit port 31, and not illustrated in the accompanying figures, does not allow the chlorine gas to escape but instead, collects and stores it, and prepares and provides the same in a useful safe form.

It is quite obvious that in accordance with the improved horizontal electrolytic cell construction of the present invention only one edge of the horizontal anode 11 need come through the frozen electrolyte seal so as to make the necessary and desired electrical connection. Accordingly, along the other three sides of the cell, it would be possible to use only a single joint between the upper and lower flanges 17 of the upper and lower metal shelves 3 and 5 or some other configuration not identical to that illustrated in FIG. 1. Suitable alternative embodiments for both the edge making electrical connection and those edges not so provided are illustrated in FIGS. 2 through 4.

FIG. 2 is an enlarged view of the portion of FIG. 1 of the horizontal electrolytic cell wherein electrical contact is made through the horizontal anode 11. The embodiment shown in FIG. 2, however, differs from that shown in FIG. 1 by including on the end of the anode 11 a metal foil cover 35. The metal foil cover 35 which is attached to the end of anode 11 can comprise any metal material resistant to air and chlorine gas. Generally, however, such metal foil cover is prepared from nickel, which material has been found to be particularly satisfactory. The purpose of the metal foil cover 35 is to prevent the escape of any chlorine gas which may penetrate the porous anode graphite and escape through the same to the atmosphere outside of the electrolytic cell and simultaneously protect the graphite from atmospheric oxidation. In this
regard, since the horizontal anode 11 is prepared from graphite and is generally a porous material a minor amount of chlorine gas evolved in the electrolysis process could pass to the outside environment through the anode itself. Accordingly, this is prevented by capping or covering the end of anode 11 with a metal foil 35, preferably, of a nickel material. It is quite clear that this feature of the present invention need not be employed solely in connection with that portion of the anode which is in electrical contact with the bus or lug 21 and electrical lead wire 23.

Accordingly, by utilizing the metal foil cover 35 environmental pollution is lessened and fear of accident resulting from escaping chlorine vapors is greatly minimized. In this regard, the use of such a metal foil cover 35 in association with the horizontal anode 11 together with the freeze-seal phenomenon previously described results in a more sealed system than is capable in conventional horizontal electrolytic cells wherein the anodes are suspended from the roof or top of the apparatus through anode stems.

FIG. 3 illustrates a further embodiment of the present invention showing that portion of the juncture of anode 11 and upper and lower refractory linings 7 and 9 wherein in electrical contact is not made through anode 11.

In the embodiment shown in FIG. 3, the anode 11 does not extend out to the outer edges of the upper and lower refractory linings 7 and 9, but is supported only by a portion of the lower refractory lining 9. Where the lower refractory lining 9 does not support anode 11 and where the upper refractory lining 7 is not in contact with anode 11, the upper and lower refractory linings are extended toward each other so as to provide a tight seal at 37. Accordingly, with respect to this embodiment shown in FIG. 3, the upper and lower refractory linings at the outer edges are not separated by the width of anode 11. Similarly, in accordance with this embodiment of the present invention, the upper and lower metal shells 3 and 5 and end flanges 17 would maintain substantial contact with each other, the same being held together by a suitable mechanical means as shown by bolt 25, or by a clamp. As was the case with respect to the embodiments shown in FIGS. 1 and 2, previously described, the tight seal associated with the interface of the upper refractory lining 7 and lower refractory lining 9 is enhanced by the freeze-seal phenomenon which occurs at the interfaces of such refractory linings and the anode 11. Here again, the electrolyte which fills the space between the anode 11 and the upper and lower refractory linings 7 and 9 will freeze and tightly seal the electrolytic cell from the exit of electrolyte and evolved chlorine gas and the introduction of undesirable air. Such freeze-seal phenomenon occurs as previously described since the electrolyte in the horizontal electrolytic cell is kept only slightly above its melting point so that at the outer areas the electrolyte freezes due to the lowering in temperature.

Since, as indicated previously, only one edge of the anode need come through the frozen electrolyte seal to make electrical connection, the remainder of the anode can be supported as shown in the embodiment of FIG. 3 where this embodiment does not allow for electrical connection due to the juncture of the upper refractory lining 7 and lower refractory lining 9 behind anode 11 supported by only a portion of the upper surface of lower refractory lining 9.

