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PROCESS FOR THE PRODUCTION OF ALUMINUM BY FUSED BATH ALUMINA
ELECTROLYSIS AND THREE-LAYER ANODE
FOR CARRYING OUT SAID PROCESS
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Fig. 5
PROCESS FOR THE PRODUCTION OF ALUMINUM BY FUSED BATH ALUMINA ELECTROLYSIS AND THREE-LAYER ANODE FOR CARRYING OUT SAID PROCESS

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My invention relates to fused salt electrolysis in the production of aluminum and is directed particularly to the integration of anodes of any kind, such as stationary, pre-baked, or Soederberg, in furnaces and to processes for the production of aluminum by electrolysis operated with baths containing fused aluminum compounds and having consumable anodes preferably formed of carbonaceous masses of various kinds. All of such consumable carbon electrodes will hereinafter simply be called "carbons" or "carbon electrodes" or "carbon anodes.

This application is in part a continuation of my pending application Serial No. 480,509, filed January 7, 1955.

The invention will be described with reference to the drawings forming part of this specification, wherein:

Fig. 1 is a vertical cross-sectional view of my new multiple furnace of the type having stationary electrodes, described in my pending patent application, in which the anodes are integrated or renewed by the method according to the present invention;

Fig. 2 is a vertical cross-sectional view of a portion of the multiple furnace shown in Fig. 1;

Fig. 3 is a horizontal cross-sectional view taken along the line A—A of Fig. 2 illustrating one kind of renewal or integrating strip that can be used for integrating the electrodes;

Fig. 4 is a cross-sectional view similar to Fig. 3 but illustrating the use of another type of integrating strip, and

Fig. 5 illustrates how electrode integration or renewal according to the invention can be brought out in conventional furnaces of the type using pre-baked anodes.

As is known, in the production of aluminum from \( \text{Al}_2\text{O}_3 \) by electrolysis in fused salt baths usually constituted of cryolite of fluorinated \( \text{Al} \) and \( \text{Na} \) compounds, the anodic carbon has to be integrated or renewed periodically to ensure continuity of the production process.

In conventional furnaces, the whole anodic furnace section is vertically adjusted by a gear mechanism to keep it at the desired distance from the varying level of the molten aluminum cathode. This distance between the carbon anode and the aluminum cathode is called electrode spacing. The anodic carbon, be it of the Soederberg type or the prebaked type, is in intimate and extensive contact with the respective metallic stubs, made of iron, cast iron, steel, etc., which lead current thereto. The anodic carbon is progressively consumed by electrolysis. The lower ends of the metallic stubs thus draw nearer to the underlying layer of fused bath, until it becomes necessary to extract the metallic conductor in order to prevent iron from coming into direct contact with and being attacked by the bath.

In furnaces of the pre-baked anode type, the consumed anode, composed essentially of one or more metallic conductors and of the residue or remainder of the anodic carbon which still covers them, is removed from the bath and replaced with a new anode to start the cycle again. In Soederberg furnaces, instead, the vertical or nearly horizontal stubs are withdrawn successively as they approach close to the fused bath. The bore left by them is normally filled up with new Soederberg paste and the stub previously extracted is fitted into the pasty anode at a more elevated position. Thereafter the cycle starts over again.

To make up for the consumption of anodic carbon by electrolysis in pre-baked anode furnaces, a nibbled new anodic carbon anode is placed at the same spot in the furnace where the old one was. In Soederberg furnaces, instead, the anodic carbon is integrated by introducing fresh paste from above, called crude or green paste, which melts and thus covers the old Soederberg anode, and in its extremely slow travel downwards, gradually bakes rendering the mechanical and electrical contact between the stubs and the baked paste more intimate and finally achieving a true coalescence. Merely by way of orientation I shall say that the voltage drop in pre-baked anodes and in Soederberg anodes is usually between 0.3 and 0.9 volt, depending upon the density of anodic current and the distance of the metallic ends from the fused bath.

The anodic structure of the conventional furnaces described above, and the respective methods of integration or renewal of the anodic carbon consumed electrolytically, are generally inefficient and troublesome in operation for the following reasons:

1. The current will not be uniformly distributed on the lower base of the carbon anode or anodes, which in turn may give rise to local overheating and to overvoltage in the anode as well as in the bath and in the cathode. The variation of the distance of the stubs from the bath causes a periodical variation of the anodic and of the over-all voltage drop of the furnace. The stresses required for periodically removing the stubs from the Soederberg anode, result in a certain amount of pollution of the carbon anode and, subsequently, of the aluminum produced. The stresses are higher because at their lower ends the stubs have attained elevated temperatures.

2. The same is true for the pre-baked anodes, if the anodic residues are not taken out of the bath in time. Finally, the contact line between the free bath surface and the flanks of the carbon anode shifts upwards continuously. This makes it difficult if not impossible to protect the anode carbon immediately above the bath against appreciable corrosion due to atmospheric oxygen. This corrosion causes great difficulties, as is well known to those skilled in the art. Another deficiency of the conventional anodic system is due to the electrolytic gases, which, in rising and licking the unprotected flanks of the carbon anode submerged in the bath, react according to the reaction \( \text{CO}_2 + \text{C} \rightarrow 2\text{CO} \).

