

April 13, 1965

G. DE VARDA ET AL

3,178,363

APPARATUS AND PROCESS FOR PRODUCTION OF ALUMINUM
AND OTHER METALS BY FUSED BATH ELECTROLYSIS

Filed Aug. 1, 1962

5 Sheets-Sheet 1

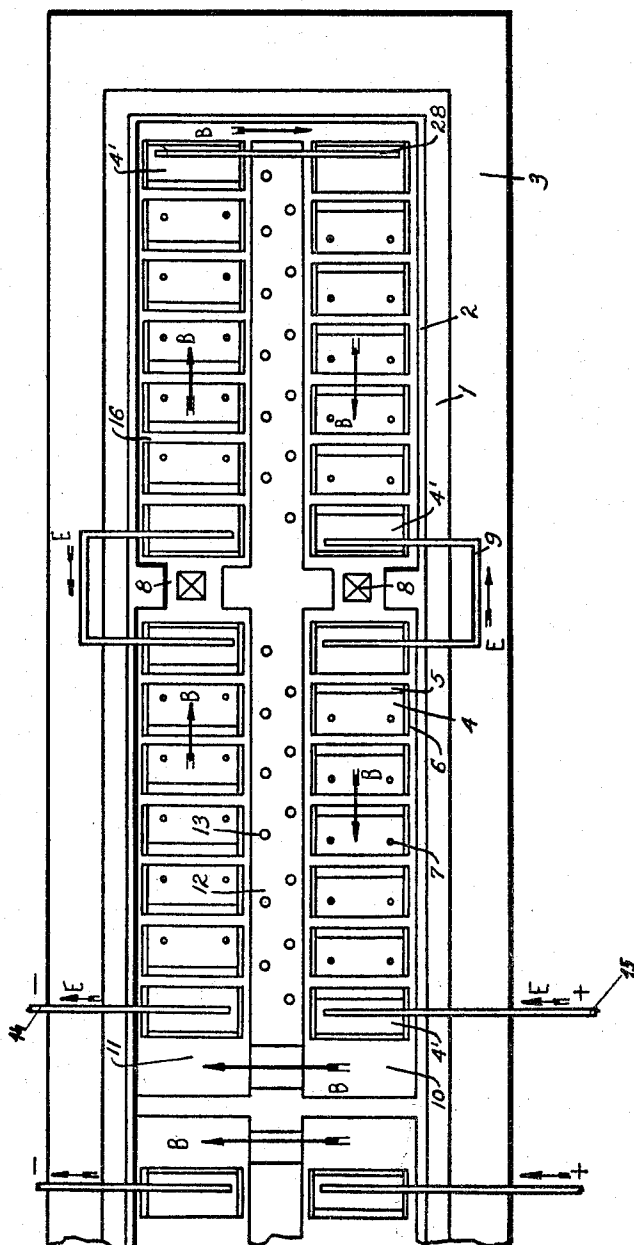


Fig. 1

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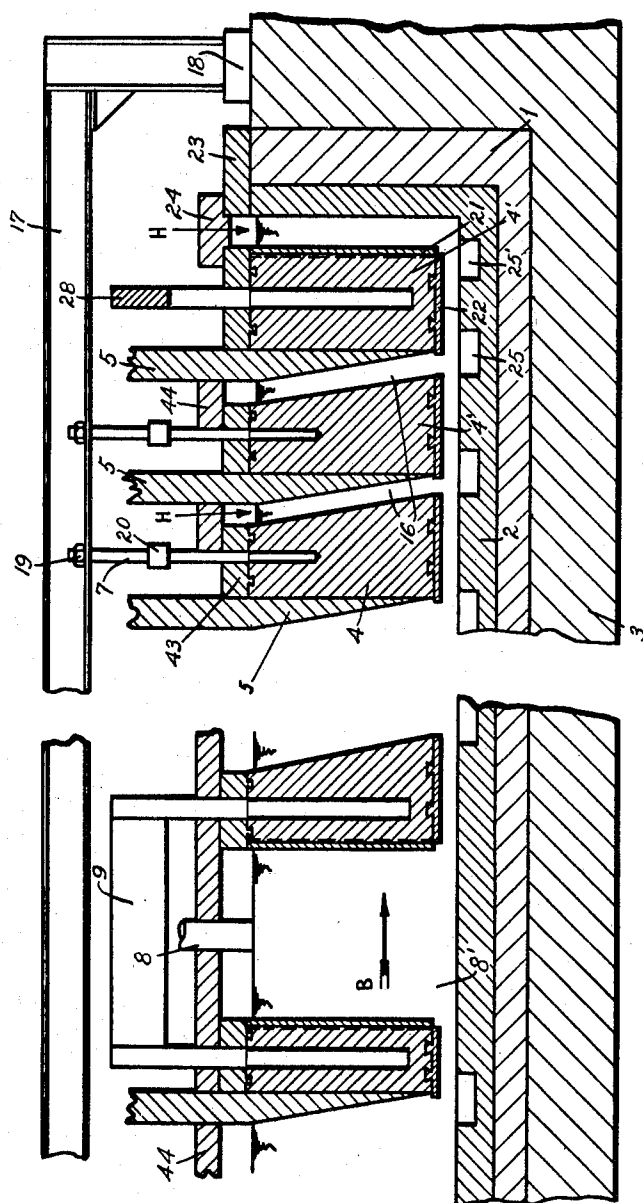


