

Nov. 13, 1962

M. F. G. JOUGUET ET AL

3,063,919

METHOD OF OPERATING HIGH AMPERAGE ELECTROLYTIC CELLS

Filed March 26, 1954

5 Sheets-Sheet 1

Fig.1

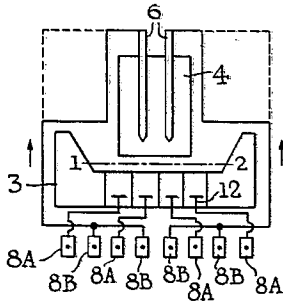


Fig.2

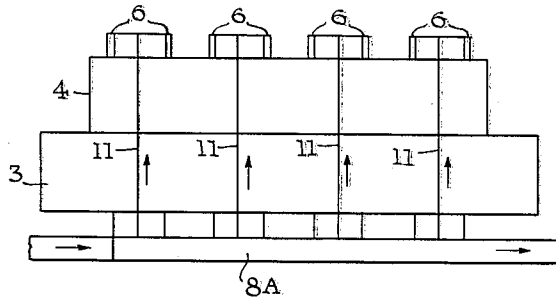


Fig.3

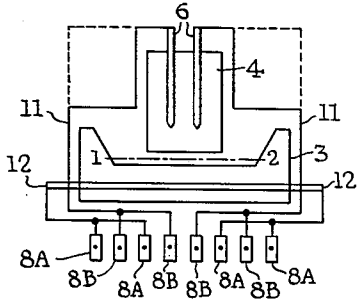


Fig.4

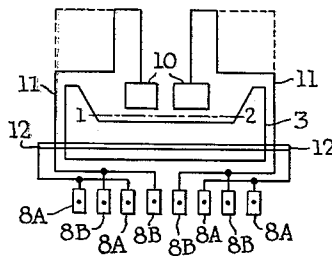


Fig.5

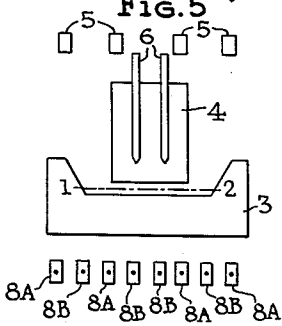
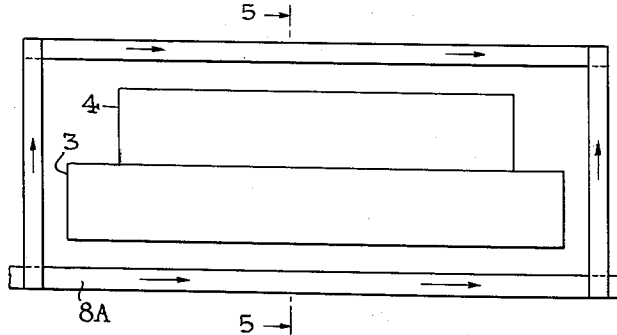


Fig.6



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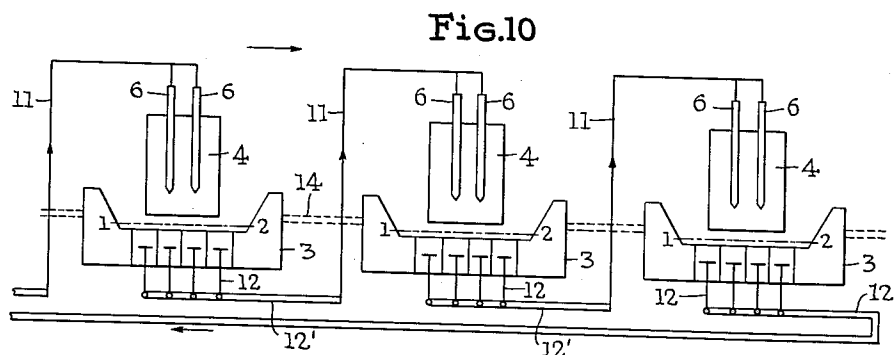
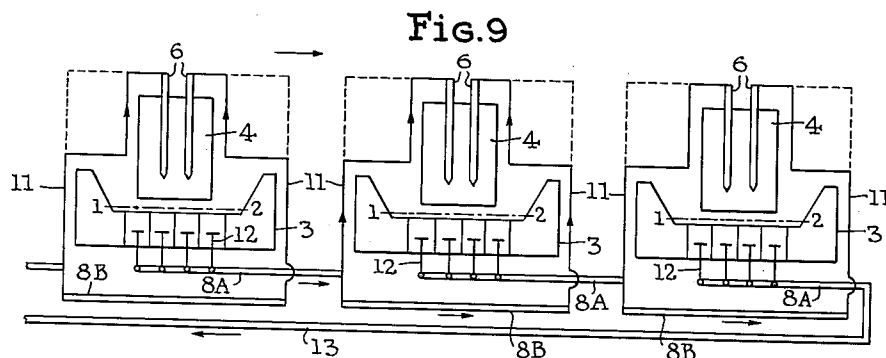
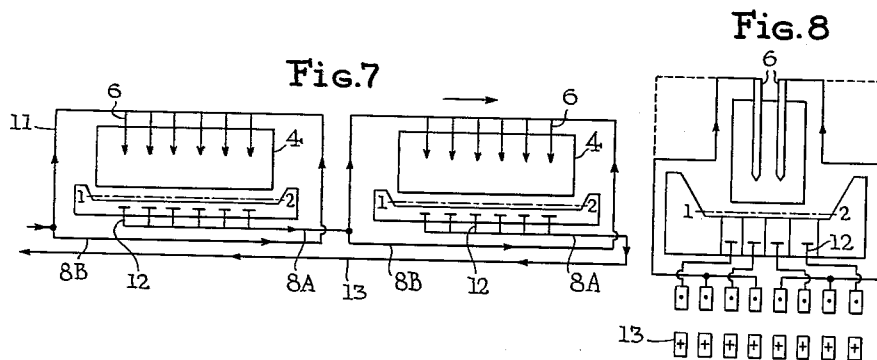
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5 Sheets-Sheet 2