A further embodiment of the present invention is shown in FIG. 4. In accordance with this embodiment, a row of spacing bricks 39 is located atop the lower refractory lining 9, the anode 11 resting on the spacing brick 39. As can be seen in FIG. 4, the use of such refractory brick 39 as shown reduces the thickness of the anode 11 supported by the lower portion of the electrolytic cell. This in turn allows for better electrical resistance throughout the system, i.e., between the anode, the cathode 13 and through the electrolyte cell lining 21 but can be employed with all of the edges of the anode so as to prevent the escape of the evolved chlorine gas. By utilizing a metal foil which conducts electricity the employment of the metal foil 35 as a cover for the end of anode 11 does not in anyway detract from the electrical contact through bus or lug 21 and electrical lead wire 23.

As an alternative embodiment utilizing spacing bricks 39, the same can be utilized in the same manner as the extensions of the lower and upper refractory linings 7 and 9 of FIG. 3. Thus, for example, smaller spacing bricks can be utilized to form the juncture of the upper and lower portions of the refractory lining of the electrolytic cell. In such case, the cathode 13 would be supported only by the upper surface of lower refractory lining 9 adjacent the spacing brick. As a still further embodiment along these same lines, it is possible that the bottom half of the electrolytic cell, i.e., the lower refractory lining, monolithically rise a distance in the order of one inch or more above the rim of the lower metal shell 5 of the bottom half of the electrolytic cell. This, again, will allow for better electrical insulation and will ensure that evolved chlorine gas does not exit from the electrolytic cell and does not come into contact with the metal shell or housing portions.

All of the above embodiments of the present invention are predicated upon the advantages of the use of the horizontal anode slab or slabs in accordance with the improved electrolytic cell construction of the present invention. In this regard, as indicated previously, such anodes are horizontal slabs of graphite which are supported between the refractory wall or lining of the top and bottom halves of the electrolytic cell with little, if any play. Accordingly, the anode as fabricated is stronger than if the same were hanging from the roof or top of the electrolytic cell by stems or necks as in conventional horizontal electrolytic cell construction. Similarly, such horizontal anode slabs are more rigidly positioned with respect to the molten metal cathode so that a better cathode-anode gap is maintained.

Similarly, as indicated previously, the refractory linings of the cell of the present invention are substantially of a hollow cylindrical or spherical shape and, as best as possible are an equal thickness throughout. This increases the strength of the lining against temperature gradients and against floating forces and provides a strong base upon which the horizontal anode rests.

In a similar manner, it is pointed out that in accordance with the present invention the horizontal anode slabs are submerged slightly in the fused electrolyte so that the same wets the cracks or any gaps between the graphite anode and the refractory cell lining above and below the same. This produces an excellent seal against the exit of electrolyte and evolved gas and entrance of air through the freeze-seal phenomenon by which the electrolyte freezes at the outer areas due to the fact that the center of the electrolyte pool is maintained only slightly above the melting point of the electrolyte material. This possibility.

Exemplary constructions of the anodes employed in accordance with the present invention are shown in FIGS. 5 and 6. Thus, for example, FIG. 5 shows a horizontal anode slab having regularly spaced apertures or holes 33 therein. These regularly spaced apertures are provided so as to allow the evolved chlorine gas below the anode to space above the electrolyte and finally out of the horizontal electrolytic cell through exit port 31. A further arrangement is shown in FIG. 6 wherein the suitable apertures are shown as elongated openings 41. It is pointed out that while FIGS. 5 and 6 show these
apertures or openings to be regularly spaced, it is, of course, obvious that any spacing can be suitably utilized as long as the evolved chlorine gas can freely travel through the anode and eventually out of the electrolytic cell where the same can be processed and stored for further use.