Fig. 2

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Fig. 3

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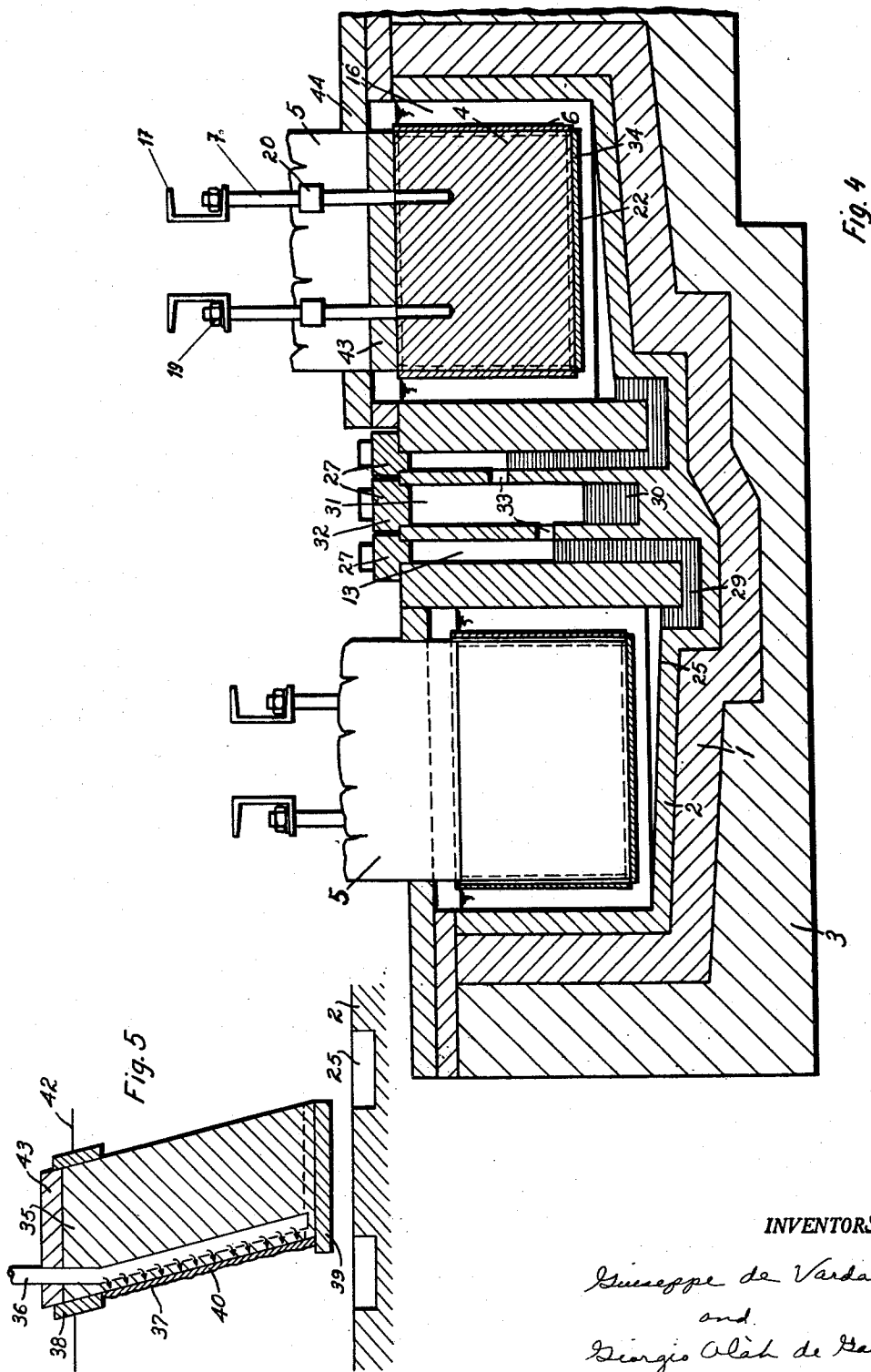
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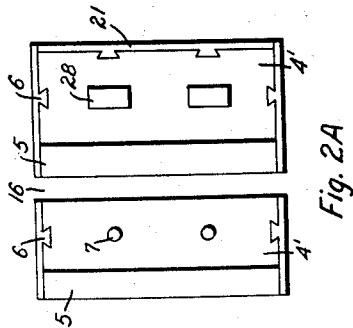