A multiple furnace having fixed electrodes has been recently described in the applicant's above-mentioned patent application Serial No. 480,509. This type of furnace has no gears or means for adjusting the inter-electrode spacing and has stationary, inclined bi-polar crosswalls of electrode carbon having no metallic conductors. Only the electrode carbons 10 and 11 at the ends of the furnace, are provided with such conductors at 12, preferably equidistant from the bath. In said furnace anodic integration or renewal is carried out by applying on the anodic face of the old anode, while leaving it "in situ," a plate 13 or 14 or pieces 15 forming a plate, of anodic carbon, operative to cover said anodic face entirely and rebuild the electrode to its initial dimensions. In operation of this furnace, it has been suggested, after tapping off the product, to expose the whole anodic surface by emptying the cell gap of the molten bath. The latter is poured into a suitable well-insulated container,
to be put back into the cell as soon as the anode has been restored as explained below. A regular plate of electrode carbon of uniform thickness (for instance 4 cm.) having the anodic face to be covered is applied against the consumed anode surface. Such a plate is slipped into the gap between the electrodes forming the cell and made to adhere to the anode in such a way that the current will not meet, during cell operation, an excessive resistance in passing through the separating layer between the old and new anode. To this end, a cobble binding material is spread beforehand over the surface to be contacted. Instead of integrating the anode by means of one single plate, one may prepare a number of rectangular strips, all equally thick, to be juxtaposed on the anodic face. They may be as long as one dimension of the anodic face, their width being a submultiple of the other dimension. If, for instance, the anodic face is 80 by 70 cm., one may employ five strips about 16 cm. by 70 cm. The single pieces are then pasted against the anode.

In the embodiment illustrated in Fig. 3, the end carbon block electrodes and the bi-polar intermediate electrodes are corrugated, and interfit.

The present invention is based on the recognition that anodic integration, with any kind of anode, may be carried out merely by leaning the integrating carbon against the old anode. Hence it becomes possible to operate on the electrode face while it is submerged in the bath. In conventional furnaces with horizontal layers, moreover, it is also possible to carry out the operation with their movable anode partly lifted from or entirely out of the bath. Of course, if no previous anodic binding layer has been used (a binding layer which subsequently could be contacting mechanically and electrically the old anode with the new anode), the space or layer between the old anode and the new anode will normally be flooded by the bath of the cell. However, it has been surprisingly found that the over-all resistance of this liquid layer and of the two carbon-bath and bath-carbon contacts is much smaller than would have been expected, provided one does not exceed upper limits of certain interfacial distances and certain current densities. This use of liquid contact, if applied to furnaces with stationary consumable anodes of the type described in the already-mentioned co-pending application, results in still further improvement. This improvement permits easier operation, a simplification of the operating steps required for integration, a reduction of labor and unit consumption. For instance, the necessity of temporarily removing the fused bath from the cell, which obviously may give rise to various difficulties, is avoided.

As already mentioned, my invention may also be conveniently extended, with structural modifications and contrivances in operation as needed, to furnaces with horizontal layers of the conventional types. In this latter case, it is possible to apply the invention to the furnace as it is or with slight structural modifications. The invention can also be applied to conventional furnaces already installed and in operation.

In multiple furnaces with stationary electrodes as proposed in my already-mentioned co-pending application, the anodic integration plate or the individual pieces for composing such a plate may be placed “in situ” without any particular difficulty. As a matter of fact, the bath density is by 30% to 40% higher than that of the electrode carbons. It may happen that friction along the contact surfaces between the new and the integrated anode may not be sufficient to withstand the hydrostatic pressure (buoyancy) of the bath. In such cases, it will be easy by means of any simple stopping device, preferably of inert material (pre-treated magnesite or alumina, or aluminum nitride, etc.) to prevent the new anode from rising afloat.

In each instance of the application of my invention described above, the electric current passes from the old anode to the new anode (integrating anode) without having to overcome a decomposition voltage drop equal to that occurring in the cell in the course of electrolysis and generally assumed to be about 1.7 volts. Instead, there is an over-all resistance, corresponding to a voltage drop, which may be in part of electrochemical origin but in practice has apparently only static effects and is considerably smaller than the decomposition voltage drop of the bath. This is better illustrated in the following tabulation:

<table>
<thead>
<tr>
<th>Over-all resistance in $\Omega$ cm. $^2$ of the contact zone at about $1000^\circ$ C. and relative voltage drop $%$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertical or Horizontal Ampere/sec. cm.</td>
</tr>
<tr>
<td>Example (a).—Dry contact, carbon plate on carbon plate, thickness of intermediate layer $&lt;1$ mm.</td>
</tr>
<tr>
<td>Example (b).—Carbonated cryolite + AlF$_3$ + AlF$_3$/carbon; thickness of intermediate layer $&lt;1$ mm.</td>
</tr>
<tr>
<td>Example (c).—Carbonated cryolite + Al$_2$O$_3$ + AlF$_3$/carbon; thickness of intermediate layer $&lt;1$ mm.</td>
</tr>
<tr>
<td>Example (d).—Carbonated cryolite + Al$_2$O$_3$ + AlF$_3$/carbon; thickness of intermediate layer $&lt;1$ mm.</td>
</tr>
<tr>
<td>Example (e).—Carbonated cryolite + AlF$_3$ + AlF$_3$/carbon; thickness of intermediate layer $&lt;1$ mm.</td>
</tr>
<tr>
<td>Example (f).—Carbonated cryolite + AlF$_3$ + AlF$_3$/carbon; thickness of intermediate layer $&lt;1$ mm.</td>
</tr>
<tr>
<td>Example (g).—Carbonated cryolite + AlF$_3$ + AlF$_3$/carbon; thickness of intermediate layer $&lt;1$ mm.</td>
</tr>
</tbody>
</table>

From the data of the above tabulation it will be seen that if operation is carried out in accordance with the present invention, with anodic integration from the bath side and with a liquid contact layer, the additional anodic voltage drop is much smaller than would have been expected knowing the decomposition voltage of a corresponding electrolytic bath. However, its value is still not negligible, taking into account that over-all voltage drop in industrial cells employed at the present time usually varies between 4.5 and 6 volts, while in the individual elements of multiple furnaces having stationary electrodes, not integrated according to the present invention, it may be lower than 3.5 volts. The supplemental voltage drops due to the thin liquid intermediate anodic layer, however, may be further reduced to a fraction of the indicated values if operation is carried out as follows:

The area of the contacting surfaces (old anode/inter- 

tegrating anode) is preferably increased using a suitable arrangement of corrugations or undulations 16 so as to have two complementary surfaces. A plate and an old 

anode of this kind may have a cross section as illustrated in 

Fig. 4, resulting in a gain in contacting surface area of 

from 30% to 100%.

The electrical contact between the integrating anode and the old anode, whether corrugated or not, may be improved by mixing substances operative to lower the over-all resistance, in the thin liquid layer interposed between the two closely spaced surfaces, this mixture acting as a better bridge for the passage of current. For this purpose, it has been found useful to employ pitch, tarry substances, for example, or hydrocarbons having a tendency to coke, so as to weld—but not on a continuous surface—the old anode with the new one. Molten metal, preferably aluminum having a degree of purity comparable to that of aluminum produced in the cell, or even small doses of
very fine dust of carbon or of carbonaceous substances may also be used.

**Operation**

Procedure, of course, varies according to whether integration of the anodes is carried out in a multiple furnace having stationary anodes or in a conventional furnace with horizontal electrode surfaces. With a stationary electrode multiple furnace, it is preferable to introduce the pre-heated plates of integrating carbon 14 or the corresponding strips 15 in a nearly vertical position into the individual gaps or cells, so as to make their bottom edges 17 rest on the layer of inert material 18 separating the electrode 19 from the lower chamber 20 for the metal (Figs. 4, 5 and 6). As can be seen in Figs. 5 and 6, the vertical edges of the single carbon 14, or of the end carbon strips 15, may be vertically guided by the inner vertical wall structure of the cells.

Small amounts (e.g., of the order of magnitude of 0.5% to 5% of the weight of the additional anode) of molten aluminum may be poured between the old anode 19 and the integrating anode 14, or a suspension of carbon dust in fused bath may be poured in, whereafter the strips, preferably having a corrugated profile as described above, are leaned at once against the corresponding old anode shaped with a complementary profile. Preferably the anode structures have a transverse upper covering or insulating strip 14b providing a horizontal shoulder against the underside of which the upper edges of the carbon 14 or carbon strips 15 can rest for holding them in place. It must be taken into account in connection with the anode mechanism that commonly the metal is heavier than the bath and that the carbon dust is lighter than the bath. Hence in the first case it is convenient to introduce molten metal from above into an already very narrow integral interstice, whereas in the second case, it be rather slow, stopping when the two anodic parts come to contact. In the case of carbon dust it is usually preferable to prepare first a small quantity of normal fused bath containing a certain percentage of coal dust intimately mixed with the bath, and then to feed this mixture to the contact zone at a suitable temperature and with a certain "head." These integrating anodes, the thickness of which varies preferably from 3 to 10 cm., will undergo the usual electrolytic consumption. Prior to applying the new integrating anode it is advisable to scrape the face of the old anode slightly with a special tool, and to save the residues of the integrating anode from the previous cycle.

With conventional type furnaces, instead, one of the convenient methods consists in completely withdrawing the anode from the bath and then inserting the anodic plate of integrating carbon 22 afloat on the bath under the anode 21 (Fig. 5). The plate is preferably provided with a raised perimetrical border 22', e.g., of one or more centimetres in height, thus forming a sort of shallow cup or side-walled raft. On this floating plate, a very thin layer of fine carbon dust 23 may be spread. Aluminum chips, or even a little of an intimate mixture of both carbon and molten aluminum, etc., may also be used. Thereafter, the hot old anode is lowered quickly so that it may fit into the flat cup (which may also have a corrugated contact surface) of the integrating plate, and the whole anodic device is further lowered. The downward thrust exerted by the old anode causes the integrating anode to form under the proper electrode spaces 25 between the renewed anode and the aluminum cathode has been restored.