It can be seen from the above that the electrolytic cell of the present invention constitutes an improvement in horizontal electrolytic cells of the type which are adapted to electrolyze a fused salt at highly elevated temperatures. Such electrolytic cell is of the type wherein a fused molten metal cathode, e.g., lead cathode, is used flowing across the bottom or lower half of the cell with the electrolyte floating on top of the same. In accordance with the present invention, increased efficiency and superior construction capabilities are achieved by having the anode as one or more horizontal slabs of graphite, the ends of which rest between the upper surfaces of the lower portion of the lining of the electrolytic cell and the lower surfaces of the upper portion of the cell lining. In this regard, as seen previously, the electrolytic cell construction of the present invention provides an improvement over those cells wherein the anodes were previously suspended from the roof or top of the cell through anode stems or necks.

It will be quite obvious that various changes and modifications may be made within the various embodiments of the present invention described and illustrated in the accompanying figures without departing from the true scope of the invention as disclosed and claimed in this application. Accordingly, it is intended that all matter contained in the foregoing description and in the drawings shall be interpreted as illustrative only and shall not be limiting of the present invention.

What is claimed is:

1. In a horizontal electrolytic cell adapted for the electrolytic decomposition at high temperatures of inorganic compounds in the presence of a cathode comprising a flowing molten metal and one or more anodes in spaced relationship to and disposed above said flowing molten metal cathode with means separately electrically connected to said anodes and to said flowing molten metal cathode through a metallic shell and refractory lining surrounding the electrolysis chamber of said electrolytic cell to pass electrical current to and from the same through a molten electrolyte flowing on said molten metal cathode, the improvement wherein said anodes comprise one or more horizontal slabs of graphite directly supported between the upper wall surface of the refractory lining of the lower portion of the electrolytic cell and the lower wall surface of the refractory lining of the upper portion of the cell.

2. The horizontal electrolytic cell of claim 1 wherein the upper and lower portions of said refractory lining and upper and lower portions of said metal shell surrounding the same define an electrolysis chamber of a substantially cylindrical or spherical shape.

3. The horizontal electrolytic cell of claim 2 wherein said horizontal slabs of graphite contain holes therethrough so as to allow the passage of evolved gas.

4. The apparatus of claim 2 wherein electrical contact with said horizontal slabs of graphite is accomplished along one edge thereof.

5. The apparatus of claim 2 wherein said horizontal slabs of graphite extend outwardly to a point substantially adjacent the outer surface of said refractory lining.

6. The apparatus of claim 2 wherein said upper and lower portions of said metallic shell and upper and lower portions of said refractory lining are each separated a distance substantially equal to the width of said horizontal slabs of graphite.

7. The apparatus of claim 2 wherein said horizontal slabs of graphite are adapted to be completely submerged in said electrolyte.

8. The apparatus of claim 2 wherein the outer edge of said horizontal slabs of graphite is capped with a metal foil.

9. The apparatus of claim 2 wherein said horizontal slabs of graphite are supported by a row of spacing bricks located atop the upper surface of the lower portion of said refractory lining.

10. In a horizontal electrolytic cell adapted for the electrolytic decomposition at high temperatures of inorganic compounds in the presence of a cathode comprising a flowing molten metal and one or more anodes in spaced relationship to and disposed above said flowing molten metal cathode with means separately electrically connected to said anodes and to said flowing molten metal cathode through a metallic shell and refractory lining surrounding the electrolysis chamber of said electrolytic cell to pass electrical current to and from the same through a molten electrolyte flowing on said molten metal cathode, the improvement wherein said horizontal electrolytic cell body comprises upper and lower refractory linings surrounded by upper and lower metallic shells defining a substantially cylindrical or spherical electrolysis chamber, the anodes comprising one or more horizontal slabs of graphite directly supported by the upper surface of said lower refractory lining, said horizontal slabs of graphite being adapted to be totally submerged in said electrolyte and containing holes therethrough for passage of evolved gas.

11. The apparatus of claim 10 wherein said horizontal slabs of graphite extend outwardly to a point substantially adjacent the outer surface of said refractory lining.

12. The apparatus of claim 10 wherein said upper and lower portions of said metallic shell and upper and lower portions of said refractory lining are each separated a distance substantially equal to the width of said horizontal slabs of graphite.

13. The apparatus of claim 10 wherein the outer edge of said horizontal slabs of graphite is capped with a metal foil.

14. The apparatus of claim 10 wherein said horizontal slabs of graphite are supported by a row of spacing bricks located atop the upper surface of the lower portion of said refractory lining.