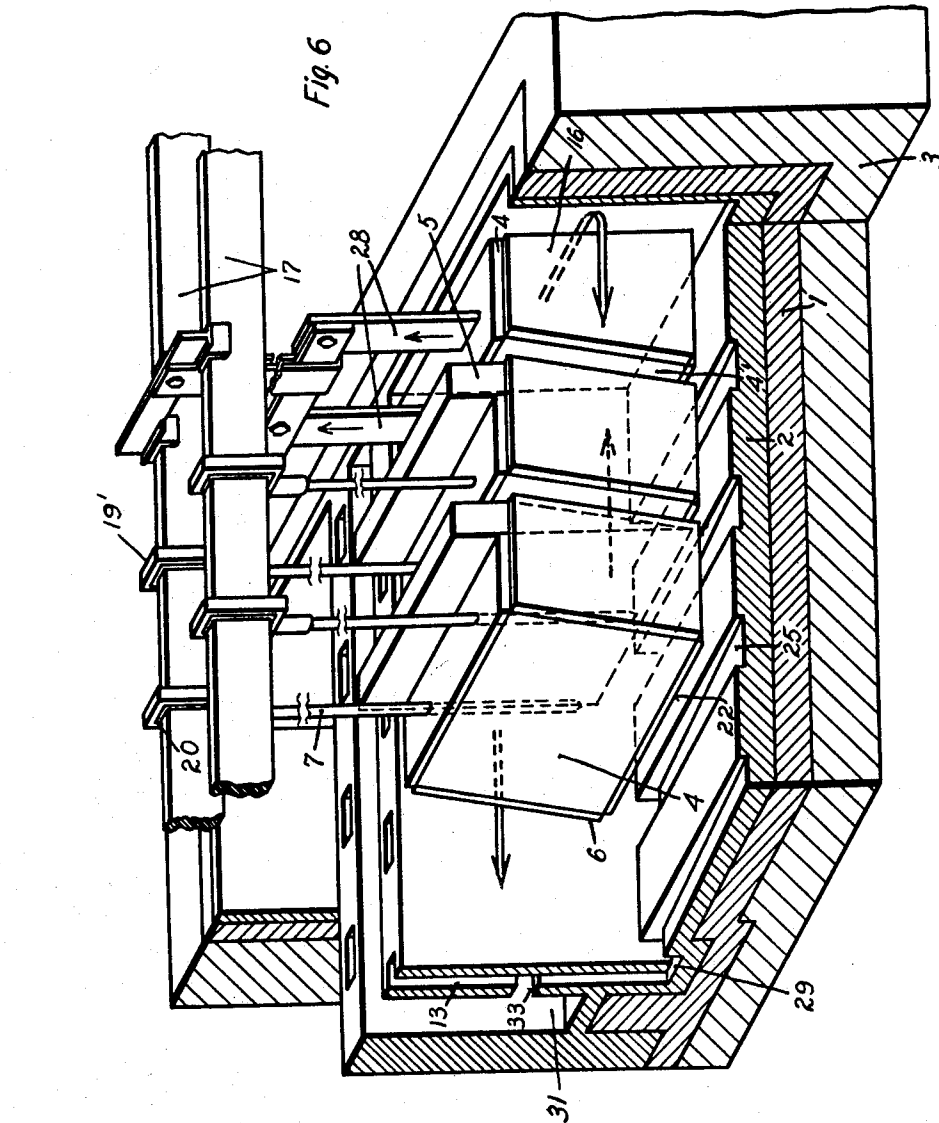
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3,178,363 APPARATUS AND PROCESS FOR PRODUCTION OF ALUMINUM AND OTHER METALS BY FUSED BATH ELECTROLYSIS