The contact between the old anode and the new anode will be considerably improved by the presence of carbon dust, or of a thin layer of molten aluminum, or of small quantities of pitch and carbon dust. The quantity of aluminum added is preferably of the order of magnitude of 0.5% to 5% of the weight of the integrating plate. As the electrolytic consumption of the anode progresses, the integrating cup or raft becomes thinner and thinner. At a certain time, its bottom is perforated and the thin layer of aluminum contained therein may discharge through the bath into the layer of cathodic aluminum. At this time or afterwards, when the cup or raft is consumed to a great extent but before the aforementioned contact liquid between the two anodic portions has discharged, the anode is lifted out of the bath, residues of the cup from a previous cycle that may remain are readily detached, and a new integrating cup is placed on the bath in the manner already described. The thickness of this cup may vary within fairly wide limits, preferred limits being between 5 and 15 cm. The same renewing or integration operation may be performed on an anode of the Soederberg self-baking type, which has become hardened in use (and will hereinafter be referred to as a "self-baked" anode). If the latter is large, it may be convenient not to lift it out of the bath but to introduce and juxtapose individually a number of integration carbon strips or mating pieces, which strips or pieces preferably are bordered at their ends beneath the submerged under-surface of the old anode.

The system and method of effecting anode renewal or integration by merely leaning the new anode against the old anode has a decided advantage when employed with stationary multiple electrode furnaces in that it is no longer necessary to drain the bath from the cell to restore the anode. This simplifies considerably the number of operations required and diminishes the time needed for performing the operations, as well as reducing the heat losses, reducing the danger of oxidizing the electrolytic carbons not covered by the bath, etc. Moreover, it is no longer necessary to spread the whole contacting face of the integration carbon with a binding material which has to be cooked in order to effect complete welding with the old anode.

The present invention also permits, with respect to the horizontal pre-baked anode furnaces as generally installed at the present time, putting into practice a proposal made long ago but not utilized so far owing to practical difficulties, namely that of providing a protective coating for the sides or flanks of the anode. Thus, an external coating layer 24 (Fig. 5) covering the top and the sides of the old or permanent carbon can be used in conjunction with the present invention to protect the anode against attack by atmospheric oxygen and by CO₂ contained in the bath, and to minimize irregular electrolytic consumption at the sides as well. When the protective layer may be fairly thin and may be formed of aluminum oxide or of magnesium oxide, both conveniently pre-treated, fused or sintered at very high temperatures. Aluminum nitride and other substances strongly resistant to attack by the bath may also be used. While Fig. 5 shows a pre-baked anode, the coating may be applied to the sides or flanks of "self-baked" anodes as hereinbefore defined as well.

The improved process herein disclosed saves labor and, in the case of horizontal furnaces, reduces consumption of anodic carbon and of the electrolytic bath. It also minimizes the possibility of polluting the produced aluminum by iron, etc., resulting in higher grade aluminum. As for the consumption of electric power, the increase of voltage due to the resistance of the durable liquid intermediate layer between the old anode and the new anode can be reduced to very small values, especially if the furnace is operated with low anodic current densities and/or if the various conventional contrivances and anode structures described herein before are utilized, the anodes having corrugated surfaces, are utilized.

It may be interesting to note that the over-all amount of power consumption in conventional furnaces for aluminum production modified according to the present invention may be sensibly reduced, for instance, by effect of the preservation of the basic anodic surface.

Another advantage of this invention is the possibility of building the permanent solid layer of the three-layer
anode in such a way that its electrical resistance and its radiating heat dissipation become extremely small. Since the pre-baked anode is no longer reduced by oxidation to a small residue of carbon, one can considerably increase the contact surface of the metallic conductor stubs embedded in the permanent carbon layer, and coat with heat-insulating material the upper part of the anode. The easy formation of the above-described three-layer anode device, and its advantageous use in electrolysis cells fed with aluminum oxide, which use is based upon the surprising behavior of the thin intermediate, at least partly liquid, layer under the passage of electric current (in that in said layer, even if liquid, there does not take place any appreciable electrolytic decomposition, and in that the over-all electric resistance of said layer can be easily reduced to very low values), may find useful application not only with aluminum cells but with other cells as well, or with the electrolysis of other fused compounds wherein the anode is consumed electrolytically and wherein oxidation is carried out at elevated temperatures. The three-layer anode becomes extremely useful, from the points of view of continuity of operation, labor saving, lower unit consumption of kilowatt-hours and of anodic material, the possibility of protecting the flanks of the permanent anodic layer with a protective layer, if desired, and so on. If the above-mentioned conditions the electrolysis is carried out in the presence of chemically very active bath components, or if multifold furnaces with stationary electrodes are used. The carbonaceous masses can be pre-baked electrodes, Soederberg pastes, graphite, etc. As disclosed in the parent application, the cathode surfaces or portions may be of graphite or graphite-covered.