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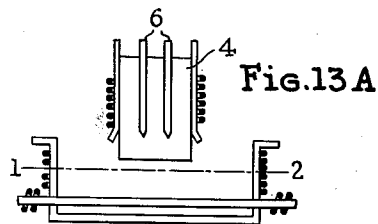
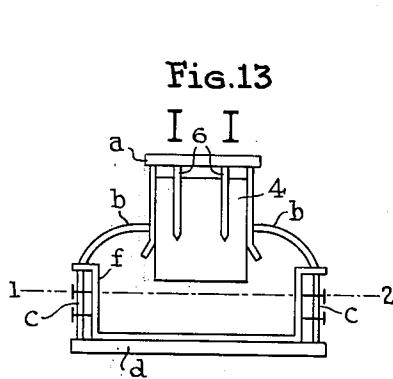
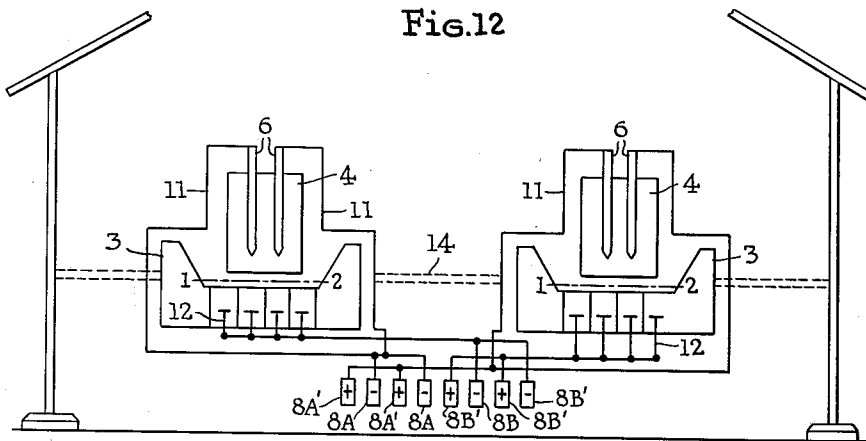
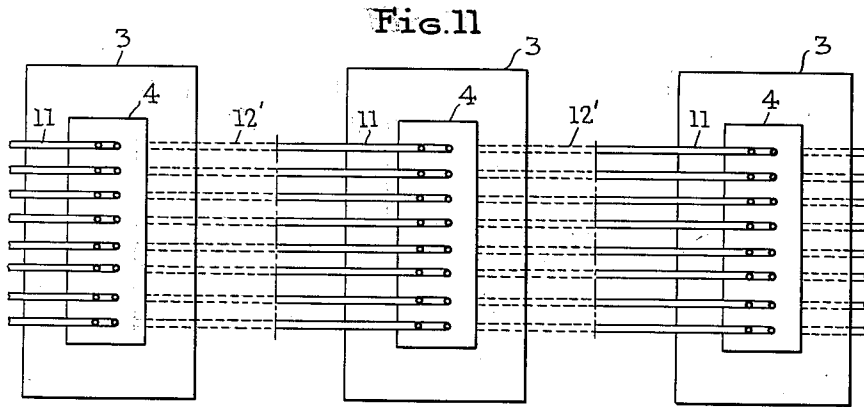
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METHOD OF OPERATING HIGH AMPERAGE ELECTROLYTIC CELLS