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14,325/61

12 Claims. (Cl. 204—67)

The invention relates to an electrolytic furnace employed particularly to produce aluminum from alumina dissolved in a bath of molten salts.

This invention is an improvement in the type of furnace described in the De Varda patents, for example U.S. 2,952,592.

That type of furnace is characterized by the massive and compact structure of multicell aluminum furnaces, in which vertical or subvertical bipolar electrodes form the cells. The furnaces and the cells are disposed chiefly in a necklace-like arrangement, the circulation of the bath being in a closed circuit. This is suitable from the thermal viewpoint, i.e. for maintenance of a molten bath and for heat economy. However, such furnaces are difficult to build, and also to work and to maintain. Such maintenance often necessitates vast demolition operations required to reach damaged zones situated inside the multicell furnace, for the purpose of repair. In such furnaces, insulating refractory materials form a bridge between the anodic surface and the opposite cathodic surface of each pair of bipolar electrodes. These materials undergo attack, probably electrochemical in nature, in the immediate vicinity of the anodic surface.

An object of this invention is to mitigate these disadvantages by supporting the electrodes independently of the inside of the furnace, to facilitate their removal.

The invention comprises a furnace, for the production of aluminum by fused bath electrolysis, which furnace is equipped with electrodes supported or suspended through or by insulating members located either entirely outside the furnace, or connected to the furnace only at parts which are not intended to be in contact with the molten electrolytic bath.

The inside surfaces of the furnace, and also the faces of the electrodes that are not intended to be electrolytically active, are coated with a refractory insulating material which is inert to the electrolytic bath, the electrodes being distinctly spaced from the inside of the furnace, at least up to a line corresponding to the highest possible level the bath may reach. No anodic part of the individual electrodes, designed to contact the electrolytic bath, is simultaneously in direct electric contact with either the cathodic part of another electrode or of the vat structure, there being no electrical connection or contact through the lining refractory, nor directly.

Such furnaces may comprise one or more vats, each vat containing stationary, vertical or subvertical electrodes of carbonaceous material or of graphite. The electrolysis space is between the faces of contrary polarity of consecutive electrodes. If more than two electrodes are used, the intermediate electrode or electrodes are bipolar electrodes, having no attached current conductors, that is, during ordinary sequential serial current flow between adjacent cells. The terminal electrodes are provided with fixed metallic current-carrying stubs which distribute the current substantially uniformly on the active surfaces of the electrodes. One series or a plurality of series of electrodes can be arranged as a closed necklace of cells, in the same furnace, provided with means for circulating the electrolytic bath about the electrodes in a series of vats. The electrodes may be supported or suspended individually, for

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example through or by members resting on the top of the furnace or vat. The bottom of the furnace vat may be shaped or formed so as to provide individual open channels (grooves) extending across the vat, to collect and discharge the metal produced by electrolysis on the cathodic faces of the individual electrodes.

The new furnace may also comprise the following features:

(a) The shape of the bottom may be such as to provide at least as many grooves or pockets as electrolysis spaces, so that each space and pocket serves to individually collect the aluminum metal produced, and then to allow the said metal to discharge through an upgoing conduit and then over an overflow device into a chamber designed for collection of metal, which chamber is itself inside the furnace;

(b) The above-described refractory coating or lining on the sides and on the bottom of the furnace, and also of the bipolar and terminal electrodes, may be fastened by dovetailed joints and/or with a bituminous preparation, pitch based for instance; or by spray-coating ("spraying");

(c) The current stubs of the terminal electrodes serve also as suspension members for the electrodes;

(d) The bipolar and terminal electrodes, and also the vat, are made of carbonaceous material. The linings of the electrodes and of the vat are made of refractory material, based either on silicon-nitride-bonded silicon carbide or on boron nitride, at least for the anodic portion of the electrodes;

(e) The furnace is heat-insulated, either by means of a nonheat-conductive external coating for each vat, or by means of a lid inhibiting the exposure of the electrolytic bath to the air, or both;

(f) The distance between the electrodes and the vat is from about 1 to about 20 centimeters depending upon the applied voltages and the conductivity of the materials of and within the cell and upon its overall dimensions, preferably about 5 centimeters;

(g) The furnace, provided with a terminal anode and intermediate bipolar electrodes, is also furnished with an anodic layer which is renewable by a continuous or a periodic integration procedure. The anodic layer is spaced from the inside of a vat or furnace in the same way as are the stationary parts of the electrodes, and is protected on its sides and bottom by a frame of refractory material extending beyond the stationary electrode. The means employed for this integration are separately arranged, and are insulated with respect to the structure of the furnace vat in the electrolysis zone;

(h) The integration discussed under (g) may be carried out periodically for instance with a gaseous hydrocarbon, preferably methane. The electrodes are bored to provide blind bottomed channels which reach only as far as the vicinity of the active anodic surfaces. The gaseous hydrocarbon is passed into the bath through said channels and thence through the pores of the electrodes. The perforated feed pipes for methane are anchored in the channels;

(i) The methane feed pipes discussed under (h) constitute bearing elements for the support or suspension of the electrodes;

(j) The integration may be carried out, simultaneously with the consumption of the anode, by progressively feeding the renewing layer from the top, in proper stack guides, of the kind described in De Varda U.S. Patent 2,959,527, issued November 8, 1960. The protective lining on the sides and on the bottom of the electrode constitutes side guides and abutment respectively, to hold the renewing layer.

The invention further comprises an improvement in

processes for production of metals by fused bath electrolysis, particularly for production of aluminum from alumina in a fluorine-containing bath, said process being carried out in a furnace according to the invention. Namely, in a furnace comprising a series of vats in a necklace-type closed circuit, the electrolytic bath is made to circulate between the sides of the furnace and the sides of the electrodes and between the bottoms of electrodes and the bottom of the vat in one direction, preferably contrary to that of the current.