It will be obvious to those skilled in the art upon a study of this disclosure that my invention permits of various modifications other than those specifically illustrated, without departing from the essence of my invention and within the scope of the claims annexed hereto.

I claim:

1. In a furnace process for aluminum production by electrolysis of fused bath, the improvement comprising restoring the electrolytically consumed layer of a bath-side face of electrolytic cell, comprising, by locating a restoring carbon layer adjacent said bath-side face of the carbon anode, from the side at which the bath is normally, said bath-side face being at least partially submerged in the bath during the restoring, the fused bath having access to the interstice so formed between said face and said restoring carbon layer, the restoring layer and said anode being in contact above the electrolysis process, the restoring carbon layer being buoyed up against the anode by the fused bath, the interstice being of such thickness that the voltage drop across it is less than the electrolysis decomposition voltage drop across the electrolysis gap of the said cell, and having a thickness not more than a minor fraction of the restoring carbon layer.

2. In an electrolysis process, the improvement comprising periodically restoring vertically movable and adjustable carbon anodes used in the electrolytic production of aluminum in a fused bath, by withdrawing the used anode upwardly out of the electrolytic bath, floating a bordered plate of anodic carbon under the withdrawn anode, charging the space of said plate confined by its borders with an electro-conductive molten aluminum material, and then lowering said anode upon said plate to submerge it together with the anode to the proper distance for carrying out electrolysis, the restoring plate being in juxtaposed relation to the anode during the electrolysis, the fused bath liquid having access to the interstice between the restoring plate and the anode during the electrolysis, the interstice being of such thickness that the voltage drop across it is less than the electrolysis decomposition voltage drop across the electrolysis gap of the said cell, and being of a thickness not more than a minor fraction of the restoring carbon layer.

3. The process of claim 2, wherein said conductive liquid is electrolytic bath liquid.

4. The process of claim 2, wherein said conductive liquid is a suspension of carbon dust in electrolytic bath liquid.

5. The process of claim 2, wherein said conductive liquid is an electrolyte.

6. The periodic process of restoring vertically movable and adjustable carbon anodes used in the electrolytic furnace production of aluminum in a fused bath which comprises withdrawing the used anode upwardly out of the electrolytic bath, floating a bordered plate of anodic carbon under the withdrawn anode, charging the space of said plate confined by its borders with aluminum chips, and then lowering said anode upon said plate to submerge it together with the anode to the proper distance for carrying out the electrolysis, the fused bath liquid having access to the interstice present between the restoring plate and the anode during the electrolysis, the interstice being of such thickness that the voltage drop across it is less than the electrolysis decomposition voltage drop across the electrolysis gap of the cell, and being of a thickness not more than a minor fraction of the restoring carbon layer.

7. The periodic process of restoring vertically movable and adjustable carbon anodes used in the electrolytic furnace production of aluminum in a fused bath, which comprises withdrawing the used anode upwardly out of the electrolytic bath, floating a bordered plate of anodic carbon under the withdrawn anode, charging the space of said plate confined by its borders with dry carbon dust, and then lowering said anode upon said plate to submerge it together with the anode to the proper distance for carrying out the electrolysis, the fused bath liquid having access to the interstice present between the restoring plate and the anode during the electrolysis, the interstice being of such thickness that the voltage drop across it is less than the electrolysis decomposition voltage drop across the electrolysis gap of the cell, and being of a thickness not more than a minor fraction of the restoring carbon layer.

8. A furnace for fused bath electrolysis, comprising a housing structure for the fused bath, a cathode therein, a multi-layer anode, and at least partly submerged in the fused bath, the cathode and anode providing an electrolysis gap therebetween, said anode comprising a fixed solid carbonaceous electroconductive layer, a replaceable, consumable, solid carbonaceous electroconductive bath-side layer, presenting the anodic active surface, and an interlayer of electrolytic conducting liquid, to enable separation and replacement of said solid bath-side layer when at least partly consumed, and means for retaining the two carbonaceous layers adjacent each other, the liquid layer being of such width that the voltage drop across it is smaller than the electrolysis decomposition voltage drop across the electrolysis gap, the liquid layer having a thickness not more than a minor fraction of the thickness of the replacing consumable layer.