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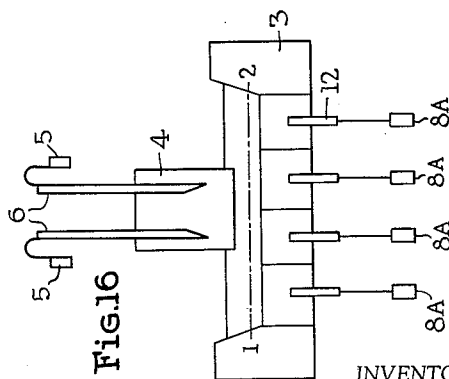
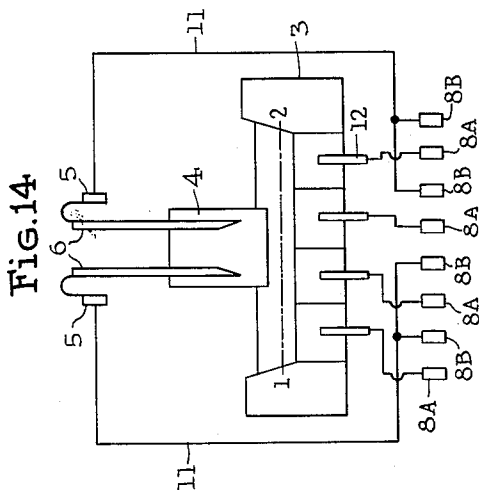
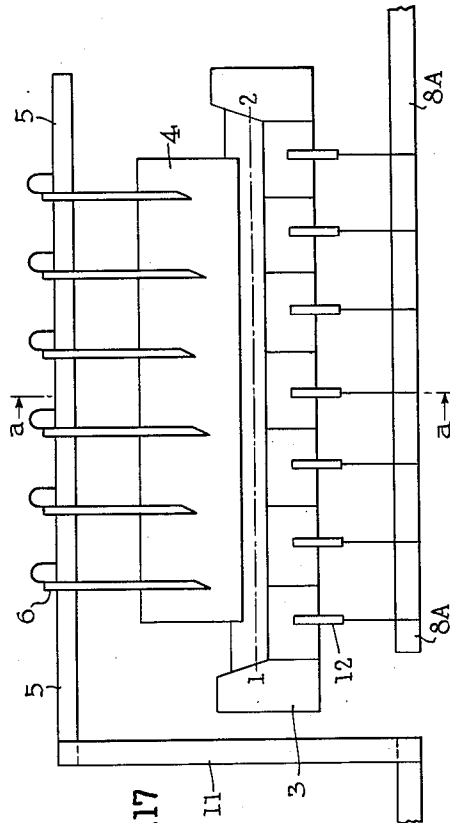
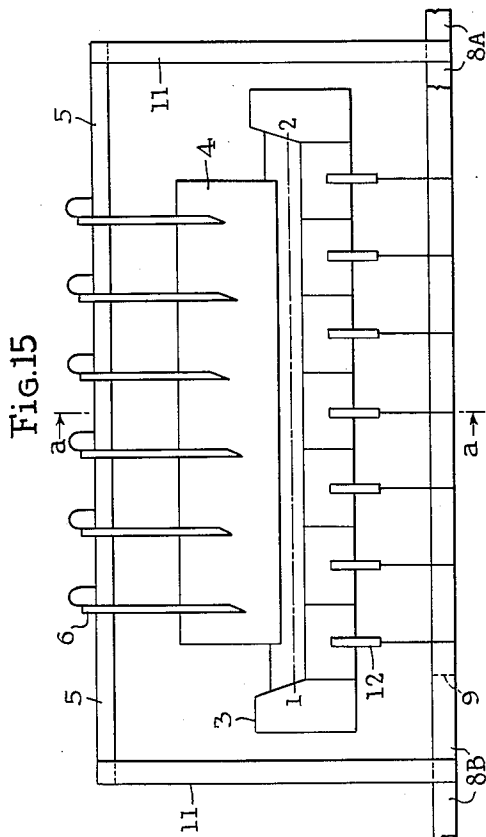
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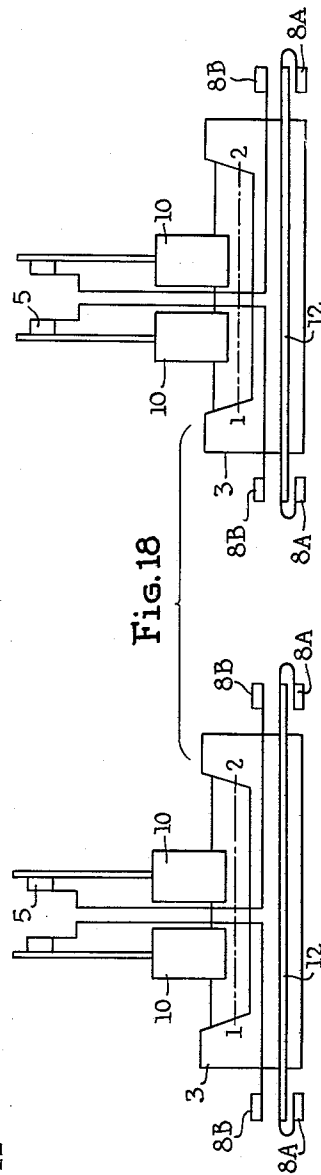
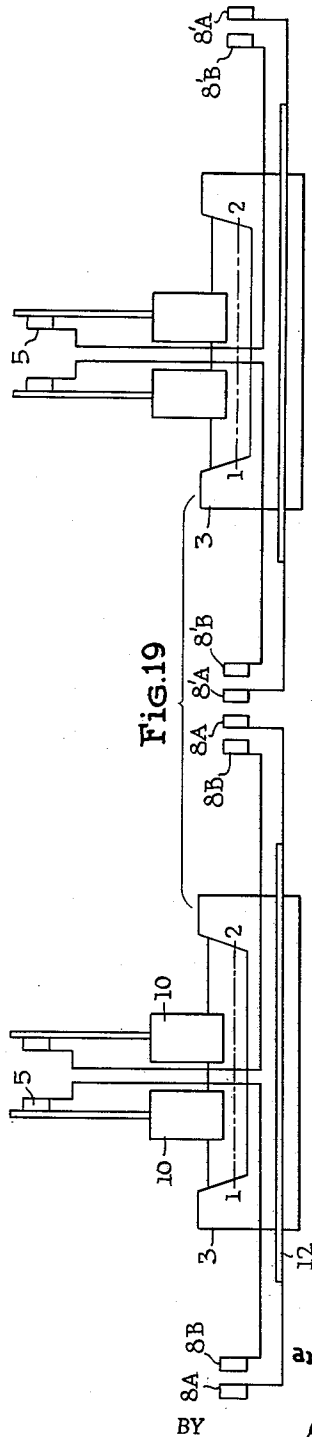
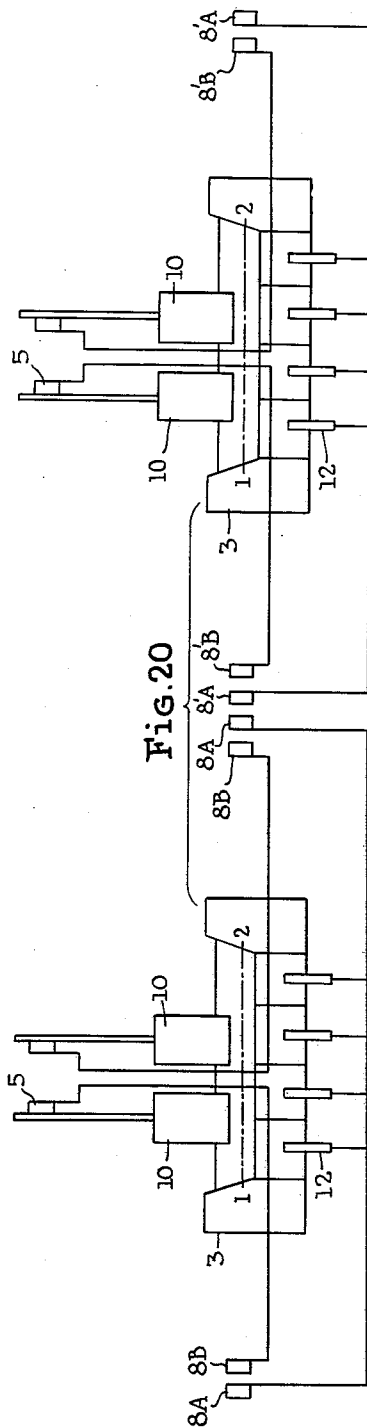
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METHOD OF OPERATING HIGH AMPERAGE ELECTROLYTIC CELLS