One advantage derived by separating the electrodes from the furnace vat, so that the electrodes no longer form one body or structure together with the remainder of the furnace, and so that the individual electrolytic cells, which were formerly entirely closed, are transformed into so many electrolytic interspaces open to the furnace cavity on all sides, except those opposite the electrodic faces, is that the multiple furnace is simplified and is better articulated. The same refractory materials which formerly have shown poor durability now have much better resistance, because solid contact between the anodic refractory and the cathodic refractory, in the same cell, is prevented.

This difference in behavior of the same materials suggests that corrosion of anodic refractory material in a multicell furnace, with closed cells, is augmented due to localized passage of a portion of the anode current to the cathode through the refractory wall of the underlying aluminum collection chamber, and through the wall separating and bridging the anode from the cathode of the adjacent bipolar electrode.

When soaked by the molten bath and altered thereby at temperatures of about 1000° C., many refractories tend to become fairly good conductors of electricity. The frames of refractory material constructed according to the instant invention coat only the anodic and the cathodic portions of each bipolar electrode, forming an independent block. The low current density and the high electric conductivity of the bipolar electrode, cause all points inside its refractory lining to be practically at the same potential, thus minimizing the conducting effect of said refractory lining. On the other hand, an appreciable potential difference is established inside the said refractories whenever the refractories act as a solid bridge between an anode and a cathode standing, i.e. supported, on the same interelectrode space. It appears that the presence of molten bath fluid in the pores of the refractory favors a certain amount of current passage, which causes parasitic anodic electrochemical phenomena, especially in that zone of contact of the anode and refractory which is nearer the cathode, the latter being either metallic or constituting bare graphite. This zone may be called the "Triple Zone." The invention reduces corrosion of the refractory by avoiding solid contact between the refractory materials of the anode and cathode zones of two adjacent bipolar electrodes forming an electrolytic cell, so that the refractory layers inside the furnace and in contact with a bipolar electrode are always separate from all the other refractory layers of the multicell furnace. Said other refractory layers are either the refractories framing the other electrodes, or the refractory lining inside the vat which contains the bath. Thus, application of a potential to the vat is avoided.

The bipolar electrodes are preferably made of graphite, that is, at least of their cathodic portion. The terminal cathodic electrodes are also graphite, and also the permanent portions of the anodic terminal electrodes of the individual series forming the necklace. From the structural viewpoint there are, in the furnace of the invention, the following two types of electrodes:

(a) Bipolar intermediate stationary electrodes, framed on their sides and on the bottom, and optionally also on top, by a layer of refractory material that is inert to the bath and to the electrolysis, while leaving free only the

surfaces intended to be electrolytically active, namely those facing the opposite electrode;

(b) Monopolar terminal stationary electrodes, also framed on their sides and on the bottom, and optionally on top, by a layer of inert refractory material, which in this case covers also the surface opposite the anodically or cathodically active surface.

Such refractory coatings prevent the consumption of the side and base faces of the bipolar electrodes and also the back faces of the terminal electrodes, which consumption would otherwise take place as a result of the electrolysis.

By keeping the thickness of the coated bipolar electrodes greater than a minimum value of about 20-30 cm., the electric losses, caused by by-pass of current through the bath outside the refractories framing the electrodes, are reduced to low and, therefore, tolerable percentages.

The electrolytically active surfaces of the bipolar electrodes, suspended in the above-described manner, are entirely immersed in the bath of fused fluorides. The bath is contained in a common vat built of material impermeable to the bath, preferably of amorphous carbon, and is coated on the bottom and on the inner sides with a layer of refractory material which does not conduct the electric current or conducts poorly, and which is inert, or hardly vulnerable. A suitable material is silicon-nitride-bonded silicon carbide, for instance that sold under the trade name "Refrax" of Carborundum, or "Crystolon" or Norton.

The vat may be provided externally, including below, with thermal insulation to maintain the furnace in thermal balance. The bath level preferably corresponds to half the thickness of the insulating refractory covering the top of the electrode. The permanent portion of each individual electrolytically consumable bipolar electrode is rigidly suspended in an interchangeable manner, but is not intended for displacement during a furnace run, the furnace being of a kind dispensing with any devices for mechanical adjustment of the inter-electrode spacing during operation. A suitable minimum distance of a few centimeters is maintained between the side surfaces of the bipolar electrodes and the inside of the vat. The distance between the electrode base and the vat bottom is preferably kept at a minimum value of a few centimeters, for instance 5 cm. While maintaining such minimum distances, the volume of bath present in the furnace is maintained at a value such that excessive floor spaces and heights of the furnace and excessive losses by current by-passage are avoided and the building and operating costs of the furnace are reduced.

Finally, on top of the improved furnace there is a layer of refractory material which is also electrically insulating, the material being covered by further layers of thermo-insulating refractories not shown in the drawings. Spy-covers are provided for occasional control or supervision of the course of the electrolysis, and occasionally also for inserting movable electrical resistances laterally between the electrodes and the vat, for use in starting the furnace. Current feed is provided exclusively through current-supplying bars, which are connected to the terminal electrodes of each series, or to terminal electrodes of each necklace of electrolytic interspaces or electrodes.