9. A furnace for electrolysis of aluminum compounds in a fused bath, comprising a housing structure for the fused bath, a cathode therein, a multi-layer anode in said structure and at least partly submerged in the fused bath, the cathode and anode providing an electrolysis gap therebetween, said anode comprising a fixed permanent carbon layer, a replaceable, consumable, bath-side carbon layer, presenting an anodic active surface, and a lasting intermediate layer of fused electrolytic bath, to enable separation and replacement of the bath-side carbon layer when at least partly consumed, and means for supporting the two carbon layers, the liquid layer being of such thickness and of such character that the voltage drop across it is smaller than the electrolysis decomposition voltage drop across the electrolysis gap, the liquid layer having a thickness not more than a minor fraction of the thickness of the replacing consumable layer.
10. A furnace for producing aluminum fused bath electrolysis, comprising a housing structure for the fused bath, a cathode therein, a multi-layer anode in said structure and at least partly submerged in the fused bath, the cathode and anode defining an electrolysis gap therebetween, said anode having an upwardly-downwardly extending bath-side anodic face and comprising two layers of solid carbonaceous electroconductive material comprising a fixed graphite layer and an electrolytically consumable and replaceable anodic carbon layer separated by an intermediate layer of molten, aluminum, to enable separation and replacement of the bath-side carbonaceous layer when at least partly consumed, and means for supporting the solid layers, the molten aluminum layer having a thickness not more than a minor fraction of the replacing consumable layer and being of such thickness that the voltage drop across it is smaller than the electrolysis decomposition voltage drop across the electrolysis gap.  

11. A furnace for fused bath electrolysis, comprising a housing structure for the fused bath, a cathode therein, a multi-layer anode in said structure and at least partly submerged in the fused bath, the cathode and anode defining an electrolysis gap therebetween, said anode having an upwardly-downwardly extending bath-side anodic face and comprising two face-to-face layers of solid carbonaceous electroconductive material, the facing surfaces of said layers being of non-planar, complementary, interfacing configuration, and a thin intermediate layer of the molten electrolytic bath between said solid layers, to enable separation and replacement of said solid bath-side layer when at least partly consumed, and means for supporting the two carbonaceous layers, the intermediate layer of molten bath being of such thickness that the voltage drop across it is smaller than the electrolysis decomposition voltage drop across the electrolysis gap.  

12. A furnace for fused bath electrolysis, comprising a housing structure for the fused bath, a cathode therein, a multi-layer anode in said structure and at least partly submerged in the fused bath, the cathode and anode providing an electrolysis gap therebetween, said anode having an upwardly-downwardly extending bath-side anodic face and comprising two face-to-face plates of solid electrically conductive carbonaceous material, the facing surfaces of said plates being corrugated and of complementary configuration, said plates having therebetween a layer of electroconductive material which remains liquid during the electrolysis, the solid bath-side layer being replaceable when at least partly consumed, and means for retaining the two carbonaceous layers in juxtaposition, the layer of liquid material being of such thickness that the voltage drop across it is smaller than the electrolysis decomposition voltage drop across the electrolysis gap.  

13. A furnace for fused bath electrolysis, comprising a housing structure for the fused bath, a cathode therein, a multi-layer anode in said structure and at least partly submerged in said fused bath, the cathode and anode providing an electrolysis gap therebetween, said anode comprising a permanent layer and a replaceable, consumable layer of solid electrically conductive carbonaceous material separated by a layer of electrically conductive material which remains molten in the electrolysis, the molten layer being of such thickness that the voltage drop across it is smaller than the electrolysis decomposition voltage drop across the electrolysis gap and being thinner than the replacing, consumable layer, being thinner than 2 mm. in thickness, and means for retaining the two carbonaceous layers in juxtaposition.  

14. A furnace for fused bath electrolysis, comprising a housing structure for the fused bath, a cathode therein, a multi-layer anode in said structure and at least partly submerged in the fused bath, the cathode structure and the anode having a fused bath electrolysis gap therebetween, said anode having a bath-side anodic face and comprising a permanent carbon layer, and an electrolytically consumable and replaceable bath-side anodic carbon layer supported in face-to-face relation with respect to said permanent carbon layer, said carbon layers being separated by a thin intermediate and lasting layer of electroconductive liquid which remains molten in the electrolysis, the flanks of said permanent carbon layer having thereagainst a chemically inert protective material for protection against attack by the constituents of the electrolytic bath and of the surrounding gases, the layer of electroconductive liquid being of such thickness that the voltage drop across it is less than the electrolysis decomposition voltage drop across the electrolysis gap.  

15. A furnace in accordance with claim 14, wherein the furnace bottom provides the cathode structure, the top of said permanent carbon layer being coated with protective material, the permanent layer being above the replaceable layer and being vertically movable and adjustable.  

16. A furnace for fused bath electrolysis, comprising a housing structure for the fused bath, a cathode therein, a multi-layer anode in said structure and at least partly submerged in the fused bath, the cathode and anode providing an electrolysis gap therebetween, said anode comprising a fixed solid electroconductive layer and a consumable and replaceable solid electroconductive bath-side layer adapted to afford the anodic active surface, said layers being positioned in juxtaposed relation to form therebetween an interstice, and an electroconductive intermediate layer which remains molten during the electrolysis in said interstice, the layer of conductive liquid being of such thickness that the voltage drop across it is less than the electrolysis decomposition voltage drop across the electrolysis gap.  