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3 Claims. (Cl. 204—67)

The present invention, which is based upon applicant's investigations, relates to methods and apparatus which make it possible to reduce or to suppress unevenness and movements of the upper metal surface in the bottom of the pot (crucible) of electrolytic cells.

In the production of aluminum, there are used electrolytic cells, the amperage of which is being constantly increased; thus, at the present time, cells working with 100,000 amperes are becoming more and more common. However, when using currents of this order of magnitude, drawbacks are occasionally present which do not manifest themselves to a harmful degree at lower amperage. In particular, the liquid aluminum present in the bottom of the crucible of the electrolytic cell no longer has a horizontal upper surface. This surface presents unevenness—variations in level—and is subject to movements which may attain several centimeters, and may even appreciably exceed the mean interpolar distance (gap) between the anode assembly and the cathode, which interferes considerably with the electrolysis. It is, therefore, most important to use means which reduce or, even, suppress such variations in level and movements of the upper surface of the metal.

It is known that, in the igneous electrolysis of alumina dissolved in a bath of molten fluorides, the potential difference at the terminals of each electrolytic cell is small and of the order of 4 to 5 volts. However, the generators which supply the direct current frequently have a terminal potential difference of 250 volts, while mercury arc rectifiers have a voltage of 500 and over. These generators must, therefore, be used to supply a certain number of electrolytic cells connected in series. That is, the current which has passed through the first cell downwards from the top and has left it through the cathode and then passes on to the anode assembly of the next cell which assembly is situated above said cell—passes vertically through the pot (crucible) in which are disposed in superposed layers first, the molten bath of fluorides and then liquid aluminum; the current passes next through the cathode and leaves the latter by means of conductors—generally formed of steel bars—and is then led above the next cell, and so forth. The conductors through which the total current passes comprise, in addition to the cell itself, the following:

- (1) The steel bars extending out of the cathode,
- (2) The conductors connecting the lower part of a cell with the upper part of the succeeding cell, and generally constituted of aluminum bars, one part of which, horizontally placed, is connected to the steel bars of the cathode, while the other part, disposed vertically, is connected at one end to the horizontal part, and at the other end to,
- (3) The current feed system horizontally disposed above the anode assembly of the succeeding cell. This feeder system is composed of several copper or aluminum bars of large cross-section, since each bar carries a considerable portion of the total current. This feeder system extends over the entire length of the electrolytic cell, since it serves to distribute the current either to prebaked multiple anodes, or to steel bars called "studs" which feed the current to continuous anodes of the Söderberg type.