Preferably, current-supplying metal bars are introduced into, or embedded in, the terminal electrodes to a depth designed to keep the contact drops as low as possible and are suitably subdivided, located, dimensioned and fastened so as to obtain regular and uniform distribution of electric current on the electrolytically active surfaces. Such bars must be electrically insulated from all of the other furnace parts, and contact with the bath is to be avoided. To make up for the anodic consumption of the fixed electrodes it is feasible to proceed according to any one of the following known methods:

(A) Periodic integration of the electrodes from the bath side by means of anodic carbon slabs, interchange-

able after their almost total consumption. The slabs come to rest against subvertical downwardly facing anodic surfaces, being held against said surfaces by the upward hydrostatic thrust of the bath. The covering layer of refractory serves as the upper stop, being applied in a position higher than that of the anodic face of an individual electrode. Note De Varda U.S. Patents 2,959,527; 2,952,592; and 2,959,528.

(B) Continuous anodic integration with compact anodic carbonaceous material fed periodically or continuously from the top, for instance through a stack of refractory material. This layer of anodic integration is stopped at its lower end (or lower edge) by a socket of refractory material, which is applied below the bottom of the bipolar electrodes (and of the terminal anodic electrodes) and will be described below in greater detail.

(C) Periodic anodic integration with a gaseous hydrocarbon such as methane which is introduced into the anode zone of each electrode under slight pressure, for instance through the supporting bars which in this case are tubular and primarily intended for the suspension of the bipolar electrodes, or of the terminal anodes. The gas is decomposed in passing through the pores of the bipolar electrode or the adjacent layer of bath and forms on the surface, or in the adjacent bath layer, a layer of spongy carbon black which is then consumed during the electrolysis.

The aluminum which separates on the cathodic surface of the electrolytic interspace first descends along the cathode, and then falls through the layer of free bath onto the bottom of the vat containing the bath.

The circulation of the bath, which is preferably in countercurrent with respect to the electric current, takes place through the free interspaces between the walls, including the bottom, of each individual vat and the electrodes therein suspended (framed with refractory material). Except for this fact the bath circulating system is similar to that described in De Varda U.S. Patent 2,952,592, issued Sept. 13, 1960.

The accompanying drawings illustrate a furnace according to the invention:

FIG. 1 is a plan view of a whole half necklace furnace and a portion of another half of a necklace of cells.

FIG. 2 is a longitudinal section of a series of cells of the necklace furnace of FIG. 1, including also an aluminum oxide feed chamber, but without the bath-lifting device shown in the various De Varda patents.

FIG. 2A is a horizontal section taken along the trace H—H of FIG. 2.

FIG. 3 illustrates a cross section of the necklace furnace of FIGS. 1 and 2 provided with pockets, arranged in a longitudinal central wall for the tapping of the aluminum produced.

FIG. 4 is a cross section of a necklace furnace of a different structure, in which the longitudinal central wall is provided with pockets with overflow and a common receptacle intended for collecting the aluminum produced in all of the series cells.

FIG. 5 illustrates, in cross section, a bipolar electrode provided with perforated pipes for introducing methane to renew or integrate anodic surfaces consumed in the electrolysis.

FIG. 6 is a cut-away perspective illustrating a portion of a furnace modified in accordance with the invention, in which for the sake of clarity the front wall of the furnace as well as the entire covering have been removed.

In FIGS. 1 and 2, the vat 1 containing the bath is made of carbonaceous material and is lined on its entire inner surface by refractory layer 2. The direction of the bath current is indicated by arrows B, whereas the electric current direction is indicated by arrows E. The vat 1 is protected on the outside by an insulating jacket 3, providing thermal insulation.

The bipolar electrodes 4 of FIGS. 2 and 3 are rigidly suspended from supporting bars 7 fastened to longitudinal

beams 17. The bars are fastened to the beams 17 by members 19 which may be bolts (FIGS. 2, 3, 4), or collars 19' (FIG. 6). Each bar 7 is electrically insulated from its suspension beam by an insulator 20. The beams 17 are also electrically insulated from the remainder of the furnace by insulators 18.

The terminal monopolar electrodes 4' are provided with current-supply bar stubs. The terminal current-supply bars 14 and 15 of FIG. 1 and the central connecting current-carrying bars 9, and also the current-supply connecting bars 28, located at the right extremity (FIG. 1) of the necklace furnace, serve also to suspend monopolar electrodes 4'.