17. An apparatus for recovering a metal by electrolysis in a fused bath comprising structure means for containing the bath, two electrodes each comprising a carbonaceous block positioned at opposite walls of the structure means, current conductors electrically connecting the ends of said two blocks and defining electrolysis gaps therebetween, each of the bipolar electrodes having an anodic face, and an intermediate liquid layer which is in substantial parallelism with the said bath-side faces and with the opposed face of the nearest carbonaceous electrode, the anode faces of the electrodes being formed of facing pieces of renewable, electrolytically consumable carbonaceous electrode material adapted to afford the anodic active surface, said facing pieces being interstices formed between the pieces and the respective electrodes a layer which is composed of carbonaceous particles and a material which remains molten during the electrolysis process. The molten material being taken from the group consisting of said metal and said bath, the fused bath having access to said interstices during the electrolysis, the layer being of such thickness that the voltage drop across it is less than the electrolysis decomposition voltage drop across the respective electrolysis gap, the layer having a thickness less than a minor fraction of the thickness of the respective bi-polar electrode, and of the respective facing piece.  

18. An apparatus for recovering aluminum by electrolysis in a fused bath comprising structure means for containing the bath, two electrodes each comprising a carbonaceous block positioned at opposite walls of the structure means, current conductors electrically connecting the ends of said two blocks and defining electrolysis gaps therebetween, each of the bipolar electrodes having a bath-side face which slants upwardly at an angle to the vertical, said faces being substantially parallel, a series of bi-polar carbonaceous electrodes positioned between the said two blocks and defining electrolysis gaps therebetween, each of the bipolar electrodes having opposite faces each of which is in substantial parallelism with the said bath-side faces and with the
opposed face of the nearest by carbonaceous electrode, the anode faces of the electrodes facing downwardly and being facing means for containing the bath of the fused salt, two electrodes each comprising a carbonaceous block positioned at opposite walls of the structure means, current conductors electroconductive connected to the blocks, each of the blocks having a bath-side face which slants upwardly at an angle to the vertical, said faces being substantially parallel, one of said faces constituting an anode face that faces downwardly and being formed of a renewable facing means of consumable carbonaceous electrode material adapted to afford the anodic active surface defining one boundary of the electrolysis gap, which facing means has at the interface formed between it and the respective electrode a layer which is composed of carbonaceous particles and a material which remains molten during the electrolysis process, the molten material being taken from the group consisting of said metal and said bath, the fused bath having access to said interstice during the electrolysis, the layer being of such thickness that the voltage drop across it is smaller than the electrolysis decomposition voltage drop across the said electrolysis gap, the layer having a thickness less than a minor fraction of the thickness of the respective carbonaceous block, and of the renewable facing means.

19. An apparatus for recovering metal by electrolysis in a fused bath comprising structure means for containing the bath of the fused salt, two electrodes each comprising a carbonaceous block positioned at opposite walls of the structure means, current conductors electroconductive connected to the blocks, each of the blocks having a bath-side face which slants upwardly at an angle to the vertical, said faces being substantially parallel, one of said faces constituting an anode face that faces downwardly and being formed of a renewable facing means of consumable carbonaceous electrode material adapted to afford the anodic active surface defining one boundary of the electrolysis gap, which facing means has at the interface formed between it and the respective electrode a layer which is composed of carbonaceous particles and a material which remains molten during the electrolysis process, the molten material being taken from the group consisting of said metal and said bath, the fused bath having access to said interstice during the electrolysis, the layer being of such thickness that the voltage drop across it is smaller than the electrolysis decomposition voltage drop across the said electrolysis gap, the layer having a thickness less than a minor fraction of the thickness of the respective carbonaceous block, and of the renewable facing means.

20. An apparatus for recovering metal by electrolysis in a fused bath comprising structure means for containing the bath of the fused salt, two electrodes each comprising a carbonaceous block positioned at opposite walls of the structure means, current conductors electroconductive connected to the blocks, each of the blocks having a bath-side face which slants upwardly at an angle to the vertical, said faces being substantially parallel, one of said faces constituting a downwardly directed anode face and being formed of a renewable facing means of consumable carbonaceous electrode material adapted to afford the anodic active surface defining one boundary of the electrolysis gap, which facing means has at the interstice formed between it and the respective electrode a layer which is composed of a material which remains molten during the electrolysis process, the molten material being taken from the group consisting of aluminum and said bath, the fused bath having access to said interstice during the electrolysis, the layer being of such thickness that the voltage drop across it is smaller than the electrolysis decomposition voltage drop across the said electrolysis gap, the layer having a thickness less than a minor fraction of the thickness of the respective carbonaceous block, and of the renewable facing means.

22. In the electrolysis of fused aluminum compounds in which the electrode spacing between anode and cathode surfaces varies periodically within predetermined limits, the improvement comprising periodically restoring the electrolytically consumed layer of an electrolytic cell carbon anode used in said electrolysis by positioning a restoring consumable carbon anode layer against the face of said anode and permitting a lasting layer of the fused electrolytic bath to remain between said face and said restoring carbon in said electrolysis, the latter layer being of such thickness that the voltage drop across it is less than the electrolysis decomposition voltage drop across the electrolysis gap between the anode and the cathodic surface, the latter layer remaining molten during the electrolysis and being of a thickness less than a minor fraction of that of the restoring anodic layer.