Applicants' investigations have established the causes

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for the non-uniform level and movements of the upper surface of the aluminum at the bottom of the pot of each electrolytic cell. They are due to the action of the vertical and horizontal components of the magnetic field of variable magnitude (strength)—present in or about the cell and caused by the currents flowing in the connecting conductors, and in the cell itself—on the vertical currents and on the horizontal currents, or on currents of varying direction flowing in the molten metal.

The present invention relates, therefore, to a method which makes it possible to reduce or, even suppress, variations in level at and movements of the upper surface of the liquid metal found in the bottom of the pot of igneous electrolytic cells intended for aluminum production, by bringing about as uniform and as vertical a distribution of current as possible over the entire surface of the cell, while suppressing, reducing or rendering more constant the vertical components of the magnetic fields produced in the pot of the electrolytic cell and, particularly, at the surface of separation of bath and liquid metal. The invention likewise seeks to reduce the strength of the horizontal components of the magnetic field. To this end, it is necessary to carry out a double action on the currents and on the fields.

By reason of the great specific resistance of the molten fluoride bath relative to that of the aluminum, the currents passing through the bath will nearly always be vertical except for spreading at the lateral edges of the anode. Such spreadings can be reduced by the use of a wedge (inclined mass "talus") of fluorides solidified on the sides of the pot. Procedures for forming linings of solidified fluorides on the sides of an electrolysis cell used in the aluminum industry are well known in the art, being disclosed, for example, in the Hoopes et al. Patent No. 1,534,321 and No. 1,534,322, issued April 21, 1925.

The currents in the metal will be vertical and uniform if the interpolar distance (gap) is constant over the whole surface of the cell, if the cathode surface has dimensions very nearly equal (close) to those of the anode surface—which latter may likewise be obtained, for example, by providing a solidified inclined mass (talus) of fluorides on the sides of the pot—and, finally, if the carbon cathodes have an equipotential surface which is as nearly as possible in a horizontal plane. This last condition can only be realized if the connections to the external circuit be made from the upper plane of the cathode by means of conductors of equal resistance.

To obtain this condition, the steel bars extending from the cathode should be disposed vertically (French Patent 953,374) and should be increased in number, each of these bars being connected to the current feeder system of the succeeding cell by conductors of equal resistance; but, whatever arrangement be adopted for the cathode outlet bars, the connections between cells should, as far as possible, be so disposed that the currents flowing from each cathode outlet bar to the feeder system of the next cell follow as nearly as possible equal resistance paths. This result can be obtained by connecting the cathode bars furthest away with the nearest end of the feeder system supplying the anode of the succeeding cell, and vice versa. Inasmuch as these longitudinal connections between cells will necessarily have different lengths, it is possible to control the cross-section of each in such a way as to obtain substantially equal resistances in each partial circuit.

Since the effect (action) on the currents is not perfect, especially at the circumference of the anodes, it is necessary to act also on the fields in order to reduce as far as possible their vertical and horizontal components at the level of the upper surface of the liquid metal.

When currents pass through horizontally disposed conductors they generate fields having a vertical component.

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In the electrolytic cells used for the production of aluminum, the following are horizontally disposed: the feeder system which distributes the current in the anode assembly; the steel cathode bars when the latter are horizontal; the horizontal conductors which supply current to the ends of the feeder system; those conductors which collect the current leaving the cathode bars and pass it on to the succeeding cell, these latter conductors are generally disposed in groups on each side of and in immediate proximity to the cell as illustrated in FIGURE 18 of the annexed drawings to be described below; and, finally, the current passing through the line of cells which forms the return path for the series. Actually, the electrolysis cells are arranged in at least two parallel rows, since it is necessary that the current be returned to the generators.

The invention will be further described and explained in connection with the following drawings which illustrate, in schematic form only, several embodiments of the invention, and wherein:

FIGURE 1 illustrates a cell provided with a Söderberg anode and vertical cathode outlet bars.

FIGURE 2 shows details of certain connections used in the embodiment of FIGURE 1.

FIGURE 3 illustrates a cell likewise provided with a Söderberg electrode, but having a horizontal cathode outlet bar.

FIGURE 4 illustrates a cell provided with prebaked anodes and horizontal outlet bars.

FIGURES 5 and 6 illustrate a further embodiment of the invention, comprising the use of a plurality of uniformly distributed overhead feeder bars, FIGURE 5 representing a diagrammatic cross-section along the line 5—5 of FIGURE 6.

FIGURES 7, 8, and 9 illustrate embodiments of the invention in which the return current from each line of cells is disposed beneath the cells.

FIGURE 10 represents a still further embodiment of the invention which eliminates the use of a feeder system.