In FIGS. 2, 3 and 4 the consumable anode portion 5 of each electrode is fed from the top through a stack, not shown in the drawings. Both the bipolar electrodes 4 and the terminal monopolar electrodes 4' are framed with a protective refractory coating that is inert both to the bath and to the electrolysis. The refractory frame comprises the side coatings 6, the base coatings 22 (FIG. 2), and the top coatings 43 (FIG. 2), and also the transverse coatings 21 in the case of the monopolar terminal electrodes 4' (FIG. 2). These coatings are fixed to the carbonaceous material of the electrode body, graphite for example, by means of dovetailed grooves, with the optional application of a mastic on pitch base 34 (FIG. 3) between the coating and the stationary electrode. In the apparatus of FIGS. 2, 3, 4 and 6 a further layer of thermo-insulating refractory (not shown in the drawings) is applied to the coatings 43, to serve also as a guide for the consumable anode portion 5, as explained above.

In FIGS. 1 and 2 the alumina feeding is effected preferably semicontinuously, through a feed measuring device 8, located in a chamber 8' outside the electrolysis zones. The lifting of the bath from the low terminal chamber 10 up to the higher chamber 11 is carried out in known manner.

In FIG. 5 is illustrated a bipolar electrode 35 suspended, not by bars but by perforate pipes 36 through which methane is introduced into the electrode body in the vicinity of the active anode surface. Methane under slight pressure leaves bores 37 and passes through the pores of the carbonaceous material layer separating it from the bath. The methane decomposes under the action of the high temperature, to form on the anodic surface, or in the adjacent bath layer, a bed of spongy and consumable carbon black 40. The bipolar electrode 35 is protected, at the bottom and on the sides, by a refractory layer 39 which is inert to the bath and to the electrolysis and is framed around its upper portion, above and below bath level 42, by inert refractory lists 38.

In FIGS. 1, 3 and 4, the central longitudinal refractory wall 12 is provided with vertical pockets 13 for reception of the metal produced, the pockets having lids 27 (FIG. 3). The metal produced in any one of the cells is conveyed to the corresponding pocket 13 through individual grooves 25 (FIG. 2), suitably dimensioned and arranged on the vat bottom to take account of the bath circulation and preferably having an inclined bottom, under each electrolysis space 16, the conveying being through a conduit 26 connecting the grooves 25 with the pockets 13. Since a portion, although very little, of the metal produced may be dragged along with the circulating bath, a further groove 25' (FIG. 2) is provided, which is located after the last electrolysis space 16 (in the direction of the bath circulation) of each series of interspaces. The groove 25' also ends in a pocket, in a manner identical with grooves 25.

In FIG. 2, the entire furnace is closed at the top by electrically and thermally insulating refractory layers 23, which are provided with spy-covers 24 to protect the bath from the surrounding atmosphere.

In FIG. 4, the pockets 13 are connected through a conduit 29 with the groove 25 of the inclined bottom. An overflow weir 33 serves to let the molten aluminum

overflow into a receptacle 31 common to each series of cells. The aluminum 30 collected in said receptacle can be poured, i.e. removed, at any time during the furnace operation, upon removing lid 32.

The furnace of the present invention may and is intended to include any one or more features of the known multicell furnaces employed for alumina electrolysis, as described and claimed in the following patents and co-pending applications:

De Varda Patents Nos. 3,029,194, 2,938,843, 2,952,592, 2,991,240, 2,959,533, 2,959,528, 2,959,527, 2,952,605; patent applications Serial Nos. 705,373, filed December 26, 1957, now Patent No. 3,063,930; 706,381, filed December 31, 1957, now abandoned; 711,577, filed January 28, 1958, now Patent No. 3,133,008, and/or to be embodied in combination with features of French specification 1,197,645 and patents of addition thereto.

We claim:

1. In a process for producing aluminum by electrolysis of alumina dissolved in a molten salt bath in a furnace wherein transverse electrodes are suspended, in which the molten salt bath is caused to flow longitudinally through a plurality of electrolysis gaps defined by opposed cathodically and anodically active surfaces, and in which the electric current serving for the electrolysis flows serially through said electrolysis gaps in the direction opposite the flow of molten salt, and further in which the molten aluminum produced in the process is collected below the electrolysis spaces in a common communicating lower region situated below the electrodes, the improvement comprising: collecting the molten aluminum in said lower region, below the molten salt bath, draining off the aluminum below each electrolysis gap in a direction extending crosswise of the direction of flow of the molten salt bath, and directing said flow of molten salt bath between the longitudinally extending side walls of the electrodes and the opposed longitudinally extending furnace walls, and also between the bottom surfaces of the electrodes and the bottom of the furnace.

2. In a process for producing aluminum by electrolysis of alumina dissolved in a molten salt bath in a furnace wherein transverse electrodes are suspended, in which the molten salt bath is caused to flow longitudinally through a plurality of electrolysis gaps defined by opposed cathodically and anodically active surfaces, and in which the electric current serving for the electrolysis flows serially through said electrolysis gaps in the direction opposite the flow of molten salt, and further in which the molten aluminum produced in the process is collected below the electrolysis spaces in a common communicating lower region situated below the electrodes, the improvement comprising: directing said flow of molten salt bath between the longitudinally extending side walls of the electrodes and the opposed longitudinally extending furnace walls, and also between the bottom surfaces of the electrodes and the bottom of the furnace.