23. In the electrolysis of fused aluminum compounds the improvement comprising periodically restoring vertically movable and adjustable carbon anodes, used in the electrolytic production of aluminum from said fused aluminum compound, by withdrawing the used anode upwardly out of the electrolytic bath, floating a plate of anodic carbon under the withdrawn anode, and then lowering said anode upon said plate to submerge it together with the anode to the proper distance for carrying out the electrolysis, the fused bath liquid being permitted to enter and being present in the interstice between the plate and the anode during the restorative process, and forming a layer of such thickness that the voltage drop across it is less than the electrolysis decomposition voltage drop across the electrolysis gap between the anode and the cathodic surface, the layer being of a thickness not more than a minor fraction of that of the restoring anodic layer.

24. In a fused bath electrolysis process in which the electrode spacing between anode and cathode surfaces varies periodically within predetermined limits, an improvement comprising providing a substantially consumable anodic layer of an electrolytic cell anode used in fused bath electrolysis processes, which comprises individually introducing and then locating a plurality of juxtaposed pieces of anodic material in side-by-side relative position against the face of said consumed anode, a layer of electrolytic bath liquid remaining between said face and said pieces and being present therebetween during the electrolysis process, the latter layer being of such thickness that the voltage drop across it is less than the electrolysis decomposition voltage drop across the electrolysis gap between the anode and the cathodic surface, the latter layer being of a thickness less than a minor fraction of that of the restoring anodic layer.

25. In a process of electrolysis of fused aluminum compounds, the improvement comprising periodically restoring a vertically movable and adjustable carbon anode consumed in said electrolysis, by positioning in an electrolytic cell, carbon in an electrolytic cell, by spreading some cokeable hydrocarbon containing material on a plate of anodic carbon, applying said plate against the face of the consumed anode from the bath side with the hydrocarbon containing material in between, said carbon anode being hot when said plate is applied, the fused bath having access to the interstice between the face of the consumed
anode and the said plate, and then passing current through said anode to the electrolytic bath, the restoring layer being sustained during restoration by its buoyancy in the bath, the restoring layer and the carbon anode being in juxtaposed relation during the electrolysis process, the fused bath in the interstice remaining fused during the electrolysis and being of such thinness that the voltage drop across it is less than the electrolysis decomposition voltage drop across the electrolysis gap of the said cell, and having a thickness not more than a minor fraction of the restoring carbon layer.

26. In a process for the recovery of aluminum in a fused bath electrolysis the improvement comprising periodical restoring the electrolytically consumed layer of an electrolytic cell carbon anode used in said electrolysis, by locating a restoring carbonaceous layer against the face of said anode and introducing a material comprising a substance of the group consisting of molten aluminum and fused bath into the interstice so formed between said face and said restoring layer, said face being at least in major part submerged in the bath during the said restoring, said layer and the carbon anode being in juxtaposed relation during the electrolysis process, at least that portion of the said substance introduced into the interstice which is below the level of the bath remaining molten during the electrolysis and being of such thinness that the voltage drop across it is less than the electrolysis decomposition voltage drop across the electrolysis gap of the said cell, and having a thickness not more than a minor fraction of the restoring carbon layer.

27. An apparatus for recovering a metal by electrolysis in a fused bath, comprising structure means for containing the bath, two terminal carbonaceous electrodes positioned in the structure means, current conductors electroconductively connected to the terminal electrodes, each of the terminal electrodes having an upwardly-downwardly directed bath-side face, at least one bi-polar carbonaceous electrode positioned between the said terminal electrodes, the bi-polar electrode having upwardly-downwardly extending opposite bath-side faces, the anode faces of the electrodes each being formed of a replaceable facing piece of consumable carbonaceous electrode material adapted to afford the anodic active surface, means for retaining the piece in juxtaposed relation to the respective electrode and having at the interstice formed between the piece and the respective electrode a layer which is composed of carbonaceous particles and a material which remains molten during the electrolysis process, the molten material being taken from the group consisting of said metal and said bath, the bath in said apparatus having access to said interstice, said molten layer being of such width that the voltage drop across it is less than the electrolysis decomposition voltage drop across the electrolysis gap of the respective cell.

28. An apparatus for recovering a metal by electrolysis in a fused bath comprising structure means for containing the bath, two terminal carbonaceous electrodes positioned in the structure means, current conductors electroconductively connected to the terminal electrodes, each of the terminal electrodes having an upwardly-downwardly directed bath-side face, at least one bi-polar carbonaceous electrode positioned between the said terminal electrodes, the bi-polar electrode having upwardly-downwardly directed opposite bath-side faces, the anode faces of the electrodes each being comprised of at least one replaceable facing piece of consumable carbonaceous electrode material adapted to afford the anodic active surface, means for retaining the piece in juxtaposed relation to the respective electrode and having at the interstice formed between the piece and the respective electrode a layer which is at least partly composed of a material which remains molten during the electrolysis process, the molten material being taken from the group consisting of said metal and said fused bath, said molten layer being of such width that the voltage drop across it is less than the electrolysis decomposition voltage drop across the electrolysis gap of the respective cell.

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