FIGURE 11 illustrates in top plan view the arrangement shown in FIGURE 10.

FIGURE 12 illustrates diagrammatically a transverse section of a further embodiment of the invention.

FIGURE 13 represents a still different form of the invention, showing a vertical section through a cell. FIGURE 13A shows a vertical section through a cell according to another variant of the invention.

FIGURE 14 illustrates diagrammatically a cell and its conductors in transverse elevation, i.e., a section taken along the line a—*a* of FIGURE 15.

FIGURE 15 shows the cell in elevation and along a section taken along the greatest length.

FIGURES 16 and 17 illustrate an arrangement similar to that shown in FIGURES 14 and 15 but embodying an additional feature of the present invention.

FIGURES 18 and 19 relate to a still further improved embodiment of the present invention. In each of these figures there are shown in transverse section across the width thereof, two adjacent cells, each cell forming part of a row of cells, all cells being connected in series.

FIGURE 20 illustrates a further embodiment of the invention along the lines of that illustrated in FIGURE 19.

In these drawings, 1—2 represents the separating surface between bath and liquid metal; 3 the electrolysis cell; 4 an anode of the Söderberg type; 5 the current feeder system; 6 the studs for introducing current into the Söderberg anode; 8A and 8B the horizontal conductors which, in the prior art, were usually arranged at the sides of the cell; 10 prebaked anodes; 12 the steel cathode bars through which the current leaves the electrolysis cell.

The invention, as previously set out, relates to means for reducing or suppressing the vertical components of the magnetic fields. While certain of these means are broadly known, they must, in the instant case, be adapted for

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their novel function or be combined with novel means.

There will be set out below the various means which can be used to obtain the desired end.

The feeder system can be supplied from both its ends, obtaining thereby an approximately 50–50% current distribution (cf. FIGURE 6); however this proportion can be varied so as to take into consideration the field composition (strength) of all the other bars. In practice, experience has shown that good results are obtained by providing for a current distribution at the ends of 40–60% and 60–40%, respectively.

The feeder system can be disposed at such a distance above the cell that the effect of the resultant vertical field at the line of separation between metal and bath is negligible. However, in the case of prebaked anodes, this necessitates considerable lengthening of the vertical conductors bringing current to the prebaked anodes. Further, continuous anodes 4 of the Söderberg type are generally provided with current inlet studs 6 and with a steel casing (not shown) which furnish a preferential path for the magnetic field and cause the formation of a field having a vertical component even when the distance between the feeder system and the line 1—2 is great. In that event, non-ferrous, nonmagnetic metals should be used for the casing and studs.

The vertical components of the magnetic fields can be reduced or suppressed by disposing the indispensable horizontal conductors in sheet-like formations composed of as large a number as possible of parallel conductors, each carrying a fraction of the total current passing through the cell which is materially less than one half of the total current passing through the cell, as will be described in the following examples;

Example 1

The organization of the cell is completely modified, as illustrated in FIGURES 1, 2, 3, and 4. The usual feeder system is completely eliminated and the studs 6 (FIGURES 1 and 3), or the prebaked anodes 10, are supplied with current by means of a certain number of vertical risers 11. (The dotted lines in FIGURE 1 and in the other figures indicate a possible other arrangement of the risers 11.) The correcting effect becomes the more marked as the number of risers is increased. In FIGURE 1 there is shown a cell provided with a Söderberg anode 4, vertical studs 6 and vertical cathode outlets 12. In the lower part of the cell are placed in the form of sheets of parallel conductors the bars 8A which connect the cathode outlets to the succeeding cell, and the bars 8B from the preceding cell which feed the aforementioned vertical risers 11. This arrangement is suitable even in the case where the cathode outlets are horizontal, as shown in the embodiment illustrated in FIGURES 3 and 4.

With such an arrangement, the field due to the feeder system is practically suppressed.

These vertical risers are constructed of flexible straps so as to permit free movement of the anode assembly, and the manner of their grouping is controlled by the necessity of leaving between them sufficient space for ready access of workmen.

The arrangement of the indispensable horizontal conductors in sheets of parallel conductors by alternating the conductors 8B supplying the anode feeder system, and conductors 8A which provide for the transfer of the current leaving the cathode bars, makes it possible to obtain in the cell as a whole regular magnetic fields which are as constant in strength as is possible.

It is likewise possible to spread out the feeder system in several longitudinal bundles covering almost the entire width of the cell (cf. FIGURE 5). The field, due to the feeder system, is not eliminated by this arrangement; however, its strength is reduced by suppressing completely its vertical component; the only field that remains extends in a direction transverse to the cell.

Example 2

The vertical component of the field due to the bars connecting the cathode of one cell to the anode of the following cell can be suppressed by using the arrangement shown in FIGURE 10. It is to be noted that, in this scheme, the cells are placed in such a manner that their largest dimension is perpendicular to the general direction of current flow whereas, normally, this major dimension is parallel to the direction of current flow. The bars 12' connecting the vertical cathode outlet bars to the anode assembly of the succeeding cell are connected in bundles but remain in sheet form; they pass through the floor 14 and terminate at the anodes of the succeeding cell.