3. A multi-cell furnace apparatus for production of aluminum by electrolysis, comprising a refractory furnace wall and bottom structure for containing a fused bath of alumina, a plurality of transverse electrodes suspended within said structure and including a terminal cathode, a terminal anode and at least one bipolar electrode having cathode and anode portions, said bipolar electrode being disposed between the terminal cathode and anode, said transverse electrodes having bottom surfaces and upwardly extending electrode walls facing the bath, pairs of opposed ones of said electrode walls having anodic and cathodic surfaces spaced apart a constant distance to define upwardly-downwardly extending electrolysis gaps, supporting means for fixedly suspending said transverse electrodes, said supporting means including a suspension beam insulated from and mounted above said furnace structure, rigid suspension means joined at one location thereof to said beam and at another location thereof to said bipolar electrode, said rigid suspension means hav-

ing an insulator electrically insulating said bipolar electrode from said beam, said supporting means further including current-supply means insulated from said beam and supporting said terminal anode and terminal cathode from said beam and electrically connected only to said terminal anode and cathode ones of said electrodes, said current supply means being spaced relative to said wall and bottom structure so that said current supply means is out of physical contact with said bath, said transverse electrodes being suspended so that the bottom surfaces and upwardly extending walls other than said opposed ones are spaced from the inside furnace wall and bottom structure at least a few centimeters.

4. A furnace apparatus according to claim 3, including framing means comprising a protective refractory coating inert to said bath and located on the bottoms and upwardly extending walls other than said opposed electrode walls.

5. A furnace apparatus according to claim 4, said framing means being attached to said electrodes by dovetail joints.

6. A furnace apparatus according to claim 4, said transverse electrodes as well as said refractory wall and bottom structure being of carbonaceous material, said framing means being of refractory material selected from the class consisting of silicon-nitride-bonded silicon carbide and boron nitride.

7. A furnace apparatus according to claim 3, said rigid suspension means comprising pipes having perforated portions imbedded in said bipolar electrode in the vicinity of said anode portion thereof for supporting said bipolar electrode while introducing a gas through said anodic surface.

8. A furnace apparatus according to claim 3, said furnace wall and bottom structure having an inner bottom wall provided with grooves located below and extending along respective ones of said electrolysis gaps for collecting the aluminum produced.

9. The invention defined in claim 3, and means for progressively feeding said renewing layer downwardly from above, comprising upwardly-downwardly extending stack guides extending at least partly within the furnace, the said protective material in the sides and bottom of said layer constituting respectively a side guide and a lower abutting socket for retaining said layer.

10. In an electrolytic furnace according to claim 3, said bipolar electrodes comprising an anode structure and a cathode structure, the cathode structure comprising a permanent graphite layer which remains stationed in the furnace during the electrolysis, the anode structure having an automatically continuously restoring anodic face comprising a moving layer of electrochemically consumable solid carbonaceous material having a substantially triangular cross section narrowing downwardly, there being a narrow interstice between the graphite layer and the moving layer, said interstice containing molten bath material, and guide means in the upper part of the furnace providing an upwardly-downwardly directed passage adapted for reception of the said layer of consumable carbonaceous material and for feeding the latter downwardly therein; the improvement comprising protecting the longitudinal side walls of the anode structure and also the bottom wall thereof with a frame providing a covering layer of refractory, electro-insulative material, said frame extending outwardly of the anode structure at the sides and bottom to form a side guide for said moving restoring layer, and also a lower abutting ledge for retaining the lower edge of said restoring layer.

11. In a furnace for making aluminum by electrolysis of alumina in a bath of molten salt, the furnace comprising a cell structure formed of upwardly-downwardly extending opposed electrodes providing an upwardly-downwardly extending electrolysis space in between, the furnace having means for causing the molten bath to move in the direction from one electrode to the next, and cur-

rent terminals for passing electric current in the opposite direction; the improvement comprising: suspension means spacing the electrodes from the side walls and bottom wall of the furnace to permit movement of the bath around the sides and bottoms of the electrodes.

12. In a furnace for making aluminum by electrolysis of alumina in a bath of molten salt, the furnace comprising a cell structure formed of upwardly-downwardly extending opposed electrodes providing an upwardly-downwardly extending electrolysis space in between, the furnace having means for causing the molten bath to move in the direction from one electrode to the next, and current terminals for passing electric current in the opposite direction; the improvement comprising: suspension means spacing the electrodes from the side walls and bottom wall of the furnace to permit movement of the

bath around the sides and bottoms of the electrodes, and means providing a refractory and electro-insulative protective covering for the bottoms and side walls of the electrodes.

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15 JOHN H. MACK, *Primary Examiner.*