The arrangement just described, which likewise eliminates the feeder system, is applicable to cells having either horizontal or vertical cathode outlets, and using either continuous Söderberg electrodes or prebaked electrodes.

FIGURE 11 gives a schematic top view of the arrangement just described. The latter eliminates completely the vertical fields in the cells. Further, by reason of this arrangement, the horizontal fields produced by the aforementioned bars have the least possible strength and the greatest possible uniformity, since they are spread out in a great sheet. As a variant of this arrangement, it is possible to dispose the conductors as shown in FIGURE 9. According to the latter the sheet of risers, instead of being placed between two cells, is placed on both sides of the cell as in the embodiments illustrated in FIGURES 1, 2, 3, 4 where the feeder system is likewise eliminated. The result obtained is the same, but the disposition of the bars is such that it interferes less with servicing of the apparatus.

Example 3

The vertical component of the magnetic field due to the line of adjacent cells which insure the return of the current to the generators can be suppressed in the following ways:

(a) By arranging the adjacent return line of cells in an adjacent building constructed of metal so that the building acts as a screen between the two lines of cells.

(b) By bringing back the return current, from each line of cells, underneath the cells as shown in FIGURES 7, 8, and 9. The return conductor 13 is either placed underneath the line of cells as shown in FIGURE 8, or between the two lines of cells as shown in FIGURE 12.

In all of the instances referred to above, the field due to the adjacent line of cells is completely eliminated, as is also that due to the bars connecting the cathodes to the anodes in the case where the cells are disposed in rows, since the return current flows in the opposite direction from the normal current.

Experience has shown that the operation of high-amperage electrolytic cells is greatly improved by the adoption of the various expedients described above. Nevertheless, it is found that the liquid aluminum in the bottom of the pots of the electrolysis cells is occasionally set into motion, and that the resultant movements may attain an amplitude sufficiently large to interfere with the electrolysis.

Accordingly, it is also a feature of the present invention to reduce, or suppress altogether such movements of the metal by diminishing or suppressing the transverse horizontal component of the magnetic field in the pot of the electrolytic cell at the separating surface between metal and bath. The electrolysis cells used in the production of aluminum are generally of rectangular shape and, in the present specification, the horizontal transverse component is that component which is perpendicular to the general direction of the electric current passing from one cell to the succeeding one.

In actual practice, it is difficult to reduce simultaneously the vertical component and the horizontal transverse component of the magnetic field and, a fortiori, to suppress both of them. The examples given above are, therefore, more particularly concerned with the provision of means

which make it possible to obtain an appreciable improvement in the operation of the cells, having in mind the desiderata set out above.

Example 4

Further improvements comprehended by the present invention will be described with reference to FIGURES 14-17 of the annexed drawings. Referring briefly to FIGURES 14 and 15 it will be observed that, in accordance with the earlier disclosure in the instant specification, the various electrical conductors supplying the cells have been disposed in such a fashion as to reduce as much as possible the vertical component of the magnetic field over the entire surface separating the metal and the bath. That is, the steel bars by which the current leaves the cell being vertically arranged, the feeder system disposed above the cell for distributing the current to the anode assembly is simultaneously supplied at its both ends, and the horizontal conductors—which are indispensable for conveying the current from the end of one cell to the other end and for collecting the current leaving the cathode—are disposed in sheets of parallel conductors placed below the cell and parallel to its greatest length.

In FIGURES 14 and 15, 1—2 represents, as before, the surface of separation between the liquid metal and the electrolytic bath. 3 is the pot of the cell; 4 the anode which, in the instant case, is a continuous anode of the Söderberg type; 5 is the feeder system which distributes the current to the studs 6 of the anode; 12 are the steel bars by which the current leaves the cathode and are electrically connected to the longitudinal conductors 8A placed underneath the cell. The longitudinal conductors 8B supply current to both ends of the feeder system 5 through the intermediary of the vertical conductors or risers 11.

Referring now to FIGURE 15, the left end of conductor 8B is joined to the current outlet of the preceding cell. Starting from point 9, the conductors 8B and 8A overlap in elevation; 8B serves to lead a portion of the current to the opposite end of the connecting bar 5, while 8A collects the current leaving the bottom of the cell through the bars 12 in order to pass it on to the succeeding cell.

These arrangements, while improving the operation of the cell, do not prevent the aluminum in the bottom of the cell from being subjected to movements which deform in an irregular manner the surface 1—2. The extent of these movements can be considerably reduced by suppressing the double feed to both ends of the connecting bar 5, that is to say, by eliminating the conductors 8B placed under the cell and the conductors 11 at the right of FIGURE 15. This results in the new arrangement shown in FIGURES 16 and 17. It has been found that with this new arrangement, the metal below the line 1—2 is much more stable, and that the bottom of the anode 4 can be brought nearer to the surface 1—2 whereby the consumption of electric current can be reduced for the same aluminum output.

Example 5

In a row of electrolytic cells for the production of aluminum, the conductors are arranged as shown in FIGURE 18. Horizontal bars 12 provide for current outlet, the conductors 8A collecting the current leaving the cathode are disposed along the long sides of the cathode of the cell, in immediate proximity of the walls, but below the bottom of the pot containing the metal. Conductors 8B which enable supply of current to the feeder system 5 at its two ends, are placed in the same manner above conductors 8A.

It has been found possible to obtain a considerable improvement in the electrolysis operation—over the arrangement shown in FIGURE 18—by disposing conductors 8A and 8B as shown in FIGURE 19 that is to say, by spacing them away from the cell and by placing

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them in the same plane as the plane of separation 1—2 between the metal and bath. There is obtained thereby, as in the case of Example 1, an appreciable improvement in the operation of the electrolytic cell.

When two lines of cells are arranged as shown in FIGURE 19, and the electric current flows in one direction in one line, and in the opposite direction in the other, the conductors 8A, 8B of one line and 8'A, 8'B of the other line can be placed side by side in such a fashion that the vertical components of the magnetic fields neutralize each other, as had already previously been proposed in the present specification (Example 3, FIGURE 12). Those conductors which are disposed at the outer sides of the lines of cells can be placed sufficiently far away to reduce the magnitude of the vertical component of the magnetic field and even on the outside of the building which then constitutes a magnetic screen. As in the case of Example 4, this modification has produced an improvement in the consumption of the electric energy per ton of aluminum produced.

Example 6

Referring to FIGURE 20: There is adopted here the same arrangement of conductors as in FIGURE 19; however, the steel bars 12 by which the current leaves the cathode are arranged vertically, as shown in FIGURE 20. Here, again, there is obtained a material improvement in the energy consumption per ton of aluminum produced.

The fields can also be reduced by using magnetic screens.

All that has been said above with regard to the shape of the field did not take into account the presence of iron, except in the case of the casing and studs of continuous anodes of the Söderberg type. In practice, when ferro-magnetic cell parts are present the resultant induction does not resemble the initial fields since, under those conditions, the tubes of force preferentially follow paths of greater permeability, at least as long as these paths are not themselves saturated.

The magnetic fields and, especially, their vertical components, can be weakened by the use of magnetic screens having a cross-section sufficient to avoid any appreciable effect due to saturation.

Considering the fields due to the adjacent line of cells which carry the current back to the generator, and also those fields due to the feeder system, the screens can be disposed as follows at the places indicated in FIGURE 13;

(1) A horizontal screen *a* connecting the upper portions of the studs and casing in a Söderberg type electrode.

(2) Inclined screens *b* joining the casing to the flat flanges of the metallic case *f* which contains the electrolytic cell.

(3) Screens *c* for increasing the thickness of the vertical walls of the case *f*.

(4) Horizontal screens *d* increasing the bottom of the case *f*.

The screens *b* are, of course, made removeable to facilitate access to workers.

Finally, it has been discovered by applicants that a building itself functions as a complete magnetic screen between two lines (rows) of cells disposed in two different buildings, even if the building is grille-like, i.e., not completely closed.

The vertical fields can also be reduced (weakened) by means of rather weak demagnetizing windings disposed at the following places shown on FIGURE 13A:

(1) About the iron casing Söderberg anodes, the lower section thereof (i.e. of the winding) producing thereby a vertical demagnetizing field which opposes the field due to the line,

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(2) About the case, thereby producing a demagnetizing field as described under (1) above,

(3) At the ends of the horizontal cathode outlets, by means of windings which vary in strength depending on the position of the bar, and which produce a demagnetizing field along a horizontal axis opposing that due to the bars disposed underneath the cell.

We claim:

1. In a method of operating a system for the igneous electrolysis of a molten bath of metallic compounds, including metallic fluorides, to produce molten metal, which system comprehends a plurality of rectangular cells having sides of materially different lengths each comprising a pot for containing the molten bath and liquid metal, an anode vertically supported above said pot, and a cathode disposed in the bottom of said pot, and conductor means for connecting said cells in series, the improvement of advantageously inhibiting detrimental deformation of the level of the molten metal in the course of the electrolysis, which comprises the steps of: forming and maintaining on the inner sides of the pot a solid lining of said fluorides and of such thickness that the surface area of the liquid metal in the pot is rendered substantially equal to the area of the adjacent opposed horizontal anode surface, whereby the flow of current in the liquid metal is substantially vertical; distributing said conductor means— which join the current outlets of the cathode of one cell to the current inlets of the anode of the next succeeding cell—into a large number of spaced parallel conductors extending directly from a cathode to a succeeding anode and disposed in a sheet-like formation, each of said conductors comprising adjacent said anode a horizontal section which extends substantially at right angles to the longest side of the next succeeding cell, and each carrying a uniform fraction of the total current passing through the cell which is materially less than one-half of the total current passing through the cell, whereby the current carried by each of said horizontal sections is independently passed into the anode of said next succeeding cell, thereby reducing the vertical component of the magnetic field generated by the current flowing in said conductor means.

2. The method of claim 1, wherein the bath comprises alumina, and the metal produced is aluminum.

3. The method of claim 1, including the step of magnetically shielding each cell.

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